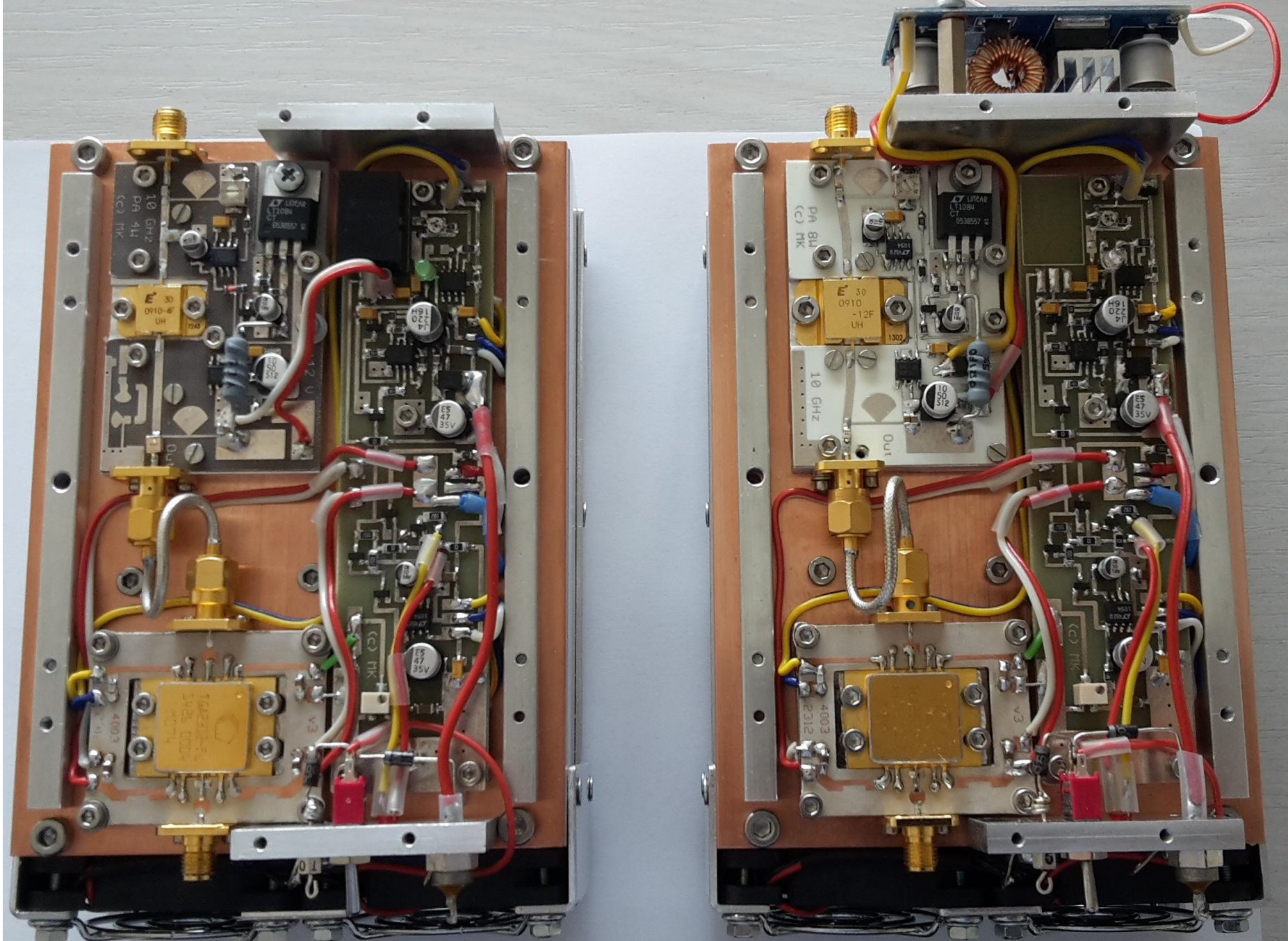


50 W SSPA 10 GHz

Mirek Kasal, OK2AQ

mirek@kasals.com

<http://www.urel.feec.vutbr.cz/esl/files/EME/EME.htm>



EME a MW seminář, Tři Studně, Březen 24-26, 2017

Outline

1. Why such high power? And why SSPA ?
2. New technology
3. TGA 2312FL and similar MMIC
4. Construction of the PA end stage
5. Driver
6. Supply and control circuits

OK2AQ

$$d1 = 1,8 \text{ m}$$

$$A1 = 2,5 \text{ m}^2$$

$$G1 = 43,6 \text{ dBi}$$

$$\text{EiRP1} = 56,6 \text{ dBi(W)}$$

= 457 kW

VK7MO

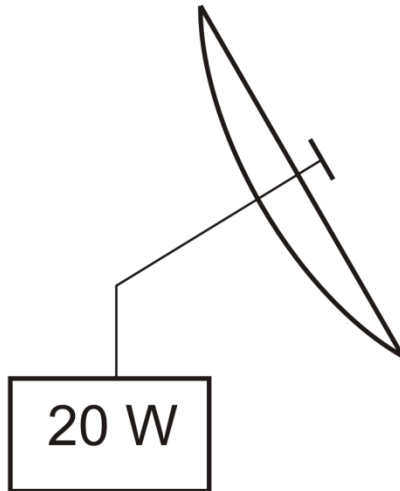
$$d2 = 0,77 \text{ m}$$

$$A2 = 0,5 \text{ m}^2$$

$$G2 = 36,2 \text{ dBi}$$

$$\text{EiRP2} = 53,2 \text{ dBi(W)}$$

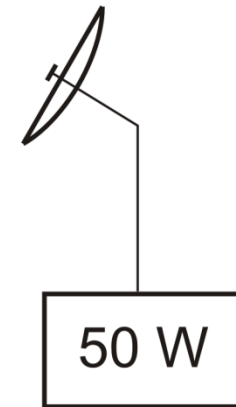
= 209 kW



S2/N

$$S2/N = \frac{P_2 G_2 L_0 G_1}{k T_s B_n}$$

$$S1/N = \frac{P_1 G_1 L_0 G_2}{k T_s B_n}$$



S1/N = S2/N - 4 dB

$$\frac{S_2}{S_1} = \frac{P_2}{P_1} \Rightarrow 10 \log \frac{50}{20} = 4 \text{ dB}$$

GaAs FET – 12 V, X A
 $\eta \sim 25\%$

SSPA

GaN FET – 24 V, $<X/2$ A
 $\eta \sim 40\%$

Higher gain,
Better thermal stability,
MMIC

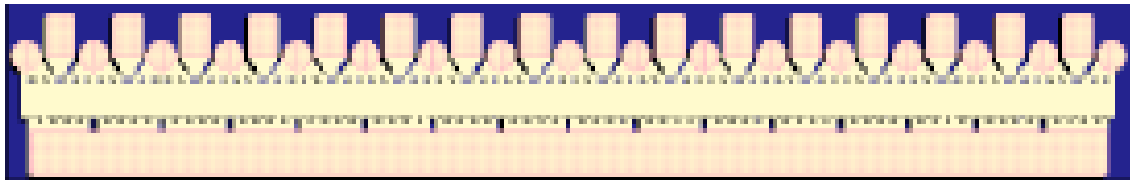
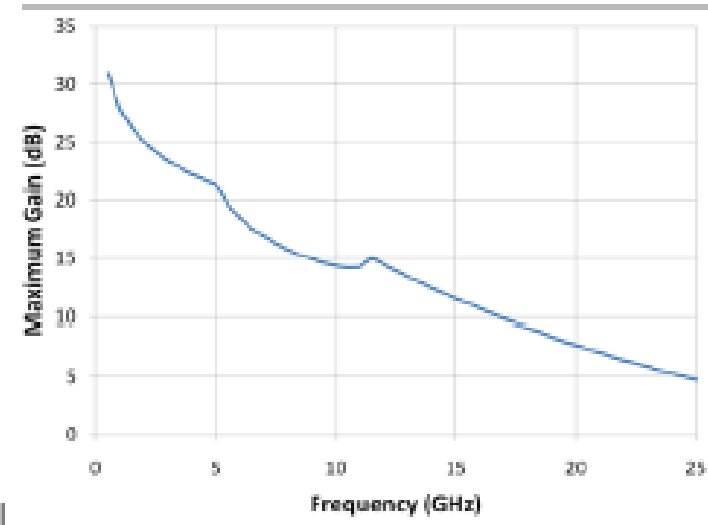
TWT High voltage in
outdoor environment

90 Watt Discrete Power GaN on SiC HEMT

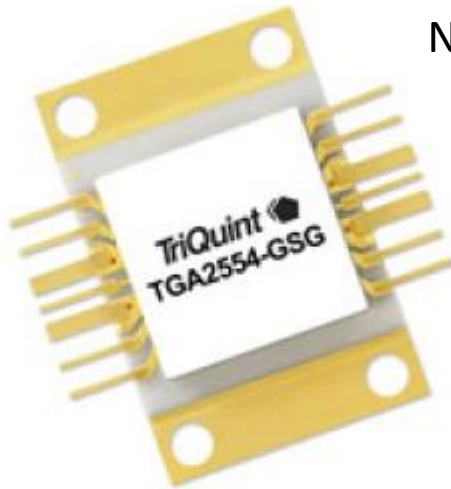
Key Features

- Frequency Range: DC - 18 GHz
- 49.6 dBm Nominal Psat at 3 GHz
- 52% Maximum PAE
- 17.5 dB Nominal Power Gain
- Bias: $V_d = 28 - 32$ V, $I_{dq} = 2$ A, $V_g = -3.6$ V Typical
- Technology: 0.25 μ m Power GaN on SiC
- Chip Dimensions: 0.82 x 4.56 x 0.10 mm

Bias conditions: $V_d = 28$ V, $I_{dq} = 2$ A, $V_g = -3.6$ V Typical



Now TriQuint + RFMD = Qorvo



Frequency (GHz)	Power (dBm)	Gain (dB)	NF (dB)	PAE (%)	Voltage (V)	IQ (mA)
8 to 11	43.5	25	-	>25	14	3,600

Product Features

- Frequency range: 8 - 11 GHz
- Saturated output power: 43.5 dBm
- Small signal gain: 25 dB
- Bias: $V_d = 14$ V, $I_{dq} = 3.6$ A, $V_g = -0.6$ V typical



Zvětšit obrázek

Č. části Mouser: 772-TGA2312-FL
Číslo části výrobce: TGA2312-FL
Výrobce: TriQuint Semiconductor
Popis: VF zesilovač 9-10GHz Gain 13dB PAE
38% GaN 60W

[Další informace o TriQuint Semiconductor TGA2312-FL](#)

[Technické informace](#)

Obrázky jsou pouze pro referenční účely
Viz specifikace produktu

[Přidat do seznamu pro srovnání](#)

Share |



Specifikace

Dokumenty (1)

Mé poznámky

Výrobce:

TriQuint

Dostupnost v reálném čase

Na skladě:	0
Na objednávce:	0
Dodací lhůta výrobce	16 týdnů/týdnů

Zadejte množství:

Koupit

Minimum: 1
Vícenásobné: 1

Stanovení ceny (EUR)

1: 871,50 €
25: Nabídka

Pro vývoz ze Spojených států může být u tohoto zboží vyžadována další dokumentace.

Stanovení ceny (CZK)

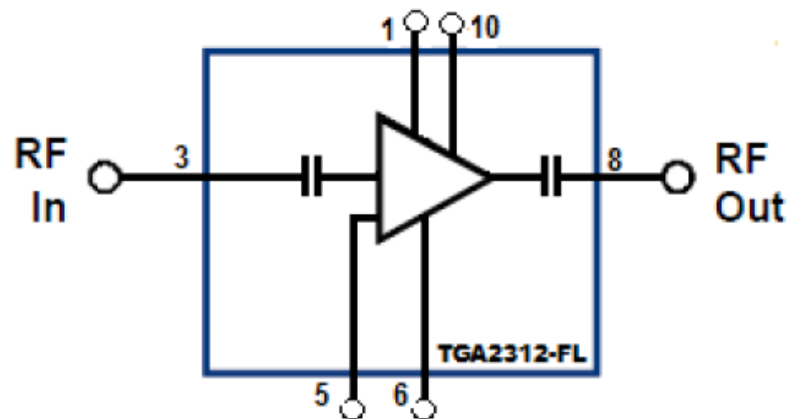
1: 30 674,70 Kč

Chcete-li doplnit projekt, prosím [Přihlásit se](#).

Product Features

- Frequency Range: 9 – 10 GHz
- P_{SAT} : 48 dBm
- PAE: 38%
- Small Signal Gain: 13 dB
- Bias: $V_D = 24$ V, $I_{DQ} = 2.4$ A, $V_G = -2.6$ V Typical
- Pulsed: PW = 100us, DC = 10%
- Integrated Thermistor Temperature Monitor
- Package Dimensions: 17.4 x 24.0 x 3.9 mm

Functional Block Diagram



Electrical Specifications

Test conditions unless otherwise noted: 25 °C, $V_D = 24$ V, $I_{DQ} = 2400$ mA, Pulsed: PW = 100us, DC = 10%, $V_G = -2.6$ V

Parameter	Min	Typical	Max	Units
Operational Frequency Range	9		10	GHz
Small Signal Gain		13		dB
Input Return Loss		15		dB
Output Return Loss		14		dB
Output Power at Saturation ($P_{in} = 38$ dBm)		48		dBm
Power-Added Efficiency ($P_{in} = 38$ dBm)		38		%
Output TOI		49		dBm
Gain Temperature Coefficient		-0.02		dB/°C
Power Temperature Coefficient		-0.001		dBm/°C
TOI Temperature Coefficient		-0.001		dBm/°C

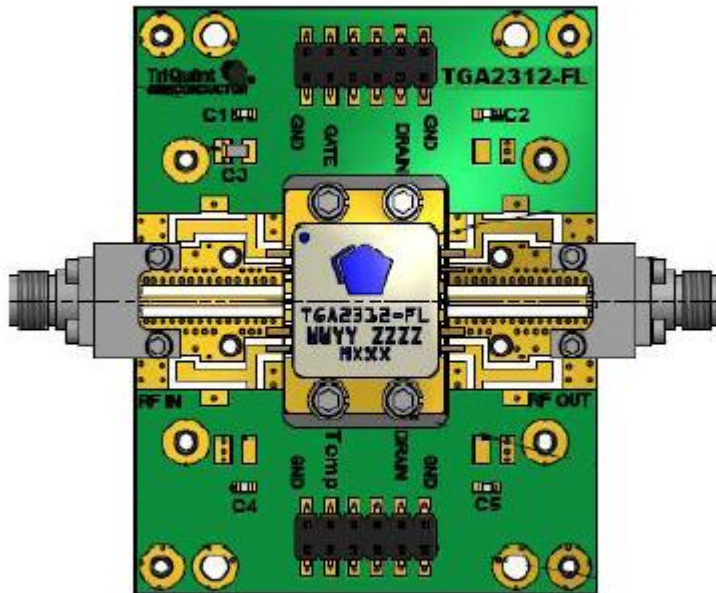
ACKNOWLEDGEMENT

THANKS to Dominique HB9BBD and Eddy ON7UN for help with TGA2312FL provision

THANKS to Charlie G3WDG for help and support with TGA2312FL bearing and PCB

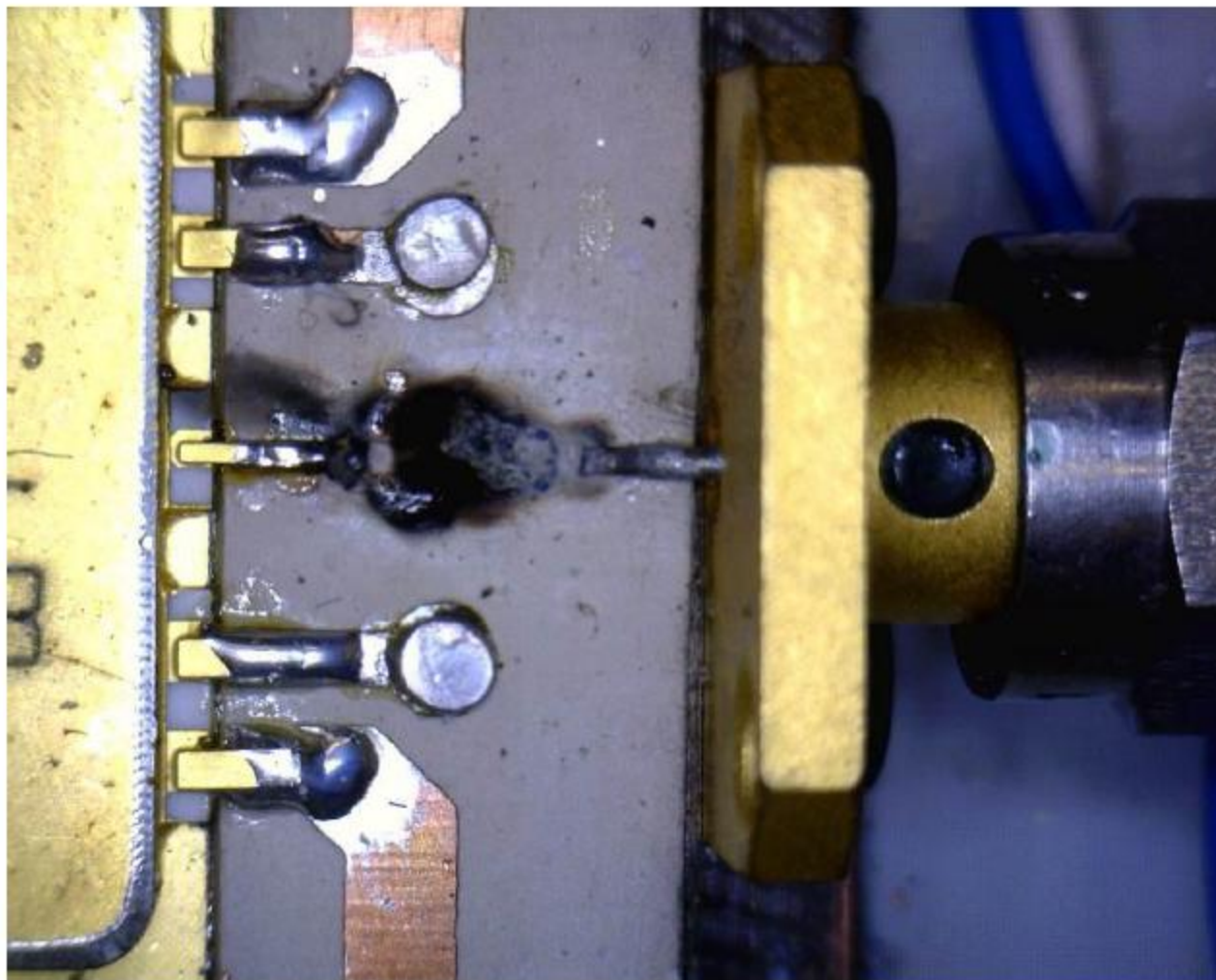
Substrate

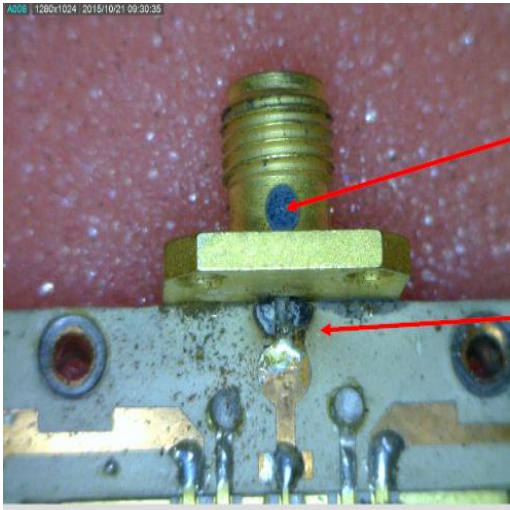
Top dielectric material is RO4350 0.020 inch thickness with 0.5 oz. copper.



With 4003 20 mil predicted rise above ambient is 71 C and on **6035HTC** it is only 25 C

0.635mm Rogers 3210

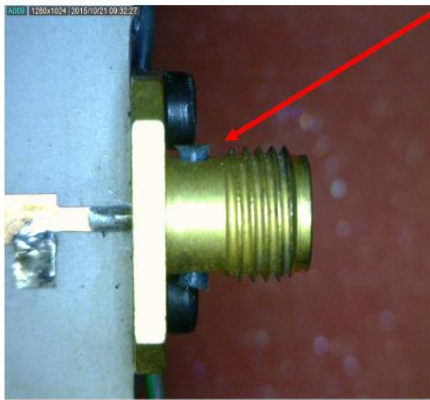




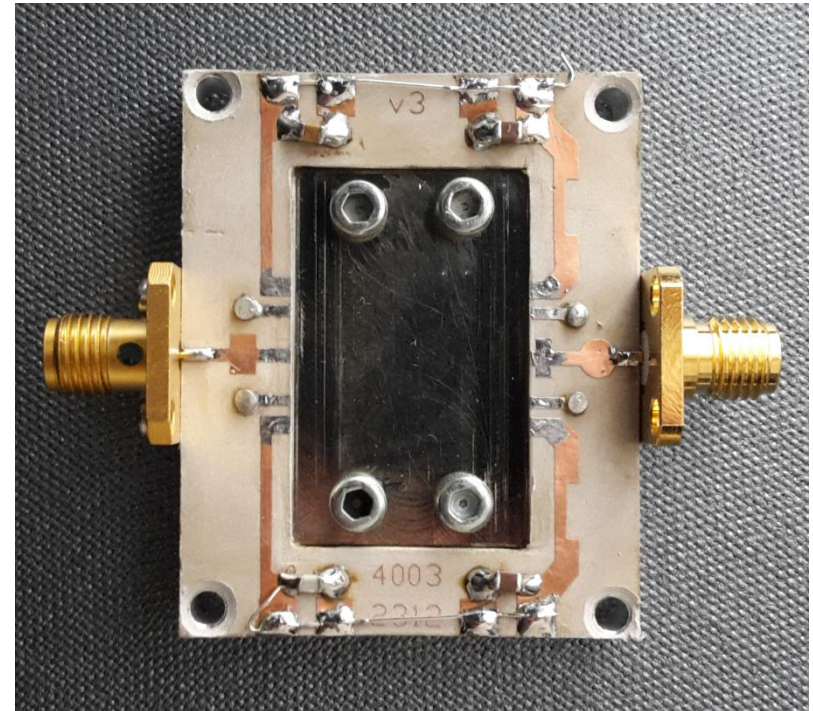
Epoxy plug is coming out of its hole

Solder joint has probably melted due to pin overheating leading to catastrophic failure

Epoxy plug movement

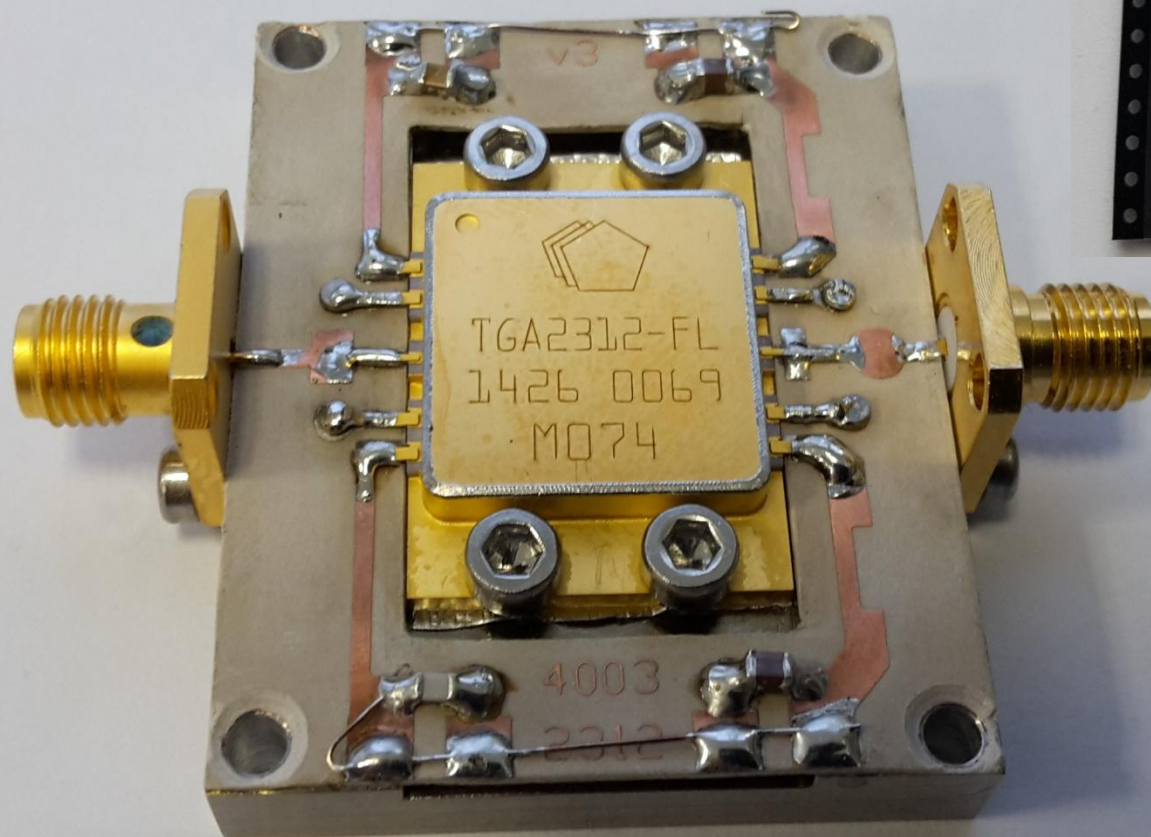


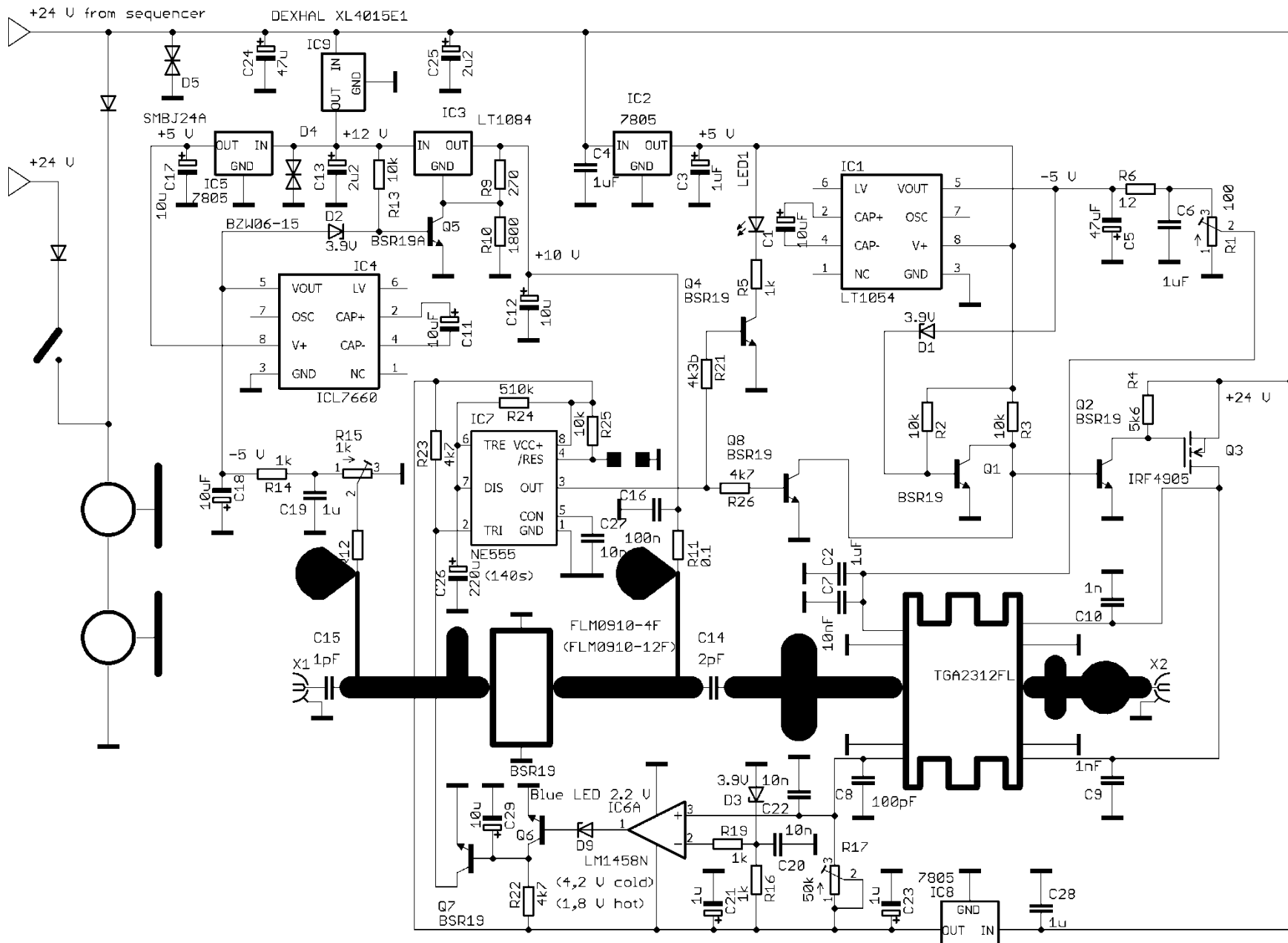
Epoxy plugs coming out

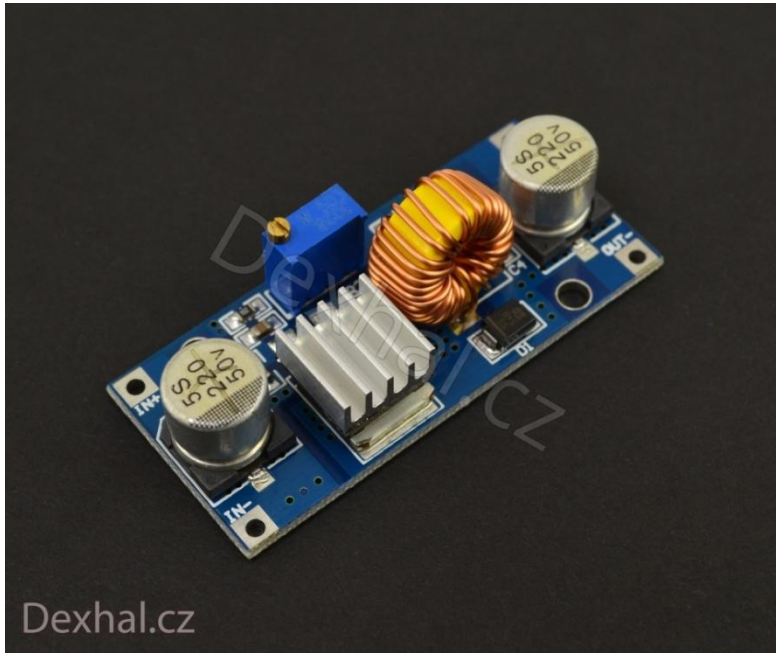


This has been seen on a number of Gigalane connectors now, on several different amplifiers with output powers of 50-90W at 10GHz. Usually both plugs are similarly affected. Hot smells have also been observed with the connector under power. Connectors also run hot to the touch.

Indium Foil

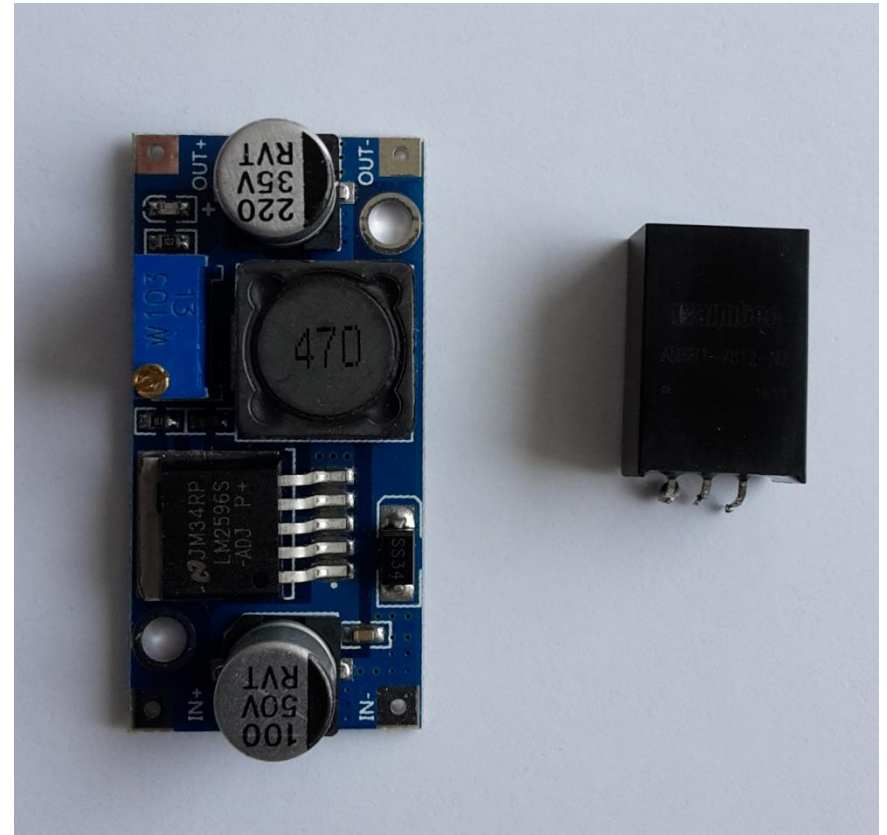


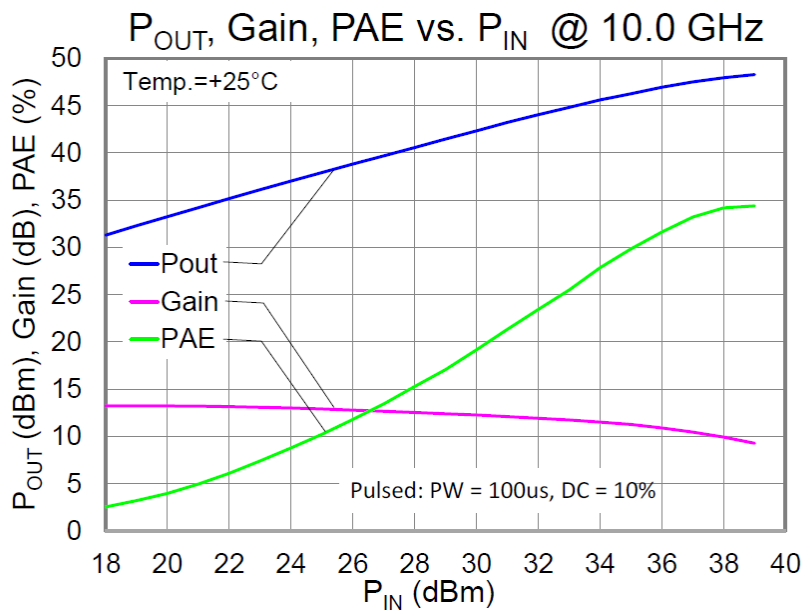
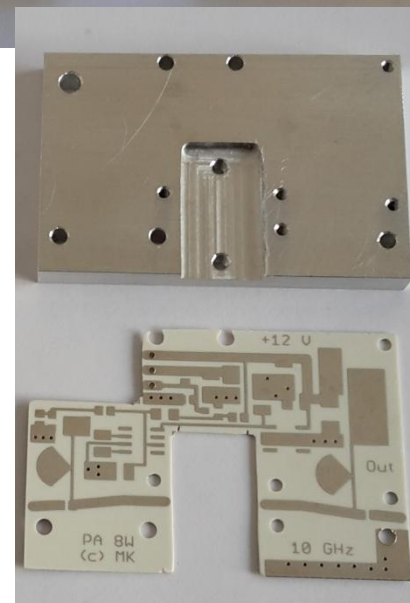
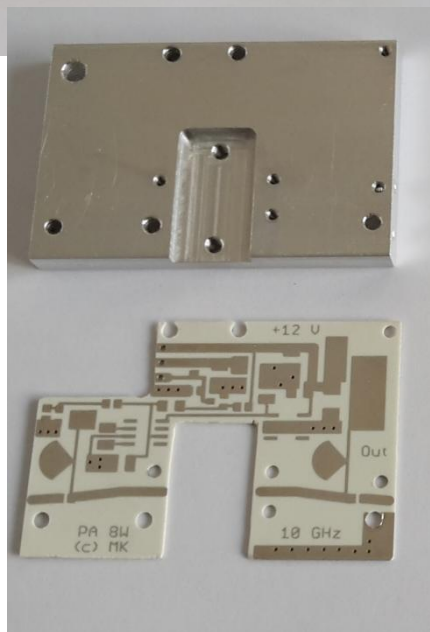
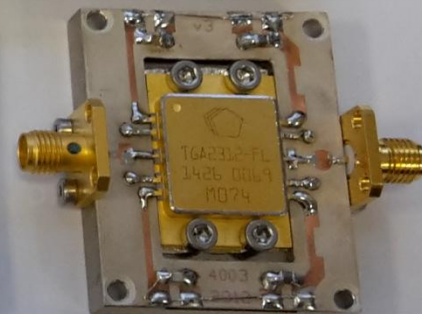
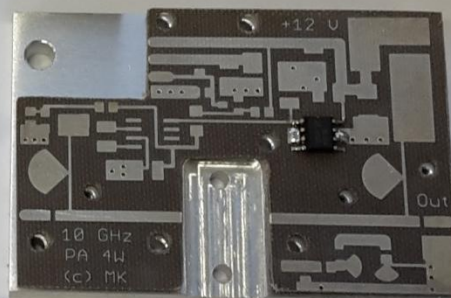
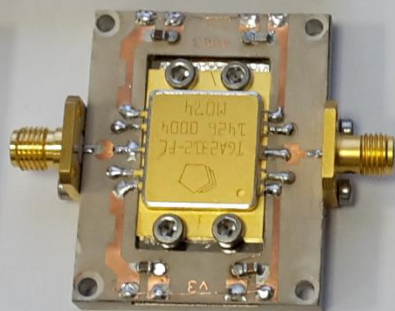
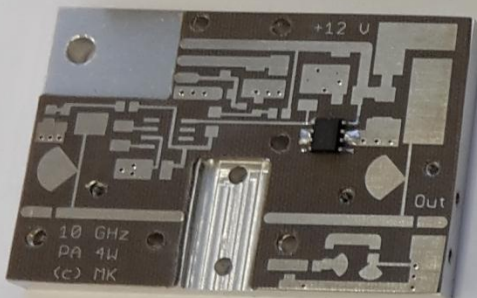
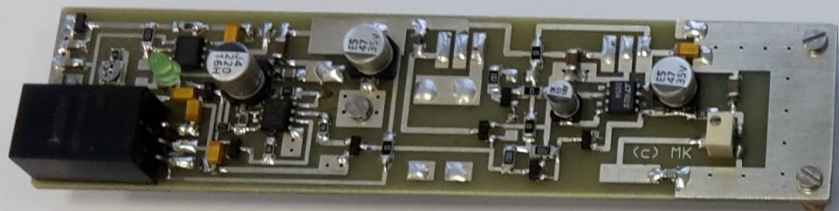




XL4015E1 – 5A

AMSR1-7812-NZ





GaAs FET TEST DATA **A**

TYPE. FLM0910-4F
 LOT-No. 613UHK01 S-No. 7243

VGS(DC)	IDS(DC)	IDS(RF)	Rth	IM3
-0.34	1159	1202	2.8	-46.80
V	mA	mA	°C/W	dBc
Freq.	9.5	10.0	10.5	GHz
P1dB	36.88	36.85	37.05	dBm
G1dB	8.15	7.63	7.98	dB

VDS = 10V

GaAs FET TEST DATA **B**

TYPE. FLM0910-4F
 LOT-No. 613UHK01 S-No. 7244

VGS(DC)	IDS(DC)	IDS(RF)	Rth	IM3
-0.34	1162	1177	2.7	-46.83
V	mA	mA	°C/W	dBc
Freq.	9.5	10.0	10.5	GHz
P1dB	36.64	36.53	36.95	dBm
G1dB	7.89	8.15	8.79	dB

VDS = 10V

GaAs FET TEST DATA **C**

TYPE. FLM0910-12F
 LOT-No. 6ZHUK01 S-No. 1302

VGS(DC)	IDS(DC)	IDS(RF)	Rth	
-0.67	3169	3382	2.3	
V	mA	mA	°C/W	
Freq.	9.5	10.0	10.5	GHz
P1dB	41.29	41.50	41.63	dBm
G1dB	6.92	7.58	6.97	dB

VDS = 10V

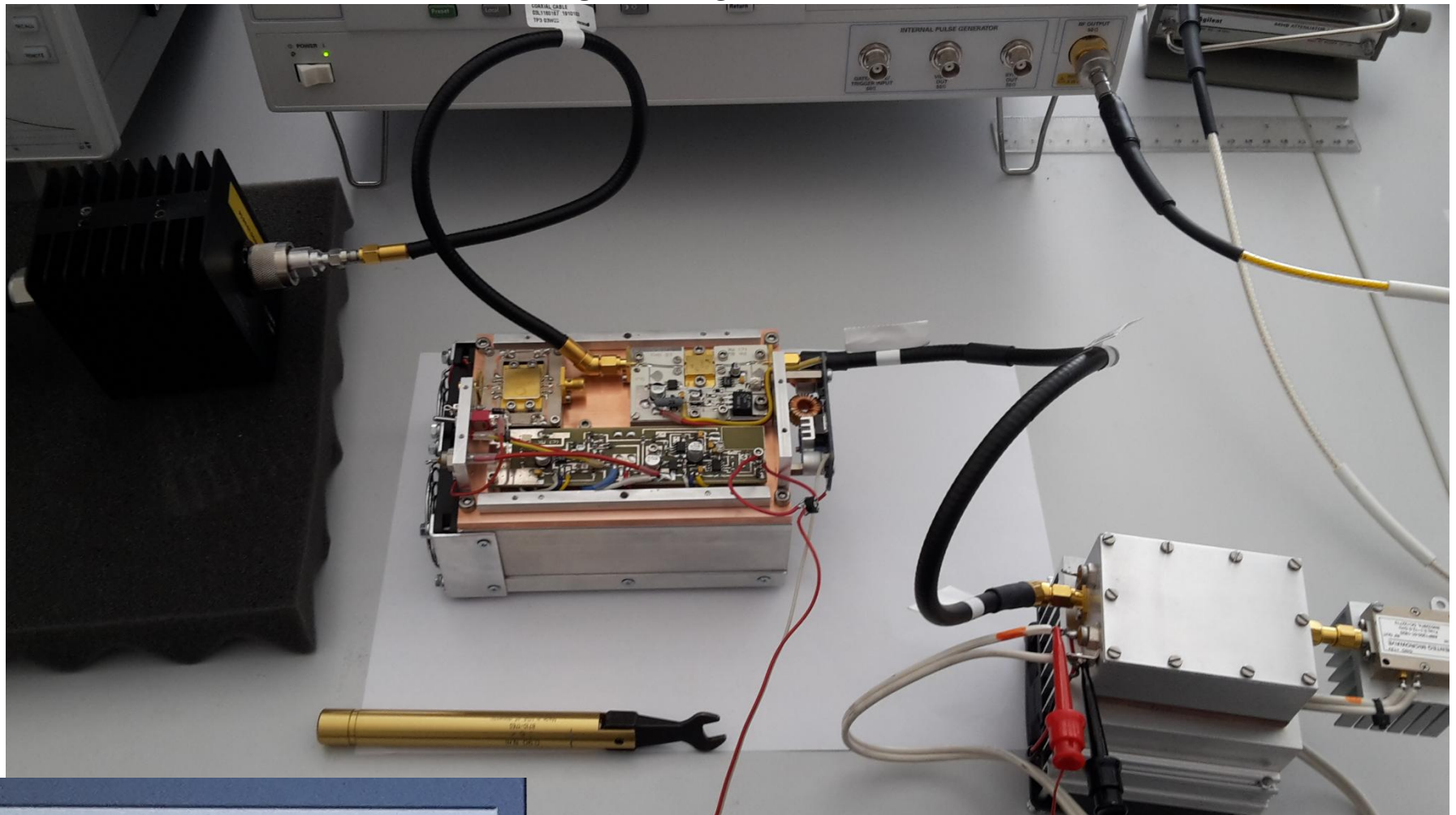
GaAs FET TEST DATA **D**

TYPE. FLM0910-12F
 LOT-No. 6ZHUK01 S-No. 1303

VGS(DC)	IDS(DC)	IDS(RF)	Rth	
-0.67	3177	3311	2.4	
V	mA	mA	°C/W	
Freq.	9.5	10.0	10.5	GHz
P1dB	41.17	40.84	41.36	dBm
G1dB	7.30	7.77	6.86	dB

VDS = 10V

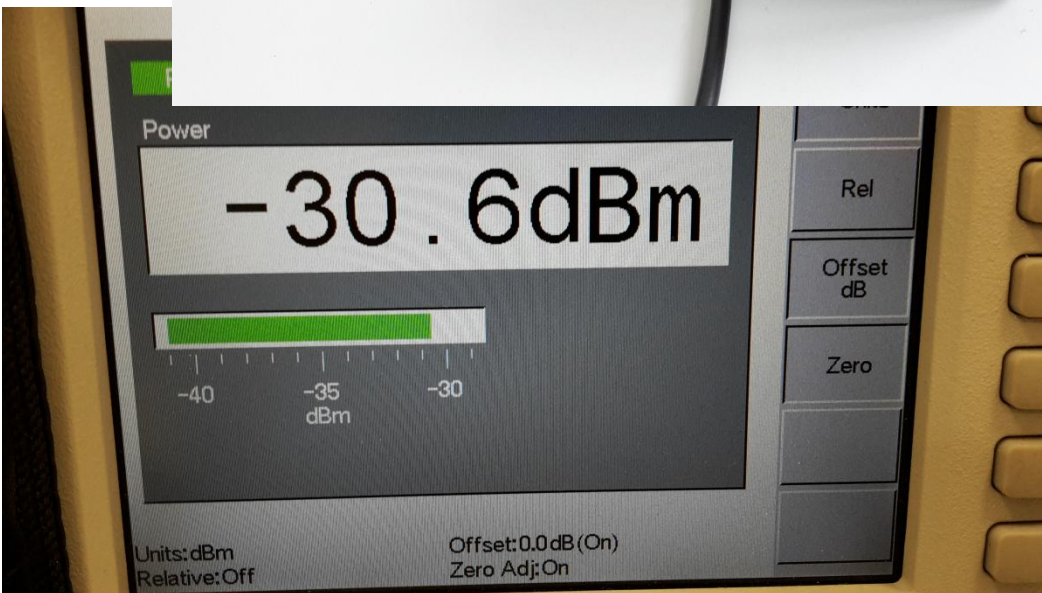
8 W Driver



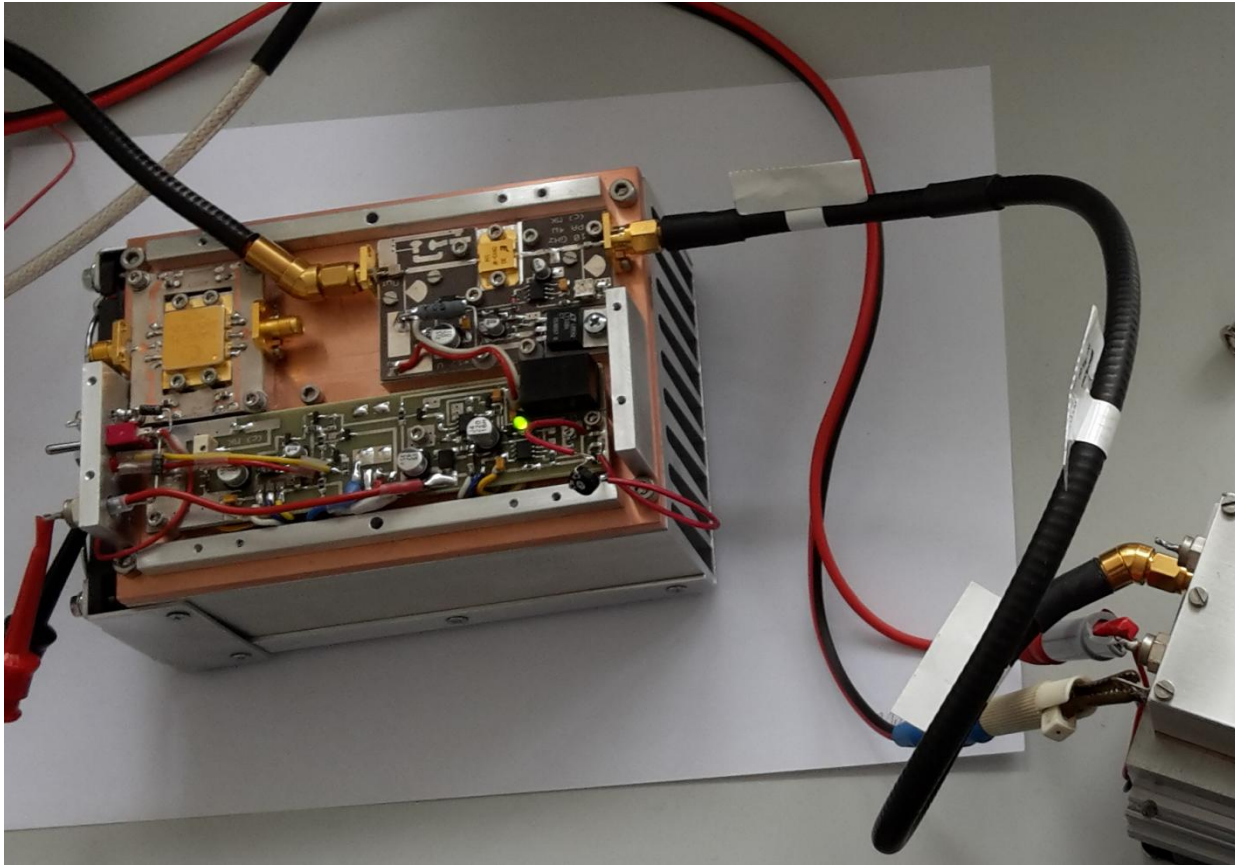
8.5 dBm

$$+ 30.6 \text{ dBm} = 39.1 \text{ dBm} \Rightarrow 8.1 \text{ W}$$

(Input 2 W, $I_{dq} = 3\text{A}$)



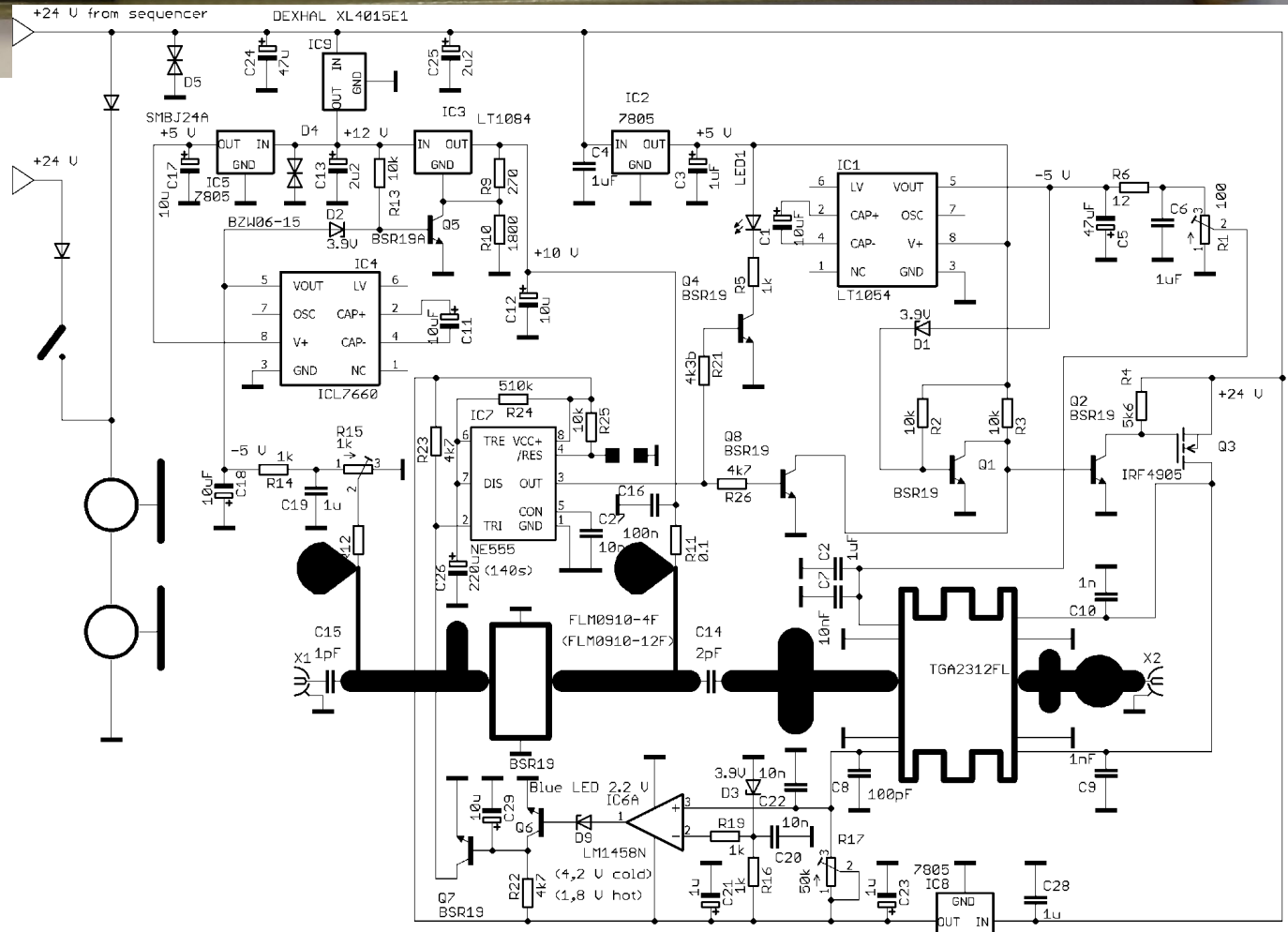
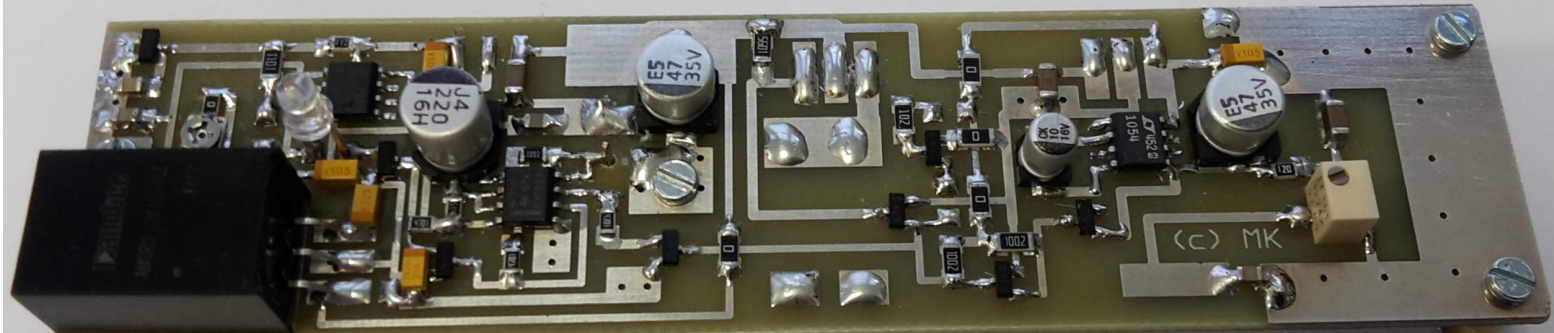
Power level
measurement



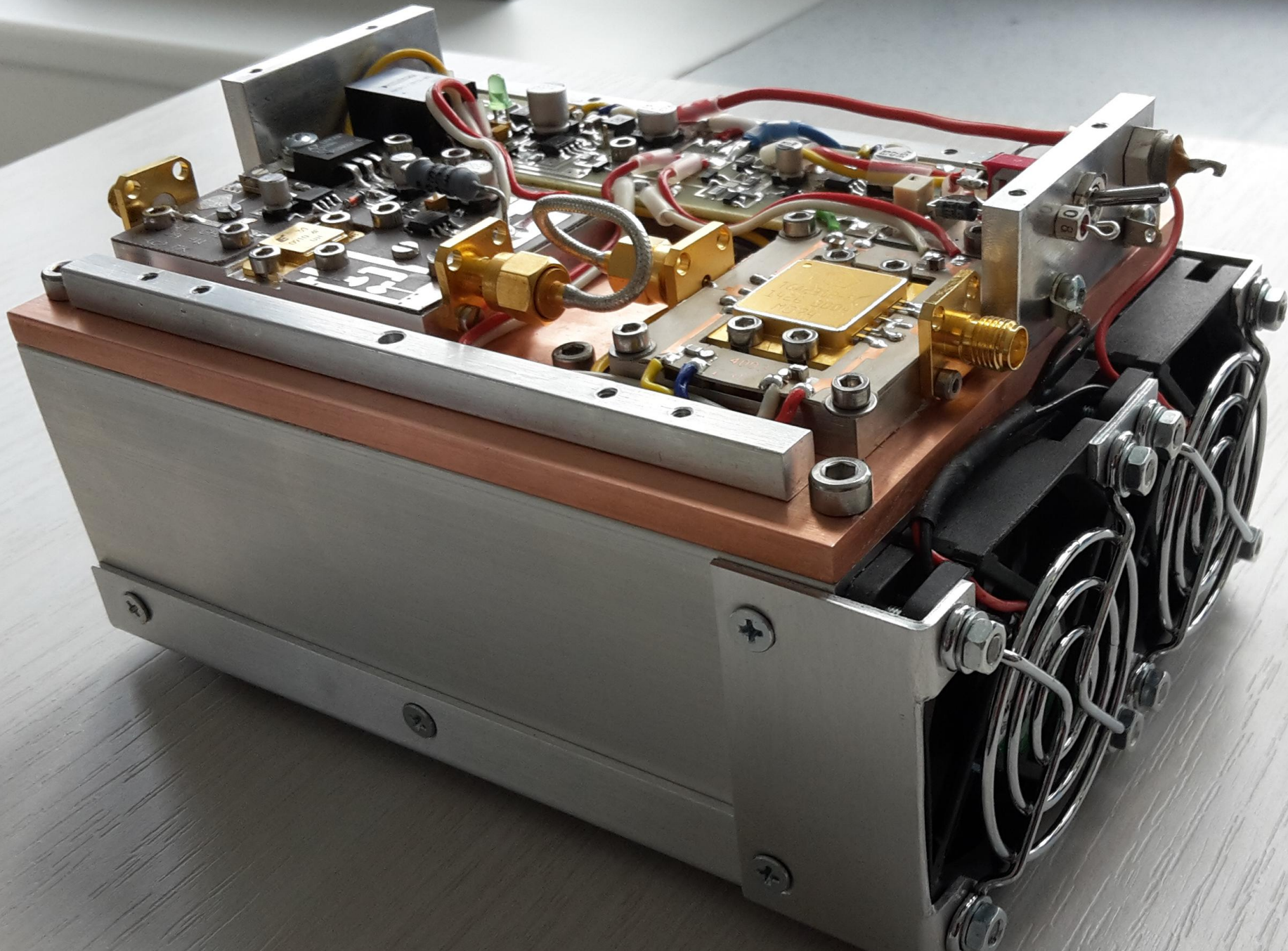
Power
6.6 dBm

$$+ 30.6 \text{ dBm} = 37.2 \text{ dBm} \Rightarrow 5.2 \text{ W}$$

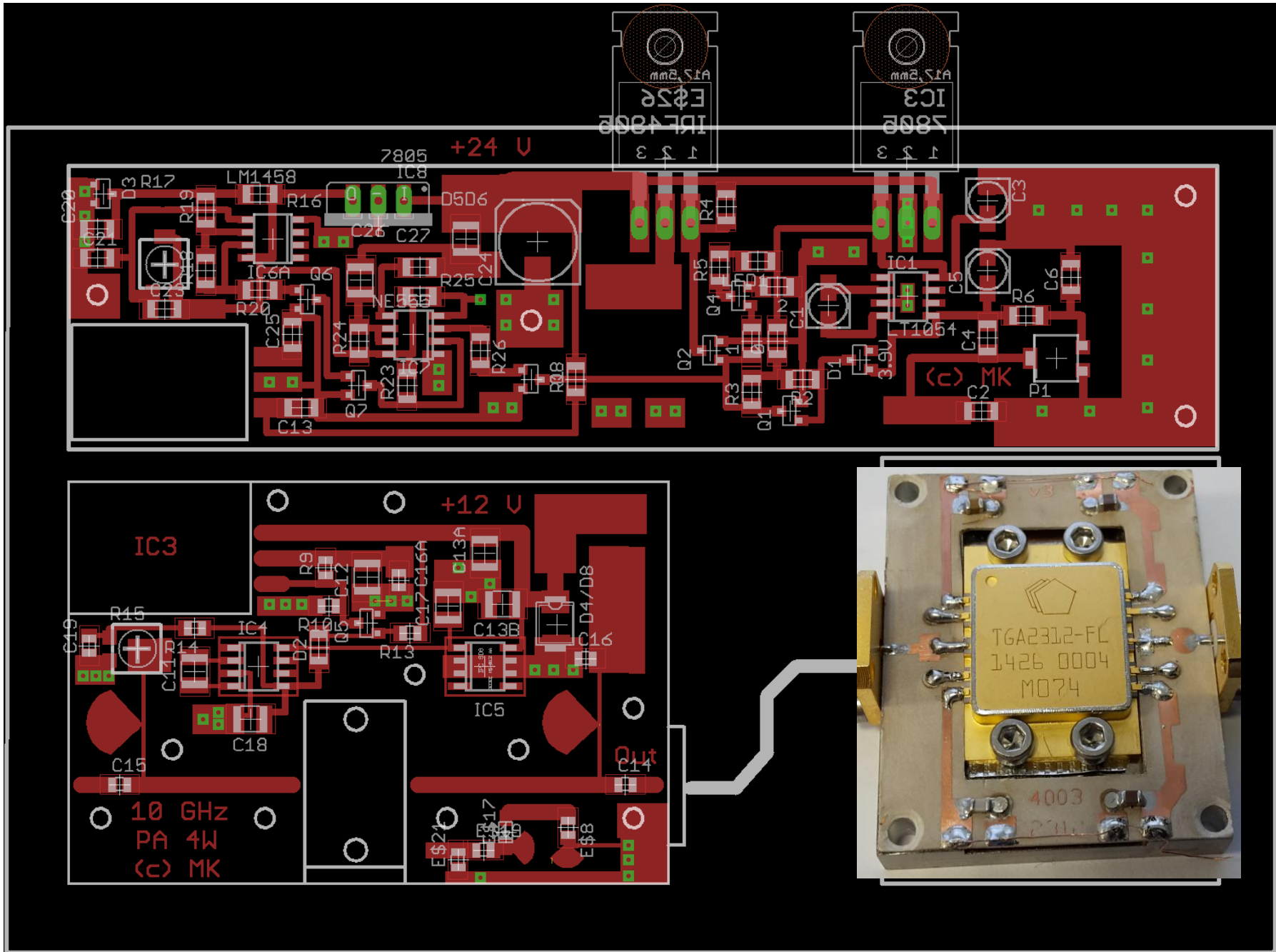
(Input 1,4 W, $I_{dq} = 1\text{A}$)



EME a MW seminář, Tři Studně, Březen 24-26, 2017

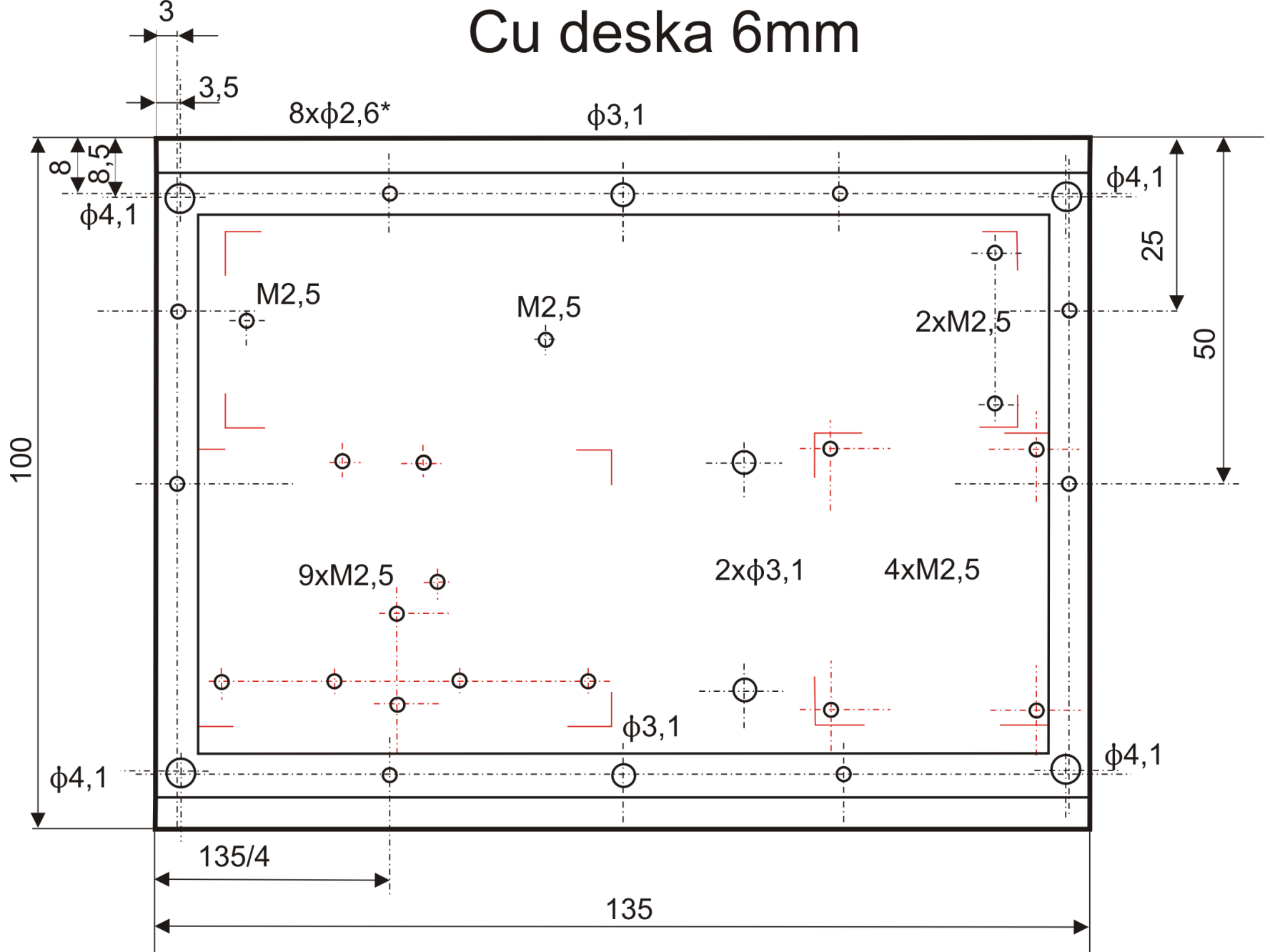


EME a MW seminář, Tři Studně, Březen 24-26, 2017



EME a MW seminář, Tři Studně, Březen 24-26, 2017

Cu deska 6mm



* ze spodní strany zapustit

PA cooling design

Thermal and Reliability Information

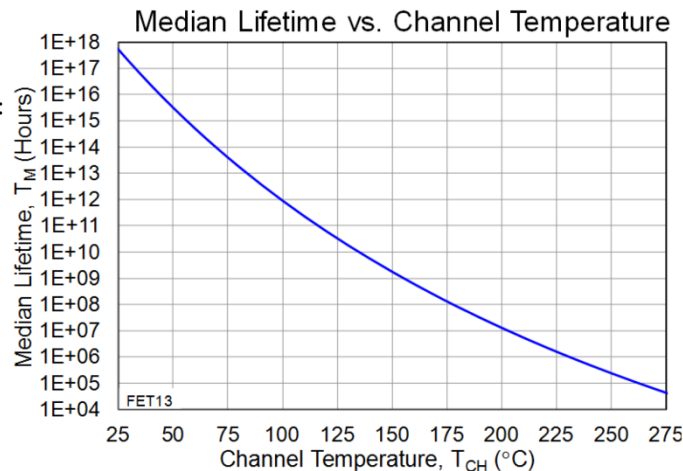
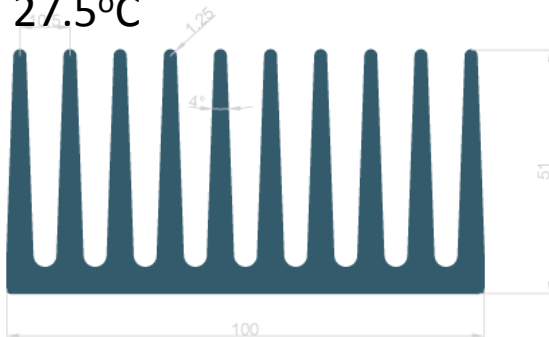
Parameter	Test Conditions	Value	Units
Thermal Resistance, θ_{JC} (Note 1)	Tbaseplate = 85 °C	0.85	°C/W
Channel Temperature, T_{CH} (Without RF Drive)	Tbaseplate = 85 °C, $V_D = 24$ V,	135	°C
Median Lifetime, T_M (Without RF Drive)	$I_{DQ} = 2400$ mA, $P_{DISS} = 58$ W, Pulsed: PW = 100us, DC = 10%	9.75×10^{10}	Hrs
Channel Temperature, T_{CH} (Under RF Drive)	Tbaseplate = 85 °C, $V_D = 24$ V, $I_{D Drive} =$	158	°C
Median Lifetime, T_M (Under RF Drive)	6360 mA, $P_{OUT} = 48$ dBm, $P_{DISS} = 87$ W, Pulsed: PW = 100us, DC = 10%	7.38×10^9	Hrs
Channel Temperature, T_{CH} (Under RF Drive)	Tbaseplate = 85 °C, $V_D = 30$ V, $I_{D Drive} =$	190	°C
Median Lifetime, T_M (Under RF Drive)	6670 mA, $P_{OUT} = 48.8$ dBm, $P_{DISS} = 124$ W, Pulsed: PW = 100us, DC = 10%	3.12×10^8	Hrs

Notes: (1) Thermal resistance measured at back of the package.

For **DC = 100%** is Θ_{JC} is 2 times higher – it is **1.7°C/W**. Dissipated heat is $5A \cdot 24V + 8W - 52W = 76W$. $T_{CH} = 50^\circ C + 27.5^\circ C + 76W \cdot 1.7^\circ C/W = 207^\circ C \rightarrow$ **lifetime** > $5E+06$ hours

$$\Theta_H = 1.4^\circ C/W \Rightarrow 0.24^\circ C/W (V)$$

$$\Delta TH = (1.6A \cdot 24V + 76W) \cdot 0.24 = 27.5^\circ C$$



Driver 8W (C)

For **DC = 50%** is $\Theta_{JC} = 1.7^{\circ}\text{C}/\text{W}$. Dissipated heat is $(5\text{A} \cdot 24\text{V} + 8\text{W} - 52\text{W})/2 = 38\text{W}$.

$T_{CH} = 50^{\circ}\text{C} + 13.7^{\circ}\text{C} + 38\text{W} \cdot 1.7^{\circ}\text{C}/\text{W} = 129^{\circ}\text{C} \rightarrow$ **lifetime > 1E+10 hodin**

$\Theta_H = 1.4^{\circ}\text{C}/\text{W} \Rightarrow 0.24^{\circ}\text{C}/\text{W (V)}$ $\Delta T_H = 0.24^{\circ}\text{C}/\text{W} \cdot (1.6\text{A} \cdot 24\text{V} + 76\text{W})/2 = 13.7^{\circ}\text{C}$

Driver 5W (A)

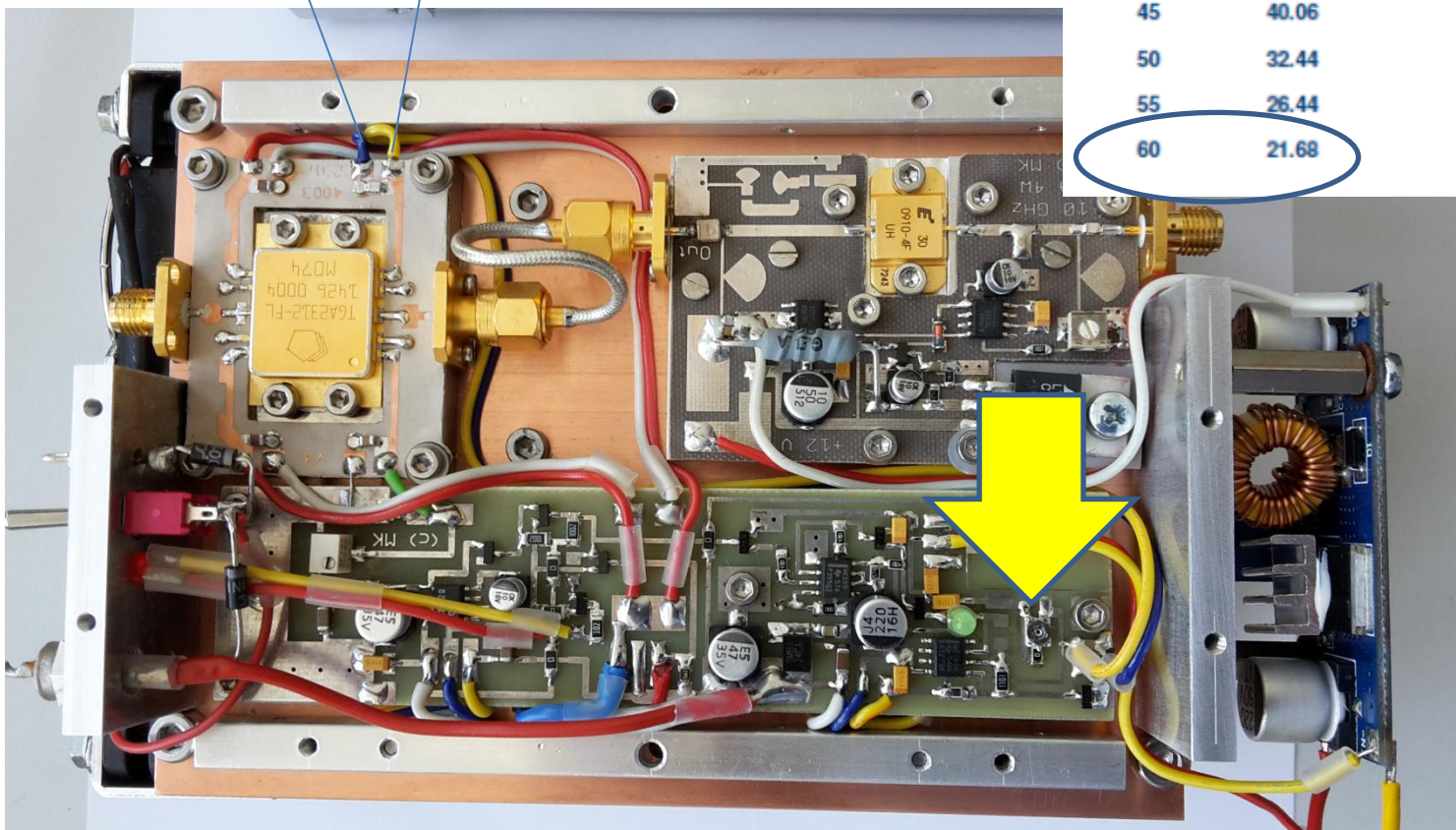
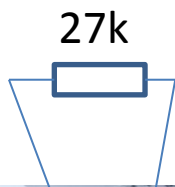
For **DC = 50%** is $\Theta_{JC} = 1.7^{\circ}\text{C}/\text{W}$. Dissipated heat is $(4.3\text{A} \cdot 24\text{V} + 5\text{W} - 42\text{W}) = 66\text{W}$.

$T_{CH} = 50^{\circ}\text{C} + 19.3^{\circ}\text{C} + 66\text{W} \cdot 1.7^{\circ}\text{C}/\text{W} = 182^{\circ}\text{C} \rightarrow$ **lifetime > 5E+07 hodin**

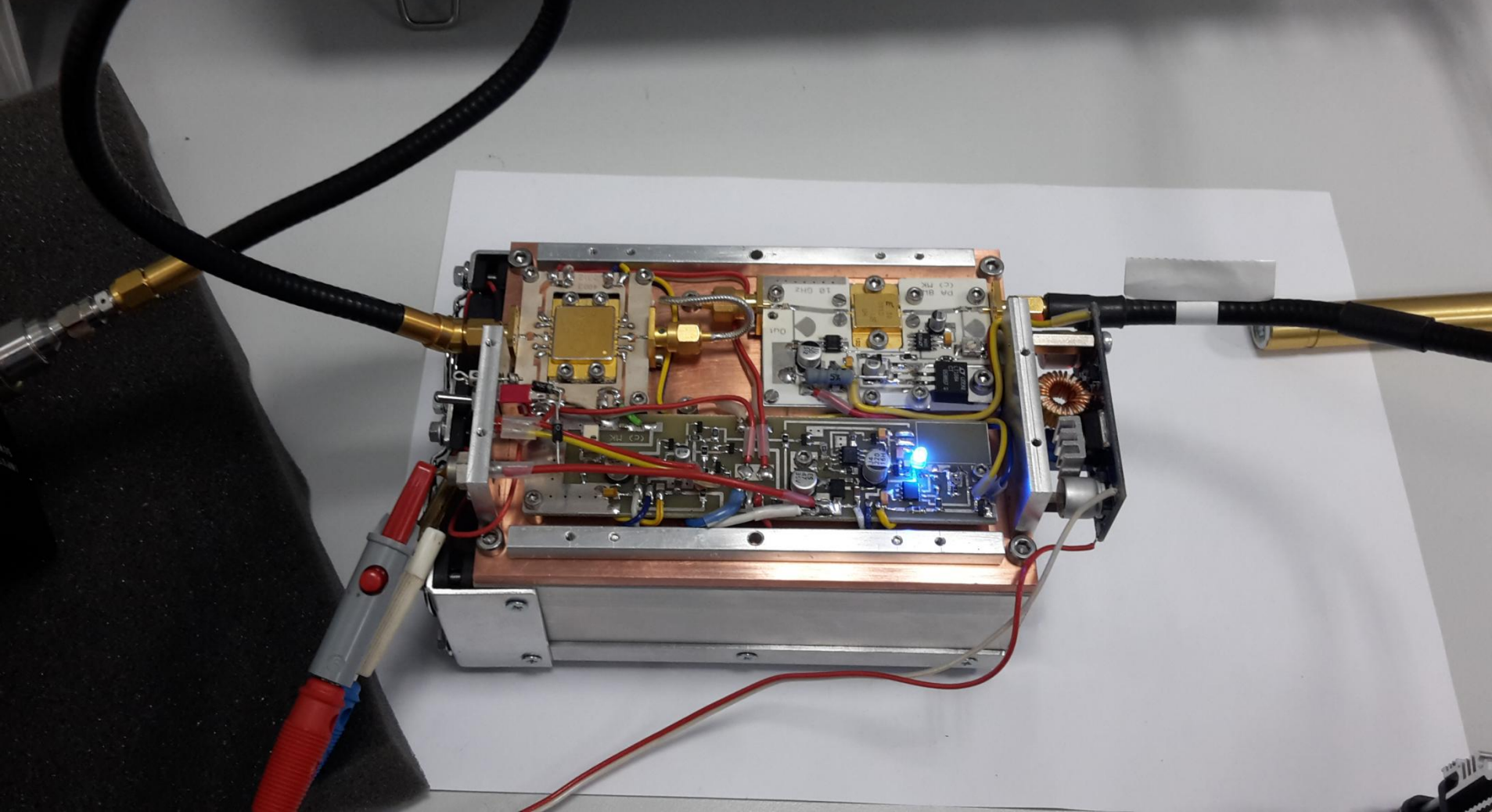
$\Theta_H = 1.4^{\circ}\text{C}/\text{W} \Rightarrow 0.24^{\circ}\text{C}/\text{W (V)}$ $\Delta T_H = 0.24^{\circ}\text{C}/\text{W} \cdot (0.6\text{A} \cdot 24\text{V} + 66\text{W}) = 19.3^{\circ}\text{C}$



Overheating protection adjustment



deg C	R (Kohm)	deg C	R (Kohm)
0	378.80	65	17.89
5	284.71	70	14.84
10	216.16	75	12.37
15	165.70	80	10.37
20	128.17	85	8.74
25	100.00	90	7.40
30	78.66	95	6.29
35	62.36	100	5.37
40	49.81	105	4.61
45	40.06	110	3.96
50	32.44	115	3.43
55	26.44	120	2.97
60	21.68	125	2.59



Power

16.6 dBm

$$+ 30.6 \text{ dBm} = 47.2 \text{ dBm} \Rightarrow 52.5 \text{ W}$$

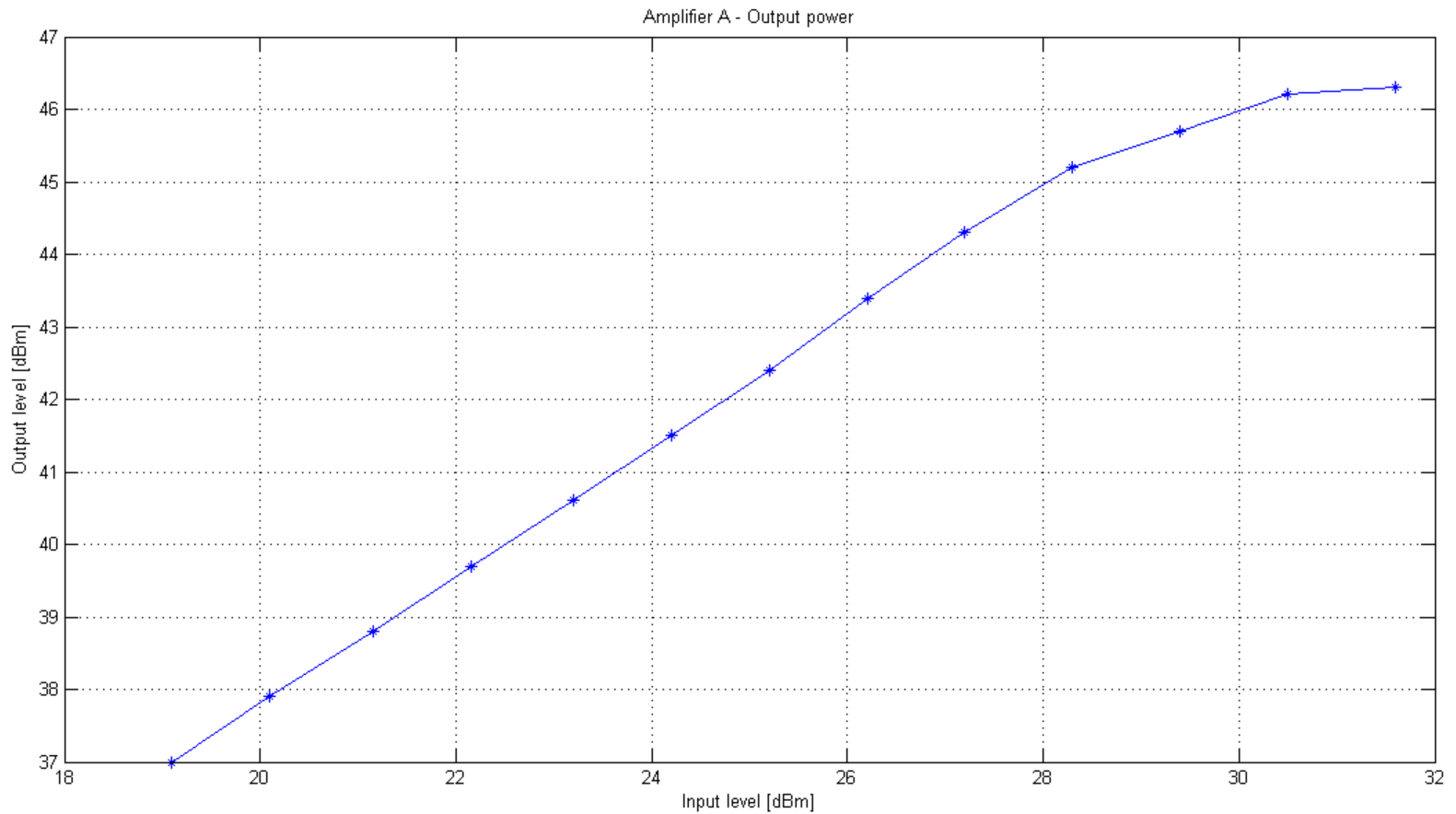
(Input 2 W, $I_{dq} = 2.3 \text{ A}$, $I_d = 4.9 \text{ A}$)

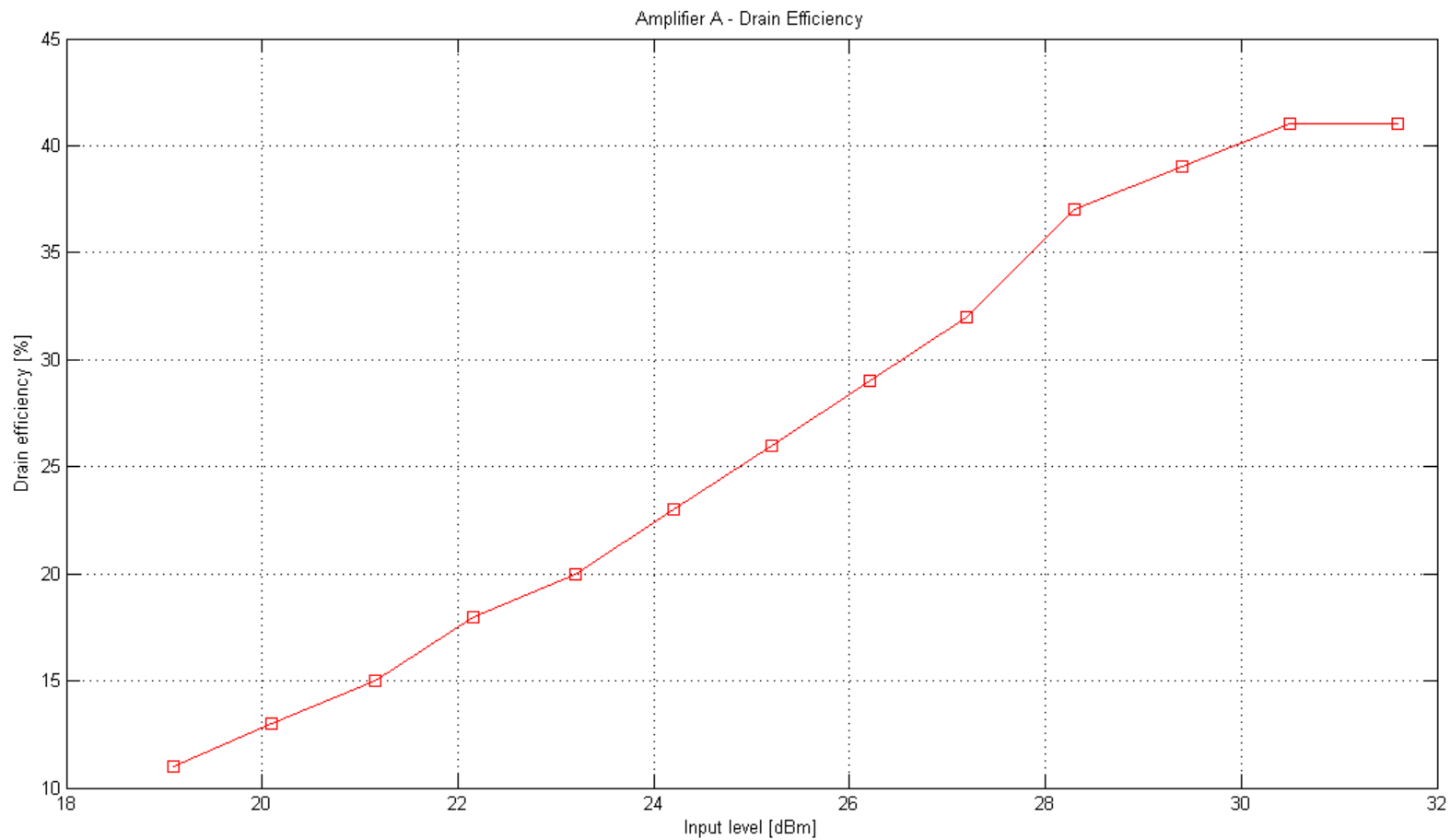
Amplifier A (5 W)

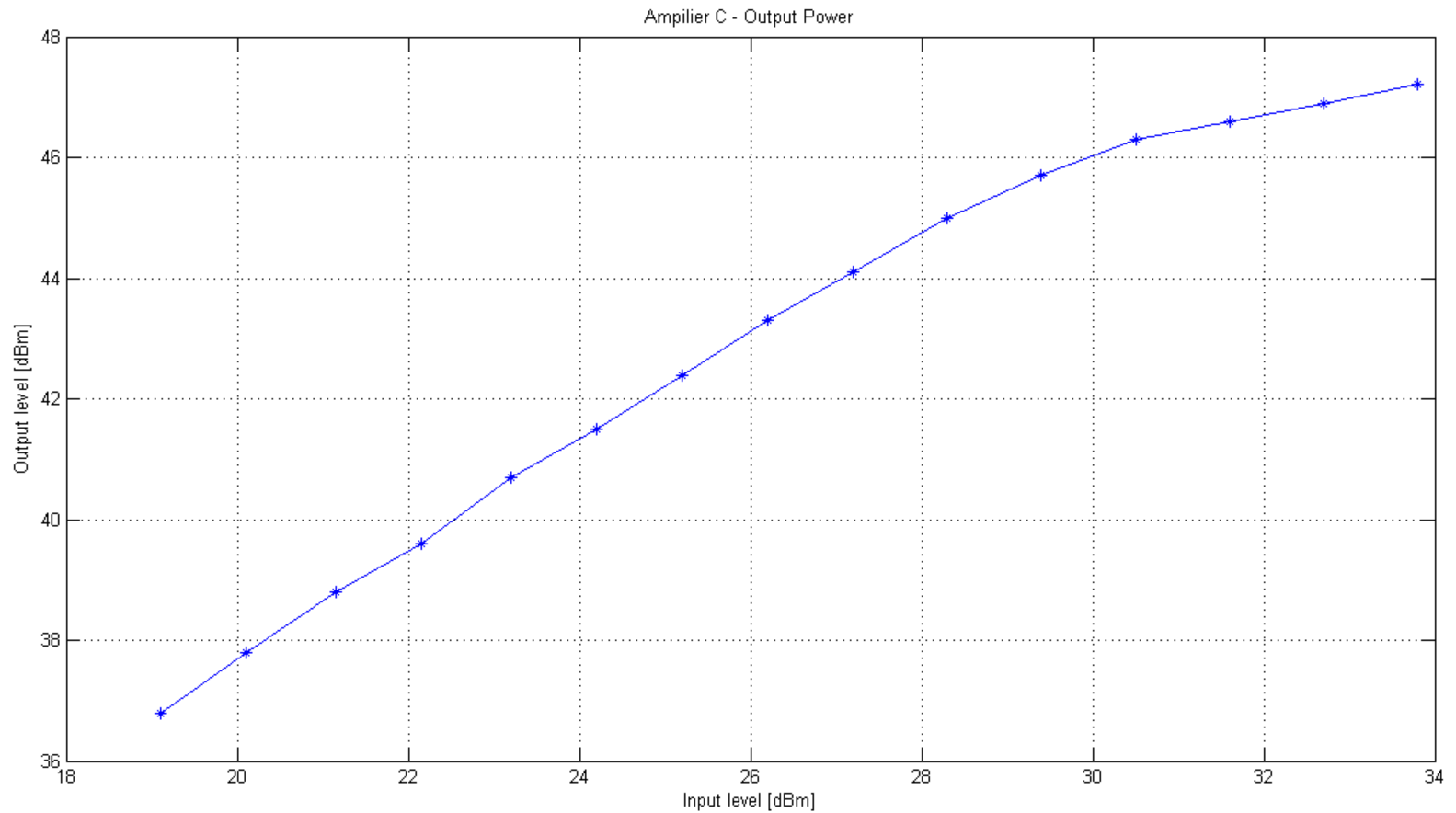
Gen Level [dBm]	Inp Level [dBm]	Inp Level [W]	Measur Level [dBm]	Id [A]	Input Power [W]	Output Power [dBm]	Output Power [W]	Drain Efficiency [%]	Total Efficiency [%]	Gain [dB]
-14	19.10	0.081	6.40	1.90	45.6	37.00	5.01	11	9	17.9
-13	20.10	0.102	7.30	2.00	48.0	37.90	6.17	13	10	17.8
-12	21.15	0.130	8.20	2.10	50.4	38.80	7.59	15	12	17.7
-11	22.15	0.164	9.10	2.20	52.8	39.70	9.33	18	14	17.6
-10	23.20	0.209	10.00	2.40	57.6	40.60	11.48	20	16	17.4
-9	24.20	0.263	10.90	2.60	62.4	41.50	14.13	23	19	17.3
-8	25.20	0.331	11.80	2.80	67.2	42.40	17.38	26	22	17.2
-7	26.20	0.417	12.80	3.10	74.4	43.40	21.88	29	25	17.2
-6	27.20	0.525	13.70	3.50	84.0	44.30	26.92	32	28	17.1
-5	28.30	0.676	14.60	3.70	88.8	45.20	33.11	37	33	16.9
-4	29.40	0.871	15.10	3.97	95.3	45.70	37.15	39	35	16.3
-3	30.50	1.122	15.60	4.24	101.8	46.20	41.69	41	37	15.7
-2	31.60	1.445	15.70	4.31	103.4	46.30	42.66	41	37	14.7
-1	32.70	1.862								
0	33.80	2.399								
1	34.70	2.951								
2	35.50	3.548								
3	36.30	4.266								
4	37.00	5.012								

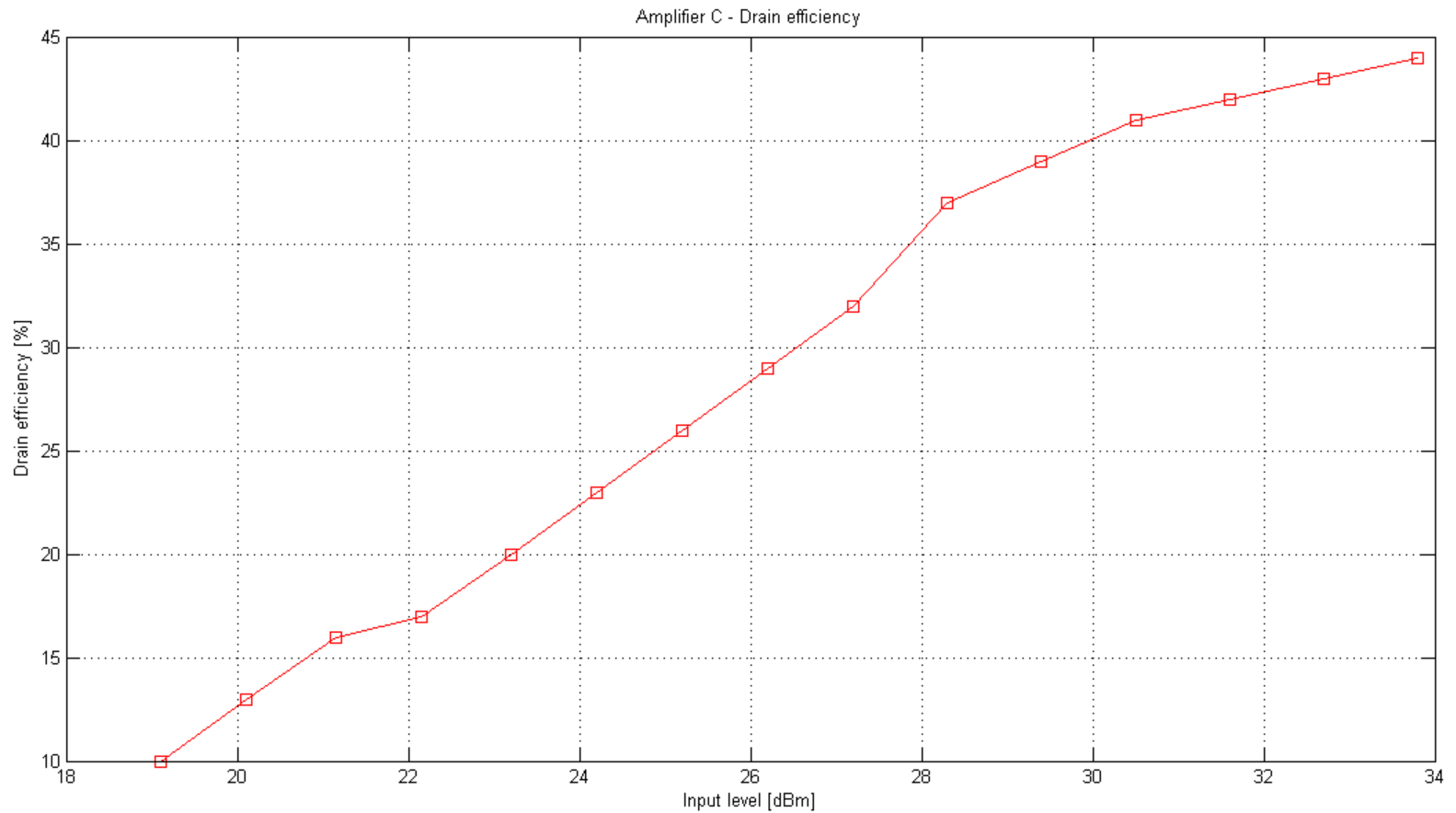
Amplifier C (8 W)

Gen	Inp	Inp	Measur		Input	Output	Output	Drain	Total	
Level	Level	Level	Level	Id	Power	Power	Power	Efficienc	Efficienc	Gain
[dBm]	[dBm]	[W]	[dBm]	[A]	[W]	[dBm]	[W]	[%]	[%]	[dB]
-14	19.10	0.081	6.20	1.90	45.6	36.80	4.79	10	6	17.7
-13	20.10	0.102	7.20	1.90	45.6	37.80	6.03	13	7	17.7
-12	21.15	0.130	8.20	2.00	48.0	38.80	7.59	16	9	17.7
-11	22.15	0.164	9.00	2.20	52.8	39.60	9.12	17	10	17.5
-10	23.20	0.209	10.10	2.40	57.6	40.70	11.75	20	13	17.5
-9	24.20	0.263	10.90	2.60	62.4	41.50	14.13	23	14	17.3
-8	25.20	0.331	11.80	2.80	67.2	42.40	17.38	26	17	17.2
-7	26.20	0.417	12.70	3.10	74.4	43.30	21.38	29	19	17.1
-6	27.20	0.525	13.50	3.30	79.2	44.10	25.70	32	22	16.9
-5	28.30	0.676	14.40	3.60	86.4	45.00	31.62	37	26	16.7
-4	29.40	0.871	15.10	4.00	96.0	45.70	37.15	39	28	16.3
-3	30.50	1.122	15.70	4.30	103.2	46.30	42.66	41	31	15.8
-2	31.60	1.445	16.00	4.50	108.0	46.60	45.71	42	32	15.0
-1	32.70	1.862	16.30	4.80	115.2	46.90	48.98	43	32	14.2
0	33.80	2.399	16.60	4.99	119.8	47.20	52.48	44	34	13.4









10 GHz PA by OK2AQ



Figure 1. Two 10 GHz power amplifiers with TGA2312FL

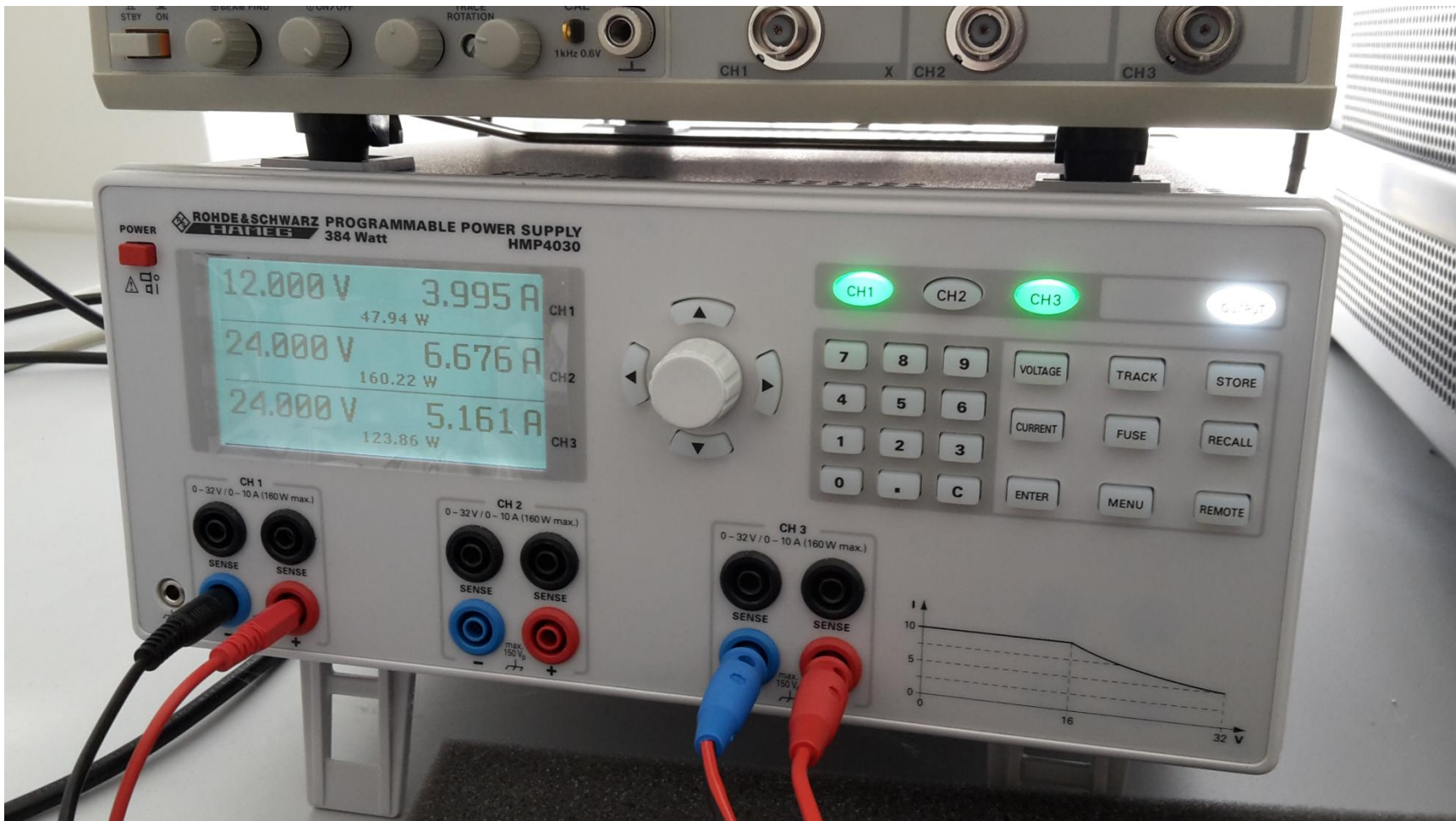
Both PA are identical except drivers. TGA2312FL internal thermistor is used for a protection against overheating. A 24V/12V step down converter is used for the drivers supply. The TGA2312FL bearing including PCB with tuned microstrip structure were designed and produced by G3WDG.

The left one developed for OK1DFC has bigger driver – 8 W and gives 52 W output power at 2.4 W at the input. The total efficiency is a little bit worse due bigger driver.

The right one developed for OK2AQ has driver 4.5 W and gives 42 W output power at 1.4 W at the input. Very good total efficiency results in slightly warm cooler after long time operation.



EME a MW seminář, Tři Studně, Březen 24-26, 2017



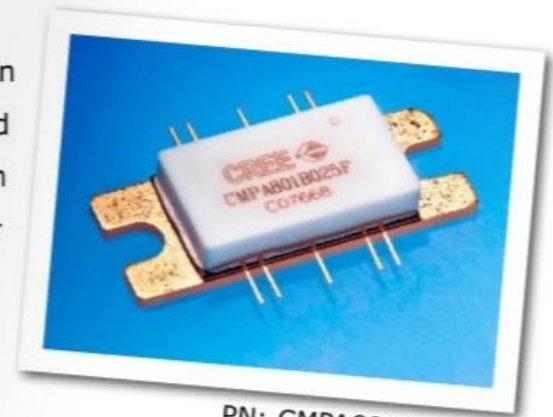
EME a MW seminář, Tři Studně, Březen 24-26, 2017



CMPA801B025F

25 W, 8.0 - 11.0 GHz, GaN MMIC, Power Amplifier

Cree's CMPA801B025F is a gallium nitride (GaN) High Electron Mobility Transistor (HEMT) based monolithic microwave integrated circuit (MMIC). GaN has superior properties compared to silicon or gallium arsenide, including higher breakdown voltage, higher saturated electron drift velocity and higher thermal conductivity. GaN HEMTs also offer greater power density and wider bandwidths compared to Si and GaAs transistors. This MMIC is available in a 10 lead metal/ceramic flanged package for optimal electrical and thermal performance.



PN: CMPA801B025F
Package Type: 440208

Typical Performance Over 8.5-11.0 GHz ($T_c = 25^\circ\text{C}$)

Parameter	8.5 GHz	10.0 GHz	11.0 GHz	Units
Output Power ¹	38.0	37.0	35.5	W
Output Power ¹	45.8	45.7	45.5	dBm
Power Added Efficiency ¹	37.0	36.0	35.0	%

Wolfspeed

Pol	Označení dodávky	Množství	J.cena	Cena	%DPH	DPH	Celkem
1.	CMPA801B025F ■ 25-W, 8.0 – 11.0-GHz, GaN MMIC Power Amplifier	2 ks	10 399,71	20 799,42	21%	4 367,88	25 167,30 CZK
Součet položek				20 799,42		4 367,88	25 167,30 CZK
Zaokrouhlení							0,70
CELKEM K ÚHRADĚ							25 168,00 CZK

Ceny jsou uvedeny v CZK a jsou stanoveny pro kurz ČNB 1USD = 25,434 Kč

DB6NT: 1 W costs ~ 67 EUR => 50 W ~ 3300 EUR
60 W ~ 4000 EUR

Děkuji Vám za pozornost
Thanks for your attention