AN10945

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174 MHz to 230 MHz DVB-T power amplifier with the BLF881

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Application note

Document information

Info	Content
Keywords	BLF881, DVB-T, VHF, ACPR, LDMOS, power amplifier, linearity, efficiency, gain flatness, peak power
Abstract	This application note describes the design and performance of a 50 W DVB-T power amplifier for the 174 MHz to 230 MHz VHF band using the BLF881 power transistor. In particular, it compares the DVB-T performance for flat gain with best ACPR tuning.

Revision history

Rev	Date	Description
AN10945#2	20150901	Modifications • The format of this document has been redesigned to comply with the new identity guidelines of Ampleon. • Legal texts have been adapted to the new company name where appropriate.
AN10945#1	20101118	Initial version

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1. Introduction

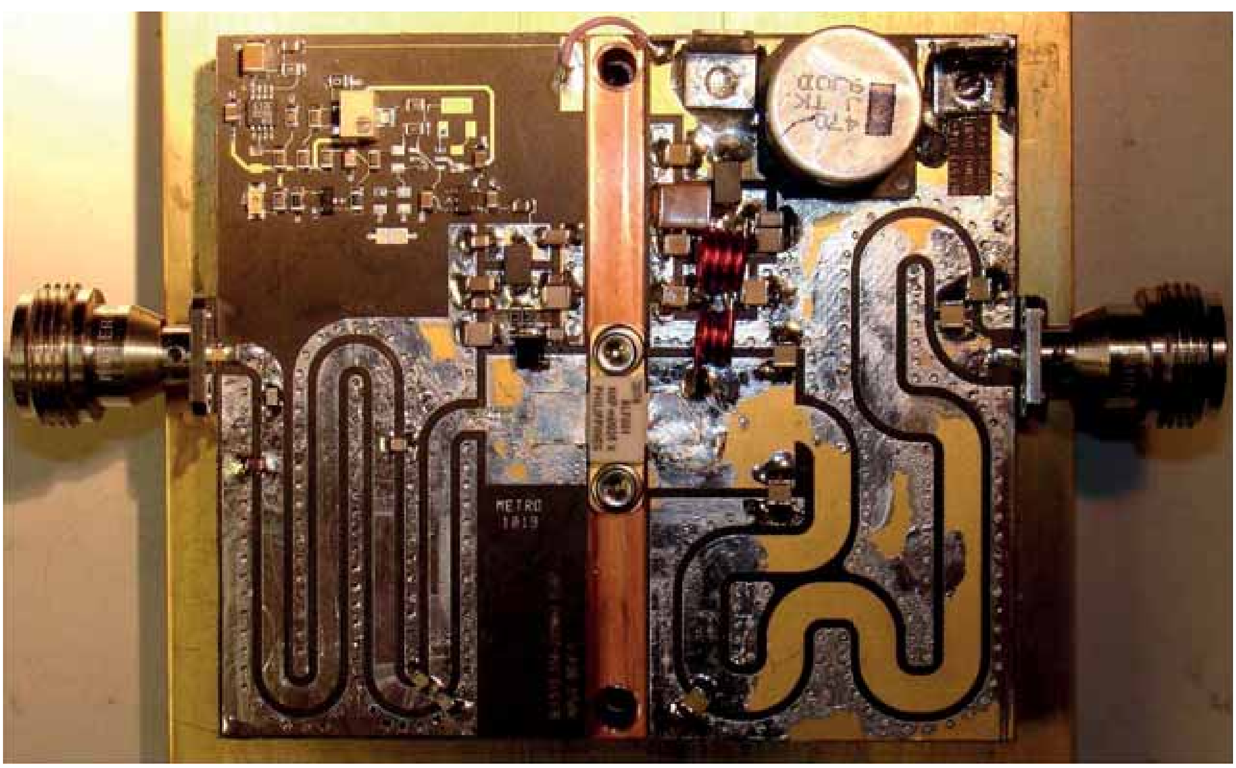
The BLF881 is a 50 V high power RF transistor based on Ampleon's high voltage LDMOS process. It is designed for use in the 470 MHz to 860 MHz UHF broadcast band, where it can deliver 140 W (peak sync) for analog TV and 33 W for DVB-T (8K).

When using the BLF881 in the VHF band, special attention is needed to achieve a broadband input match due to the high Q (6 at 174 MHz) at these lower input frequencies. With care, an input return loss better than 6 dB can be achieved across the 28 % fractional bandwidth.

Another issue at VHF frequencies is that the load pull contours for power, gain and efficiency are all relatively steep and distinct from each other, so the designer has to make significant trade-offs between linearity, efficiency and gain flatness for a broadband output network.

In this design, we compare two differently tuned outputs:

- Flat gain: where gain flatness is optimized over the band while balancing peak power at the band top and bottom, but sacrificing efficiency.
- Best ACPR: where ACPR and efficiency are optimized over the band, while balancing efficiency at the band top and bottom, but sacrificing gain flatness.



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Output tuned for best ACPR.

Fig 1. The assembled DVB-T BLF881 amplifier

2. Test summary

The amplifier was characterized under the conditions shown in Table 1.

Table 1. RF performance summary

Characteristic	Output tuned for	
	Flat gain	Best ACPR
Frequency range	174 MHz to 230 MHz	174 MHz to 230 MHz
Drain-Source voltage (V_{DS})	50 V	50 V
Quiescent drain current (I_{Dq})	0.5 A	0.5 A
Minimum input return loss	6 dB	6 dB
Peak DVB-T power	no CCDF data	55.2 dBm to 55.4 dBm
Peak pulse power at 202 MHz	53.4 dBm	52.4 dBm
ACPR at P_L = 40 W	−24 dB to −34 dB	−30 dB to −32 dB
DVB-T drain efficiency (η_D) at P_L = 40 W	23 % to 29 %	30 % to 37 %
Peak pulse efficiency at 202 MHz	50 %	63 %
Minimum gain at P_L = 40 W	30.5 dB	28.1 dB
Gain flatness	1.4 dB	5.9 dB

3. Design methodology

Initial input tuning was determined with an Agilent Advanced Design System (ADS) using the equivalent input circuit provided for UHF applications. When the amplifier did not tune as predicted by this model, it was found that the equivalent circuit was not accurate at lower frequencies. To more accurately model the device input impedance, ADS was used to measure the input impedance of the non-linear BLF881 model in a large-signal harmonic balance simulation. This modelled impedance data was then used to more accurately model the tuning of the amplifier's input network. The modelled input impedance data is shown in Table 2.

Table 2. Modelled input impedance (Z_i)

P_i = 10 dBm, Z_L = 4 + j0 Ω, V_{DS} = 50 V, I_{Dq} = 0.5 A.

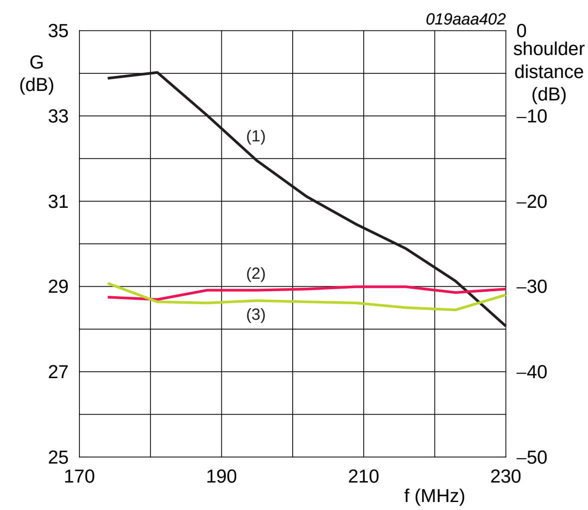
Frequency	Z_i
170 MHz	1.2 – j7.2 Ω
200 MHz	1.2 – j6.1 Ω
230 MHz	1.2 – j5.3 Ω

The optimal load impedance was determined by a load pull analysis using ADS. The compromise load points were chosen to favour peak power, followed by efficiency, while ignoring gain flatness. A load impedance of 4 + j0 Ω across the band met these criteria. The tuning of the output was then determined for this 4 Ω load impedance using a linear small-signal analysis. The 56 pF capacitors used to short-circuit the second harmonic were also determined using this analysis.

The resulting output network needed only minor tuning to deliver the best ACPR results as shown in this application note. The flat gain tuned output was determined by iterative tuning after examination of the load pull data to see which way the load impedance had to move across the band.

4. RF performance

4.1 Best ACPR tuning



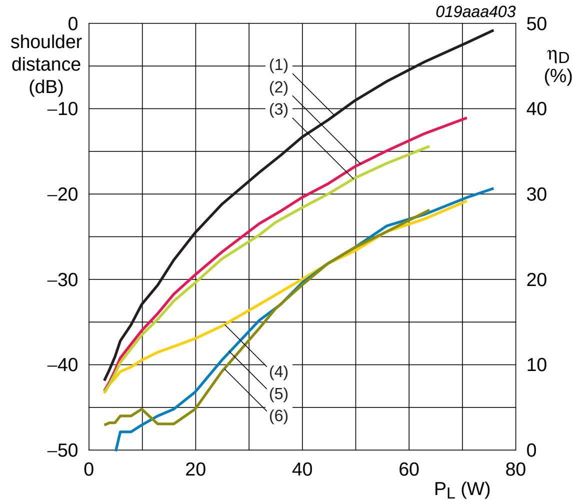
V_{DS} = 50 V; I_{Dq} = 0.5 A; DVB-T = 8K (OFDM); ACPR measured within 30 kHz bandwidth at f_c = ± 4.3 MHz.

(1) Gain.

(2) Lower adjacent.

(3) Upper adjacent.

Fig 2. DVB-T gain and ACPR at P_L = 40 W



V_{DS} = 50 V; I_{Dq} = 0.5 A; DVB-T = 8K (OFDM); ACPR measured within 30 kHz bandwidth at f_c = ± 4.3 MHz.

(1) η_D = 202 MHz.

(2) η_D = 174 MHz.

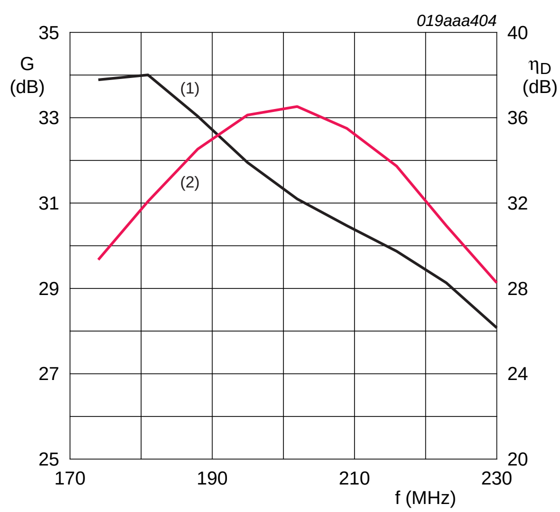
(3) η_D = 230 MHz.

(4) ACPR = 174 MHz.

(5) ACPR = 202 MHz.

(6) ACPR = 230 MHz.

Fig 3. DVB-T ACPR and drain efficiency

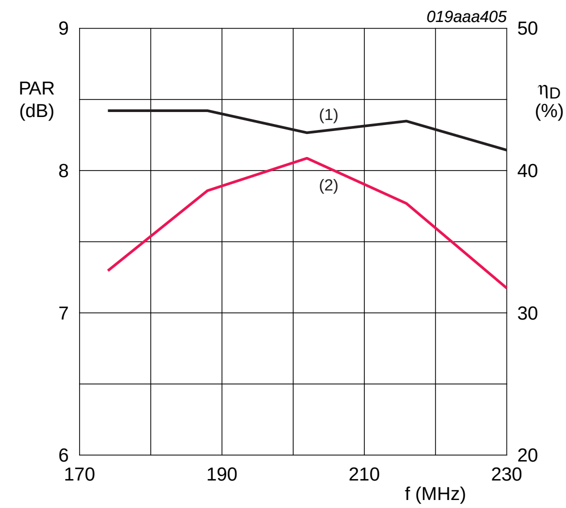


V_{DS} = 50 V; I_{Dq} = 0.5 A; DVB-T = 8K (OFDM).

(1) Gain.

(2) Drain efficiency.

Fig 4. DVB-T gain and drain efficiency at P_L = 40 W

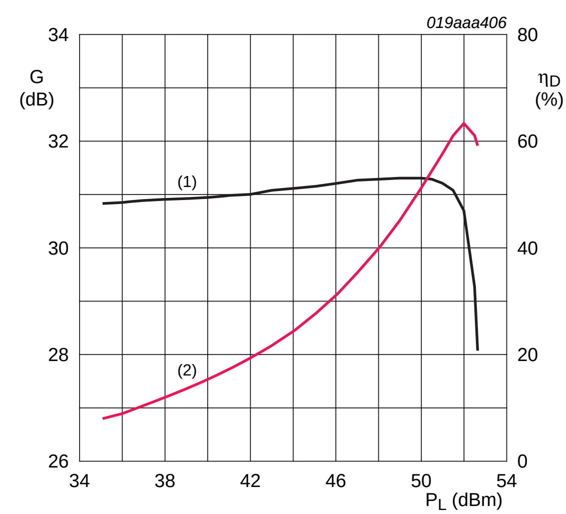


V_{DS} = 50 V; I_{Dq} = 0.5 A; DVB-T = 8K (OFDM); PAR at 0.01 % probability on the CCDF.

(1) PAR.

(2) Drain efficiency.

Fig 5. DVB-T PAR and drain efficiency at P_L = 50 W

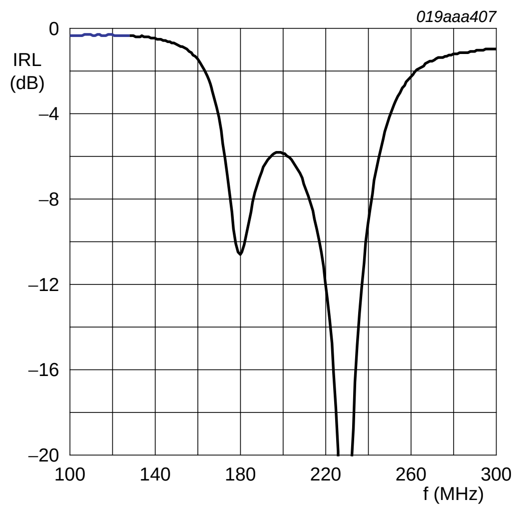


V_{DS} = 50 V; I_{Dq} = 0.5 A; t_p = 12 μs.

(1) Gain.

(2) Drain efficiency.

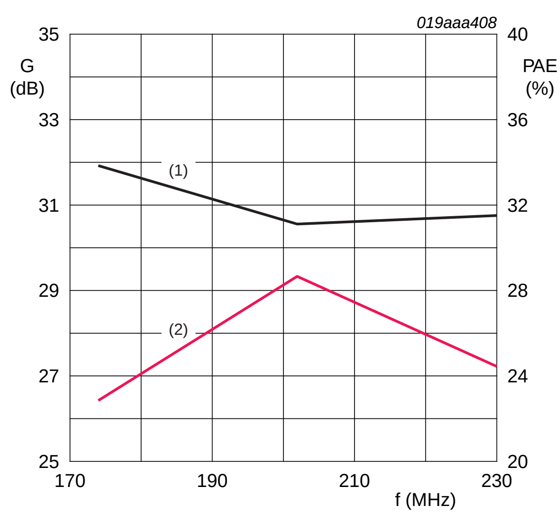
Fig 6. Pulse gain and drain efficiency at 202 MHz



V_{DS} = 50 V; I_{Dq} = 0.5 A; P_i = 10 dBm.

Fig 7. Input return loss

4.2 Flat gain tuning

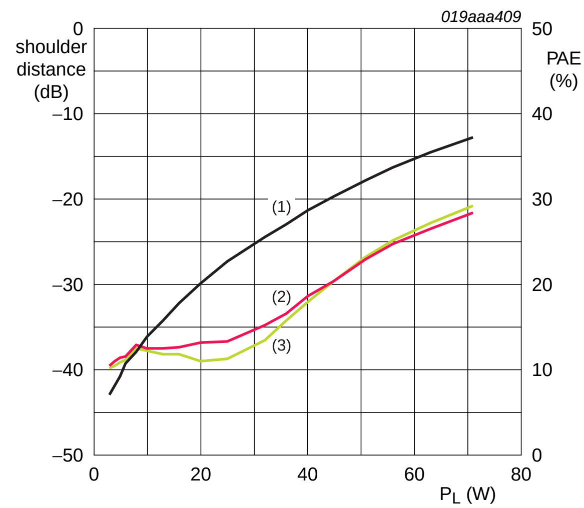


V_{DS} = 50 V; I_{Dq} = 0.5 A; DVB-T = 8K (OFDM).

(1) Gain.

(2) PAE.

Fig 8. DVB-T gain and power added efficiency at P_L = 40 W



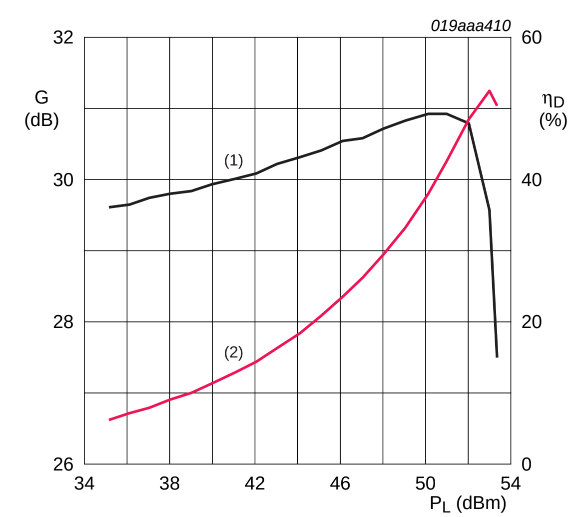
V_{DS} = 50 V; I_{Dq} = 0.5 A; DVB-T = 8K (OFDM); ACPR measured within 30 kHz bandwidth at $f_c = \pm$ 4.3 MHz.

(1) Efficiency.

(2) Upper adjacent.

(3) Lower adjacent.

Fig 9. DVB-T ACPR and power added efficiency at 202 MHz



V_{DS} = 50 V; I_{Dq} = 0.5 A; t_p = 12 μs.

(1) Gain.

(2) Drain efficiency.

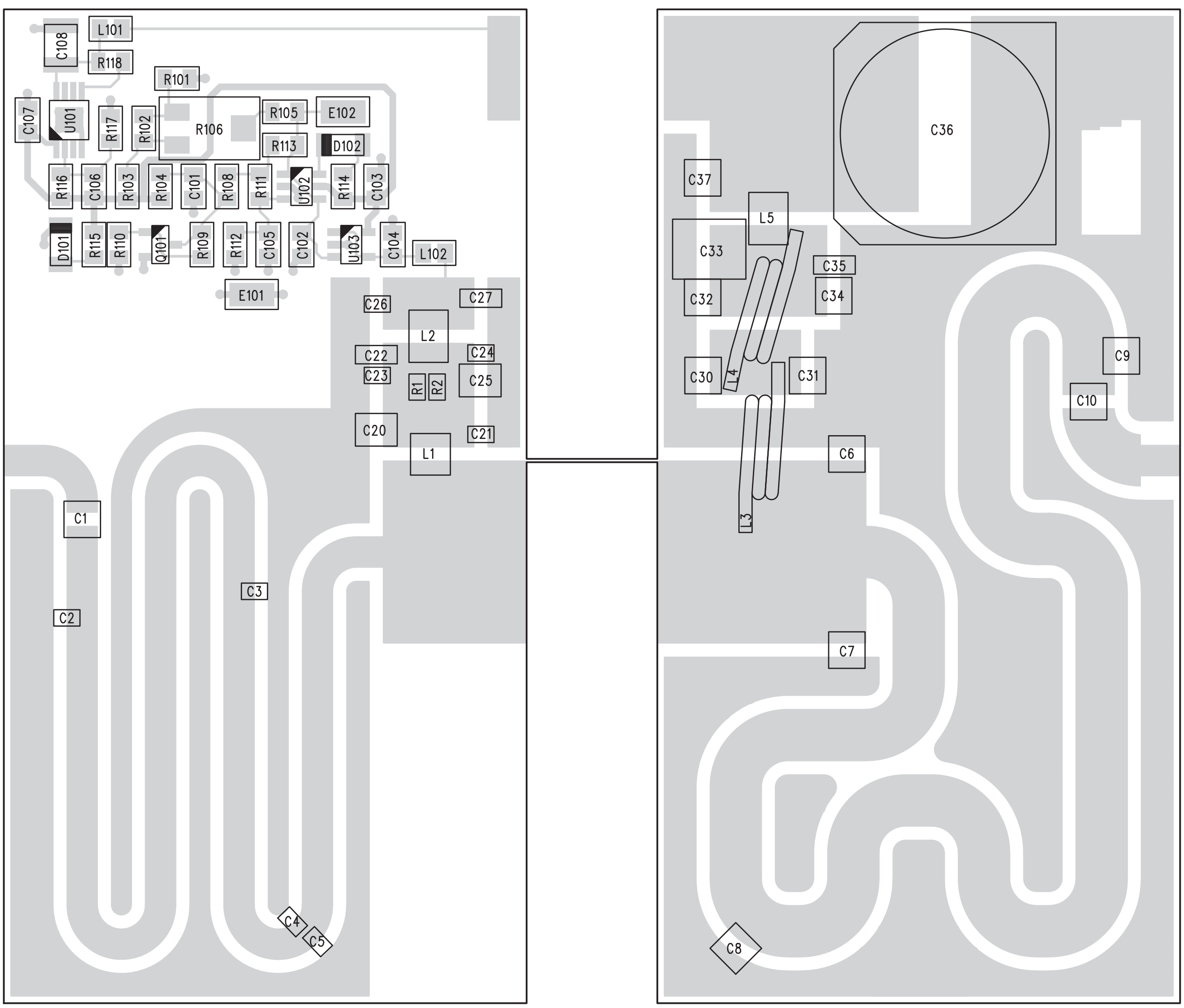
Fig 10. Pulse gain and drain efficiency at 202 MHz

Note that the peak power with flat gain tuning is up to 0.5 dB higher than with best ACPR tuning. Linearity (evident with poorer ACPR and more gain expansion with power) and efficiency are both significantly worse with flat gain tuning. A more suitable approach to achieving flat gain than tuning the output is probably to use a simple gain slope network at the amplifier input. A frequency-selective lossy network could also be used to improve input return loss across the band.

The flat gain tuning was achieved with C8 = 2 × 68 pF (ATC 800B) mounted 33 mm from the start of the 4 mm output microstrip (compared to 82 pF and 41 mm, for best ACPR tuning) and C9 = 33 pF (compared to 30 pF for best ACPR tuning).

5. PCB and schematic

The PCB was designed to accommodate either the BLF881 or the BLF573, a 300 W LDMOS RF power transistor designed for broadcast applications and industrial, scientific and medical applications in the HF to 500 MHz band.



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PCB is a Rogers 5880, height = 0.79 mm, copper thickness = 35 µm.

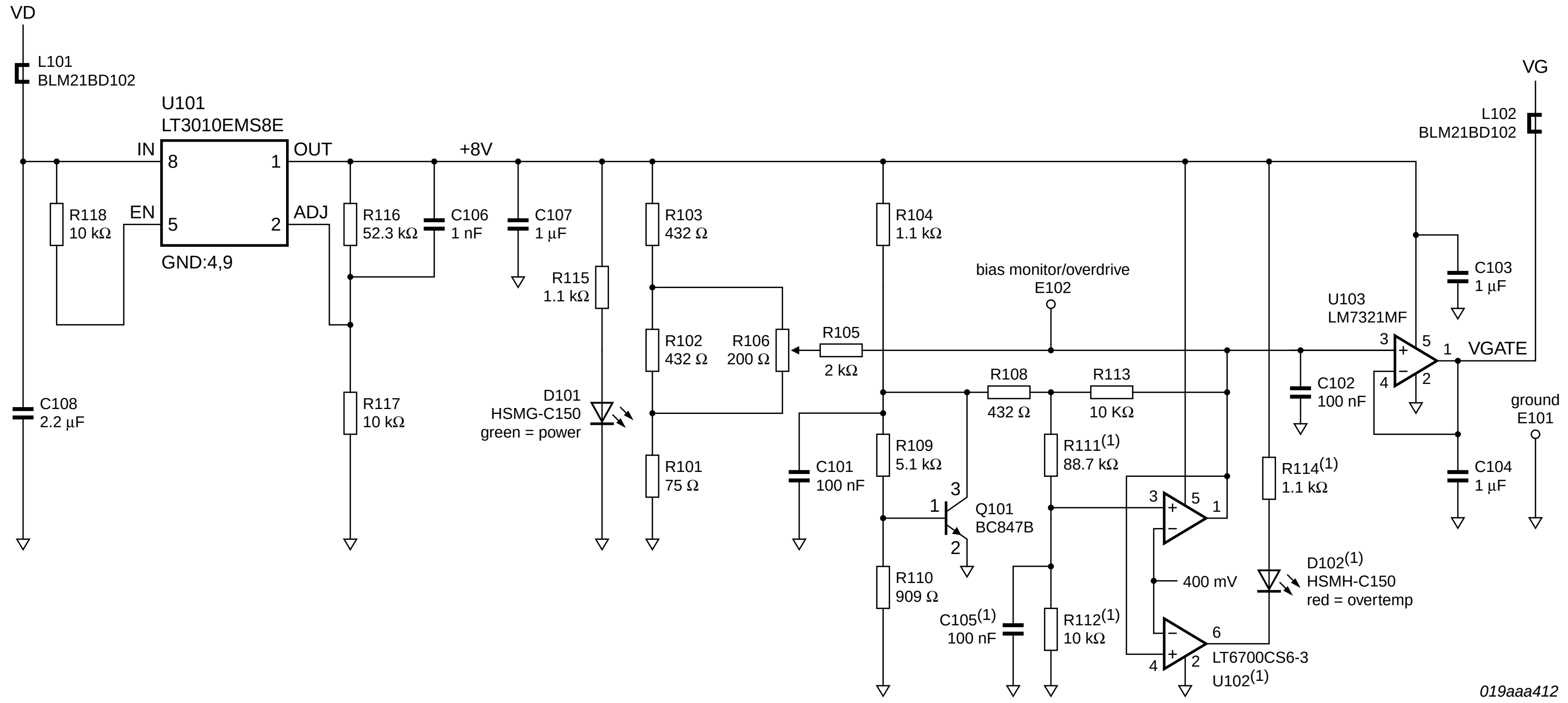
Fig 11. PCB layout

Table 3. Bill of Materials

Component	Description	Value	Remarks
RF circuit			
C1, C21	capacitor; 100 V 5 % NPO; 0805	1 nF	ATC 800R
C2	capacitor; 100 V 5 % NPO; 0805	18 pF	ATC 100B
C3, C4, C5	capacitor; 100 V 5 % NPO; 0805	100 pF	-
C6, C7	capacitor; 500 V 5 % NPO	56 pF	-
C8	capacitor; 500 V 5 % NPO	82 pF	-
C9	capacitor; 500 V 5 % NPO	30 pF	-
C10, C31	capacitor; 500 V 5 % NPO	510 pF	-
C20, C25, C30, C34, C37	capacitor; 250 V 5 % NPO; 1210	10 nF	-
C22, C27	capacitor; 25 V 10 % X7R; 1206	10 μF	-
C23, C26	capacitor; 50 V 10 % X7R; 0805	100 nF	-
C24	capacitor; 25 V 10 % X7R; 0805	1 μF	-
C32	capacitor; 100 V 10 % X7R; 1210	100 nF	-
C33	capacitor; 100 V 10 % X7S; 2220	10 μF	TDK C5750X7S2A106M
C35	capacitor; 100 V 10 % X7R; 1206	1 μF	TDK C3216X7R2A105K
C36	capacitor; 63 V aluminium electrolytic	470 μF	-
L1	inductor; 5t; air	18.5 nH	Coilcraft A05T
L2, L5	ferrite bead; 5 A	45 Ω at 100 MHz	Fair-Rite 2743019447
L3	inductor; 3t; 20 AWG; 3 mm; ID	-	-
L4	inductor; 4t; 20 AWG; 4 mm; ID	-	-
R1, R2	resistor; 5 %; 100 ppm; CF; 0805	2.2 Ω	-
E1, E2	tab; Faston; 0.25 inch	-	-
Bias circuit			
L101, L102	ferrite bead; 200 mA; 0805	1 k Ω at 100 MHz	-
C101, C102, C105	capacitor; 50 V 10 % X7R; 0805	100 nF	-
C106	capacitor; 100 V 5 % NPO; 0805	1 nF	-
C103, C104, C107	capacitor; 50 V 10 % X7R; 0805	1 μF	-
C108	capacitor; 100 V 10 % X7R; 1210	2.2 μF	-
D101	LED; green; 1206	-	-
D102	LED; red; 1206	-	-
U101	voltage regulator	-	Linear LT3010EMS8E
U102	dual comparator	-	Linear LT6700CS6-3
Q101	transistor NPN; 45 V; 100 mA; GP	-	NXP BC847B
U103	rail-rail opamp	-	National LM7321MF
R106	potentiometer; 5t cermet	200 Ω	-
R3, R4	resistor; 5 %; 100 ppm; CF; 2010	1 Ω	positioned under L4
R112, R113, R117, R118	resistor; 1 %; 100 ppm; CF; 0805	10 kΩ	-
R104, R114, R115	resistor; 1 %; 100 ppm; CF; 0805	1.1 kΩ	-
R105	resistor; 1 %; 100 ppm; CF; 0805	2 kΩ	-

Table 3. Bill of Materials

Component	Description	Value	Remarks
R102, R103, R108	resistor; 1 %; 100 ppm; CF; 0805	432 Ω	-
R116	resistor; 1 %; 100 ppm; CF; 0805	52.3 kΩ	-
R109	resistor; 1 %; 100 ppm; CF; 0805	5.11 kΩ	-
R101	resistor; 1 %; 100 ppm; CF; 0805	0.0 Ω	-
R111	resistor; 1 %; 100 ppm; CF; 0805	88.7 kΩ	-
R110	resistor; 1 %; 100 ppm; CF; 0805	909 Ω	-
E101, E102	test point	-	-



(1) These components are optional.

Fig 12. Bias circuit schematic

6. Abbreviations

Table 4. Abbreviations

Acronym	Description
ACPR	Adjacent Channel Power Ratio
CCDF	Complementary Cumulative Distribution Function
DVB-T	Digital Video Broadcast - Terrestrial
LDMOS	Laterally Diffused Metal-Oxide Semiconductor
OFDM	Orthogonal Frequency Division Multiplex
PAE	Power Added Efficiency
PAR	Peak-to-Average power Ratio
PCB	Printed-Circuit Board

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