AR201096

ART2K0, 13 to 41 MHz

v1.7 – Jan 27, 2022

AMPLEON

Application Report

Document information	
Status	General publication
Abstract	Measurement results of a concept module based on ART2K0 optimized for 13.5MHz, 27MHz and 41 MHz pulsed and CW applications.

1. Revision History

Table 1 – Report revisions

Revision	Date	Description	Author
1.0	2020.06.25	Initial document	Yevhen Tymofieiev
1.1	2020.07.11	Initial data for 13.5MHz (tunning A) included. RF performance for ACC and OMP packages at 27MHz	Yevhen Tymofieiev
1.2	2020.07.15	Minor updates and additional patent-related text	Coen Centen
1.3	2020.07.27	RF performance at 13.5MHz in CW mode	Yevhen Tymofieiev
1.4	2020.09.25	RF performance at 13.5MHz in pulsed mode	Yevhen Tymofieiev
1.5	2020.12.09	Updated performance at 27MHz. 13.5 and 41MHz will follow in the next revision	Yevhen Tymofieiev
1.6	2021.03.11	Updated performance at 13.5MHz. Added general comments on thermal management. 41MHz will follow in the next revision	Yevhen Tymofieiev
1.7	2022.01.27	Updated performance at 27 and 41MHz	Yevhen Tymofieiev

2. Contents

3. List of figures

4. List of tables

5. General description

This report presents the measurement results of the push-pull class E demo amplifier designed for ISM applications at various frequencies from 13 to 41 MHz using ART2K0, Advanced Rugged Technology (ART) LDMOS power transistor.

The transistor version in overmolded plastic package (ART2K0PE) with straight leads has been used to enable the automated assembly process. It is expected that the modules based on the ceramic package (ART2K0FE) and overmolded plastic gullwing package (ART2K0PEG) would have comparable performance.

The module was tuned for three subbands to get maximum performance at 13.5 MHz (tuning A), 27MHz (tuning B) and 41MHz (tuning C). **Only the values/position of some critical SMD components have been changed**.

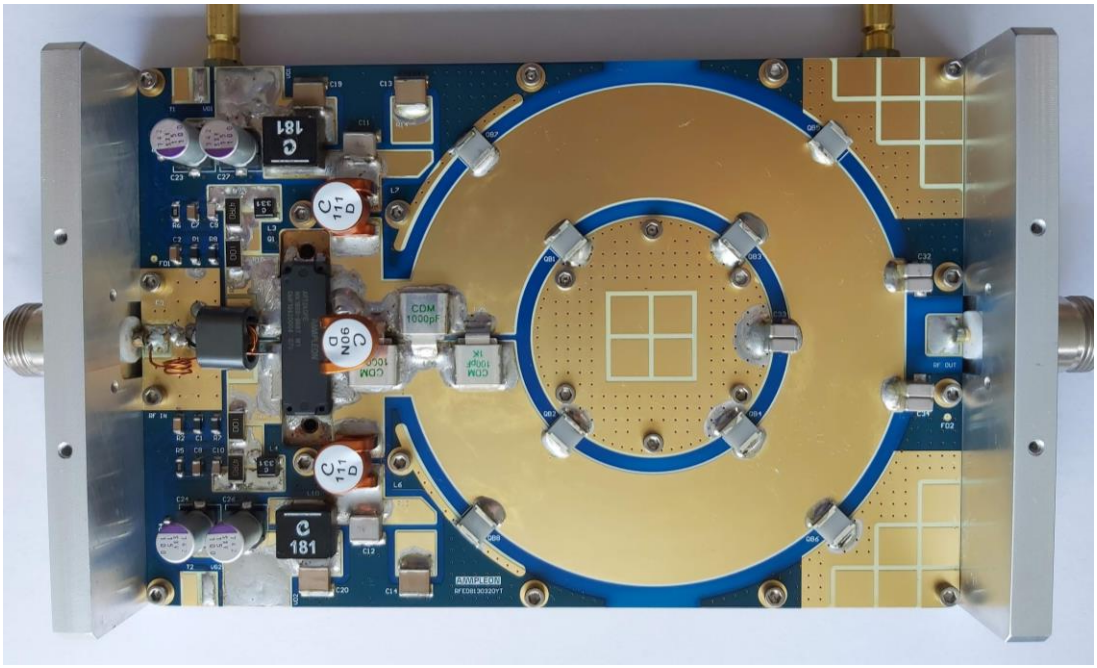

Figure 1 – View of the push-pull class E amplifier

Table 2 – Mechanical characteristics

Parameter	Description	Unit
L x W	172 x 114	mm
PCB assembly height	20	mm

For more information related to module design, bill of materials, integration, please contact Ampleon marketing/sales representative.

5.1 Push-pull class E amplifier

The designed amplifier is a push-pull class E amplifier based on a balun realized using a multi-layer printed circuit board. Ampleon has made an invention for this structure to keep the printed circuit board size limited and the amplifier performance still very high. For this invention, Ampleon has filed a Patent. Customers can make royalty-free use of this Patent in their amplifier whenever they do this in combination with the use of Ampleon devices.

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

5.2 Thermal performance

The amplifier can operate in CW mode with an output power of 1kW and higher. Because the losses in the balun rise with the frequency, only the 41MHz variant (tuning C) requires the use of the thermally conductive interface (gap pad) under balun. Thermal management of the balun in the 13.5MHz and 27MHz variants (tuning A and B) can be done just with the thermally conductive SMD bridges (Q-bridges).

6. 13.5MHz Amplifier (tuning A)

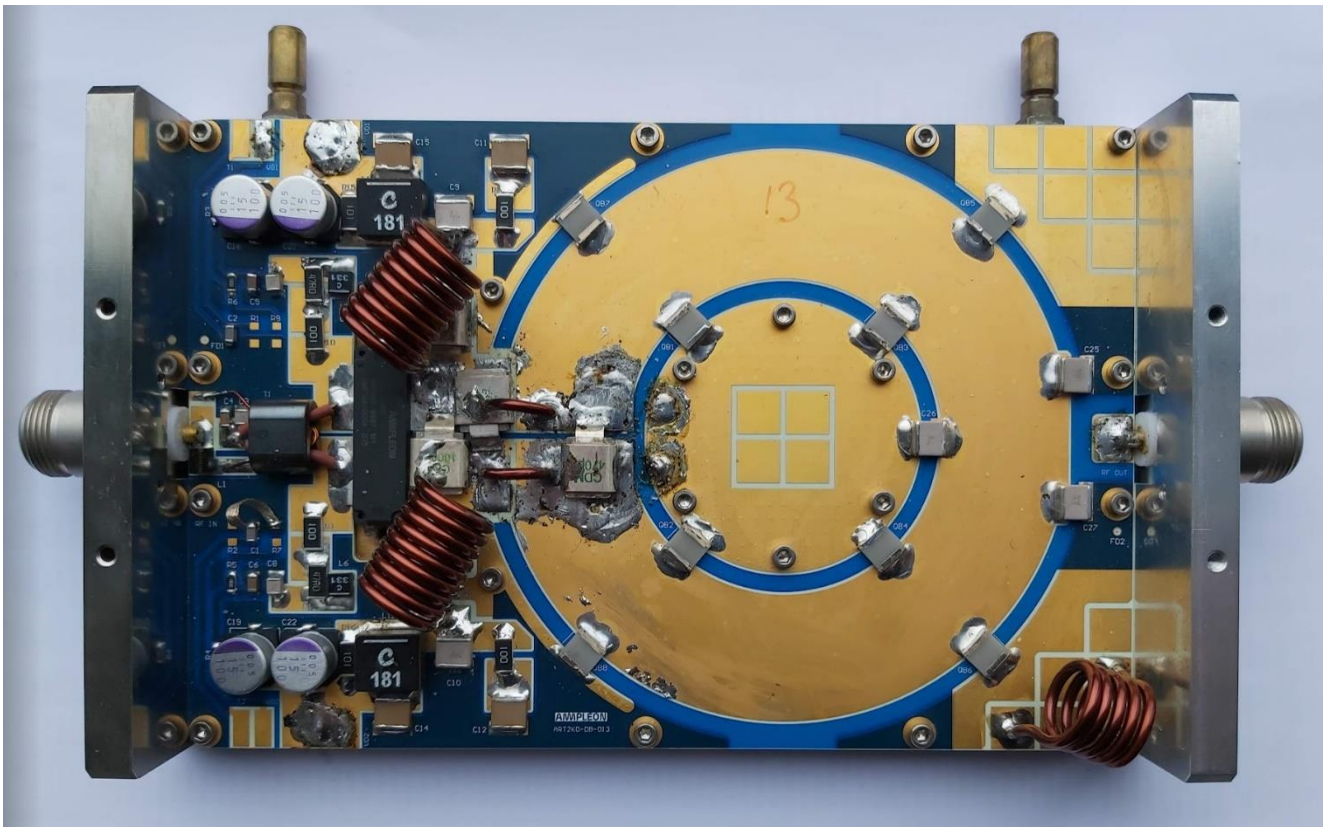

Figure 2 – View of the push-pull class E amplifier. Tuning A

6.1 RF characteristics

Table 3 – RF characteristics at F=13.5MHz in CW mode (tuning A, max efficiency tuning), ART2K0PE

Test signal: F=13.5MHz, CW; total I_{Dq}=100mA; $T_{cooling\ water}$ =25°C

V_{DS}	Gmax (dB)	P1dB (W)	P6dB (W)	P10dB (W)	Eff_P1dB (pct)	Eff_P6dB (pct)	Eff_P10dB (pct)
50	32.6	605	**892**	913	74.5	**89.1**	89.8
55	33.0	704	**1078**	1103	73.0	**89.0**	89.7

The amplifier was driven with the sine wave at the input. Driving the amplifier with a square wave signal may boost performance. Results of ongoing research to be added in the next version of the application report.

Although none of the amplifiers failed during the extensive tests with 10, 12 and 14dB compression, it is not recommended to overdrive transistors that hard due to possible long-term reliability issues.

The amplifier was tuned for max efficiency by adding the 150nH serial inductor between the RFOUT pad on PCB and the output connector (not shown in the picture).

The level of harmonics remains low at any compression level thanks to the excellent amplitude and phase balance of the balun.

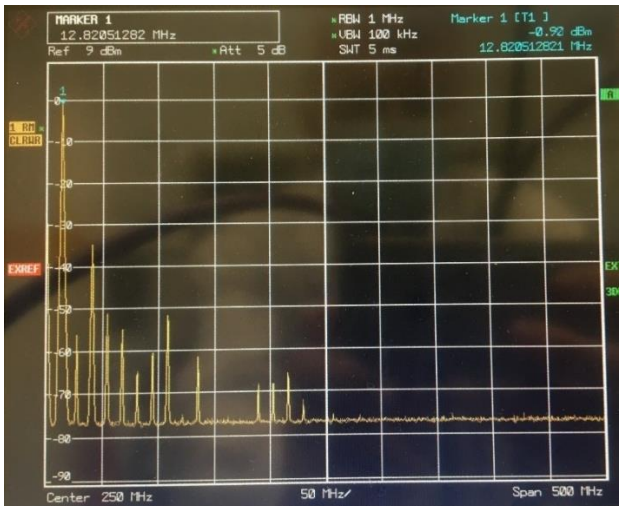

Figure 3 – Level of harmonics at P3dB, 13.5MHz (tuning A)

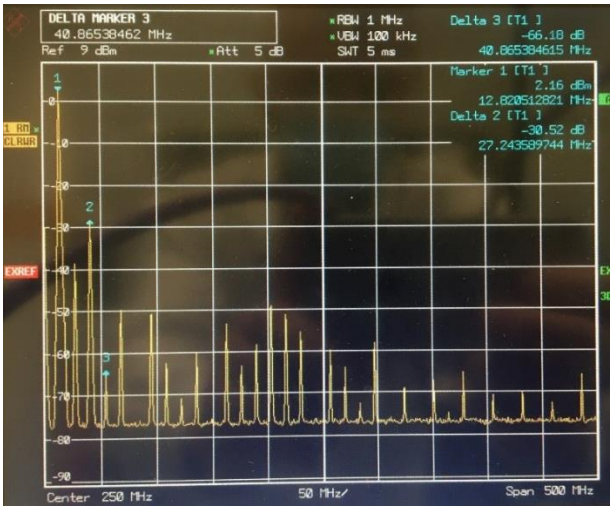

Figure 4 – Level of harmonics at P12dB, 13.5MHz (tuning A)

6.2 Ruggedness at 13.5MHz (tuning A)

Ruggedness was tested using shorted 45° coaxial cables at the output of the demo amplifier, Vds=55V, P12dB. VSWR of the load with the shortest cable - 70:1, VSWR of the load with the longest cable - 40:1.

Test signal: CW pulsed, 100us pulse width, 10% duty cycle.

Test result: **passed at all phases.**

7. 27MHz Amplifier (tuning B)

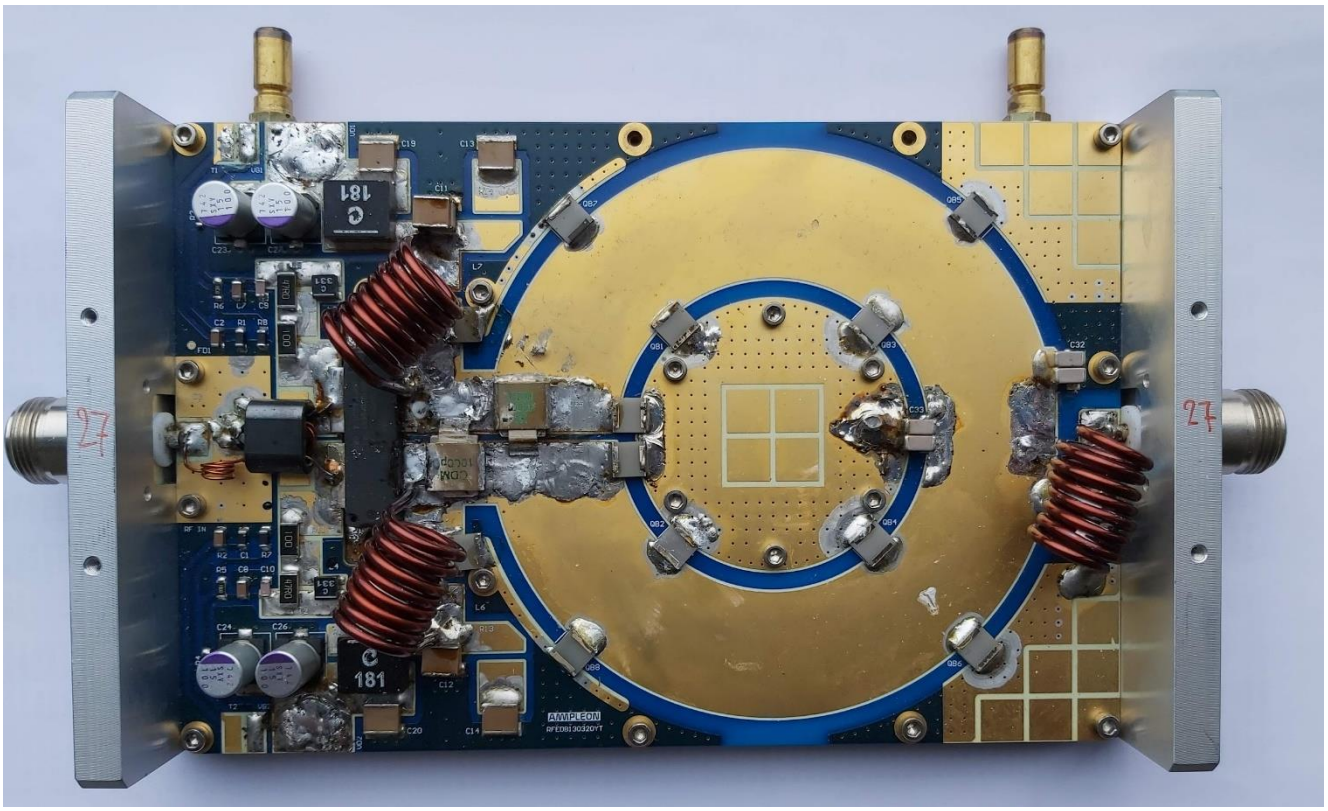

Figure 5 – View of the push-pull class E amplifier. Tuning A

7.1 RF characteristics

Table 4 – RF characteristics at F=27MHz in CW mode (tuning B, optimal power/efficiency), ART2K0PE

Test signal: F=27MHz, CW; total I_{Dq}=100mA; $T_{cooling\ water}$ =25°C

V_{DS}	Gmax (dB)	P1dB (W)	P6dB (W)	P10dB (W)	Eff_P1dB (pct)	Eff_P6dB (pct)	Eff_P10dB (pct)
45	28.6	445	**999**	1027	56.4	**86.3**	87.7
50	28.8	481	**1129**	1169	54.9	**85.9**	87.5

Table 5 – RF characteristics at F=27MHz in CW mode (tuning B, max efficiency), ART2K0PE*

Test signal: F=27MHz, CW; total I_{Dq}=100mA; $T_{cooling\ water}$ =25°C

V_{DS}	Gmax (dB)	P1dB (W)	P6dB (W)	P10dB (W)	Eff_P1dB (pct)	Eff_P6dB (pct)	Eff_P10dB (pct)
45	28.8	425	**836**	856	60.8	**87.2**	88.4
50	29.2	455	**1005**	1059	57.8	**86.9**	88.1

*- To tune for max efficiency, add a 50-100nH inductor between RF_out pad on PCB and output connector.

The amplifier was driven with the sine wave at the input. Driving the amplifier with a square wave signal may boost performance. Results of ongoing research to be added in the next version of the application report.

Although none of the amplifiers failed during the extensive tests with 10, 12 and 14dB compression, it is not recommended to overdrive transistors that hard due to possible long-term reliability issues.

The level of harmonics remains low at any compression level thanks to the excellent amplitude and phase balance of the balun. 9th harmonic seems to be resonating in the cavity under the balun, but still quite low around -30dBc.

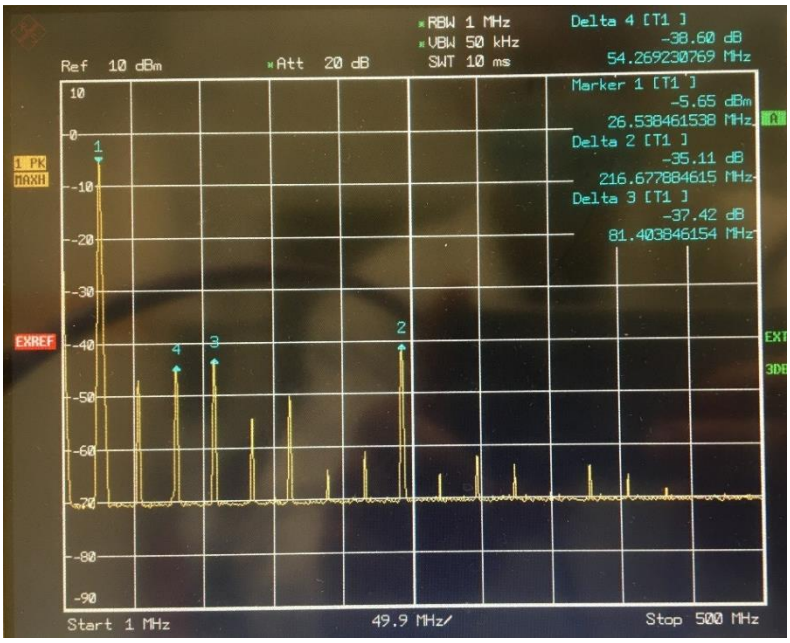

Figure 6 – Level of harmonics at P3dB, 27MHz (tuning B)

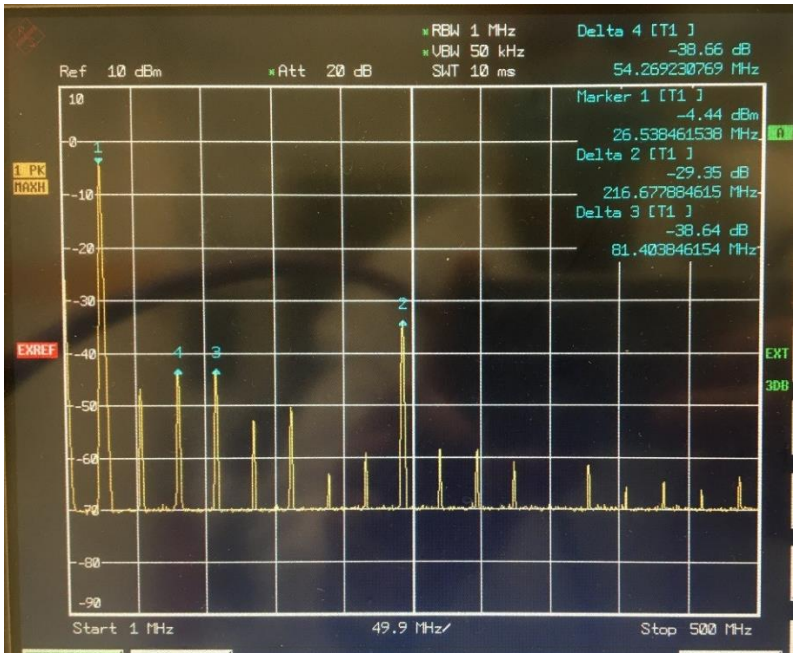

Figure 7 – Level of harmonics at P12dB, 27MHz (tuning B)

7.2 Thermal performance at 27MHz (tuning B)

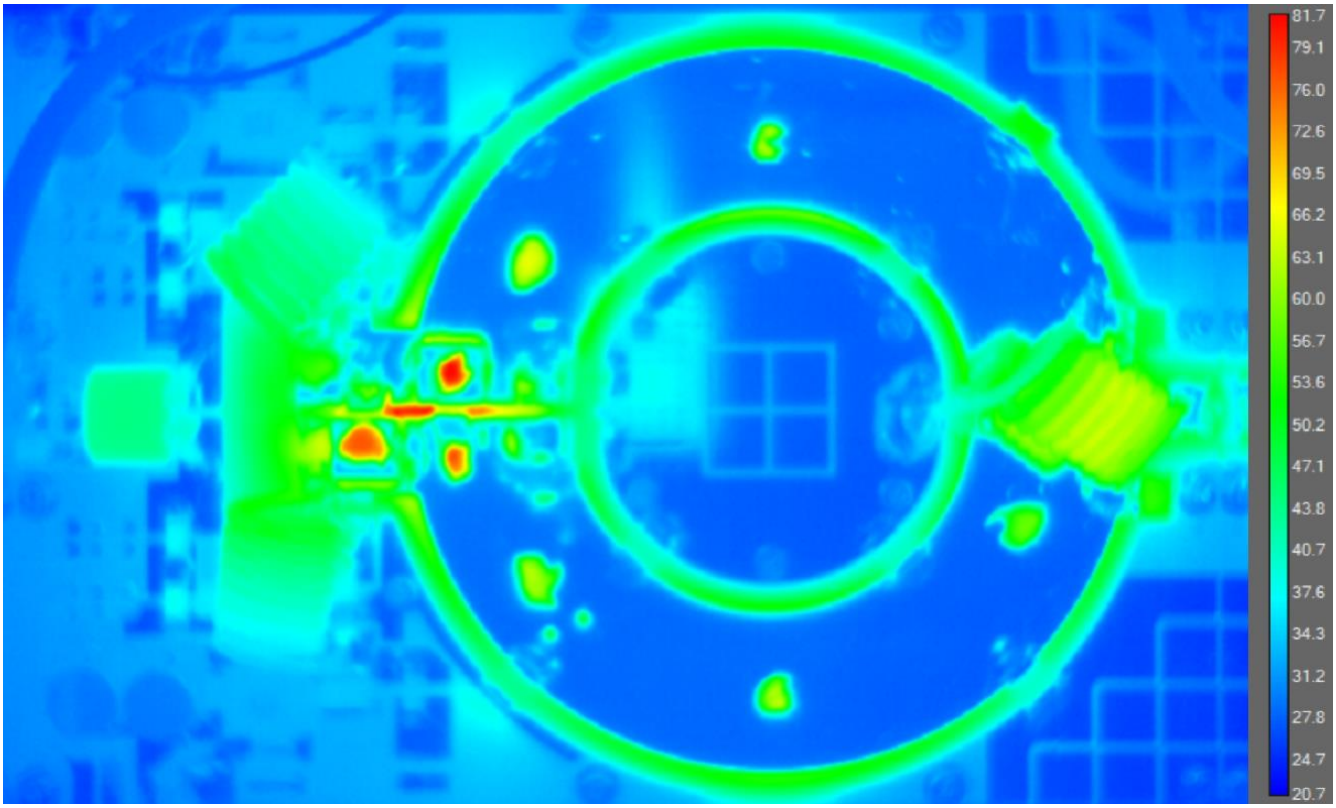

Figure 8 – Thermal performance at 27MHz (tuning B)

Thermally conductive SMD bridges (Q-bridges) help to reduce max temperature from 110°C to 82°C.

Another option could be a local use of the thermally conductive interface (gap pad) under a matching capacitor.

7.3 Ruggedness at 27MHz (tuning B)

Ruggedness was tested using shorted 45° coaxial cables at the output of the demo amplifier, Vds=48V, P12dB. VSWR of the load with the shortest cable - 70:1, VSWR of the load with the longest cable - 40:1.

Test signal: CW pulsed, 100us pulse width, 10% duty cycle.

Test result: **passed at all phases.**

7.4 Degradation of RF characteristics under mismatch (VSWR 2:1)

RF performance was tested using 90° coaxial cables between the output of the demo amplifier and 25 Ohm load (VSWR 2:1). Test signal: CW pulsed, 100us pulse width, 10% duty cycle.

Table 6 – RF characteristics under mismatch; tuning B, max efficiency; F=27MHz; pulsed mode; Vds=45V; ART2K0PE

VSWR	Phase (°)	Gmax (dB)	P1dB (W)	P3dB (W)	P6dB (W)	Eff_P1dB (pct)	Eff_P3dB (pct)	Eff_P6dB (pct)
1.05 *	-	28.6	433	703	827	61.6	79.6	87.2
2 **	0	29.6	624	714	734	69.9	73.3	74.4
2	90	29.3	354	487	522	78.4	93.3	96.5
2	180	29.3	447	635	720	77.3	92.3	95.3
2	270	28.3	559	985	1428	55.4	74.3	90.0

* - VSWR of the dummy load 50 Ohm.
** - VSWR of two 50 Ohm dummy loads connected in parallel equivalent to the single 25 Ohm load at the output of the amplifier.

8. 27-41MHz Amplifier (tuning C)

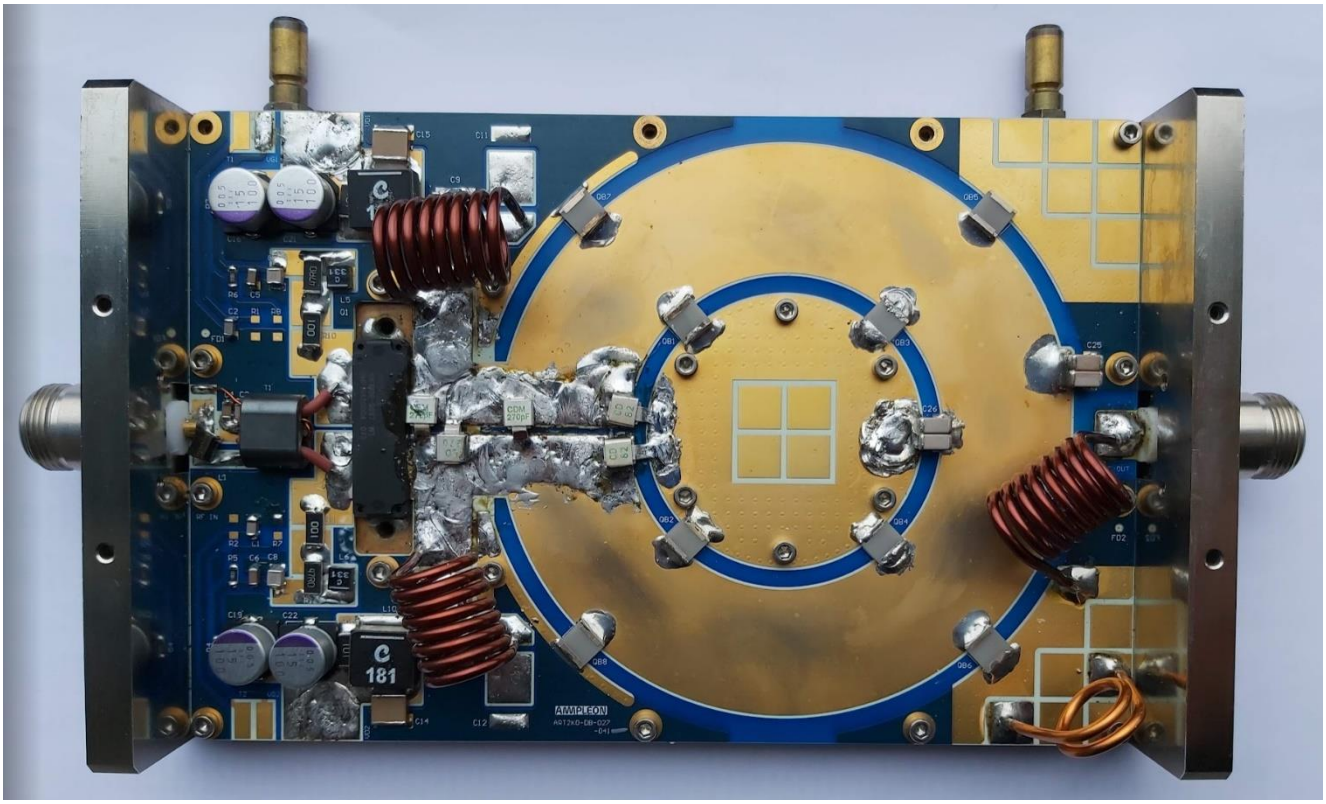

Figure 9 – View of the push-pull class AB amplifier. Tuning C

8.1 RF characteristics

Table 7 – RF characteristics in CW mode, 65V, tuning C, ART2K0PE*

Test signal: Vds=65V, CW; total I_{Dq}=100mA; $T_{cooling\ water}$ =25°C

F (MHz)	Gmax (dB)	P1dB (W)	P3dB (W)	P6dB (W)	Eff_P1dB (pct)	Eff_P3dB (pct)	Eff_P6dB (pct)
25	30.2	506	923	1371	33.9	46.2	63.5
27.12	**30.1**	**689**	**1336**	**1822**	**44.5**	**63.1**	**73.8**
30	30.2	779	1139	1529	48.7	59.5	69.0
35	29.3	890	1287	1689	50.4	60.3	68.4
40	28.9	1119	1795	1899	57.4	72.0	75.6
40.68	**28.8**	**1262**	**1815**	**1914**	**61.5**	**72.9**	**76.2**
45	29.2	720	1123	1716	50.8	63.5	78.4

* - CW performance shown is for reference only. Use more mica/PTFE capacitors in parallel to reduce the temperature of hot spots in CW mode.

Table 8 – RF characteristics in CW mode, 50V, tuning C, ART2K0PE

Test signal: Vds=50V, CW; total I_{Dq}=100mA; $T_{cooling\ water}$ =25°C

F (MHz)	Gmax (dB)	P1dB (W)	P3dB (W)	P6dB (W)	Eff_P1dB (pct)	Eff_P3dB (pct)	Eff_P6dB (pct)
25	29.3	491	1156	1262	43.9	73.7	77.8
27.12	**29.5**	**593**	**1018**	**1204**	**54.5**	**72.6**	**79.0**
30	29.4	571	817	1060	55.0	66.2	75.2
35	28.7	655	925	1205	56.2	66.7	75.1
40	28.4	995	1212	1331	70.8	77.0	79.3
40.68	**28.3**	**1018**	**1225**	**1323**	**72.3**	**78.2**	**80.5**
45	28.7	468	735	1078	54.5	67.3	81.1

8.2 Thermal performance at 41MHz (tuning C)

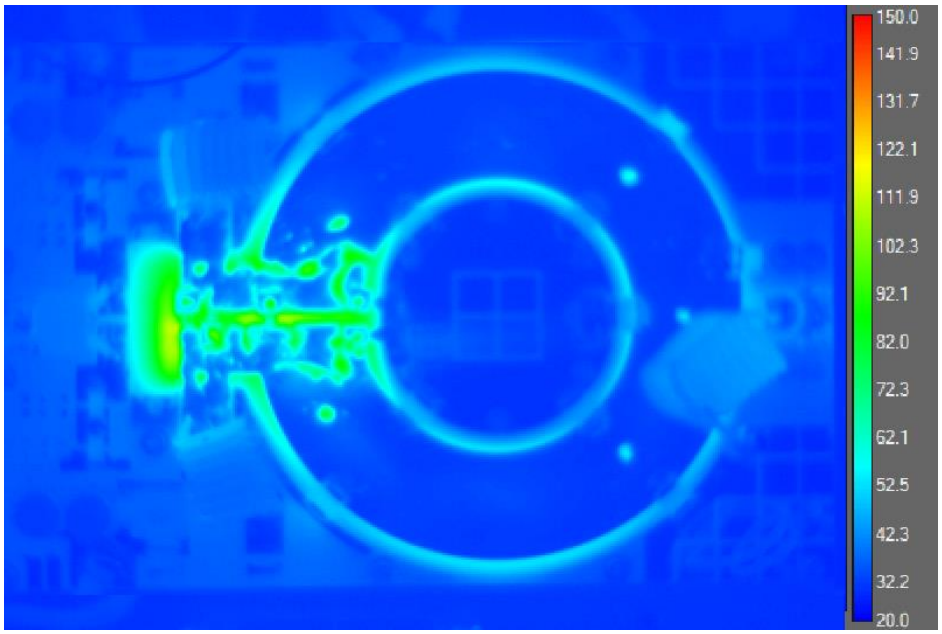

Figure 10 – Thermal performance at 41MHz, P1dB (1000W CW), tuning C

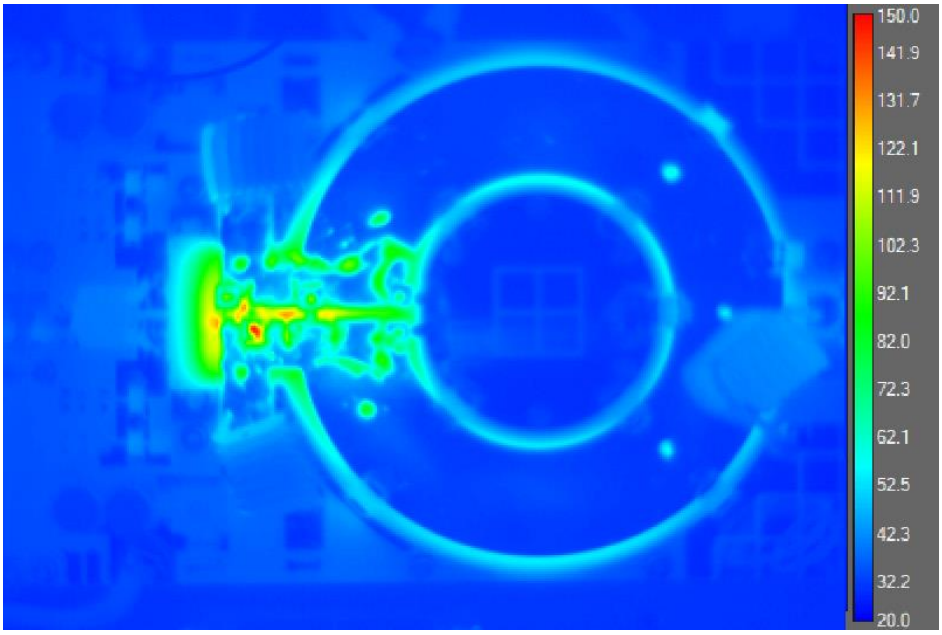

Figure 11 – Thermal performance at 41MHz, P3dB (1200W CW), tuning C

9. Legal information

9.1 Definitions

Draft — The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. Ampleon does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

9.2 Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, Ampleon does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. Ampleon takes no responsibility for the content in this document if provided by an information source outside of Ampleon.

In no event shall Ampleon be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, Ampleon's aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Terms and conditions of commercial sale of Ampleon.

Right to make changes — Ampleon reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

Suitability for use — Ampleon products are not designed, authorizedthe or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an Ampleon product can reasonably be expected to result in personal injury, death or severe property or environmental damage. Ampleon and its suppliers accepts no liability for inclusion and/or use of Ampleon products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

Applications — Applications that are described herein for any of these products are for illustrative purposes only. Ampleon makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using Ampleon products, and Ampleon accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the Ampleon product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

Ampleon does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using Ampleon products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). Ampleon does not accept any liability in this respect.

Export control — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from competent authorities.

9.3 Trademarks

Notice: All referenced brands, product names, service names and trademarks are the property of their respective owners.

Any reference or use of any 'NXP' trademark in this document or in or on the surface of Ampleon products does not result in any claim, liability or entitlement vis-à-vis the owner of this trademark. Ampleon is no longer part of the NXP group of companies and any reference to or use of the 'NXP' trademarks will be replaced by reference to or use of Ampleon's own trademarks.

9.4 Contact information

For more information, please visit: http://www.ampleon.com

For sales office addresses, please visit: http://www.ampleon.com/sales