10 to 50 Watt GaN Amplifiers for Military and Commercial Applications

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Teledyne Cougar

A new line of gallium nitride based amplifiers offers a wide range of power and gain options for RF engineers designing robust broadband systems

Teledyne Cougar's new line of medium-power broadband amplifiers is a unique family of performance-based solutions designed for demanding applications. This line covers 20 to 2600 MHz and uses gallium nitride (GaN) technology. Each amplifier is hermetically sealed and includes multiple RF performance options so engineers can specify standard catalog or custom-tuned performance. The amplifiers include an internal sequencer, ensuring application of the proper gate voltage applied to the FET prior to voltage applied to the drain. Higher gain versions include pre-amps, providing excellent noise figure and IP performance. The small package footprint is designed for high performance applications and operates from –40 to +85°C.

Figure 1 · Teledyne Cougar offers a new line of broadband medium power amplifiers.

Control Circuitry

The package sizes are small and heat sinking is required to draw off the heat developed by the units. External DC blanking control is available on all models listed in Figure 1, which allows for the DC power to shut down on the output power module. TTL low or no voltage on the blanking pin turns the DC power back on. In addition, a voltage sequencer is included that prevents the power module to turn on before the proper gate voltage is applied to the GaN FETs. The larger packages shown in Figure 1 also include an over-temperature shut down that turns the DC off on the output module until its temperature drops to a safe level. A temperature sensor is located near the GaN die that provides a voltage in proportion to the temperature and is sent to a comparator circuit that trips a TTL high voltage if it exceeds the factory preset voltage indicating an over temperature condition. A hysteresis is built so that when the unit cools down about 5 degrees it automatically turns the DC power back on. The trip temperature is set at the factory. It tends to go up slightly with increased RF signal, hence you do not get premature shut down with a short duration burst signal.

Model A2CP2595 Pre-amp/Driver

Table 1 shows seven GaN-based medium power amplifiers, providing output powers from 8 to 50 watts. Also shown is the preamp/driver A2CP2595 used as a front end amplifier that provides 23-24 dB gain and 3.5 dB NF. The graph in Figure 2 shows the respective output powers of this driver as 3-4 watts at P_{3dB} and about 2 watts at P_{1dB}. It can drive the AVP598, AVP2515 and the AVP3030 to full output power shown in Figure 2 and covers 20-2600 MHz. The pre-amp stage uses

Model	Freq Range MHz	Gain Typ.	N.F. Typ.	P1dB Typ	P3dB Typ	Watts P3 Typ	IP3/IP2/Pout TYP	Driver D.C Volts Nom.	Driver D.C mA Nom.	D.C Volts Nom.	DC A Q/@P3dB Typ.
AVP598	20-400	16.5	2.5	38	43.2	20.9	50/64/40	N/A	N/A	28	0.85/1.5
AVP514	20-400	40	3.5*	38	43.2	20.9	50/62/40	12	185	28	1.25/1.95
A2CP2595	20-500	24	3*	34	36.2	4.2	45/58/27	12	185	28	0.39/0.47
"	500-2500	24	3	32.5	34	2.5	40/56/27	12	185	28	0.39/0.47
AVP2515	600-2600	17	4.5	35	41	12.6	48/50/37	N/A	N/A	28	0.85/1.50
AVP2524	600-2600	41	4.5	35	41	12.6	47/48/37	15	185	28	1.25/1.9
AVP2030	650-2200	16	4.5	39	44	25.1	53/65/40	N/A	N/A	28	0.85/2.6
AVP2034	650-2200	40	4.5	39	44	25.1	52/62/40	15	370	28	1.25/3.1
AVP2050	900-2000	14	4	42	48	63.1	55/68/43	N/A	N/A	28	1.6/5.50

All specifications subject to change. * Freq >=100 MHz

Table 1.

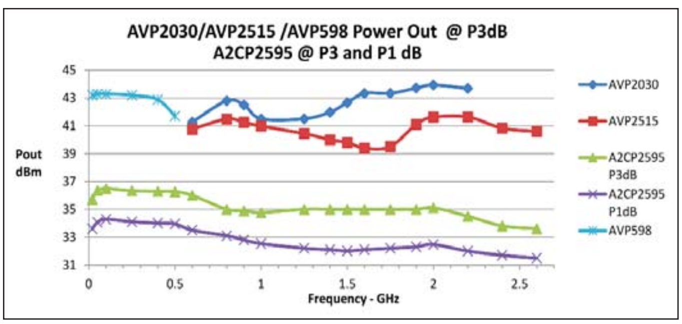


Figure 2.

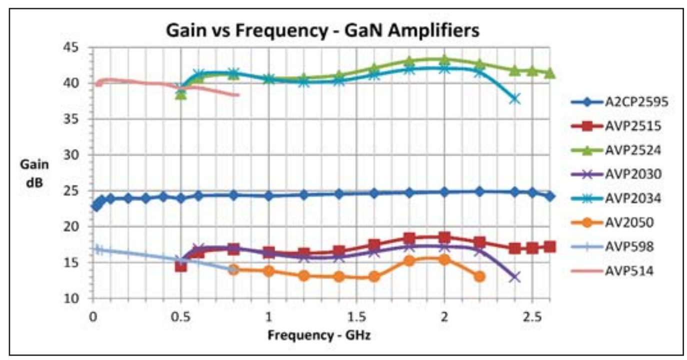


Figure 3.

+12 or +15 volts to minimize power drain. The driver uses a single-ended GaN feedback stage. The AVP514, the AVP2524 and the AVP2034 each combine the A2CP2595 with the AVP598, the AVP2515 and the AVP2030 power modules to obtain about 40 dB of gain as shown in Figure 3 for this series of amplifiers.

Models AVP598 and AVP514

The AVP598 is a 20-500 MHz power module without a pre-amp driver that delivers over 20 watts from 20 to 500 MHz with 16 dB of gain, 40 dB of gain with the AVP514 that combines a pre-amp/driver. Microwave matching structures are not required because this is a low frequency amplifier, hence more constant output power can be obtained across the full 20-500 MHz bandwidth. It produces up to 25 watts of power as shown in Figure 2.

Models AVP2515 and AVP2524

The AVP2515 is a power module without a pre-amp driver that delivers 8-11 watts from 600 to 2600 MHz with about 17 dB of gain and 41 dB of gain with the pre-amp/driver with the AVP2524. The output power module can preset at the factory for various levels of quiescent current. For maximum output power the higher bias levels yield a higher output but specifications may restrict using the higher bias. Data has been taken to measure this effect. A quiescent bias of 750 mA yields about 8 watts output at 3 dB compression and a bias of 1 amp yields about 11 watts at 3 dB compression. The power added efficiency (PAE) is about 21.5% at the lower bias, Figure 4, but increases to just under 27% at the 1 amp bias level, as shown in Figure 5.

Models AVP2030 and AVP2034

The AVP2030 is a power module without a pre-amp driver that delivers about 15-24 watts from 650 to 2200 MHz and 20 to 24 watts above 1.5 GHz with about 17 dB of gain and 41 dB of gain with the AVP2034 which combines the pre-amp/driver. The matching circuit favors the high end of the band which results in the higher output as shown in Figure 2. These models also come with factory set bias as required by the application. GaN devices in general yield higher output powers with a higher bias current. All of the models described in Table 1 use class AB bias to maximize PAE. The AVP2030 PAE peaks at 36% at 2 GHz with a 1.3 amp bias. The current rises to 2.4 amps at the 24 watt output with 3 dB of compression as shown in Figure 6. The AVP2034 PAE peaks at about 30% which factors in the power used by the pre-amp/driver.

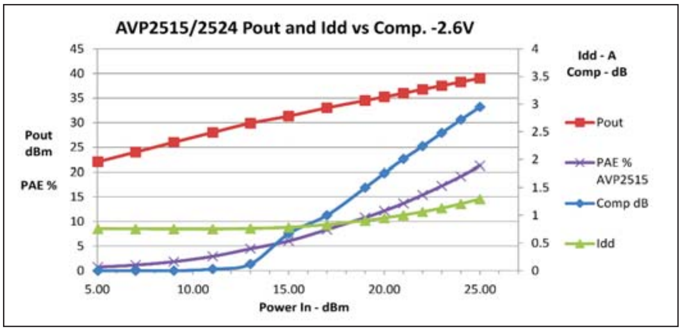


Figure 4.

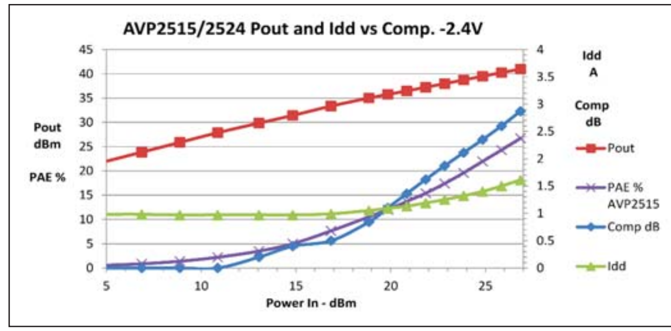


Figure 5.

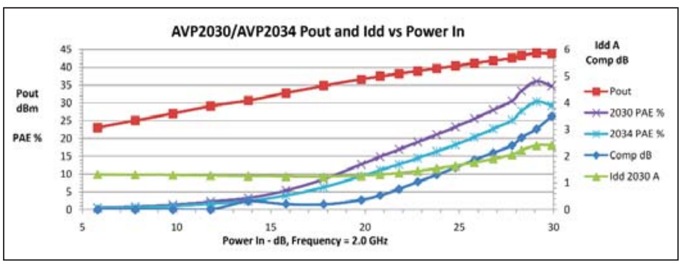


Figure 6.

AVP2050

The AVP2050 is the highest power module in this series. The curves in Figure 7 show the output power with the input level adjusted to provide 50-55 watts. This power curve represents about 3 dB of compression. The power added efficiency is shown by the purple curve. It ranges from 32 to 43% across the 900 to 2000 MHz band. The matching structures were designed to favor the high end of the band as described for the AVP2030 amplifier. Matching is an analog function that can be tailored to any narrower band as required. Since RF and microwave amplifiers are analog devices this is no surprise. The DC current can be biased as low as about 800 mA before there is a drop in gain. Substantial data has been taken using 1.0 and 1.6 amps of quiescent bias. The fundamental nature of a class AB GaN amplifier in this series yields about 1 dB more power at P_{3dB} with a quiescent bias that is about 30-40% higher than the lowest bias level that does not result in gain reduction.

Figure 8 shows the AVP2050 power module power out vs. power in (green trace), which reaches 71 watts at the P_{3dB} point at 2 GHz. A similar curve (not shown) shows the unit reaching 67 watts at 1 GHz.

For the power levels described by this series of amplifiers there can be "cumulative compression," which is the compression by the output module plus the driver compression. For these GaN devices the 3 dB compression point of the output modules yields close to the best PAE, but the cumulative compression might be closer to 4-5 dB depending on the driver used.

Noise Figure

The noise figures for the A2CP2595, AVP2515 and the AVP2030 are shown in Figure 9 and are typically 3-3.5 dB except at the band edges. The A2CP2595 uses a MESFET pre-amp stage and the graph show the typical 1/*f* characteristic where the NF rises to 8.8 dB at 20 MHz. The graph in Figure 10 shows the AVP598 NF at 0.5 and 0.9 amps bias where it is looking only at the GaN device. The NF is only 2.5 dB at 20 MHz and rises up to 2.8 dB at 500 MHz. This demonstrates that the GaN device employed does not have the high 1/*f* characteristic of the MESFET below 100 MHz.

The NF of the AVP2050 is also shown in Figure 10 for a 1 and 3 amp bias. The shape of the two curves is about the same with the 3 amp bias resulting in approximately a 1 dB increase in NF from the 3 dB nominal value. The

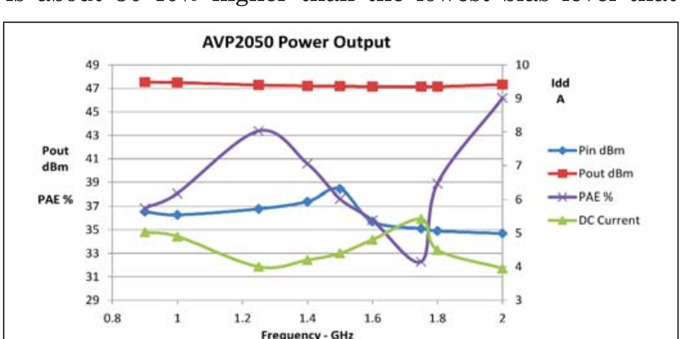


Figure 7.

Figure 8.

NF is actually lower at the band edges than at mid-band which is related to the matching network.

Intermodulation Products

IP3, IP2 and 2nd harmonics were measured on all the products shown in this series at two different bias levels and as a function of frequency at 2-3 dB below each amplifier's respective P_{3dB} point. Also, the IPs were measured from +20 dBm output up the P_{3dB} point. This data is considered useful for evaluating this Power Series for applications where linearity as a function of input level is useful for determining system linearity for signal levels other than maximum output power.

The concept of the intercept point (IP) is based on a linear function, but with a power amplifier there is a wide range of powers over which it might be used. GaN technology has a somewhat softer compression than a bi-polar or GaAs FET and thus must operate over a wider range of non-linearity. In the interest of space only one bias level will be shown here.

The IP3 vs. P_{out} for the AVP598/ AVP514 for four frequencies is shown in Figure 11. From +20 dBm up to + 30 dBm the IPs appears to be linear but then as the amplifier gets biased to a higher current due to the increased

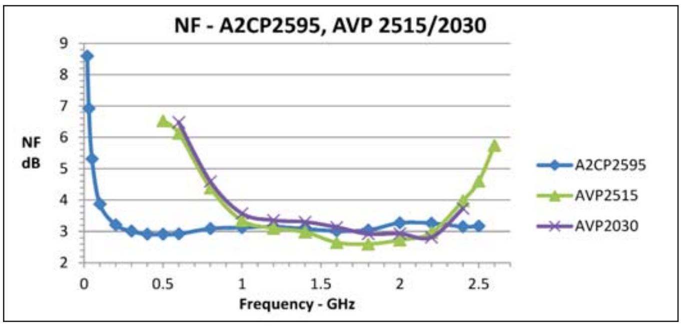


Figure 9.

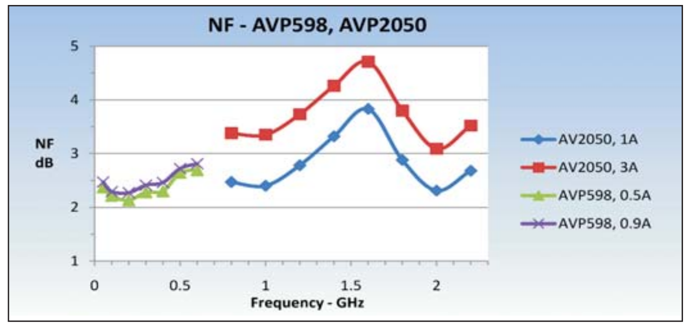


Figure 10.

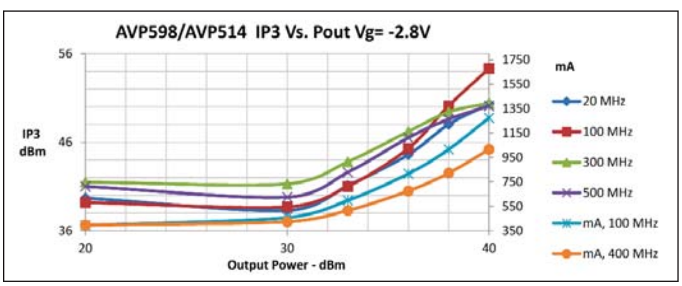


Figure 11.

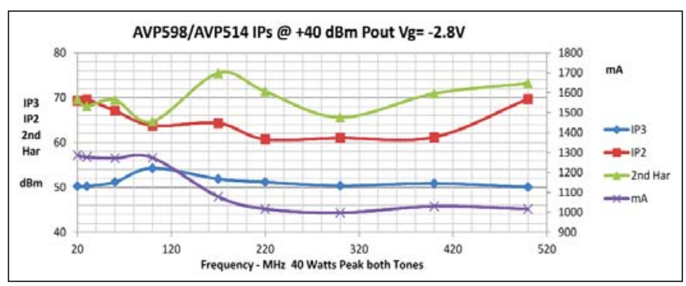


Figure 12.

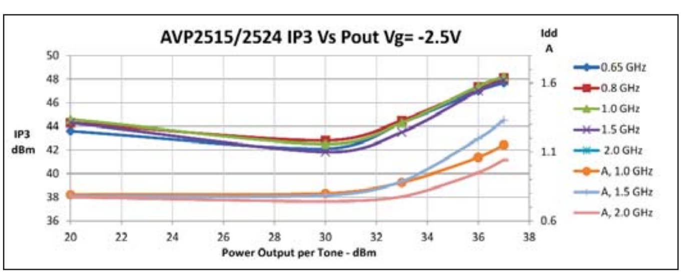
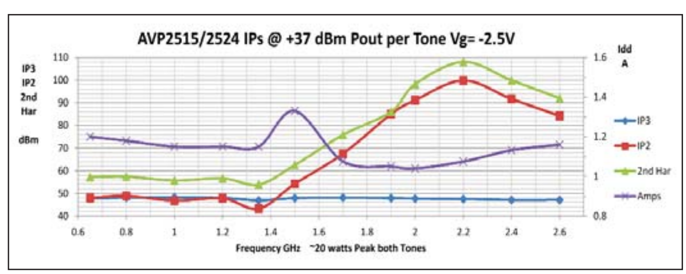


Figure 13.



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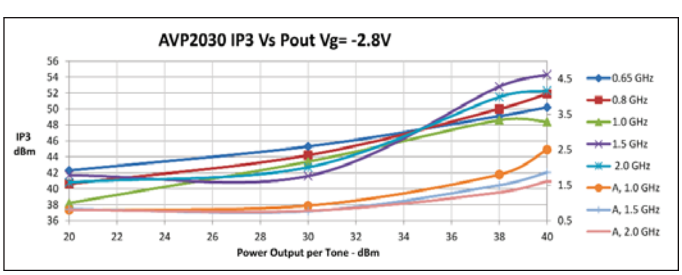

Figure 15.

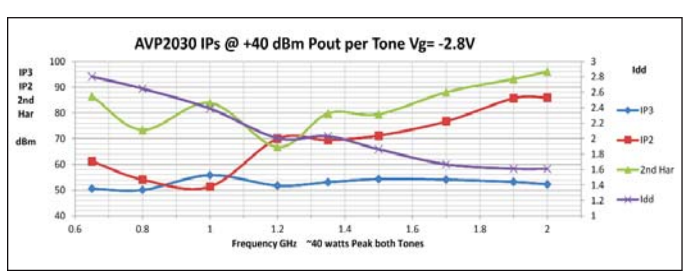

Figure 16.

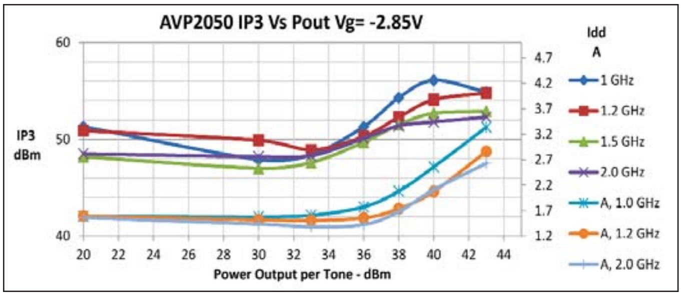

Figure 17.

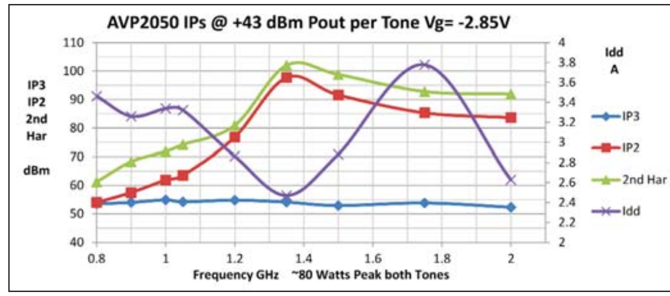

Figure 18.

input signal level, the apparent IP increases to +50 dBm or better at +40 dBm out for each tone. This holds true across the 20-500 MHz frequency band as shown is Figure 12. IP2 is greater than +60 dBm for these 2 models. +40 dBm out for each tone represents 40 watts peak power.

The IP3 vs. P_{out} for the AVP2515/AVP2524 for five frequencies is shown in Figure 13. The graph shows the IP3 dropping from +44 to +42 with an output change from +20 to +30 dBm, but then increases to +48 dBm at +37 dBm output power. The IP3 is very constant at +48 dBm output across the 650 to 2600 MHz band as shown in Figure 14 at this output level. The IP2 does not exceed the IP3 until the second harmonic of the fundamental is outside the upper frequency of the bandwidth. This is also shown in Figure 14. From 1.6 GHz and up the IP2 and 2nd harmonic exceed +60 dBm, are both greater than +90 dBm from 2.0 GHz and higher.

The IP3 vs. P_{out} for the AVP2030/AVP2034 is shown in Figure 15. From +20 to +30 dBm output actually increases from +42 to +44 dBm and then rises to +48 dBm at 1 GHz with the highest IP3 measuring +54 dBm at 1.5 GHz and +52 dBm at 2.0 GHz with a +40 dBm output each tone. The IP2 suppression reaches +70 dBm and higher from 1.2 GHz up through 2 GHz. The IP2 suppression experiences a low of only +50 dBm at around 1 GHz as shown by the curves in Figure 16.

IP3 for the AVP2050, the highest power amplifier in this series, measures from +47 to +52 dBm from +20 to +33 dBm output power, then climbs to about +52 to + 54 dBm for +38 to +43 dBm output power (each tone) as shown in Figure 17. The IP2 performance exceeds +60 dBm from 1 GHz and continues to rise and exceeds +80 dBm from 1.35 GHz to 2 GHz as shown in Figure 18. As with the AVP2030, the sum of each 20 watt tone results in 80 watts peak RF power level in the amplifier when making this measurement. The current does change with frequency as shown, depending on the effective efficiency for a given frequency.

Conclusion

Teledyne Cougar's new line of medium power compact thin-film amplifiers offer a broad range of gain and power output for flexibility in achieving performance goals in higher power environments.

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