AR231088

CLP24H4S30P, 2.4-2.5GHz

v1.0 — 07 July 2023 **Application Report**

v1.0 Document information	
Status	General Publication
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Abstract	Measurement results of 2.4-2.5GHz amplifier with the CLP24H4S30P

1. Revision History

Table 1: Report revisions

Revision	Date	Description	Author
1.0	2023.07.20	Initial document	Naser H.R Miveroud

2. Contents

3. List of figures

4. List of tables

5. Description

This report presents measurement results of Ampleon's 2.4-2.5GHz 30W GaN-HEMT driver amplifier. The device used is CLP24H4S30P, 50V GaN-HEMT transistor. The presented demo is operating at full 2.4-2.5GHz ISM band. The results are presented for a typical application. However, the demo can be tuned for different efficiency/power tradeoffs.
The CLP24H4S30P transistor comes in a 7x7 mm surface-mount DFN package. The power is enough to drive Ampleon's 350W CLF2425H4LS300P GaN-HEMT transistor. The demo has very small size of only 30 x 20 mm.

For further details and conditions, customers can contact an Ampleon marketing/sales representative.

Table 2: Mechanical characteristics

Parameter	Description	Unit
L x W	30 x 20	mm
PCB assembly height	4	mm

Table 3: Board Specifications

Parameter	Value
Manufacturer	Rogers
Type	TC350
Dk	3.5 @ 10GHz
Df	0.0037 @ 10GHz
Total PCB thickness	0.508 mm (20mil)
Copper thickness	35um (1 oz)
Board dimensions	30 x 20 mm

6. Demo Board

Figure 1 illustrates the demo board's top view. Transistor's thermal/GND pad is soldered to the PCB by total number of 56 (7x8) via array each 0.3mm in diameter and apart from each other by 0.6 mm center-to-center. Vias are type II vias (resin filled vias) to facilitate easy assembly of SMT components including the transistor.

The demo board has very compact size of 2cm x 3cm only.

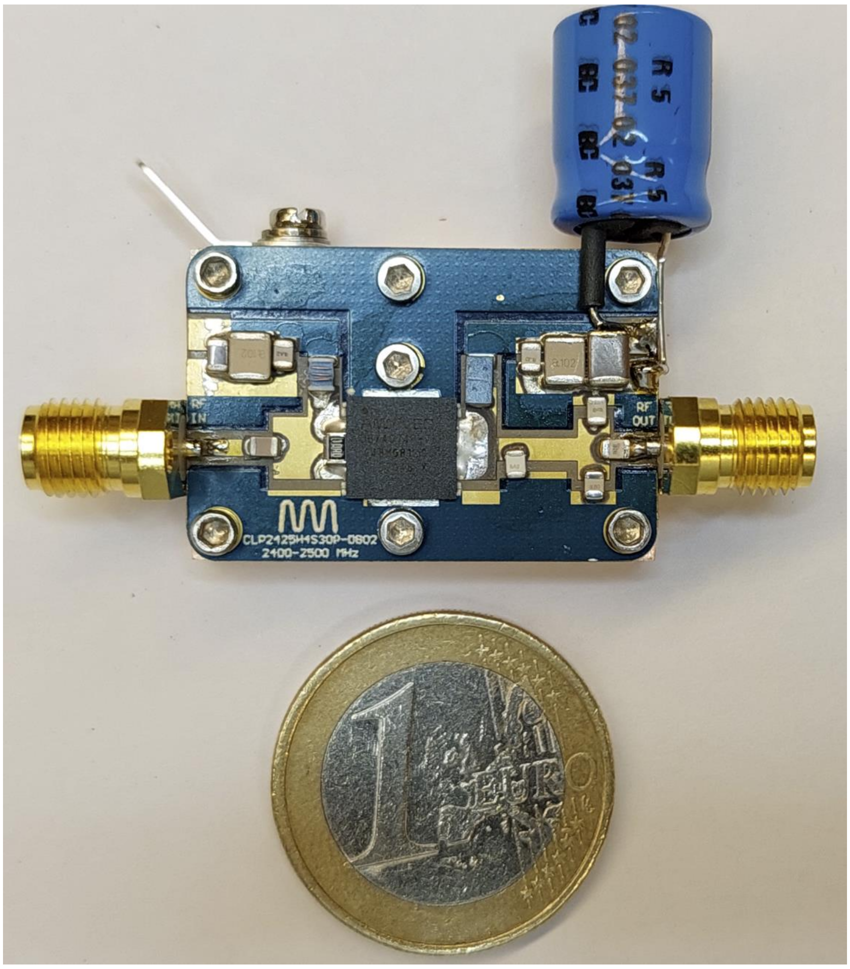

Figure 1 Demo top view

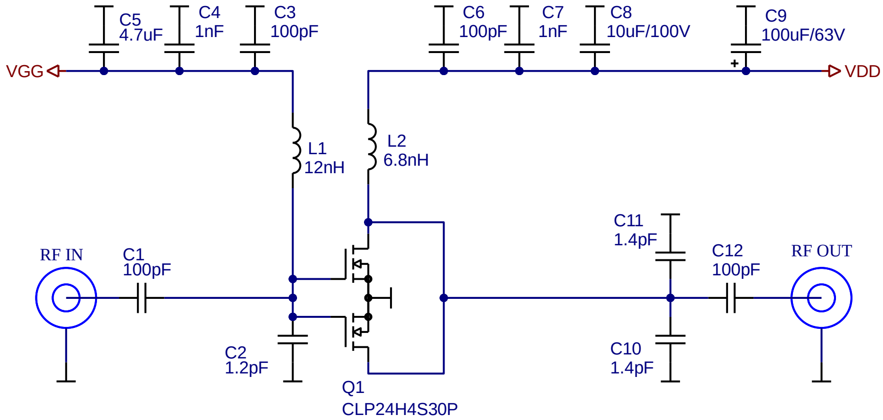

Figure 2 Schematic diagram of the demo

Table 4 summarizes the key parameters of the demo. Output power is more than 30W in CW mode. Measurement is done at the output connector (RF OUT) of the demo followed by 2.4 -2.5 GHz circulator.

Tables 5 and 6, and Figures 3 to 8 depict detailed values of the measurement for the demo.

Table 4: General Specifications, T_{base_plate} = 25ºC

Symbol	Parameter	Unit	Min	Typ	Max
F	Frequency of operation	MHz	2400	-	2500
V_{DD}	Drain voltage of GaN transistor	V	-	-	50
I_{DD}	Current consumption of GaN transistor	mA	-	800	-
P_{OUT}	Output power[1]	W	-	30	-
η_{DRAIN}	Drain efficiency[2]	%	-	75	-
Gain	Gain[3]	dB	-	17	-
P_{DISS}	Dissipated power	W	-	10	-
H	Level of harmonics	dBc	-	-	- 30

[1] *Typical output power of 30W is achieved with V_{DD} = 50V at 3dB compression point (P_{3dB}).*

[2] *Typical efficiency of 75% is achieved with V_{DD} = 50V at 3dB compression point (P_{3dB}).*

[3] *Typical Gain of 17dB achieved at 3dB compression point.*

6.1 RF characteristics

Test signal: CW; VDD = 50V, Idq =1mA; T_{base_plate} = 25ºC.

Table 5: RF characteristics in CW mode, VDD = 50V, Idq = 1mA

Freq (MHz)	Gmax (dB)	P1dB (W)	P3dB (W)	Eff_P1dB (%)	Eff_P3dB (%)	Eff_max (%)	Pout @ Eff_max (W)
2400	20.7	26.7	**33.5**	68.9	75.0	**75.1**	**33.5**
2450	20.3	21.4	**30**	69.3	78.0	**78.0**	**30**
2500	19.3	16.3	**25.5**	64.1	74.6	**74.6**	**25.5**

Test signal: CW pulsed, 100us pulse width,10% duty cycle VDD = 50V, Idq =1mA; T_{base_plate} = 25°C.

Table 6: RF characteristics in CW Pulsed mode, VDD = 50V, Idq = 1mA

Freq (MHz)	Gmax (dB)	P1dB (W)	P3dB (W)	Eff_P1dB (%)	Eff_P3dB (%)	Eff_max (%)	Pout @ Eff_max (W)
2400	21.3	25.7	**34.5**	67.2	75.9	**76.0**	**35.5**
2450	20.7	20.9	**30.5**	68.3	78.7	**78.8**	**31.0**
2500	19.6	16.4	**26**	64.2	74.8	**75.2**	**26.5**

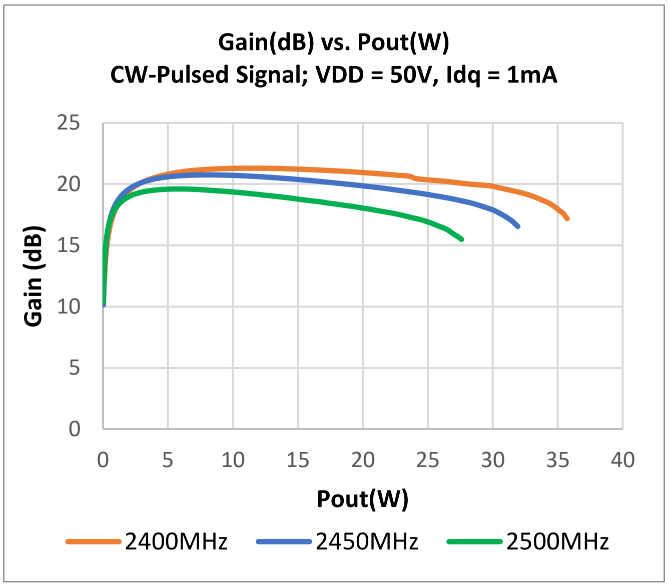

Figure 3 Gain (dB) over output power (W), CW-pulsed signal, VDD = 50V, Idq = 1mA; Pulse-Width = 100us , duty-cycle = 10%

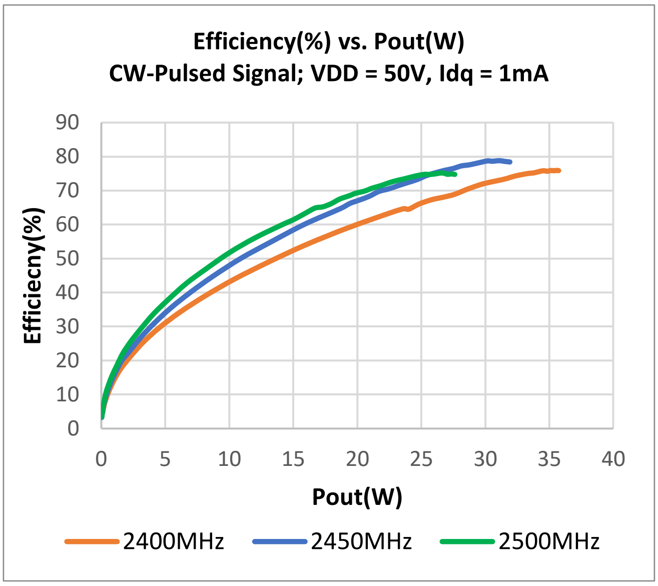

Figure 4 Efficiency (%) over output power (W), CW-pulsed signal, VDD = 50V, Idq = 1mA; Pulse-Width = 100us , duty-cycle = 10%

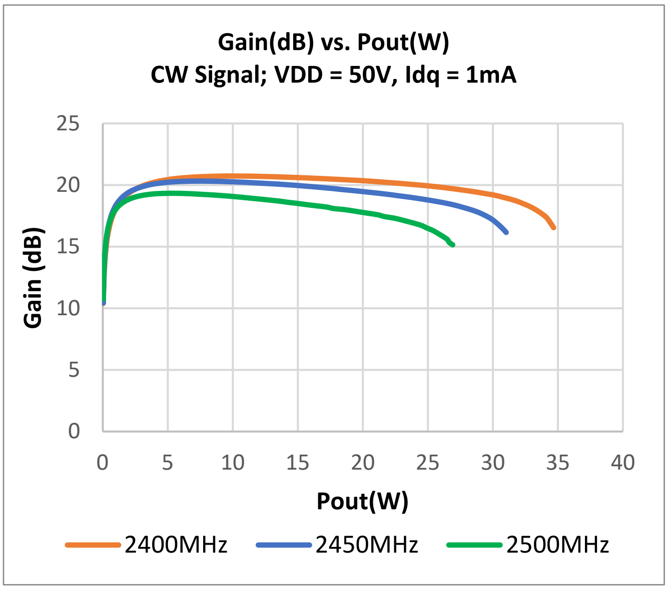

Figure 5 Gain (dB) over output power (W), CW signal, VDD = 50V, Idq = 1mA

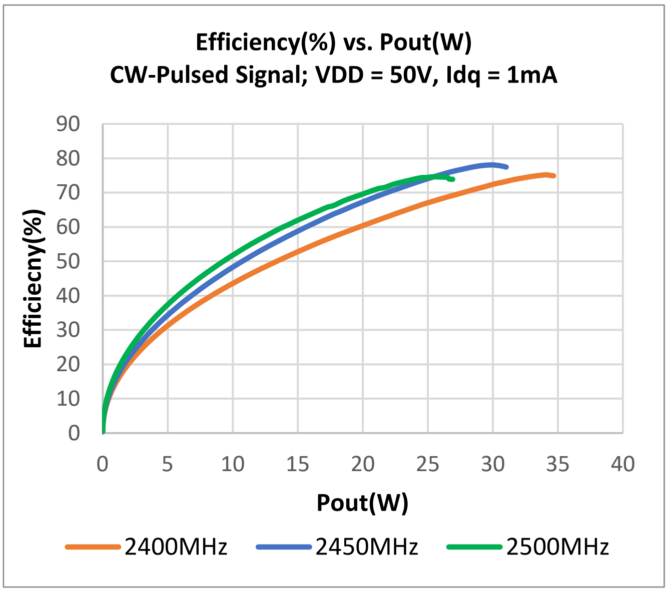

Figure 6 Efficiency (%) over output power (W), CW signal, VDD = 50V, Idq = 1mA

6.2 Thermal characteristics

Figure 7 illustrates the IR image of the demo after reaching thermal equilibrium with water cooling. The maximum temperature in the demo is 52.3 ºC. Measurements is done at f = 2.4Ghz, and P1dB = 27W under CW signal while temperature of the baseplate kept at 30ºC.

The test condition in which the IR image of Figure 7 is captured is as follows:

- CW Signal
- VDD = 50V, Idq = 1mA
- Pout = 27 W
- Efficiency = 69 %
- Gain = 19.7 dB

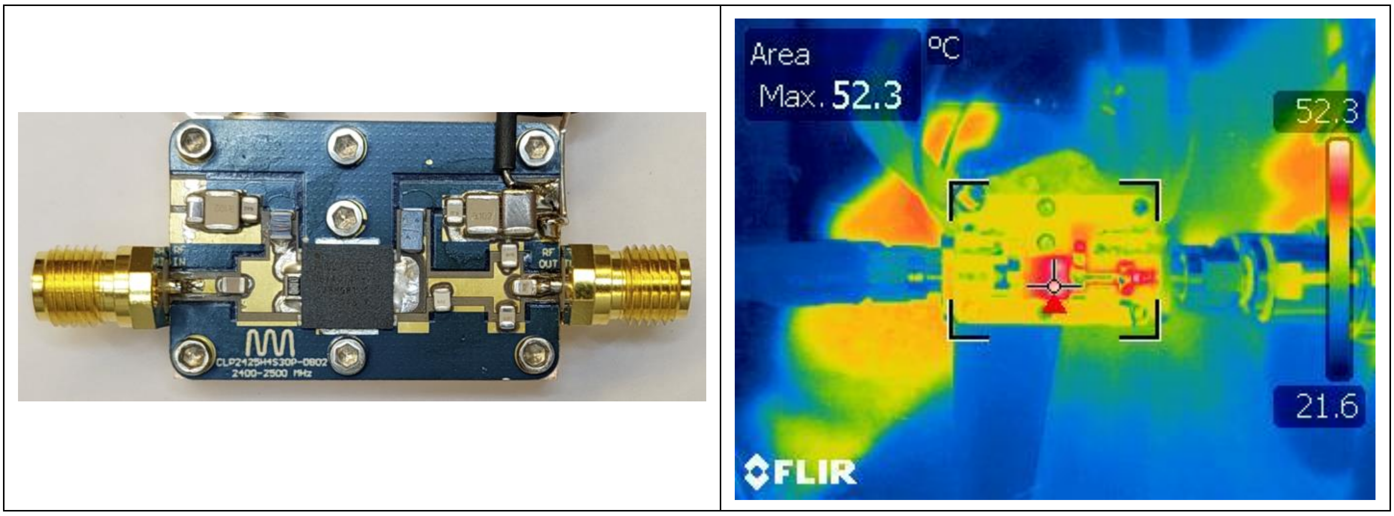

Figure 7 IR image of the demo after reaching thermal equilibrium and operating at P1dB, V_{DD} = 50V, T_{base_plate} = 30ºC

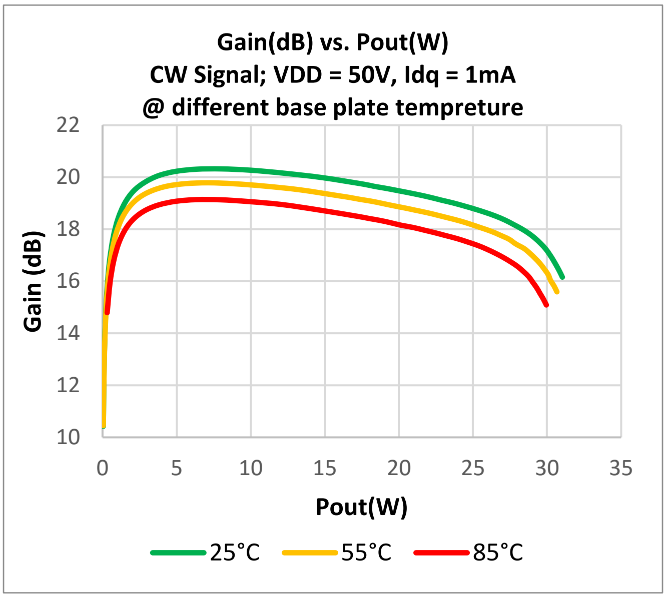

Figure 8 Gain(dB) vs. Pout(W) vs Tbase-plate (°C)

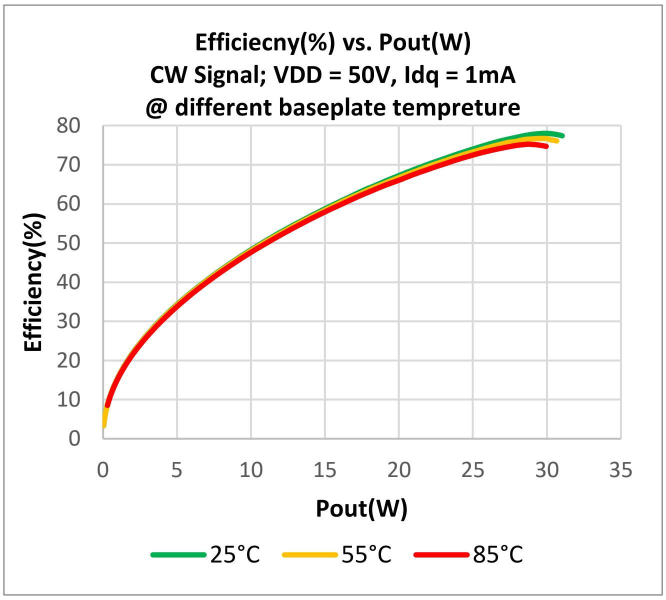

Figure 9 Efficiency (%) vs. Pout(W) vs Tbase-plate (°C)

Table 7: RF performance over temperature. CW Signal, VDD = 50V, Idq = 5mA, f = 2450MHz

Temperature (°C)	Gmax (dB)	P1dB (W)	P3dB (W)	Eff_P1dB (%)	Eff_P3dB (%)	Eff_max (%)	Pout @ Eff_max (W)
25	20.3	21.3	**29.8**	69.3	78.0	**78.0**	**29.9**
55	19.8	20.6	**29.3**	67.7	76.7	**76.7**	**29.5**
85	19.1	20.3	**28.8**	66.5	75.3	**75.3**	**28.8**

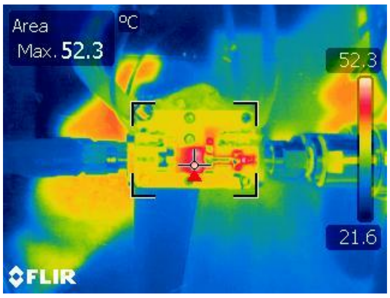

Figure 10 T_{base} = 25°C, CW signal, P1dB, 2400 MHz

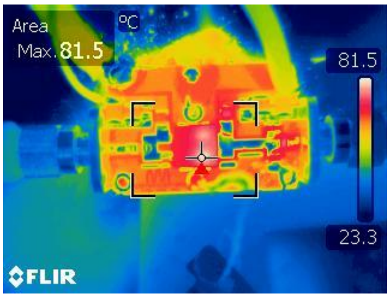

Figure 11 T_{base} = 55°C, CW signal, P1dB, 2400 MHz

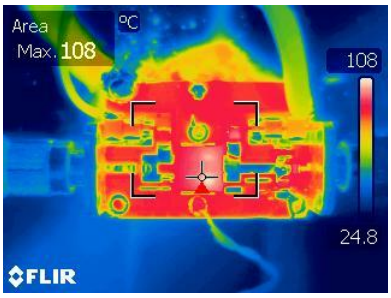

Figure 12 T_{base} = 85°C, CW signal, P1dB, 2400 MHz

7. Bill of materials

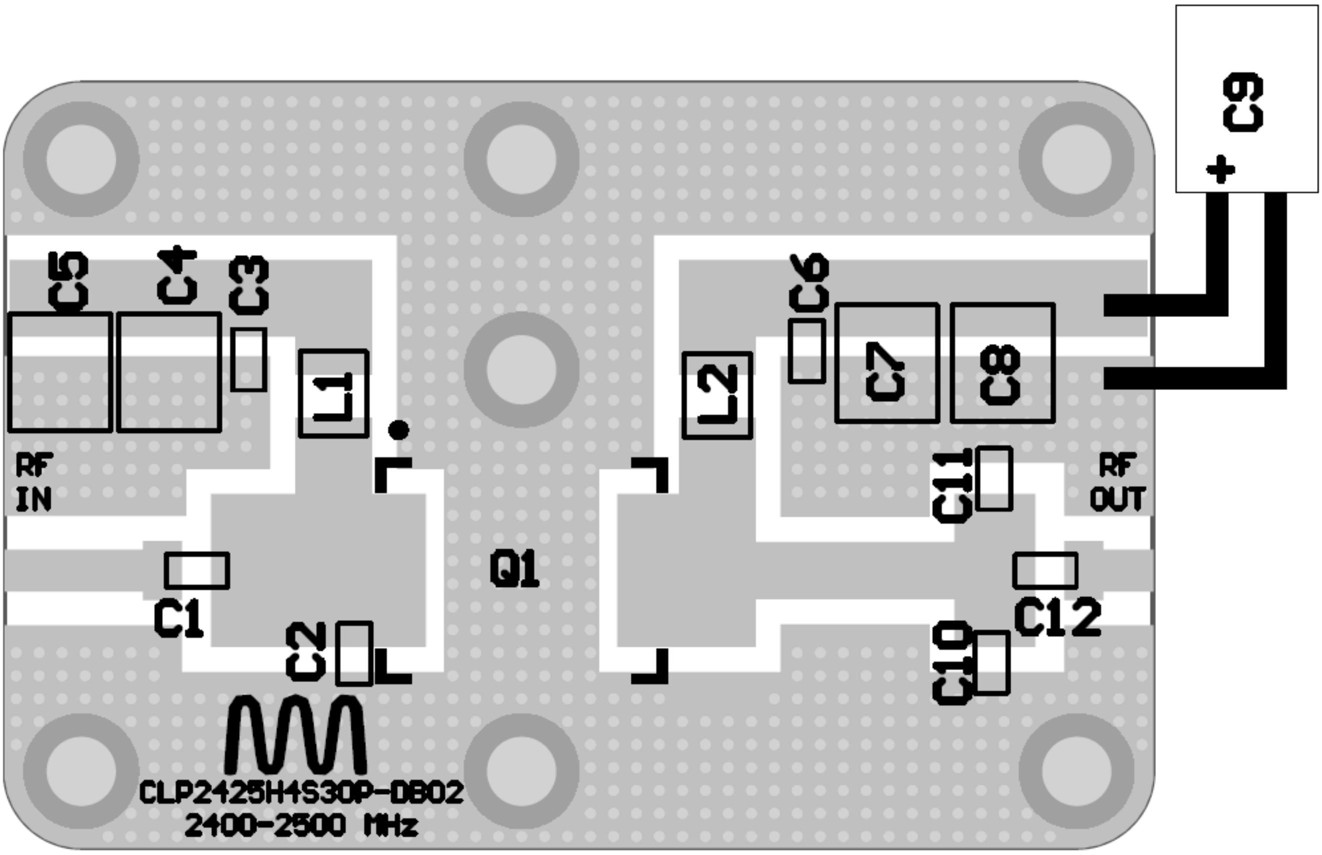

Figure 13 PCB layout and component assembly

Table 8: Bill of Materials

Designator	Group	Value	Tolerance	Name	Manufacturer	Quantity
C1, C3, C6 C12	Capacitor	100pF	±5%	ATC600F101JW250XT	ATC	4
C4, C7	Capacitor	1000pF	±10%	ATC800B102KW50XT	ATC	2
C5, C8	Capacitor	4.7uF/100V	±10%	C2012X7R1H475K	TDK	2
C2	Capacitor	1.2pF	±0.1pF	ATC600F1R2BW250XT	ATC	1
C10, C11	Capacitor	1.4pF	±0.1pF	ATC600F1R4BW250XT	ATC	1
C9	Capacitor	100uF/63V	±10%		various	2
L1	Inductor	12nH	±2%	0805HP-12NXGRC	Coilcraft	2
L2	Inductor	6.8nH	±2%	0805HP-6N8XGRC	Coilcraft	2
Q1	GaN Transistor			CLP24H4S30P	Ampleon	1
PCB Material TC350, 20mil with Type II vias						

7.2 Correct Power ON/OFF Sequence

Depletion mode transistors including GaN require proper sequence to power ON and OFF. If the correct procedure is not followed, the device can be damaged immediately or to be degraded.

To Turn the device ON:

1. Set VGS to -5V
2. Apply VDS = 50V
3. Slowly increase VGS until reaching desired Idq level
4. Apply input RF signal

To Turn the device OFF:

1. Turn the input RF signal off
2. Reduce VGS to -5V
3. Reduce VDS to 0V (in case there is a big capacitor on the drain bias, give enough time to the capacitor to be discharged)
4. Turn the VGS off (VGS =0V)

7. Abbreviations

Table 9: Abbreviations

Parameter	Description
F	Frequency
CW	Continuous Wave
Gmax	Maximum Gain
P1dB	1 dB Compression Point of the Gain
V_{DD}	Drain Voltage
VGS	Gate Voltage
η_{DRAIN}	Drain Efficiency
GaN	Gallium Nitride
VSWR	Voltage Standing Wave Ratio
δ	Duty Cycle
t_p	Pulse Width
RF	Radio Frequency
P_L	Power Delivered to 50Ω Load at RF OUT Connector
S21	Small Signal Gain (S-parameter measurement in 50Ω System)
Pin	Input Power to the Amplifier at RF IN Connector
Pout	Output Power of Amplifier at RF OUT Connector

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