

AN10858

174 MHz to 230 MHz DVB-T power amplifier with the BLF578

Rev. 02 — 26 March 2010

Application note

Document information

Info	Content
Keywords	BLF578, LDMOS, DVB, planar balun
Abstract	This application note describes the design and performance of a 200 W DVB power amplifier in the 174 MHz to 230 MHz band using the BLF578 power transistor. The amplifier uses innovative planar baluns and a temperature-compensated bias circuit.



Revision history

Rev	Date	Description
02	20100326	<ul style="list-style-type: none">• Section 2.5 “Thermal considerations” and Section 3 “Measurements”: updated• Table 3 “Bill of materials for DVB-T amplifier”: C13 value updated
01	20091202	Initial version

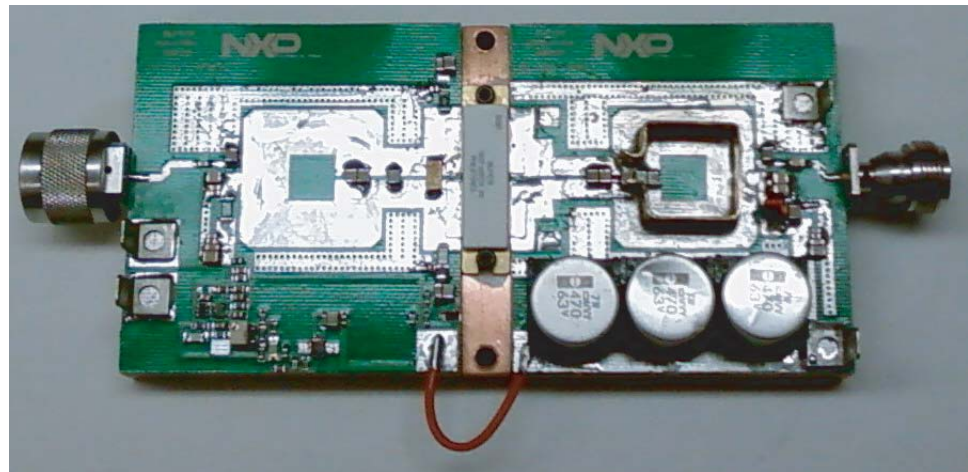
1. Introduction

Over the past few years, new product design in the broadcast industry has been dominated by emerging digital modulation standards, particularly for new digital terrestrial television transmitter systems.

DVB-T OFDM modulation produces crest factors of around 13 dB, causing peak power levels within transmitter power amplifiers of more than 20 times the average (thermal) power level. These high peak powers create design challenges, such as determining the size and shape of RF components suitable for short voltage peaks, and which are often critical. However, the low average power presents an opportunity to use high-power components in more compact designs than would be possible if continuous operation at peak power were required.

The BLF578 is a 1200 W LDMOS power transistor for broadcast transmitter applications and industrial applications from 10 MHz to 500 MHz. The transistor can deliver an average of 200 W DVB-T over the full VHF band. The excellent ruggedness of this device makes it ideal for digital transmitter applications. This application note describes the use of the BLF578 in the design of a compact broadband power amplifier intended for high-PAR DVB-T service in the 174 MHz to 230 MHz VHF television band.

The amplifier uses planar impedance transformers, rather than the coaxial cable transmission line transformers that have dominated HF and VHF power amplifier design for the past few decades. While tuned planar structures are not able to handle as much average power as broadband transmission line transformers, they have a number of advantages, including reduced cost, simpler manufacturing, and better harmonic filtering.



001aak533

Fig 1. The assembled DVB-T amplifier

The assembled amplifier is shown in [Figure 1](#). The PCB layout and bill of materials can be found in appendix A. Mechanical drawings are provided in appendix B.

1.1 Design objectives

Desired DVB-T features include:

- BLF578 power amplifier device
- Gain (G) ≥ 23.5 dB
- Gain flatness ≤ 1.5 dB
- Drain efficiency (η_D) ≥ 29 %
- Input return loss (IRL) ≤ -10 dB
- Temperature compensated bias circuit

Additional Continuous Wave (CW) and pulse characteristics include:

- CW $P_{L(1dB)} \geq 950$ W
- Efficiency at output power at 1 dB gain compression ($P_{L(1dB)}$) ≥ 70 %
- Pulse $P_{L(1dB)} \geq 1000$ W
- 2nd Harmonic ≤ -30 dBc
- 3rd Harmonic ≤ -20 dBc

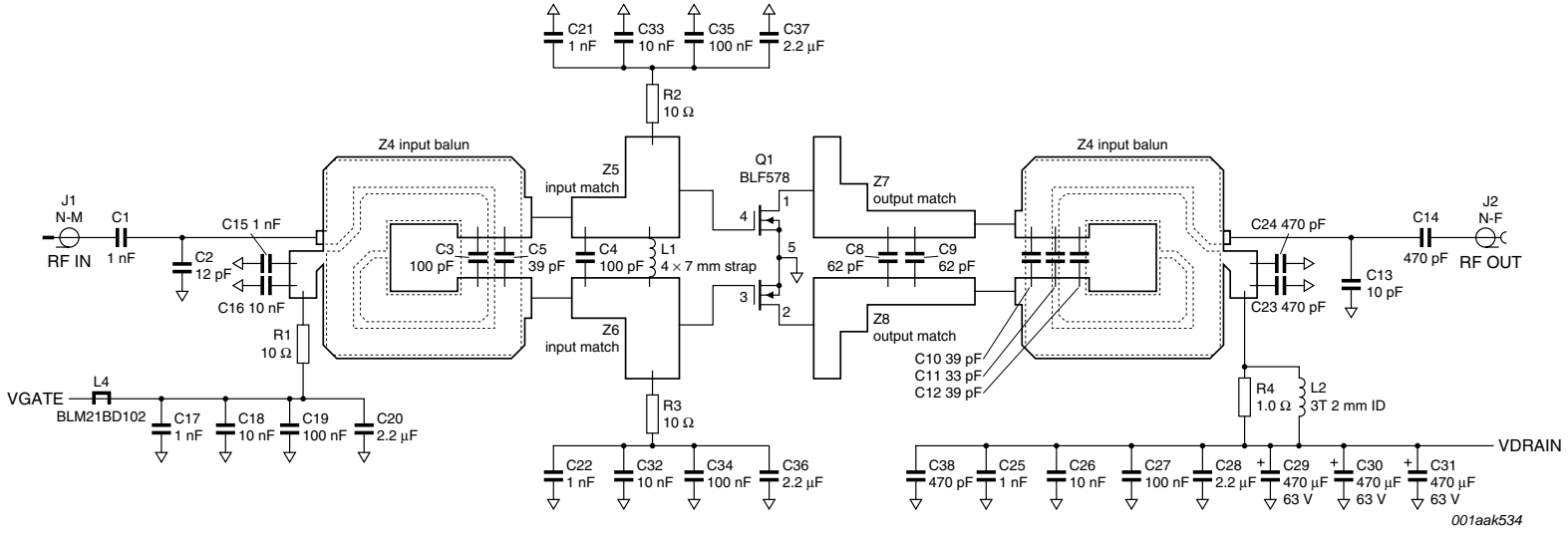
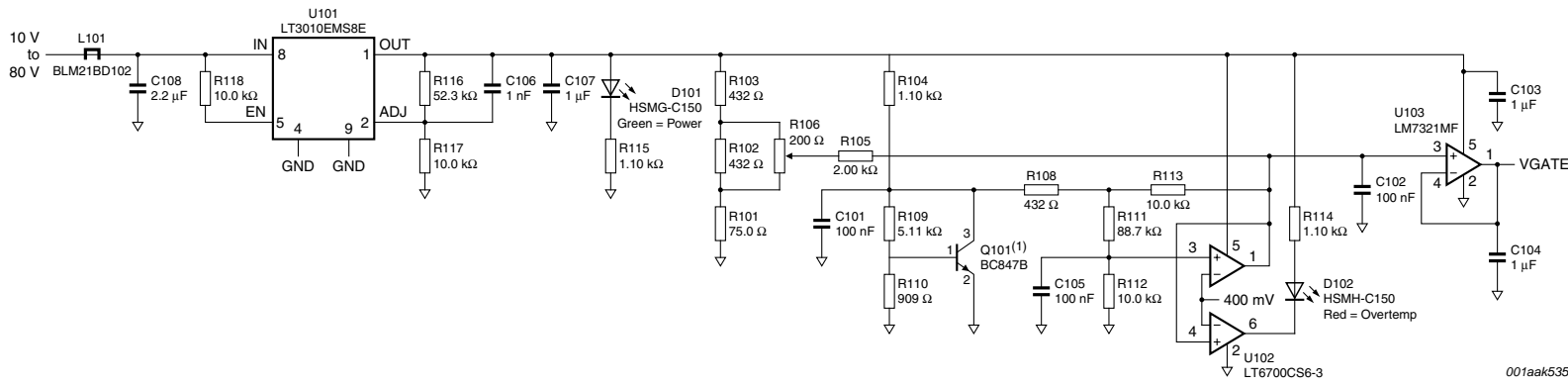


Fig 2. RF circuit with DVB-T output tuning schematic



(1) Install Q101 upside-down through the slot in the PCB close to Q1 (BLFG578): bound to heatsink.

Fig 3. Bias circuit schematic

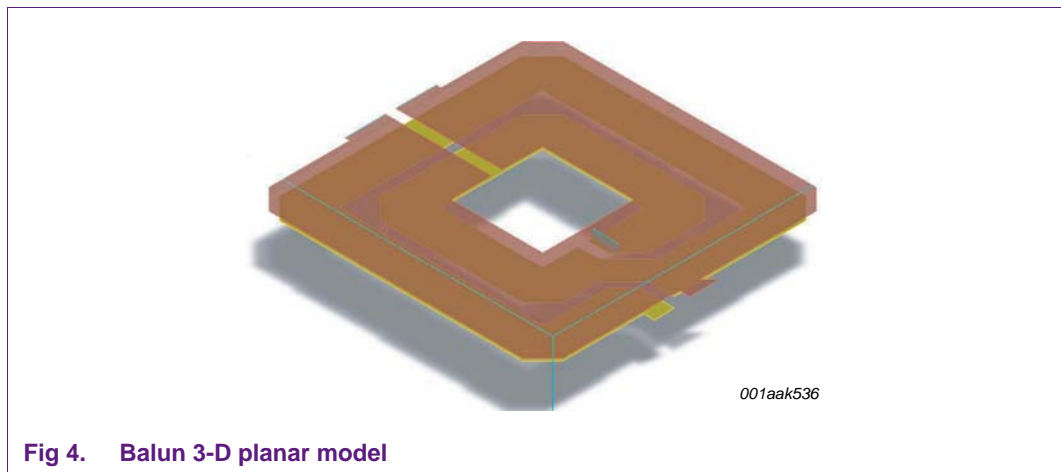
2. Design and simulation

The primary objective of this amplifier design is to demonstrate the capabilities of the BLF578 LDMOS RF transistor in a DVB-T broadcast application. However, another significant objective is to investigate the use of planar impedance transformers as an alternative to coaxial transmission line transformers.

2.1 Planar balun

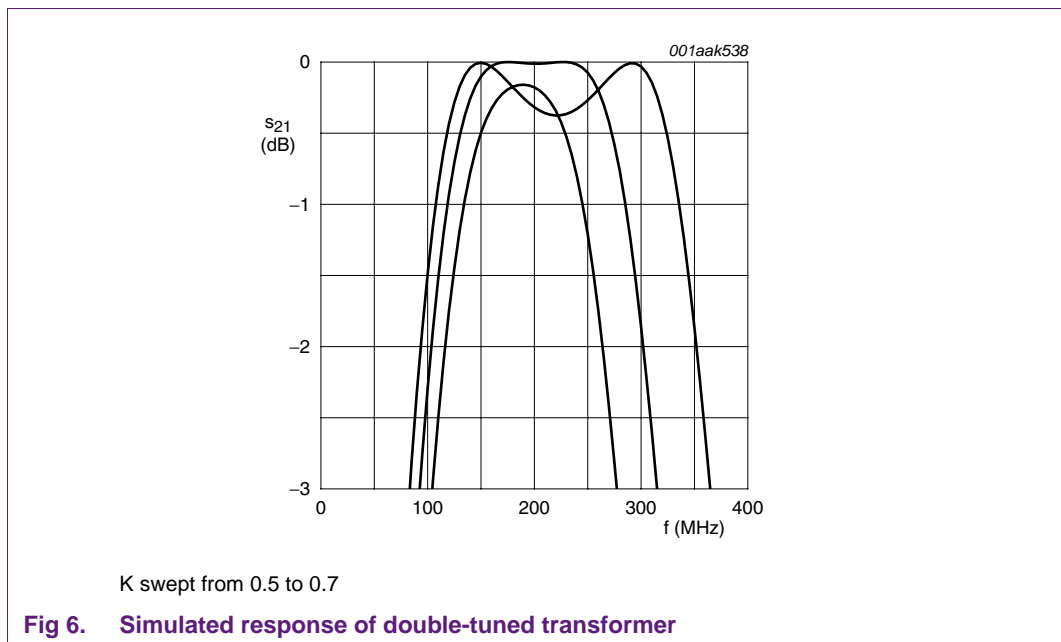
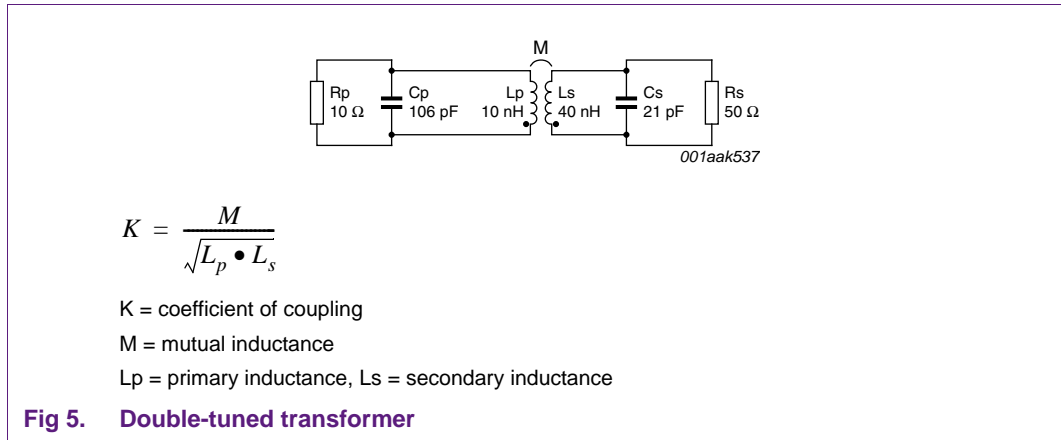
Push-pull operation has several key benefits for sub-GHz power amplifier design: the fundamental frequency components of the two device currents are equal and opposite, thus eliminating troublesome common lead effects. The composite impedance presented at the push-pull device input and output is a factor of four higher than what would be presented by a single-ended device producing the same power. Balanced-to-unbalanced transformers (baluns) are then normally required to transform the differential device input and output to the single-ended amplifier interfaces.

A balun is usually implemented as a coaxial Transmission Line Transformer (TLT), with ferrite loading at lower frequencies. Frequently, a balun has a 1 : 1 impedance ratio, and impedance transformation is provided by a combination of microstrip and LC matching sections and additional coaxial transmission line transformers. However, while a coaxial TLT is a remarkably versatile component, it occupies a significant amount of volume, tends to be expensive and troublesome to manufacture. This amplifier design uses 5 : 1 baluns constructed as part of the PCB layout to provide the balanced-to-unbalanced transformation and part of the impedance transformation.



Conventional microstrip baluns (e.g. Marchand baluns [Ref. 4](#)) are popular at higher frequencies because of their good bandwidth and good phase matching; but since they consist of quarter-wave coupled lines, they are usually too large for the VHF band. Instead, the baluns used in this amplifier are implemented as double-tuned transformers, i.e. coupled resonators.

The use of magnetically-coupled LC resonators as double-tuned transformers is described in detail in the literature; see [Ref. 1](#), [Ref. 3](#) and [Ref. 5](#). The balun was initially modelled as a conventional transformer, according to the procedure described by Abrie [Ref. 1](#); see [Figure 5](#).

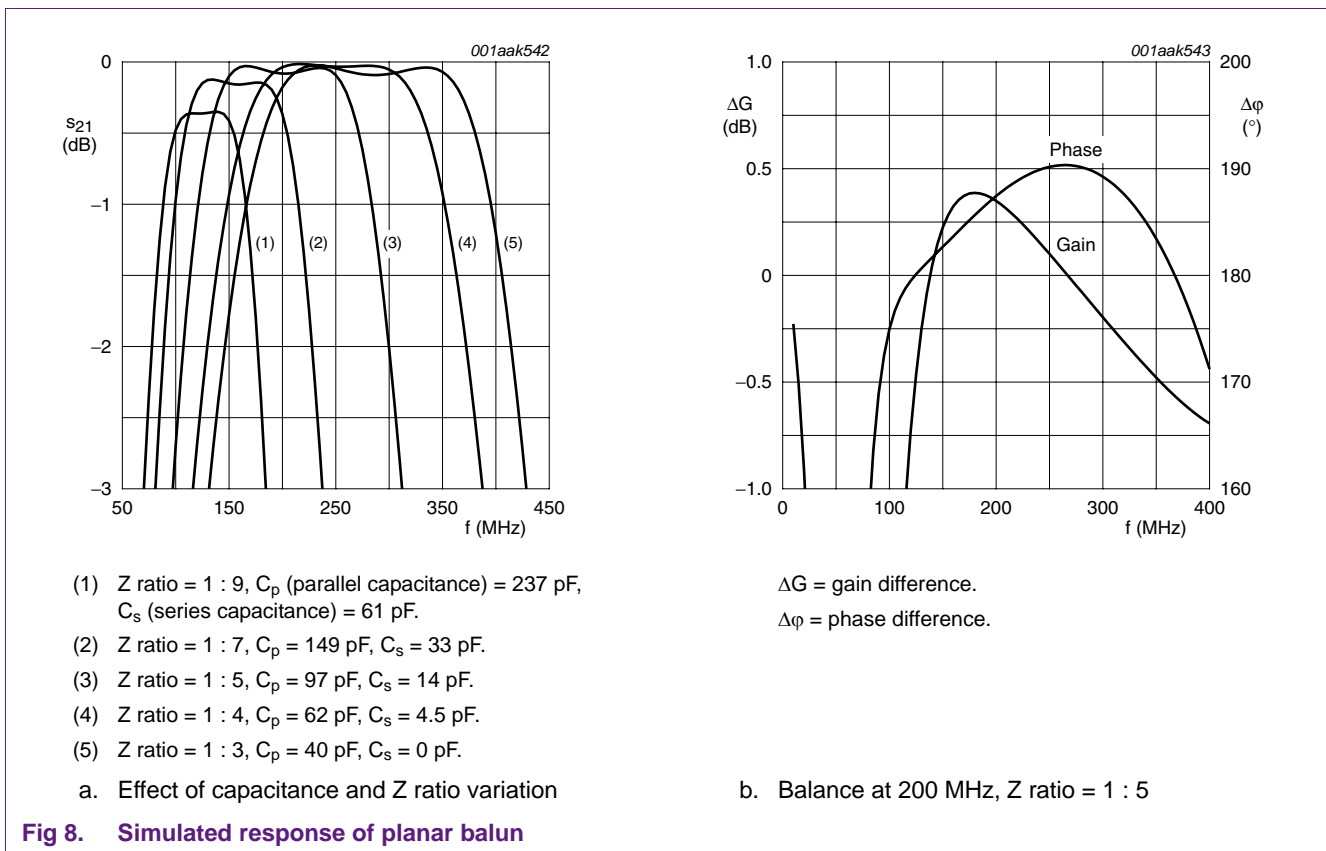
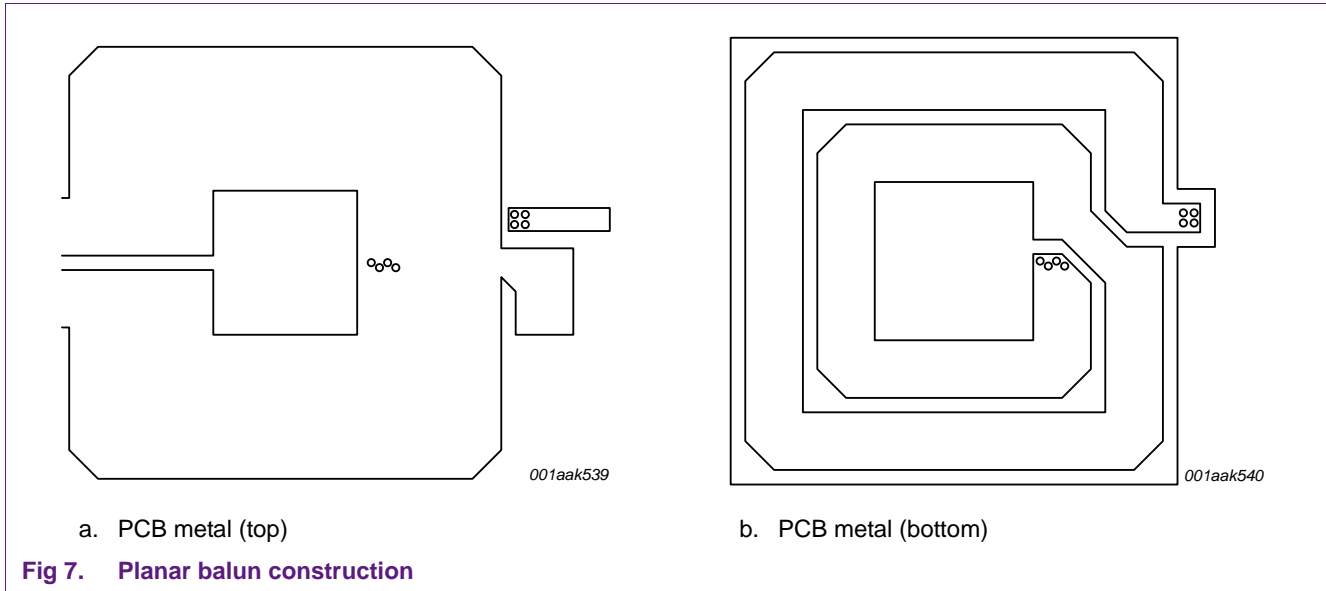


However, it proved impractical to mathematically transform this circuit into a structure of broadside-coupled microstrip transmission lines, mainly due to the added complexity of impedance transformation and the need for a multi-turn secondary ‘winding’. Instead, the approach taken was to construct a 3-D planar model of a practical structure, based on the substrate and baseplate already defined for the amplifier; and to use a 3-D planar electromagnetic simulator to determine the optimum input/output impedance ratio, values of the resonating capacitors, and to iterate dimensions if required.

Initial microstrip lengths were chosen to provide a primary inductance approximately equal to the primary inductance of the transformer model (taking into account the close proximity of the baseplate), and a two-turn secondary shorter than a quarter-wavelength at 230 MHz. The microstrip was made as wide as possible for current handling.

This was a straightforward exercise using RF design packages ADS Momentum and Sonnet, resulting in the planar structure shown in [Figure 4](#) and [Figure 7](#). The same balun structure can be used (after retuning) over a 100 MHz to 350 MHz range, as shown in [Figure 8](#).

The balun secondary is not returned to ground, but instead it is connected to the center of the primary which should always be close to a 0 V potential at RF. This was done for ease of construction, as a true ground termination would have necessitated either a pedestal in the baseplate pocket or a jumper strap for the secondary output.



2.2 BLF578 impedance

The construction of the BLF578 is based on the high voltage 50 V LDMOS process, and because it is intended for applications in the ISM and broadcast markets with frequencies up to 500 MHz, it contains no internal matching.

NXP Semiconductors provides a non-linear simulation model of the BLF578 for use with the Jaisan Advanced Design System. However equivalent device input and output impedance models are, when available, more convenient to use for initial impedance matching. Figure 10 shows equivalent circuits for the BLF578, which have the usual limitations:

- The equivalent input circuit corresponds well with the non-linear model and the broadband performance of the device up to 500 MHz
- The parallel resistance (R_p) in the equivalent output circuit needs to be adjusted for the appropriate operating point
- The equivalent output circuit does not vary the drain-source capacitance (C_{DS}) according to its non-linear dependence upon frequency, therefore it is inaccurate at frequencies outside the 200 MHz to 230 MHz range

Table 1. BLF578 typical impedances

Differential impedances are derived from equivalent input and output models.

f (MHz)	Source impedance (Z_S) (Ω)	Load impedance (Z_L) (Ω)
170	$2.35 + j3.77$	$3.15 - j0.75$
200	$2.36 + j3.17$	$3.06 - j0.85$
230	$2.36 + j2.71$	$2.97 - j0.95$

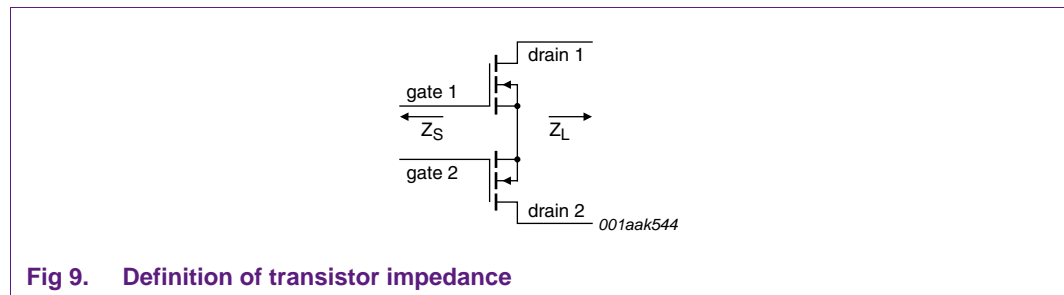
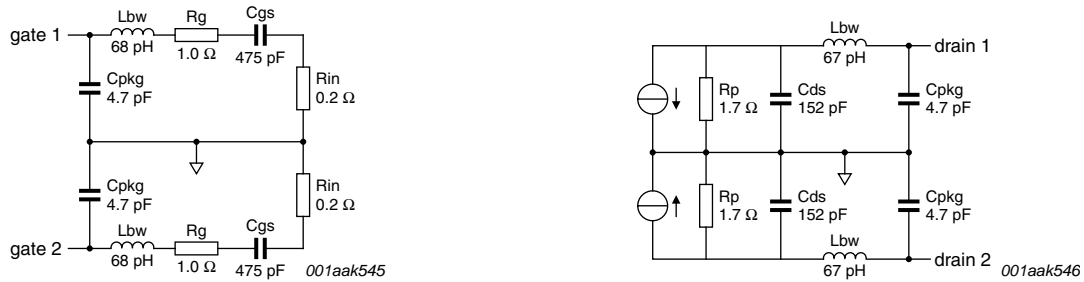


Fig 9. Definition of transistor impedance



- Rg = gate resistance.
- Cgs = gate-source capacitance.
- Cpkg = package capacitance.
- Rin = equivalent input resistance.
- a. Equivalent VHF input circuit
- Lbw = bond-wire inductance.
- Rp = equivalent parallel output resistance.
- $R_p = (V_{DD} - V_{knee})^2 / (P_L) = (50 - 5)^2 / (1200)$.
- Cds = drain-source capacitance.
- b. Equivalent VHF output circuit for $P_L = 1200$ W

Fig 10. BLF578 equivalent input and output impedance models

2.3 Matching and power feed networks

Although the baluns provide some impedance transformation, additional networks are needed between the 10 Ω differential impedance of the baluns and the 3 Ω to 6 Ω (parallel, differential) at the transistor terminals. These were implemented as simple LC sections (microstrip lines with shunt capacitors), and were calculated with the help of a (software) Smith chart.

It is important for stability that the impedances presented to the RF transistor are low at low frequencies. Figure 11 shows the simulated differential impedance.

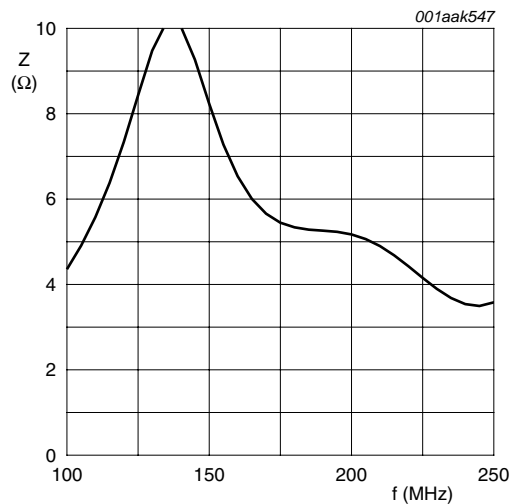


Fig 11. Simulated output network differential impedance

To achieve best efficiency, it is important that the common-mode impedance presented to the RF transistor at the second harmonic is as low as possible. This is shown in Figure 12.

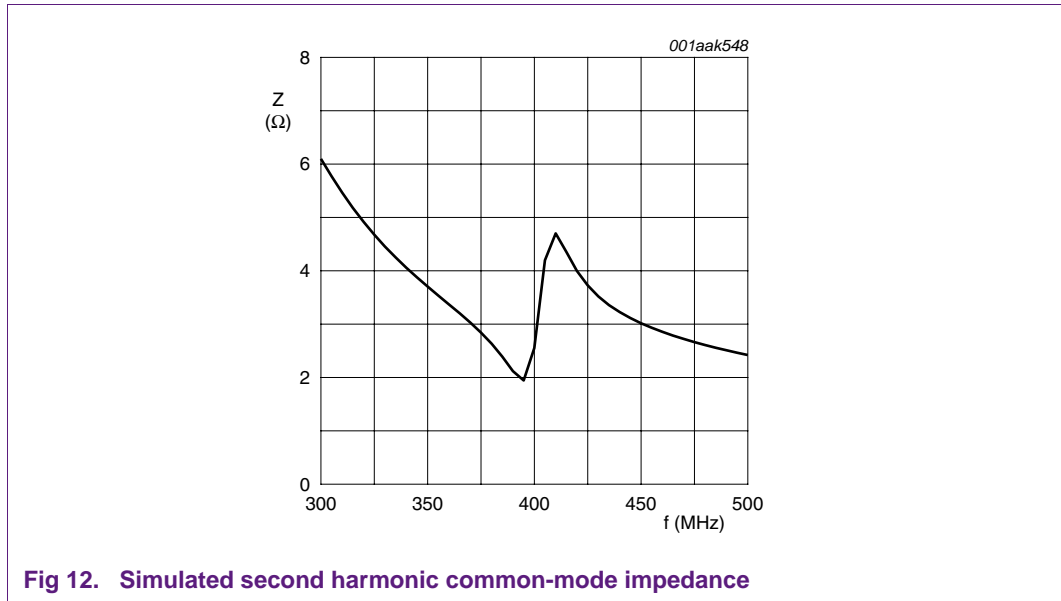


Fig 12. Simulated second harmonic common-mode impedance

linear DVB-T applications, both the low frequency differential impedance and the second harmonic common-mode impedance are sufficiently low. However, for a CW design, efficiency is improved by reducing the second harmonic impedance to less than 1 Ω. Some investigation should be done to verify that the low frequency differential impedance is low enough to ensure stability when a Voltage Standing Wave Ratio (VSWR) of 10 : 1 output mismatch is swept through all phases.

It is critical for stability (i.e. to keep the device from oscillating and destroying itself) that the gates ‘see’ a low-resistance, non-reactive termination at low frequencies. This is provided by gate resistors R2 and R3. It is important that these resistors are connected to a good broadband RF ground; see [Figure 13](#).

It is important for both stability and reduced intermodulation that the power feed network is free from low-frequency resonances. This is shown in [Figure 13](#).

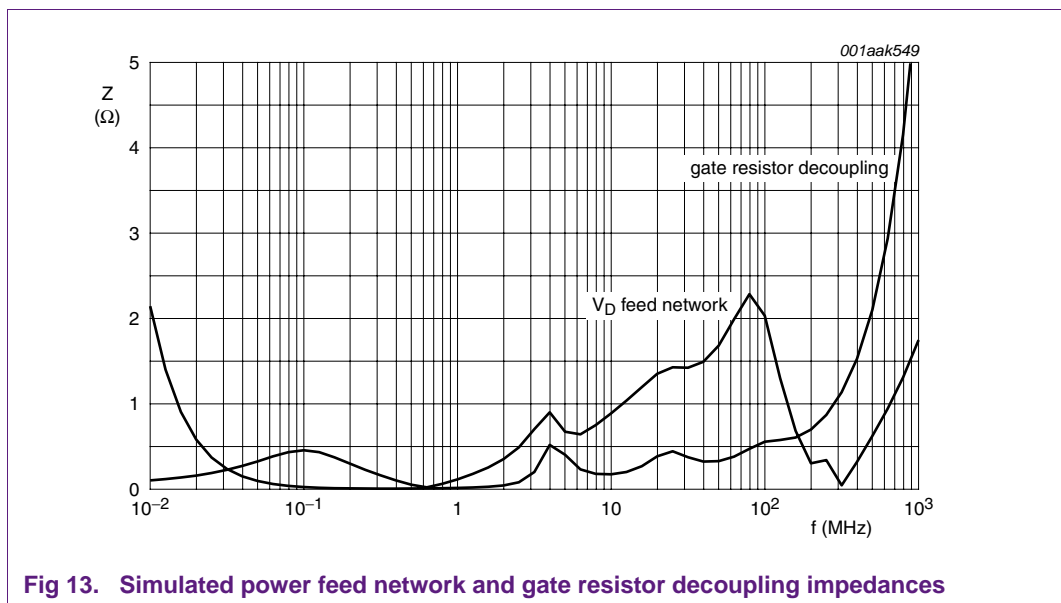


Fig 13. Simulated power feed network and gate resistor decoupling impedances

2.4 Temperature-compensated bias circuit

The quiescent drain current I_{Dq} (and hence the operating point) of the BLF578 is set by adjusting the gate-source voltage V_{GS} with a constant-voltage bias source. In an LDMOS device, the gate-source threshold voltage V_{GSth} is inversely proportional to temperature, with a slope of about $-2 \text{ mV}/^\circ\text{C}$. To maintain a constant quiescent current, the voltage generated by the bias supply should vary as a function of the junction temperature T_j of the RF device.

It is difficult to track the junction temperature exactly. However, reasonable results are obtained by monitoring the temperature of the baseplate, which is close to the RF transistor, with the temperature compensated bias circuit used in this amplifier. This circuit is shown in [Figure 3](#).

The temperature sensing device (Q101), is attached through a hole in the PCB to the baseplate near Q1. Its collector current is proportional to temperature, which results in a collector voltage slope of about $-10 \text{ mV}/^\circ\text{C}$. Part of this temperature-dependent voltage is summed with the adjustable bias voltage from potentiometer R106 to generate the temperature-compensated final bias voltage.

The RF characteristics of the BLF578 with high drive levels are sensitive to the DC impedance presented to the gates, so operational amplifier U103 is used to buffer the bias voltage. Note that this operational amplifier must be capable of driving very large capacitive loads without instability.

Voltage regulator (U101) generates the stable +8 V used to power the rest of the bias circuit. Note that because it is regulating the voltage from the +50 V drain supply it must be rated for high input voltages. The LT3010 used here is rated for 80 V operation.

Comparator (U102) provides an overtemperature monitoring and bias shutdown feature. It is not very important for a demonstration amplifier like this, but is significantly more useful in a production amplifier.

2.5 Thermal considerations

Even with the lower average output power (200 W) in DVB-T operation, the BLF578 still dissipates 400 W to 500 W. To keep T_j below the recommended operating temperature of 170°C with a heatsink temperature of 70°C , the junction-to-heatsink thermal resistance $R_{th(j-h)}$ must be less than 0.2 K/W. Unfortunately, the internal junction-to-case thermal resistance $R_{th(j-c)}$ is 0.13 K/W by itself, which only leaves 0.07 K/W for the interface between the case and the heatsink.

Note that it is **not** possible to accomplish this with conventional thermal grease: since the surface area of the SOT539A flange available for heat transfer is about 3 cm^2 , and the thermal conductivity of conventional thermal grease is less than $0.8 \text{ W/m}\cdot\text{K}$, the layer of grease would have to have a consistent void-free thickness of less than $17 \mu\text{m}$ — impractically thin. Additionally, experiments have shown that a device flange retained only by two bolts (i.e. nothing clamping the entire device lid) may bow by as much as $20 \mu\text{m}$ at junction temperatures of 200°C .

The only practical solution that will allow the BLF578 to be bolted down (when used in these low-efficiency operating conditions) is to use one of the new high-conductivity thermal interface compounds (e.g. ShinEtsu X23-7762, Bergquist TIC4000, Electrovac eiNano) or a low-resistance polymer solder hybrid phase change material (e.g. Chomerics

T777) with a thermal conductivity of at least 4 W/m-K and a finished bond line thickness no greater than 20 μm . Additionally, both the device flange and the mounting surface must be flat to better than 10 $\mu\text{m}/\text{cm}^2$, with an average surface roughness R_A less than 1 μm . If a transistor clamp is not used, bolt torque must be limited to about 0.7 N·m (for an M3 bolt) to avoid flange distortion, or disc spring washers must be used to maintain a clamping force of 50 N to 70 N for each bolt.

The solution used for the amplifier described in this application note was to solder the device to a copper heat spreader ('insert') which is then bolted to the heatsink with conventional techniques. (Note that when soldering the device to the heat spreader, it is critical to clamp the device or use a vacuum to eliminate any voids in the solder.)

The primary side (top of PCB) of the output balun can dissipate a lot of power — up to 3 % of the output power at 170 MHz — due to input return losses from the DC and RF drain currents and the resonant current flowing in the transformer. The input return losses are exacerbated by the poor electrical conductivity of the deposited copper electrode conventionally used in PCB substrates. While this power (6 W) can be safely dissipated in DVB-T operation with some forced convection, higher average power CW modes of operation require the addition of a 'cooling fin' (visible in [Figure 1](#)) for safe operation.

3. Measurements

The fully assembled amplifier is shown in [Figure 1 on page 3](#). Note the brass 'cooling fin' soldered to the output balun as a heat sink. As discussed in the previous section, the primary winding of the output transformer can dissipate as much as 3 % of the output power; so some additional cooling was needed during the 600 W CW harmonic measurements. The cooling fin is not necessary for DVB-T operation, but it can safely be retained as it has negligible effect on the tuning.

A range of tuning options were tested on the assembled amplifier, but only minor adjustments were made. In particular, the input matching network was left untouched as it performed exactly as simulated.

3.1 Single tone measurements with DVB-T tuning

[Figure 14](#) shows the output gain and power added efficiency (PAE) under a power sweep for low, mid, and high frequency channels. Because of the amplifier's limited average power handling, these measurements were made with a pulsed source. The lower power results correlate closely (within 0.1 dB) with the results of their corresponding CW measurements.

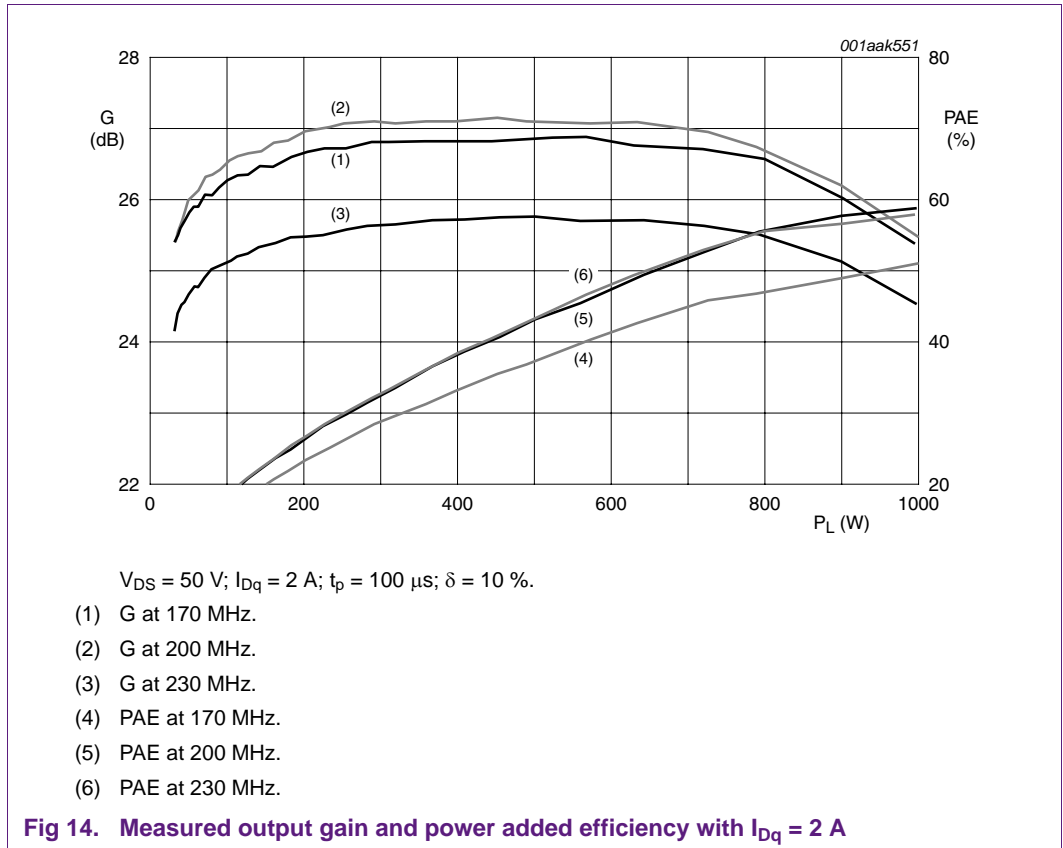


Figure 15 shows the output gain and power added efficiency of the amplifier operated in deep Class AB ($I_{Dq} = 100 \text{ mA}$) instead of the more linear bias ($I_{Dq} = 2 \text{ A}$) used for DVB-T operation. Since the amplifier tuning remains the same, the $P_{L(1\text{dB})}$ level remains the same (about 950 W) for both bias levels.

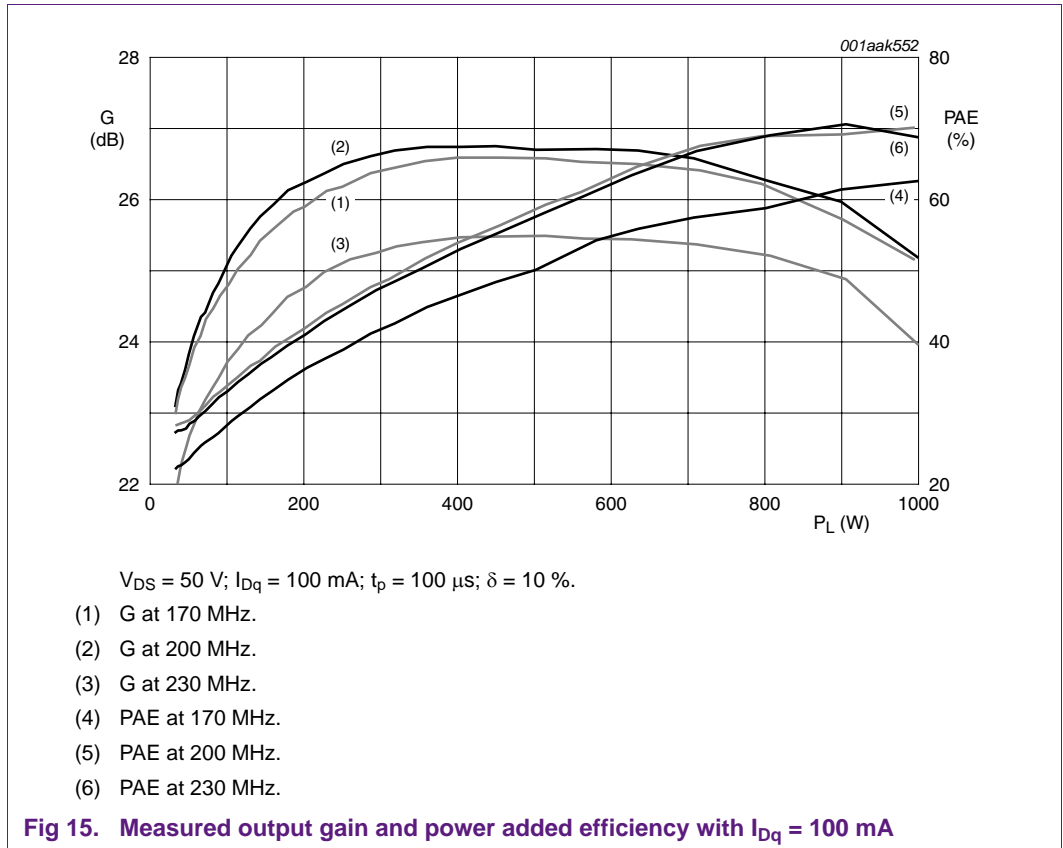


Fig 15. Measured output gain and power added efficiency with $I_{Dq} = 100\text{ mA}$

Figure 16 shows the input return loss, which exhibits an excellent match over the VHF band. This curve was measured at $I_{Dq} = 2\text{ A}$, but it remains almost unaffected by bias and drive levels.

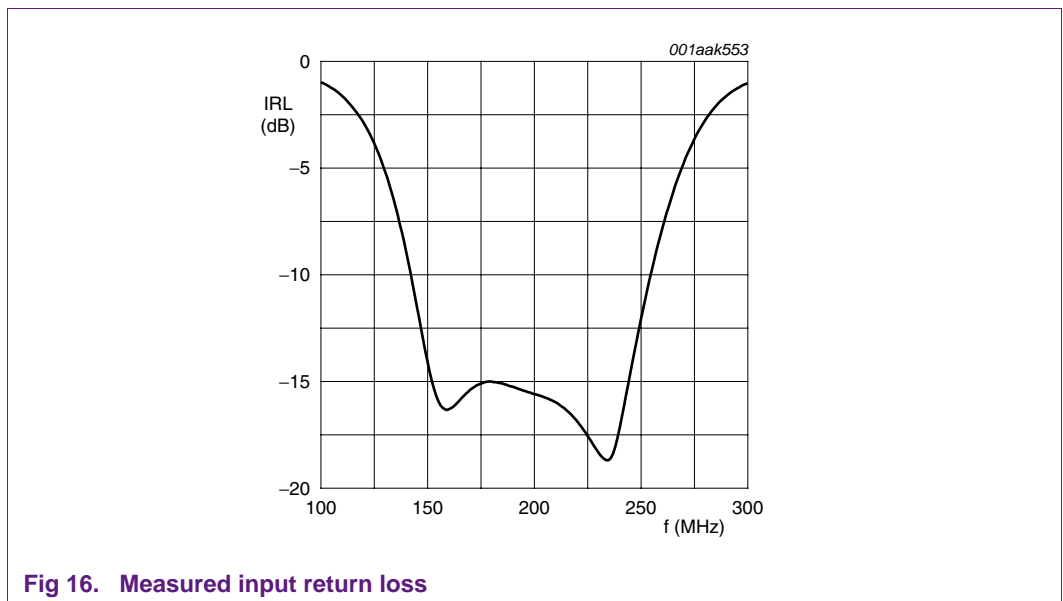
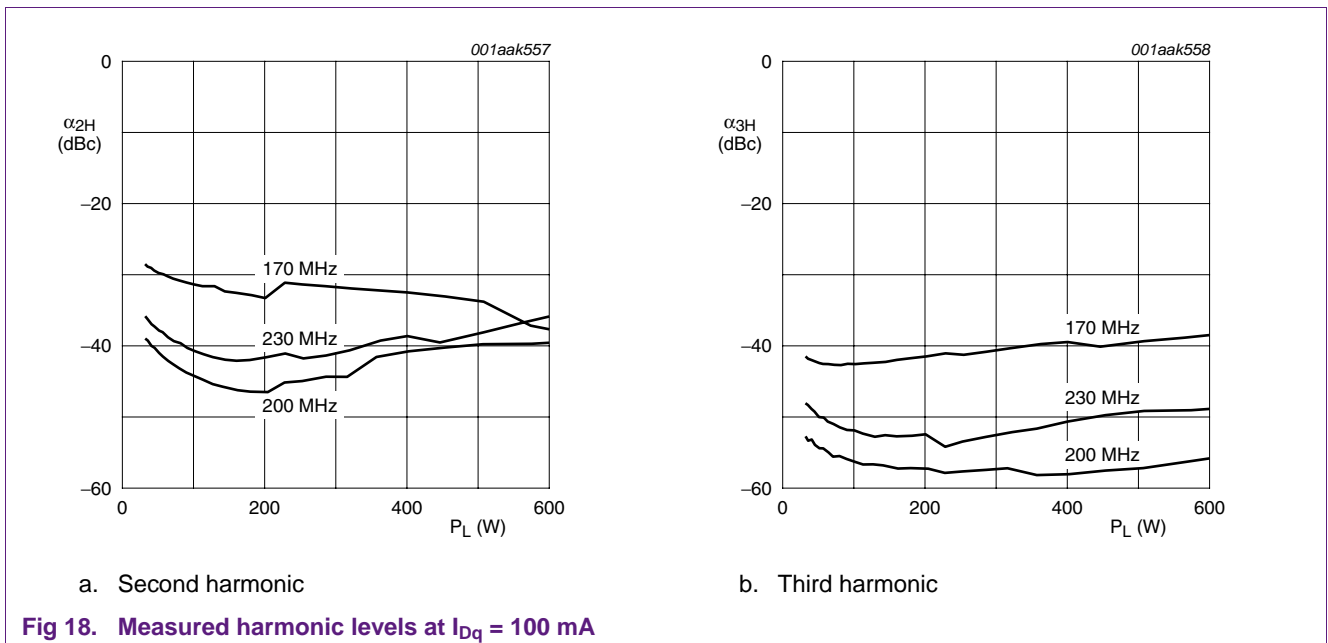
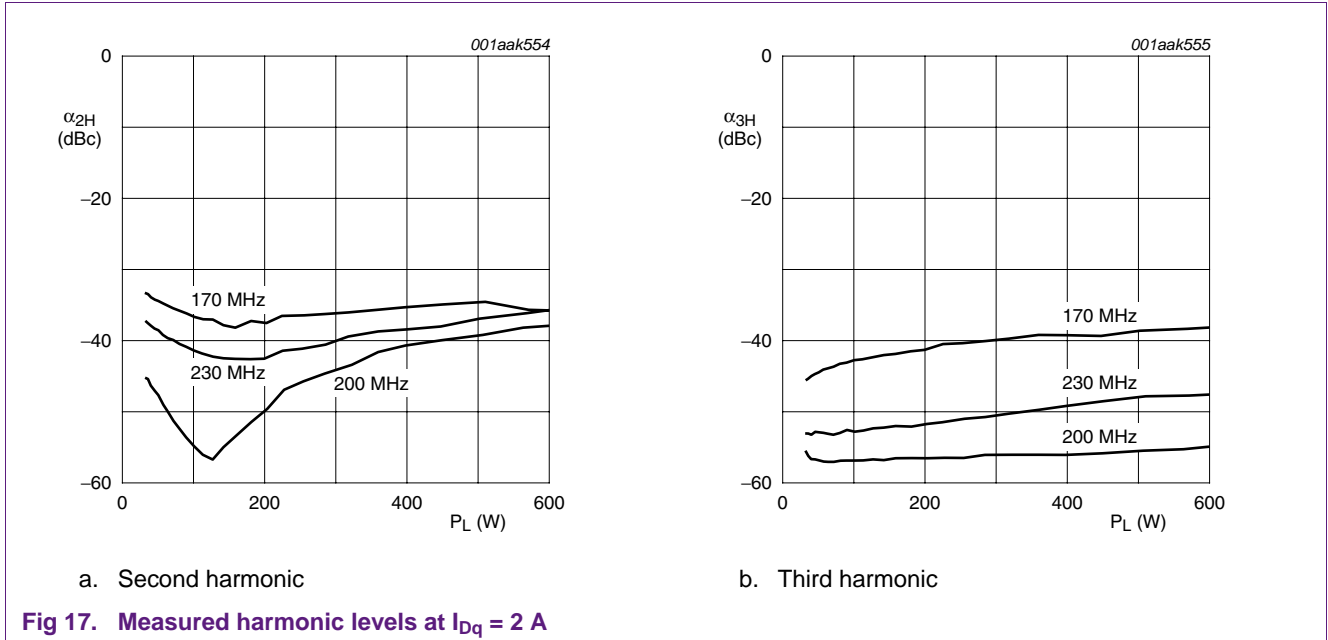


Fig 16. Measured input return loss

Figure 17 and Figure 18 show the amplifier's harmonic suppression. Much of the second harmonic suppression is inherent in the push-pull topology, but the low third harmonic levels are the result of the frequency selectivity of the output balun.



3.2 DVB-T measurements

DVB-T programs are made of OFDM signals which contain 1705 (2 K mode) or 6817 (8 K mode) carriers that are approximately 4 kHz (2 K) or 1 kHz (8 K) apart. This kind of signal has a high crest factor (PAR) of around 13 dB, which means that the amplifier receives a signal with a peak power of 20 times the average power. The AM/AM and AM/PM non-linearities of the amplifier will degrade this signal, increasing the Block Error Rate (BER) and causing spectral regrowth in adjacent channels.

In practice, digital pre-distortion is always used to compensate for a certain amount of power amplifier non-linearity and single-channel band-pass filters are used at the transmitter output to reduce the adjacent channel interference.

It has been empirically determined that (memory effect aside), a power amplifier that compresses an 8 K DVB-T signal to a crest factor of 8 dB can still be effectively linearized by digital predistortion. Since it is more convenient to measure the output spectrum than the crest factor, the shoulder distance of the output signal is measured at the edge of the adjacent channel (± 4.3 MHz); see [Figure 19](#). A shoulder distance of -30 dBc has been found to correlate well with an 8 K DVB-T signal compressed to a crest factor of 8 dB.

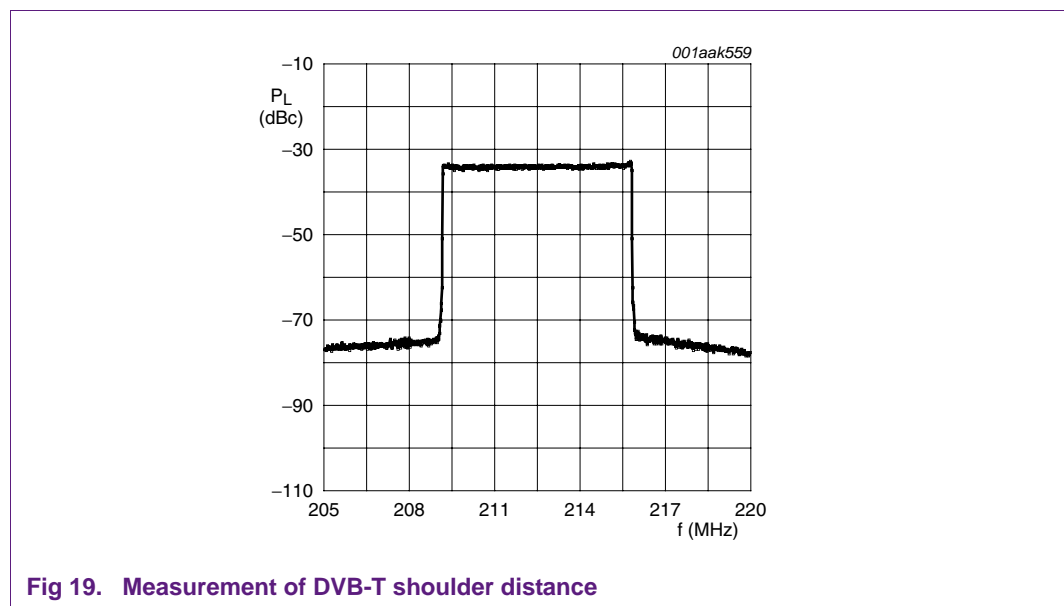


Fig 19. Measurement of DVB-T shoulder distance

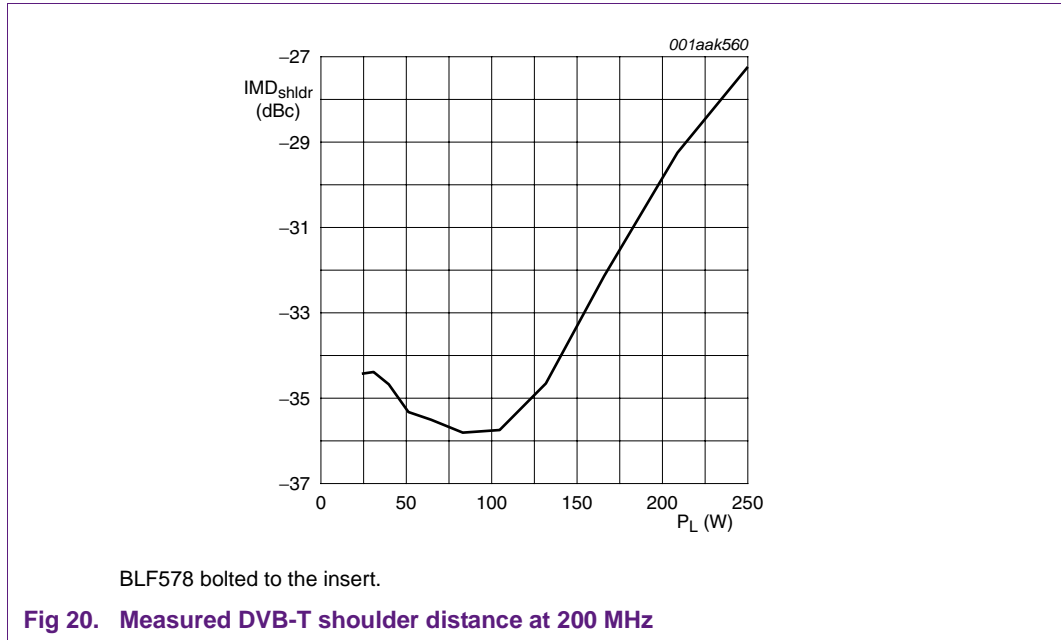
[Table 2](#) summarizes the output power and efficiency that corresponds to this -30 dBc shoulder level, for low, mid, and high frequency channels. The stimulus for this measurement was an 8 K DVB-T signal with a CCDF (0.01 % probability) of 9.6 dB; the -30 dBc shoulder distance measured at the output corresponds to an 0.01 % CCDF of 8 dB.

Table 2. DVB-T power and efficiency

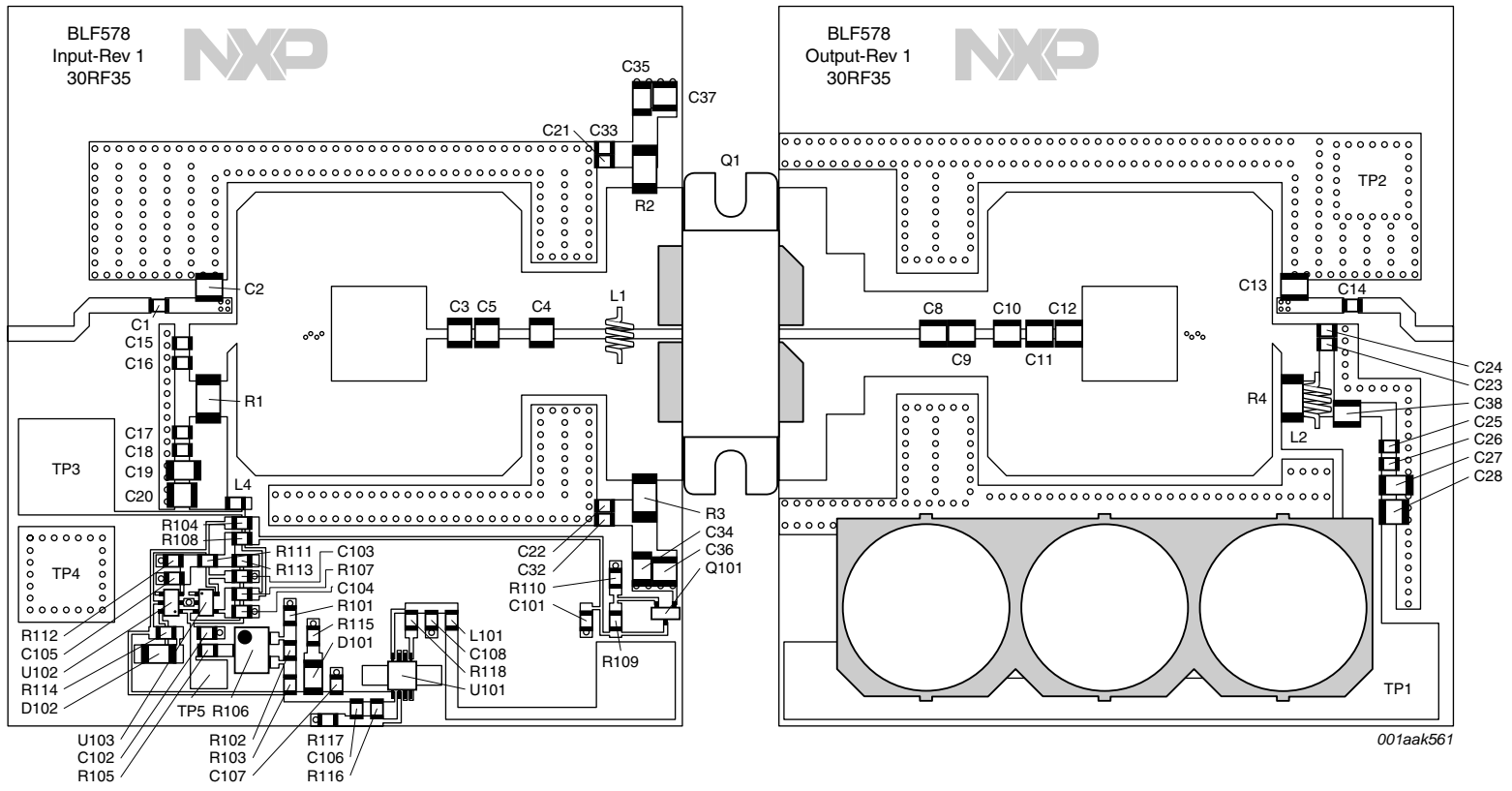
Output power dissipation for -30 dBc shoulder distance at ± 4.3 MHz with DVB-T (8 K OFDM) signal; BLF578 soldered to the insert.

f (MHz)	P _L (W)	P _i (dBm)	I _D (A)	Efficiency (%)
170	197	27.0	12.8	30.8
200	206	27.4	11.7	35.2
230	202	28.5	11.8	34.2

Figure 20 shows the DVB-T back-off performance, which is the shoulder distance as a function of the output power dissipation.



4. Appendix A: PCB layout and bill of materials



Substrate is Taconic RF-35, thickness 0.76 mm (30 mil), copper plated to 70 μm.

Fig 21. DVB-T amplifier component layout

Table 3. Bill of materials for DVB-T amplifier

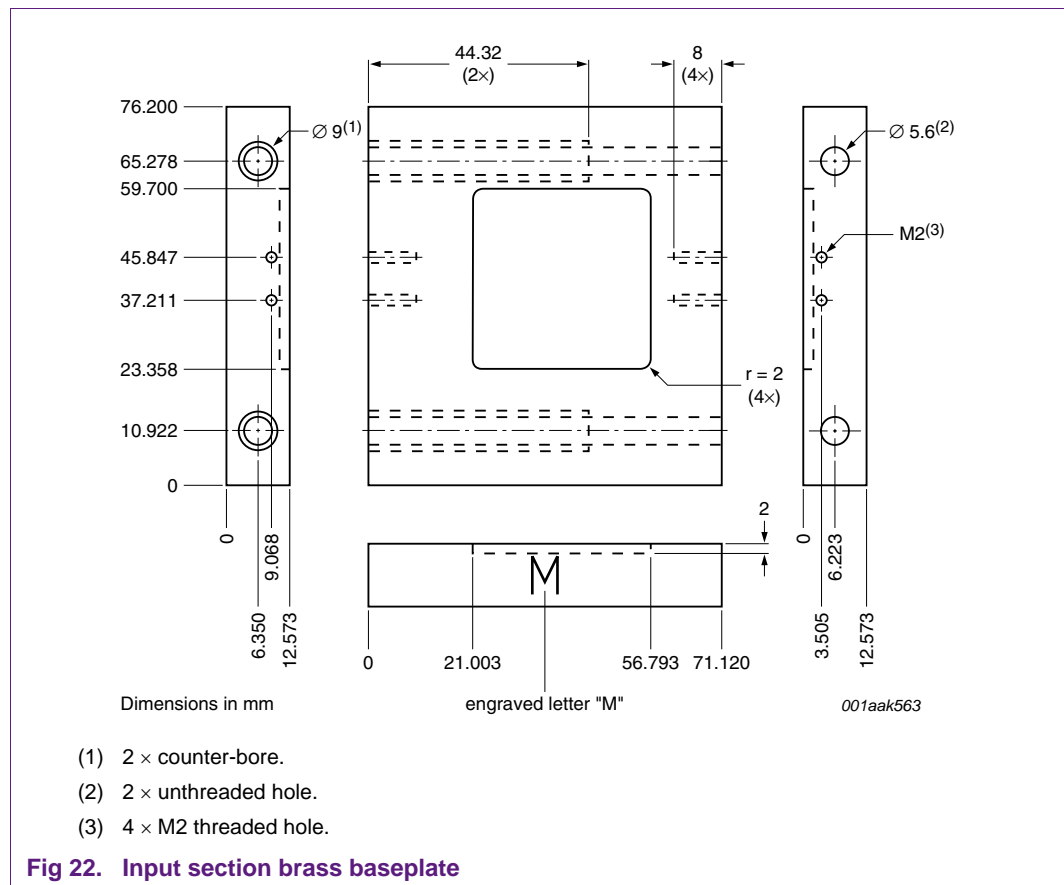
Designator	Description	Part number	Manufacturer
C1, C15, C17, C21, C22, C25, C106	1 nF 100 V 5 % NP0, 0805	GRM2195C2A102JA01D	MuRata
C2	12 pF 500 V 2 % NP0, case B	ATC800B120GT500X	American Technical Ceramics
C3, C4	100 pF 500 V 2 % NP0, case B	ATC800B101GT500X	American Technical Ceramics
C5, C10, C12	39 pF 500 V 2 % NP0, case B	ATC800B390GT500X	American Technical Ceramics
C8, C9	62 pF 500 V 2 % NP0, case B	ATC800B620GT500X	American Technical Ceramics
C11	33 pF 500 V 2 % NP0, case B	ATC800B330GT500X	American Technical Ceramics
C13	12 pF 500 V 2 % NP0, case B	ATC800B120GT500X	American Technical Ceramics
C14, C23, C24, C38	470 pF 200 V 5 % NP0, case B	ATC ATC800B471JT200X	American Technical Ceramics
C16, C18, C26, C32, C33	10 nF 250 V 10 % X7R, 0805	C0805C103KARACTU	Kemet
C19, C27	100 nF 250 V 10 % X7R, 1206	GRM31CR72E104KW03L	MuRata
C20, C28, C36, C37, C108	2.2 μ F 100 V 10 % X7R, 1210	GRM32ER72A225KA35L	MuRata
C29, C30, C31	470 μ F 63 V	EMVY630GDA471MMH0S	UCC
C34, C35, C101, C102, C105	100 nF 50 V 10 % X7R, 0805	GRM21BR71H104KA01L	MuRata
C103, C104, C107	1 μ F 50 V 10 % X7R, 0805	GRM21BR71H105KA12L	MuRata
D101	LED, green, 1206	HSMG-C150	Avago
D102	LED, red, 1206	HSMH-C150	Avago
J1	N connector, male	-	-
J2	N connector, female	-	-
L1	4W \times 7L \times 2H Cu strap	-	-
L2	2T 18AWG 2 mm ID	-	-
L4, L101	ferrite bead, 1000R 200 mA, 0805	BLM21BD102SN1D	MuRata
Q1	BLF578 POWER LDMOST	BLF578	NXP Semiconductors
Q101	NPN 45 V 100 mA GP, SOT23	BC847B	NXP Semiconductors
R1, R2, R3	10 Ω 5 % 100 PPM CF, 2010	-	-
R4	1 Ω 5 % 100 PPM CF, 2010	-	-
R101	75 Ω 1 % 100 PPM CF, 0805	-	-
R102, R103, R108	432 Ω 1 % 100 PPM CF, 0805	-	-
R104, R114, R115	1.1 k Ω 1 % 100 PPM CF, 0805	-	-
R105	2 k Ω 1 % 100 PPM CF, 0805	-	-
R106	200 Ω 5T CERMET SMD	3214X-1-201E	BOURNS
R107	0 Ω 1 % 100 PPM CF, 0805	-	-
R109	5.11 k Ω 1 % 100 PPM CF, 0805	-	-
R110	909 Ω 1 % 100PPM CF, 0805	-	-
R111	88.7 k Ω 1 % 100 PPM CF, 0805	-	-
R112, R113, R117, R118	10.0 k Ω 1 % 100 PPM CF, 0805	-	-
R116	52.3 k Ω 1 % 100 PPM CF, 0805	-	-
TP1, TP2, TP3, TP4	0.250 in faston TAB	-	-

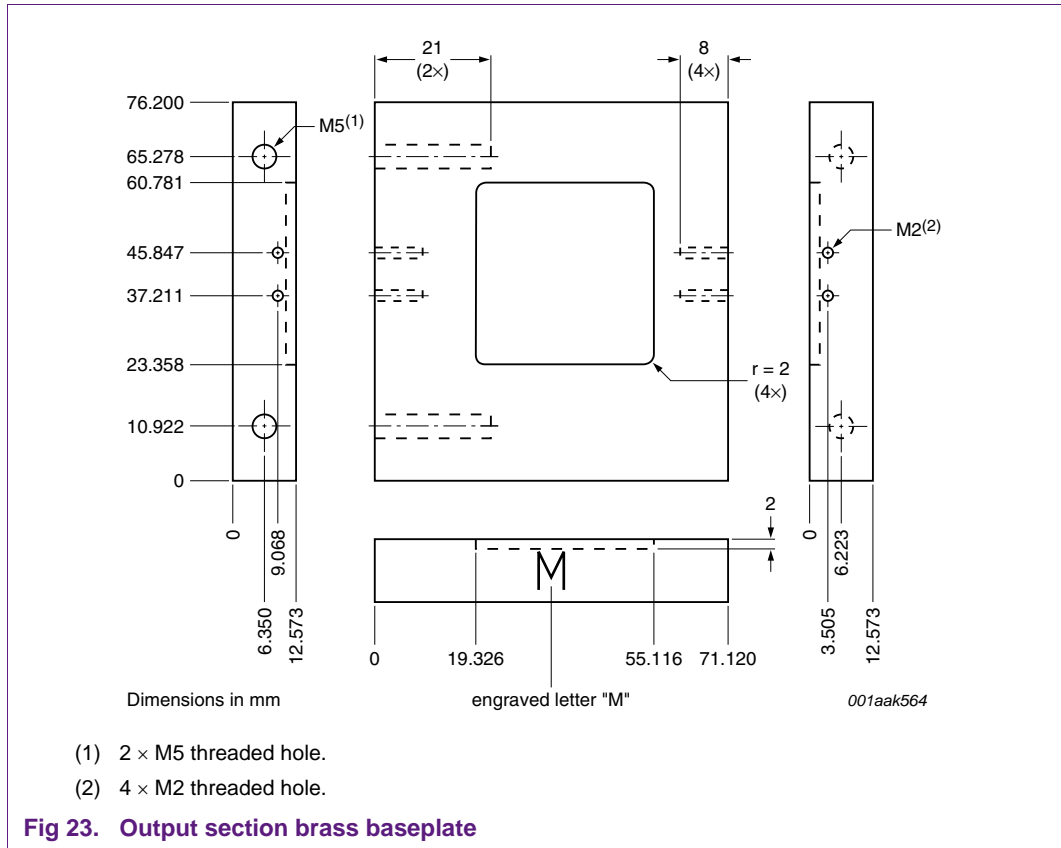
Table 3. Bill of materials for DVB-T amplifier ...continued

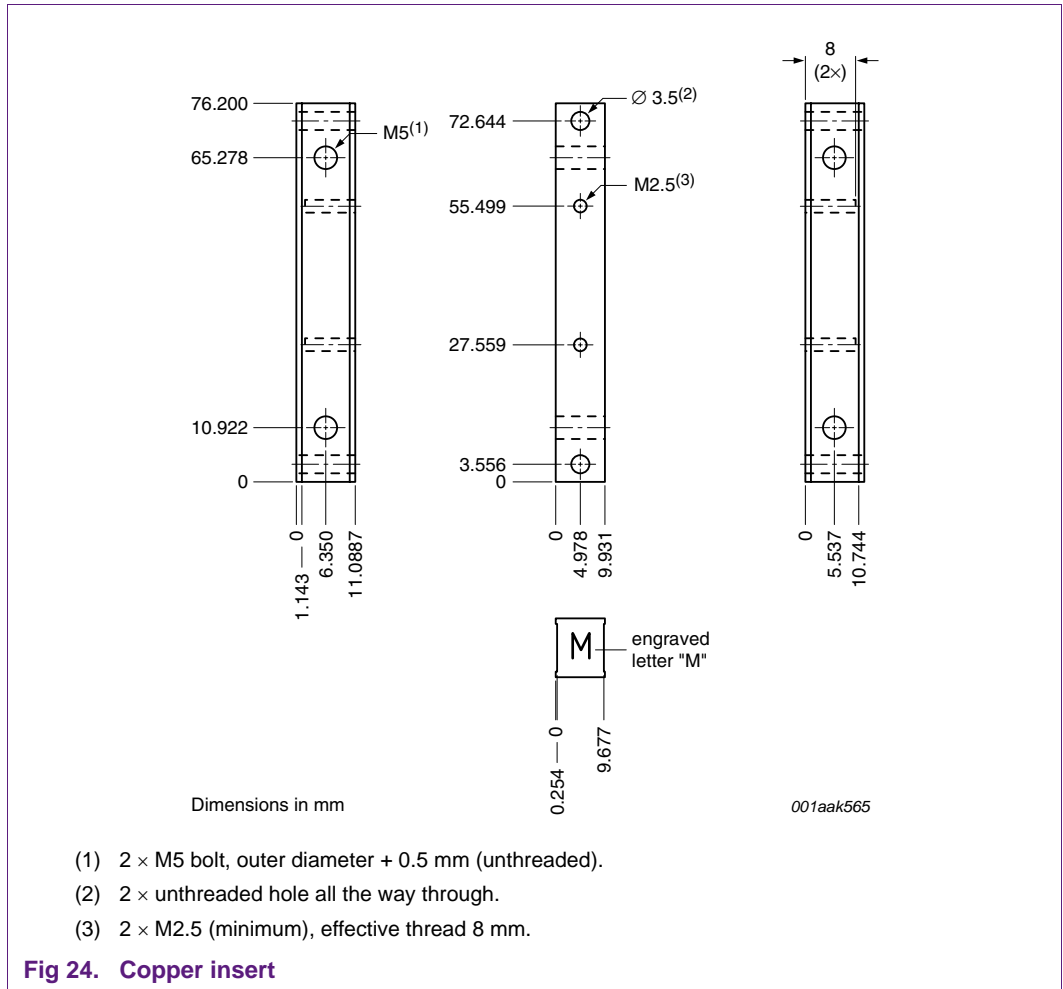
Designator	Description	Part number	Manufacturer
U101	adjustable voltage regulator; 50 mA 3 V to 80 V LDO, MSOP8	LT3010EMS8E	Linear Technology
U102	comparator, dual W/400MV REF, SOT23-6	LT6700CS6-3	Linear Technology
U103	opamp, R-R I/O unlimited C load, SOT23-5	LM7321MF	National Semiconductor

5. Appendix B: Mechanical drawings

The amplifier is constructed with separate input and output PCBs soldered to brass baseplates, with the BLF578 mounted (soldered or screwed) to a copper insert clamped between the input and output sections. The entire assembly is then clamped to the heat exchanger. Mechanical drawings for these components are shown in [Figure 22](#), [Figure 23](#), and [Figure 24](#). Note the 2 mm pocket milled in the baseplates below the baluns.







6. Abbreviations

Table 4. Abbreviations

Acronym	Description
CW	Continuous Wave
CCDF	Complementary Cumulative Distribution Function
DVB	Digital Video Broadcast
DVB-T	Digital Video Broadcast - Terrestrial
IR	InfraRed
LC	inductor-Capacitor network
LDMOS	Laterally Diffused Metal-Oxide Semiconductor
OFDM	Orthogonal Frequency Division Multiplex
PAR	Peak-to-Average power Ratio
PAE	Power Added Efficiency
PCB	Printed-Circuit Board
VSWR	Voltage Standing-Wave Ratio

7. References

- [1] P.L.D. Abrie, The Design of Impedance-Matching Networks for Radio-Frequency and Microwave Amplifiers. Dedham, MA: Artech House, 1985, ch. 4.
- [2] D. Jaisson, "Planar impedance transformer," IEEE Transactions on Microwave Theory and Techniques, vol. 47, no. 5, May 1999.
- [3] H.L. Krauss, C.W. Bostian, F.H. Raab, Solid State Radio Engineering. New York: John Wiley, 1980, ch. 3.
- [4] N. Marchand, "Transmission-line conversion transformers," Electronics, vol. 17, pp. 142-146, 1944.
- [5] J.C. Park, J.Y. Park, "Wideband LC balun transformer using coupled LC resonators embedded into organic substrate", Microelectronics Journal, vol. 11, no. 56, 2008.
- [6] S.J.C.H. Theeuwen, W.J.A.M. Sneijers, J.G.E., J.A.M. de Boet, "High voltage RF LDMOS technology for broadcast applications," Proc. Microwave Integrated Circuit Conference, EuMIC 2008, pp. 24-27, 2008.

8. Legal information

8.1 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. NXP Semiconductors 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.

8.2 Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors 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.

In no event shall NXP Semiconductors 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, NXP Semiconductors' 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 NXP Semiconductors.

Right to make changes — NXP Semiconductors 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 — NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in medical, military, aircraft, space or life support equipment, nor in applications where failure or malfunction of an NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors accepts no liability for inclusion and/or use of NXP Semiconductors 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. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on a weakness or default in the customer application/use or the application/use of customer's third party customer(s) (hereinafter both referred to as "Application"). It is customer's sole responsibility to check whether the NXP Semiconductors product is suitable and fit for the Application planned. Customer has to do all necessary testing for the Application in order to avoid a default of the Application and the product. NXP Semiconductors 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 national authorities.

8.3 Trademarks

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

9. Tables

Table 1. BLF578 typical impedances	9	Table 3. Bill of materials for DVB-T amplifier	20
Table 2. DVB-T power and efficiency	17	Table 4. Abbreviations	23

10. Figures

Fig 1. The assembled DVB-T amplifier	3
Fig 2. RF circuit with DVB-T output tuning schematic	5
Fig 3. Bias circuit schematic	5
Fig 4. Balun 3-D planar model	6
Fig 5. Double-tuned transformer	7
Fig 6. Simulated response of double-tuned transformer	7
Fig 7. Planar balun construction	8
Fig 8. Simulated response of planar balun	8
Fig 9. Definition of transistor impedance	9
Fig 10. BLF578 equivalent input and output impedance models	10
Fig 11. Simulated output network differential impedance	10
Fig 12. Simulated second harmonic common-mode impedance	11
Fig 13. Simulated power feed network and gate resistor decoupling impedances	11
Fig 14. Measured output gain and power added efficiency with $I_{Dq} = 2\text{ A}$	14
Fig 15. Measured output gain and power added efficiency with $I_{Dq} = 100\text{ mA}$	15
Fig 16. Measured input return loss	15
Fig 17. Measured harmonic levels at $I_{Dq} = 2\text{ A}$	16
Fig 18. Measured harmonic levels at $I_{Dq} = 100\text{ mA}$	16
Fig 19. Measurement of DVB-T shoulder distance	17
Fig 20. Measured DVB-T shoulder distance at 200 MHz	18
Fig 21. DVB-T amplifier component layout	19
Fig 22. Input section brass baseplate	21
Fig 23. Output section brass baseplate	22
Fig 24. Copper insert	23

11. Contents

1	Introduction	3
1.1	Design objectives	4
2	Design and simulation	6
2.1	Planar balun	6
2.2	BLF578 impedance	9
2.3	Matching and power feed networks	10
2.4	Temperature-compensated bias circuit	12
2.5	Thermal considerations	12
3	Measurements	13
3.1	Single tone measurements with DVB-T tuning	13
3.2	DVB-T measurements	17
4	Appendix A: PCB layout and bill of materials	19
5	Appendix B: Mechanical drawings	21
6	Abbreviations	23
7	References	24
8	Legal information	25
8.1	Definitions	25
8.2	Disclaimers	25
8.3	Trademarks	25
9	Tables	26
10	Figures	26
11	Contents	27

Please be aware that important notices concerning this document and the product(s) described herein, have been included in section 'Legal information'.

© NXP B.V. 2010.

All rights reserved.

For more information, please visit: <http://www.nxp.com>

For sales office addresses, please send an email to: salesaddresses@nxp.com

Date of release: 26 March 2010

Document identifier: AN10858_2