Reference Design

CDI-RD-001

F465: 10W 2-Stage GaN Amplifier

Revision 1.0

May 13, 2015

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Introduction

The recent introduction of the Sumitomo F465 10W 2-Stage GaN device has opened the door for high efficiency, broadband, medium to high power designs requiring a small physical footprint. The ability of the RF design engineer to tune the input, inter-stage, and output match of this versatile device to suit his specific application requirements makes this device appealing on many levels. A single device can be selected to achieve moderate gain and efficiency covering a wide bandwidth. Likewise, the same device can be tuned to a narrower band to achieve much higher gain and efficiency. The recently created RF Applications Lab from Component Distributors, Inc. (CDI) has had the privilege of getting first access to this device for evaluation purposes to further showcase the versatility of the F465. This application note will cover the first F465 reference design operating over a decade of bandwidth (30MHz to 600MHz) achieving high saturated efficiency (>50%) and high saturated power (>41.5dBm) while maintaining gain greater than 28dB operating at a drain voltage of 28V. In conjunction with the development of the F465 reference design board, CDI developed a GaN bias board capable of sequencing two independent gate voltages as well as a single drain supply voltage for two GaN devices.

F465 Specifications

The Sumitomo F465 is a partially pre-matched 10W GaN amplifier with an integrated driver stage. It is housed in a low-cost plastic package. The two stage amplifier offers high power and high gain, as well as excellent efficiency. It is suitable for use in broadband applications from DC – 3 GHz. User-defined input, inter-stage and output matching circuits allow the performance to be tuned for specific band of interest.

Features

- 2-stage GaN in Plastic Package (6.5mm x 7mm)
- HAST Compliant GaN Technology
- Operating drain voltage within 28V to 50V
- CW Output Power: 10W @ 28V, 20W @ 50V
- Suitable for Broadband Applications from DC – 3GHz

CDI Application Lab F465 Reference Design

All CDI Application Lab reference designs consist of two independent board designs interconnected to provide a safe and reliable way to evaluate GaN technology. First, the GaN bias board (the blue PCB pictured in Figure 1) controls the sequence and level of bias voltages applied to the device gates and drains. The GaN bias board also provides a level of protection against the inadvertent loss of gate supply voltages to prevent catastrophic failure of depletion mode GaN devices. More information regarding the GaN bias board operation can be found at http://rf.cdiweb.com. The second board in the reference design is the RF PCB (the green PCB pictured in Figure 1) contains the F465 device and RF specific matching components (baseband and RF matching capacitors and inductors). The RF board is

mounted on a milled aluminum block that acts as a heat sink as well as provides mechanical support for the SMA and ribbon cables attached to the RF board.

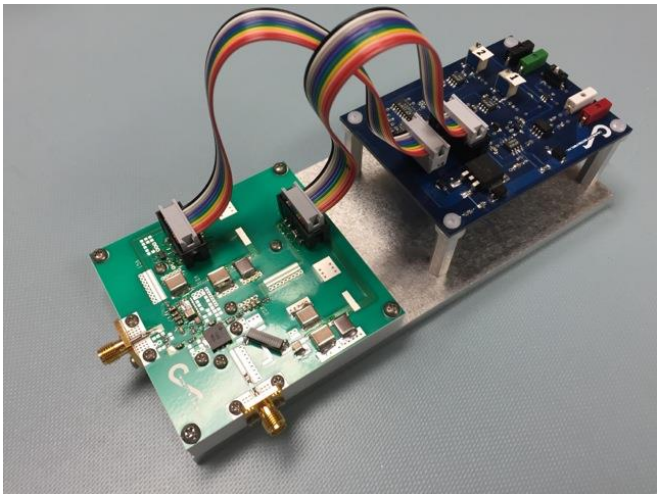

Figure 1 - F465 Reference Design

F465 RF Board

The matching components of the RF board were selected in ADS with the assistance of the F465 non-linear model. Rogers RO4350B material (20mil thick with 1oz cu/1oz plating) was selected for this design. The via array located under the F465 device consists of 56 copper filled 7.5mil radius vias oriented in a honeycomb pattern. This layout provides a low thermal resistance path to remove heat from the F465 device. In addition to the simulated matching components, additional pads were placed in the RF layout to accommodate tuning the F465 to operate at different frequencies. This is easily done since the F465 input, inter-stage, and output matching are all done externally to the device.

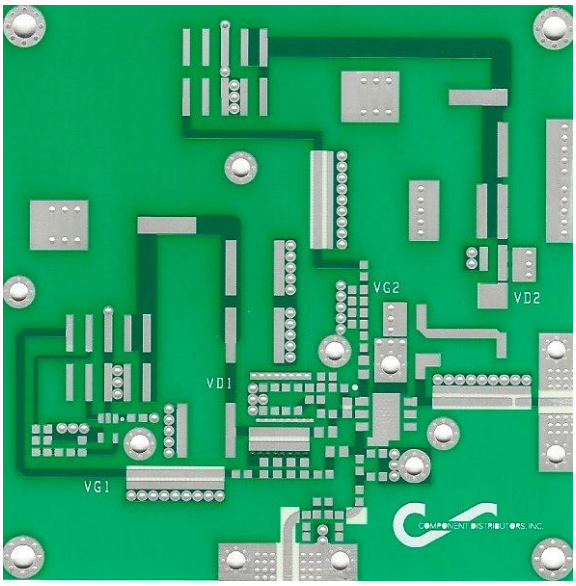

Figure 2 - F465 Reference Design RF Board

Matching Networks

The first stage input match for the F465 reference design consists of an RL network used to flatten out the gain across frequency of the first stage without using feedback. The absence of feedback allows for this amplifier to be used with either CW or pulsed applications. The input to the first and second stages are high Q which makes broad matching somewhat difficult. The main goal is to get acceptable gain across the operating bandwidth. The RF board for the F465 reference design allows for the use of many matching topologies to be used for the first stage input and inter-stage matches. The inter-stage match for this design uses a shunt R with series RL components to match the F465 for optimal gain across the frequency band. Since this design covers over a decade of bandwidth, the gain flatness of the entire lineup was optimized using the input match as well as the inter-stage match. Figure 3 shows the S_{11} measurements of the first and second stage of the F465 non-linear model for ADS that is available upon request (rf@cdiweb.com). The non-linear model provided an excellent starting point for selecting matching components with little empirical tuning required to achieve target performance. The non-linear model is also available for AWR.

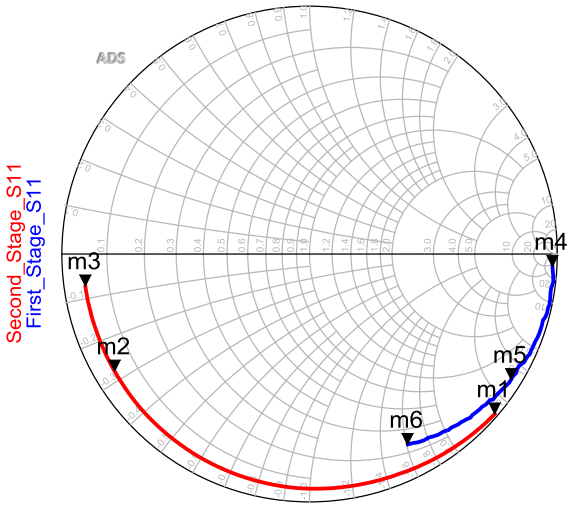

Figure 3 - First and Second Stage S_{11} ADS Measurements

Measured Performance

Figure 4 shows the final component values used for the F465 reference design. After fabrication, the F465 reference design was measured across frequency and power at the CDI RF Application Lab. Table 1 details the gain and efficiency for targeted output power levels while Figure 5, Figure 6, and Figure 7 show the full CW power sweep generated in an automated LabView test environment. The gain is within a ±1dB window from 30MHz to 600MHz at output powers of 40dBm, 41dBm, and 41.5dBm. The saturated power is just above 41.5dBm with an efficiency greater than 50%.

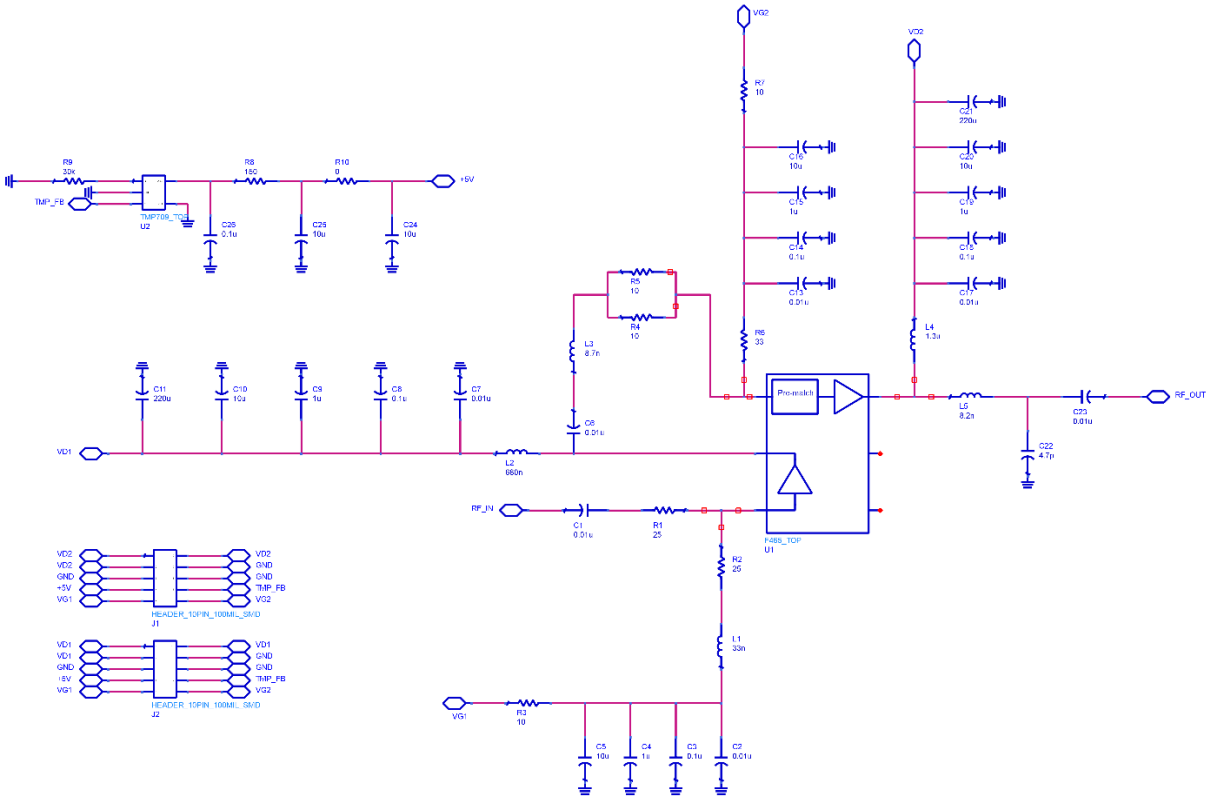

Figure 4 - F465 Reference Design Schematic

	Pout = 40 dBm		Pout = 41 dBm		Pout = 41.5 dBm	
Freq [MHz]	Gain [dB]	Eta [%]	Gain [dB]	Eta [%]	Gain [dB]	Eta [%]
30	30.92	68.93	29.26	72.75	28.18	74.50
100	32.15	64.22	30.70	68.80	29.53	70.47
200	32.07	53.66	30.84	58.31	29.95	60.47
300	31.41	47.62	30.05	51.76	29.24	54.01
400	30.89	41.40	30.27	46.06	29.93	48.54
500	31.37	43.78	30.37	48.15	29.76	50.39
600	31.73	45.45	30.73	50.55	29.97	52.98

Table 1 - F465 Reference Design Performance

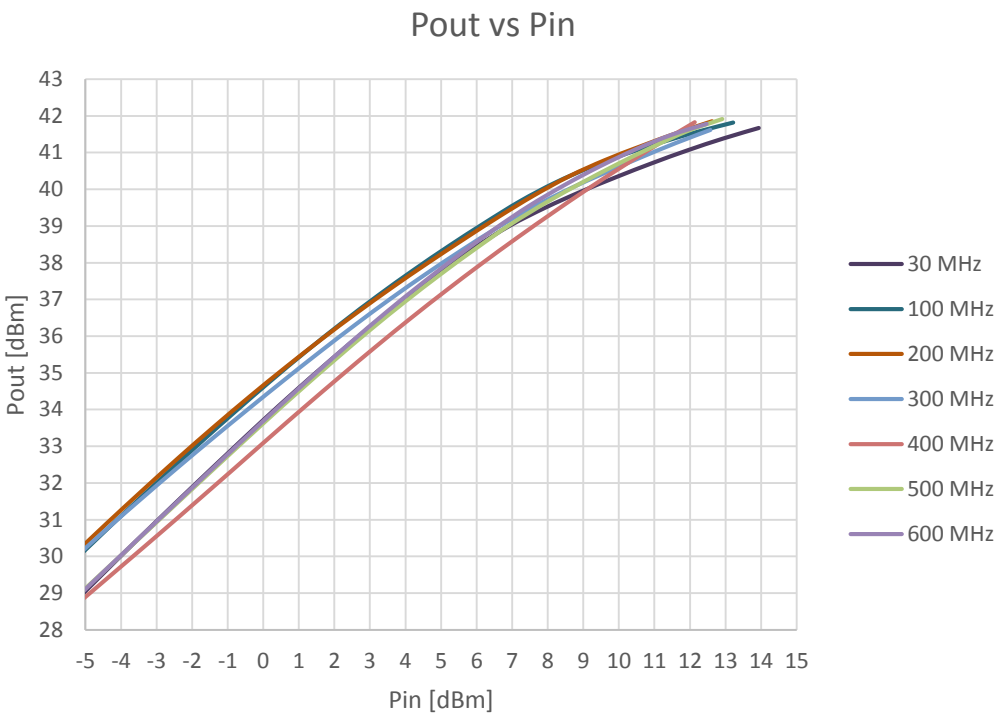

Figure 5 - F465 CW Sweep - Pout vs Pin

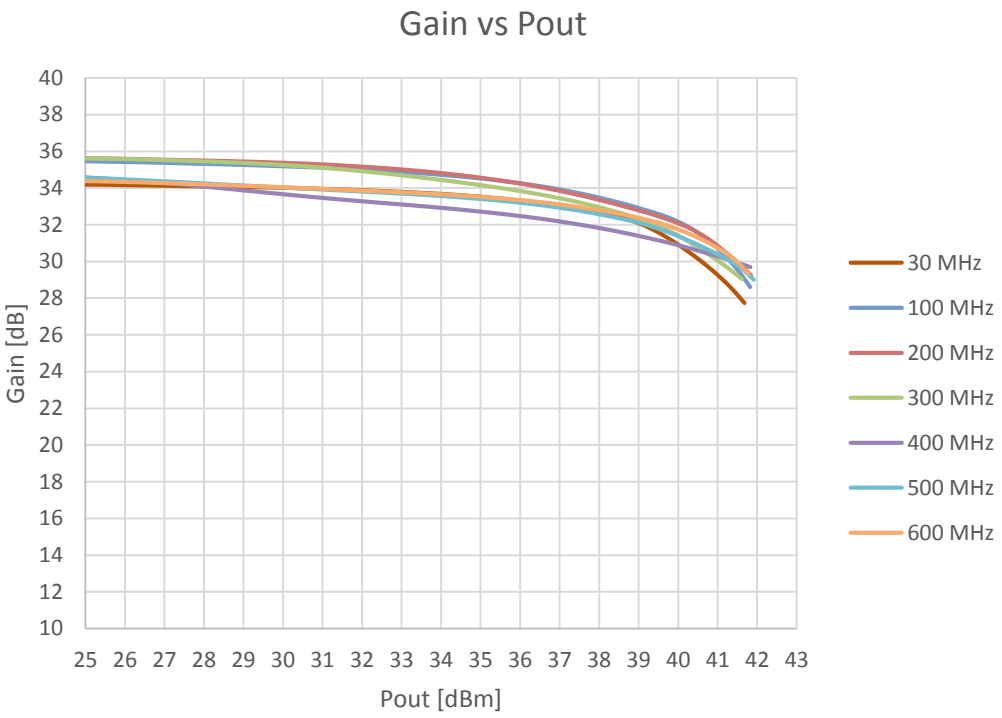

Figure 6 - F465 CW Sweep - Gain vs. Pout

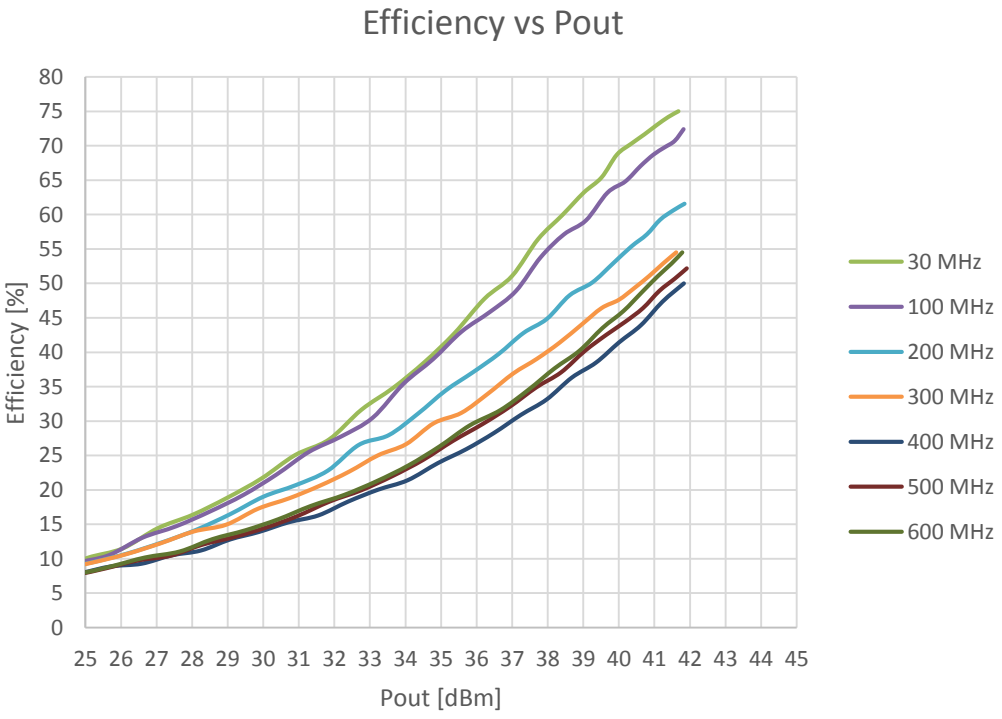

Figure 7 - F465 CW Sweep - Efficiency vs Pout

Conclusion

CDI's RF Applications Lab team has created a reference design for a broadband GaN amplifier, utilizing a prototype 2-stage GaN device from Sumitomo Electric Design Innovations.

This reference design operates over a decade of bandwidth (30MHz to 600MHz) while achieving high saturated efficiency (>50%) and high saturated power (>41.5dBm). The gain is maintained at greater than 28dB with the GaN device operating at a drain voltage of 28V.

A complete Bill of Materials for the reference design is provided on the following page.

For more information regarding this reference design, or to find out how CDI's RF Applications team can help get your design to market faster, please contact us at: rf@cdiweb.com

RF Board BOM

REF DES	Value	Description	Manufacturer	Part Number
R1	25	RES SMD 25 OHM 5% 1/10W 0603	Riedon	CLR0603
R2	25	RES SMD 25 OHM 5% 1/10W 0603	Riedon	CLR0603
R3	10	RES SMD 10 OHM 5% 1/10W 0603	Riedon	CLR0603
R4	10	RES SMD 10 OHM 5% 1/10W 0603	Riedon	CLR0603
R5	10	RES SMD 10 OHM 5% 1/10W 0603	Riedon	CLR0603
R6	33	RES SMD 33 OHM 5% 1/8W 0805	Riedon	CLR0805
R7	10	RES SMD 10 OHM 5% 1/10W 0603	Riedon	CLR0603
R8	150	RES SMD 150 OHM 5% 1/10W 0603	Riedon	CLR0603
R9	30k	RES SMD 30k OHM 5% 1/10W 0603	Riedon	CLR0603
R10	0	RES SMD 0.0 OHM 5% 1/10W 0603	Riedon	CLR0603
L1	33nH	IND 33NH 5% 0603	Gowanda	CC0603-033J
L2	680nH	IND 680NH 20% 0805	Gowanda	CC0805-680J
L3	8.7nH	IND 8.7NH 5% 0603	Coilcraft	0603HP-8N7XJE
L4	1.3uH	IND 1.3UH 2.7ADC	Coilcraft	4310LC-132KEB
L5	8.2nH	IND 8.2NH 5% 0603	Coilcraft	0603HP-8N2XJE
C1	0.01uF	CAP CER 0.01UF 50V 10% 0505	Passive Plus	0505X103KP500
C2	0.01uF	CAP CER 0.01UF 50V 10% 0505	Passive Plus	0505X103KP500
C3	0.1uF	CAP CER 0.1UF 16V 10% X7R 0805	Kemet	C0805C104K4RACTU
C4	1.0uF	CAP CER 1UF 16V 10% X7R 0805	Kemet	C0805C105K4RACTU
C5	10uF	CAP CER 10UF 16V 20% X5R 0805	Kemet	C0805C106M4PACTU
C6	0.01uF	CAP CER 0.01UF 50V 10% 0505	Passive Plus	0505X103KP500
C7	0.01uF	CAP CER 0.01UF 50V 10% 1111	Passive Plus	1111X103KP500
C8	0.1uF	CAP CER 0.1UF 200V 20% 2225X	Passive Plus	2225X104MW201
C9	1uF	CAP CER 1UF 100V 20% 2225X	Passive Plus	2225X105MW101
C10	10uF	CAP CER 10UF 100V 20% X7S	TDK	C5750X7S2A106M230KB
C11	220uF	CAP ALUM 220UF 100V 20%	Panasonic	EEV-FK2A221M
C13	0.01uF	CAP CER 0.01UF 50V 10% 0505	Passive Plus	0505X103KP500
C14	0.1uF	CAP CER 0.1UF 16V 10% X7R 0805	Kemet	C0805C104K4RACTU
C15	1.0uF	CAP CER 1UF 16V 10% X7R 0805	Kemet	C0805C105K4RACTU
C16	10uF	CAP CER 10UF 16V 20% X5R 0805	Kemet	C0805C106M4PACTU
C17	0.01uF	CAP CER 0.01UF 50V 10% 1111	Passive Plus	1111X103KP500
C18	0.1uF	CAP CER 0.1UF 200V 20% 2225X	Passive Plus	2225X104MW201
C19	1uF	CAP CER 1UF 100V 20% 2225X	Passive Plus	2225X105MW101
C20	10uF	CAP CER 10UF 100V 20% X7S	TDK	C5750X7S2A106M230KB
C21	220uF	CAP ALUM 220UF 100V 20%	Panasonic	EEV-FK2A221M
C22	4.7pF	CAP CER 4.7PF 250V +/-0.1PF 0603N	Passive Plus	0603N4R7BW251
C23	0.01uF	CAP CER 0.01UF 50V 10% 0505	Passive Plus	0505X103KP500
C24	10uF	CAP CER 10UF 16V 20% X5R 0805	Kemet	C0805C106M4PACTU
C25	10uF	CAP CER 10UF 16V 20% X5R 0805	Kemet	C0805C106M4PACTU
C26	0.1uF	CAP CER 0.1UF 16V 10% X7R 0805	Kemet	C0805C104K4RACTU
U1	F465	Sumitomo 20W GaN Amplifier	Sumitomo	F465
U2	TMP709	IC RES-PROG TEMP SWITCH SOT23-5	Texas Instruments	TMP709AIDBVT