APPLICATION INFORMATION

2.4 GHz power amplifier with the BFG425W and the BFG21W

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ABSTRACT

- Description of the product

  The BFG425W is a double polysilicon wideband transistor and the BFG21W is a double polysilicon bipolar power transistor.
- Application area

  Low voltage high frequency wireless applications.
- Presented application

  A 2-stage power amplifier for a 2.4 GHz WLAN with bias circuitry for load power adjustment an on/off switching.
- Main results

  Operating at a single supply voltage of 3.0 V and an input power of 0 dBm, the amplifier delivers an output power of 22 dBm with a power added efficiency of 44%.

2.4 GHz power amplifier with the BFG425W and the BFG21W

INTRODUCTION

The Philips transistors BFG425W and BFG21W used in this amplifier, are manufactured according to the double polysilicon process and are characterised by a transition frequency greater than 20 GHz at low supply voltages. The amplifier is well suited for the new generation low voltage high frequency applications. This application note describes a two-stage power amplifier, designed to be used in 2.4 GHz WLAN systems.

With only two transistors a small sized power amplifier line-up is realized, offering 22 dBm of output power with 44% power added efficiency at 0 dBm input power and a single 3 V supply voltage. Biasing is done by a circuit around an NPN transistor pair, which also performs load power adjustment and the possibility for on/off switching. Thanks to the low component count and simple matching networks, the entire power amplifier (including bias part) only measures 10 × 20 mm.

PERFORMANCE OVERVIEW

The following initial conditions apply for the power amplifier measurements (unless otherwise stated):

- Supply voltage 3.0 V
- Control voltage 3.0 V
- Frequency 2.45 GHz
- Source and load impedance 50 Ω
- Input power 0 dBm.

Table 1 Characteristics of the 2.4 GHz WLAN power amplifier

SYMBOL	PARAMETER	CONDITION	VALUE	UNIT
P_o	output power		22.4	dBm
G_P	power gain		22.4	dB
I_{supply}	supply current		136	mA
η_{PA}	power added efficiency		44	%
$VSWR_{IN}$	input voltage standing wave ratio		2	
$\lvert s_{21}/s_{12} \rvert^2$	isolation	relative to input power; V_{ctrl} < 0.6 V	40	dB
Spurious		VSWR = 6; all phases	–55	dBc
I_L	leakage current	off-state; V_{ctrl} < 0.6 V	<10	μA
d_{2H}	2nd harmonic distortion		–42	dBc
d_{3H}	3rd harmonic distortion		–35	dBc

For other applications with this amplifier circuit, the following conditions apply

- Supply voltage from 3.0 to 5.0 V; for CW mode of operation, the supply voltage must be smaller than 4.0 V, for pulsed mode greater than 4.0 V.
- Control voltage greater than 2.2 V for the ON-state and smaller than 0.6 V for the OFF-state.
- Frequency range from 2.4 to 2.5 GHz.

2.4 GHz power amplifier with the BFG425W and the BFG21W

CIRCUIT DESCRIPTION

Figure 1 shows the circuit diagram of the WLAN power amplifier including both RF transistors, matching circuits and biasing circuit.

The RF chain of the power amplifier consists of two transistor stages: a BFG425W (TR1) wideband transistor and a BFG21W (TR2) power transistor, both operating in class AB. In accordance with this mode and the required output power of each stage, the measured source and load impedances of both transistors are given in Table 2.

The SOT343R packaged R transistors have two emitters leads, which have to be carefully grounded to ensure stable operation and performance according to specification. The layout of this power amplifier offers an emitter-to-ground inductance of typically 130 pH.

The biasing part of the power amplifier is build around an NPN transistor pair, TR3a and TR3b. The circuit delivers a temperature compensated bias voltage for both RF stages. The circuit offers maximum gain when the control voltage is greater than 2.2 V. The bias voltage for the first stage is approximately 0.90 V and for the second stage approximately 0.65 V.

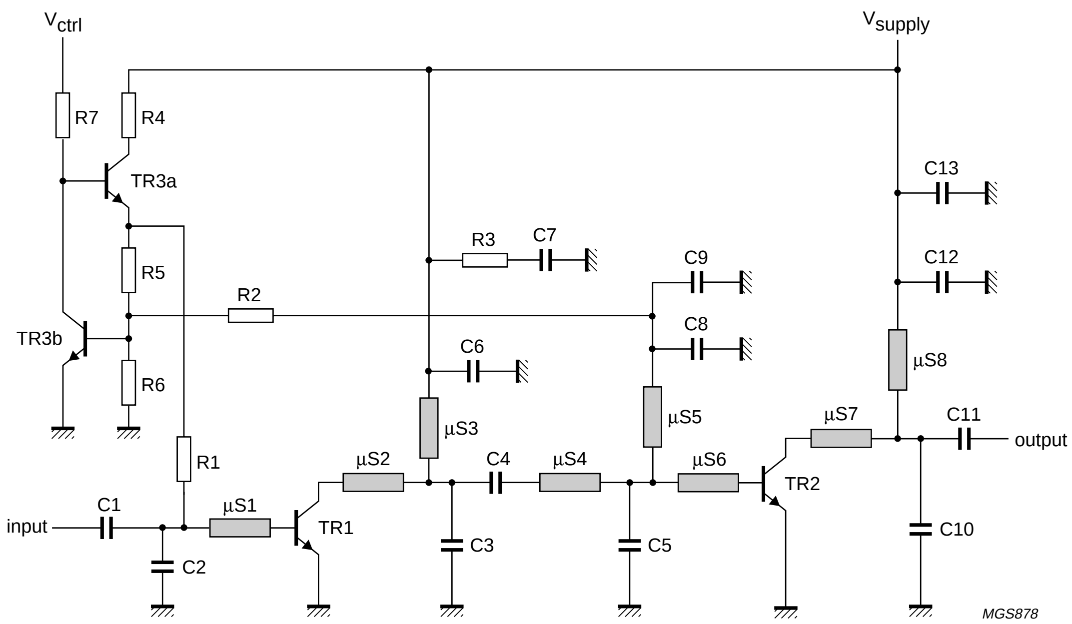

Fig.1 Circuit diagram.

Table 2 Source and load impedances of the applied RF transistors

TRANSISTOR	CONDITIONS	SOURCE IMPEDANCE (Z_S)	LOAD IMPEDANCE (Z_L)
BFG425W	V_{CE} = 3.0 V; V_{BE} = 0.9 V; P_o = 15 dBm; G_P = 14 dB; f = 2.45 GHz	20 + 27 j Ω	45 + 37 j Ω
BFG21W	V_{CE} = 3.0 V; V_{BE} = 0.65 V; P_o = 22.5 dBm; G_P = 7.5 dB; f = 2.45 GHz	8 – 11 j Ω	11 – 11 j Ω

2.4 GHz power amplifier with the BFG425W and the BFG21W

COMPONENT LIST

Table 3 Component list for the 2.4 GHz WLAN power amplifier circuit

COMPONENT	VALUE	UNIT	SIZE - MANUFACTURER
TR1	BFG425W		SOT343R Philips
TR2	BFG21W		SOT343RPhilips
TR3	PUMX1		SOT363 Philips
R1	560	Ω	0603 Philips
R2	10	Ω	0603 Philips
R3	10	Ω	0603 Philips
R4	220	Ω	0603 Philips
R5	82	Ω	0603 Philips
R6	330	Ω	0603 Philips
R7	1	kΩ	0603 Philips
C1	2.2	pF	0603 Philips
C2	1.2	pF	0603 Philips
C3	0.47	pF	0603 Philips
C4	2.2	pF	0603 Philips
C5	1.8	pF	0603 Philips
C6	10	pF	0603 Philips
C7	10	nF	0603 Philips
C8	10	pF	0603 Philips
C9	1	nF	0603 Philips
C10	2.2	pF	0603 Philips
C11	6.8	pF	0603 Philips
C12	10	pF	0603 Philips
C13	1	nF	0603 Philips
µS1	L = 6.5; W = 0.45	mm	
µS2	L = 3.0; W = 0.15	mm	
µS3	L = 7.5; W = 0.15	mm	
µS4	L = 2.0; W = 1.15	mm	
µS5	L = 7.5; W = 0.15	mm	
µS6	L = 2.0; W = 1.15	mm	
µS7	L = 5.0; W = 0.45	mm	
µS8	L = 6.5; W = 0.15	mm	
PCB	FR4		ε_r = 4.6; d = 0.71 mm

2.4 GHz power amplifier with the BFG425W and the BFG21W

BOARD LAYOUT

Figure 2 shows the layout of the power amplifier printed circuit board, which has the following properties:

- FR4 bilayer (backside ground)
- d = 0.71 mm
- t = 35 µm (Cu cladding, not coated)
- ε_r = 4.6
- tanδ = 0.02.

The position of components C2, C3, C5 and C10 is critical.

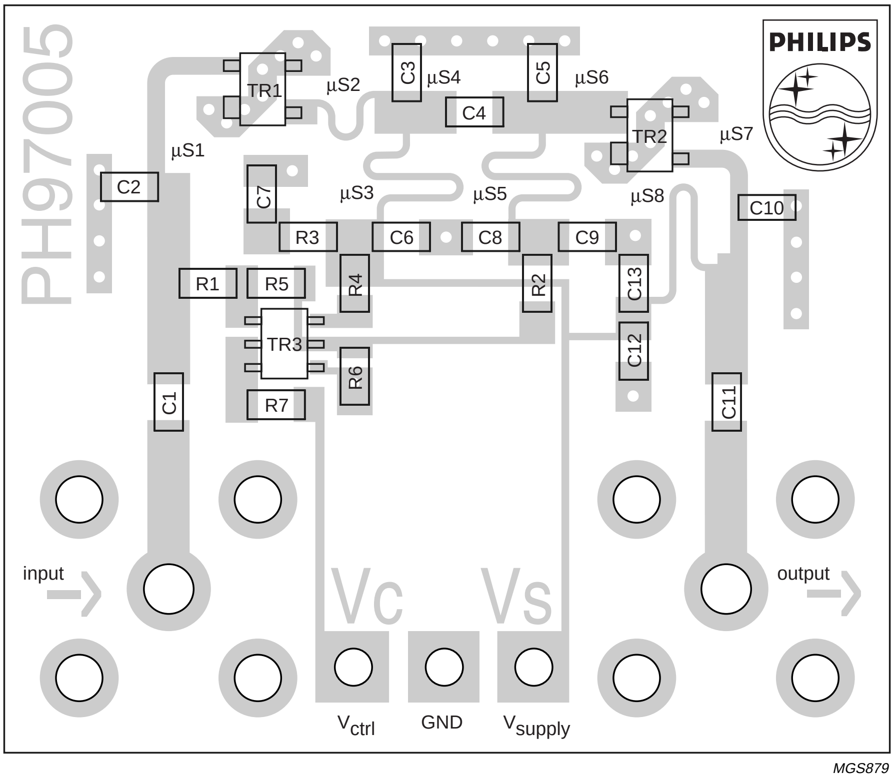

Fig.2 Layout of the WLAN power amplifier printed circuit board.

2.4 GHz power amplifier with the BFG425W and the BFG21W

SPICE PARAMETERS

The spice parameters of the two applied transistors are given in Table 4 and Table 5.

Table 4 Spice parameters of the BFG425W

.SUBCKT BFG425W 1 2 3
L1 2 5 1.1E-09
L2 1 4 1.1E-09
L3 3 6 0.25E-09
Ccb 4 5 2.0E-15
Cbe 5 6 80.0E-15
Cce 4 6 80.0E-15
Cbpb 5 7 1.45E-13
Cbpc 4 8 1.45E-13
Rsb1 6 7 25
Rsb2 6 8 19
Q1 4 5 6 6 NPN
.MODEL NPN NPN
+ IS = 4.717E-17
+ BF = 145
+ NF = 0.9934
+ VAF = 31.12
+ IKF = 0.304
+ ISE = 3.002E-13
+ NE = 3
+ BR = 11.37
+ NR = 0.985
+ VAR = 1.874
+ IKR = 0.121
+ ISC = 4.848E-16
+ NC = 1.546
+ RB = 14.41
+ IRB = 0
+ RBM = 6.175
+ RE = 0.1779
+ RC = 1.780
+ CJE = 3.109E-13
+ VJE = 0.9
+ MJE = 0.3456
+ CJC = 1.377E-13
+ VJC = 0.5569
+ MJC = 0.2079
+ CJS = 6.675E-13
+ VJS = 0.4183
+ MJS = 0.2391
+ XCJC = 0.5
+ TR = 0.0
+ TF = 4.122E-12
+ XTF = 68.2
+ VTF = 2.004
+ ITF = 1.525
+ PTF = 0
+ FC = 0.5501
+ EG = 1.11
+ XTI = 3
+ XTB = 1.5
.ENDS

2.4 GHz power amplifier with the BFG425W and the BFG21W

Table 5 Spice parameters of the BFG21W

.SUBCKT BFG21W 10 11 12
Lbbond 2 5 7.209E-10
Lblead 5 8 2.251E-10
Lbfoot 8 11 1.1E-10
Cbfoot 8 12 1.17E-13
Lebond 3 6 5.15E-11
Lelead 6 9 6.914E-11
Lefoot 9 12 1.739E-10
Cefoot 9 12 1.95E-13
Lcbond 1 4 5.711E-10
Lclead 4 7 2.251E-10
Lcfoot 7 10 1.1E-10
Ccfoot 7 12 1.17E-13
Cbc 5 4 2E-15
Cbe 5 6 8E-14
Cce 4 6 8E-14
Cbpb 2 14 3.3E-13
Cbpc 1 13 3.47E-13
Cmet 1 3 1.7E-12
Rsub1 14 15 249.2
Rsub2 13 15 464.4
Rmut 3 15 100
Dio 16 1
+ D1
Rs 15 16 3.5
.MODEL D1 D
+ IS = 4.99E-13
+ N = 1.189
Q1 1 2 3 3 NPN
+ AREA = 1
.MODEL NPN NPN
+ IS = 3.835E-16
+ BF = 92
+ NF = 1
+ VAF = 35
+ IKF = 2.8
+ ISE = 9.005E-13
+ NE = 2.262
+ BR = 8.9
+ NR = 1.009
+ VAR = 2.25
+ IKR = 0.6507
+ ISC = 2.503E-15
+ NC = 1.209
+ RB = 1.492
+ IRB = 0
+ RBM = 0.3202
+ RE = 0.3429
+ RC = 0.8
+ CJE = 3.026E-12
+ VJE = 0.9
+ MJE = 0.2861
+ CJC = 1.041E-12
+ VJC = 0.6964
+ MJC = 0.308
+ CJS = 1.844E-12
+ VJS = 0.4237
+ MJS = 0.2606
+ XCJC = 0.5
+ TR = 1.5E-10
+ TF = 5.05E-12
+ XTF = 74
+ VTF = 0.8
+ ITF = 6.5
+ PTF = 0
+ FC = 0.875
+ EG = 1.11
+ XTI = 4.3
+ XTB = 0.5
.ENDS

2.4 GHz power amplifier with the BFG425W and the BFG21W

MEASUREMENTS

The result of the measurements is given in the Figs 3 to 8. The following initial conditions apply for all measurements (unless otherwise specified):

- V_{supply} = 3.0 V
- V_{ctrl} = 3.0 V
- f = 2.45 GHz
- P_i = 0 dBm.

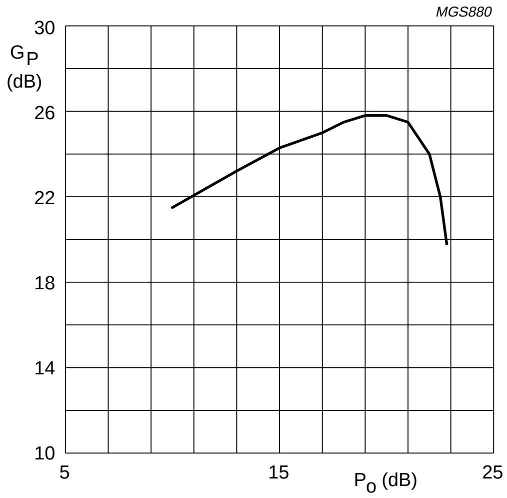

Fig.3 Power gain as a function of the output power.

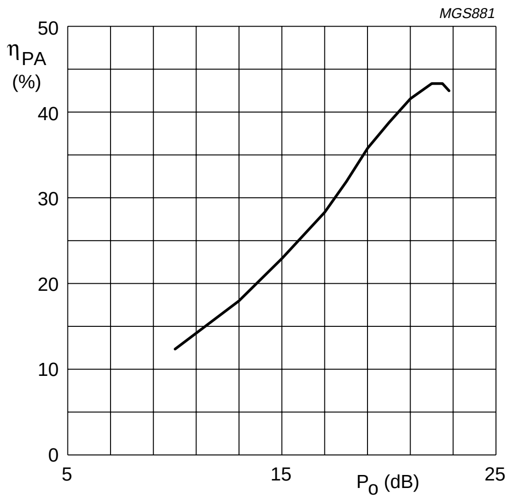

Fig.4 Power added efficiency as a function of the output power.

2.4 GHz power amplifier with the BFG425W and the BFG21W

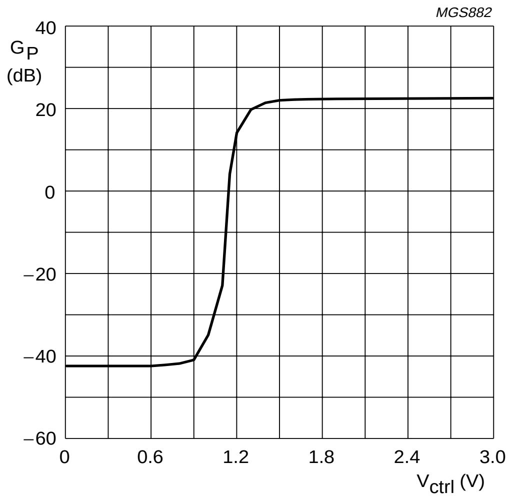

Fig.5 Power gain as a function of the control voltage.

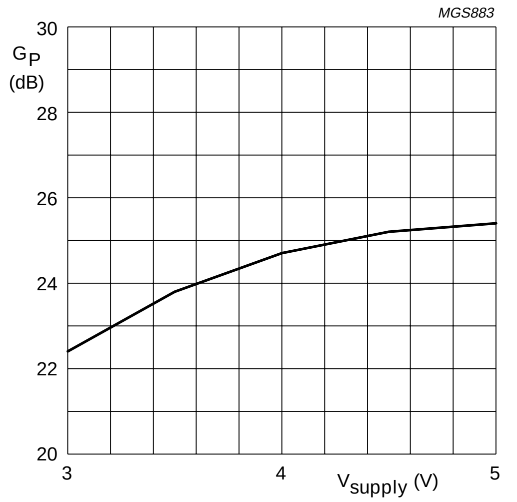

Fig.6 Power gain as a function of the supply voltage.

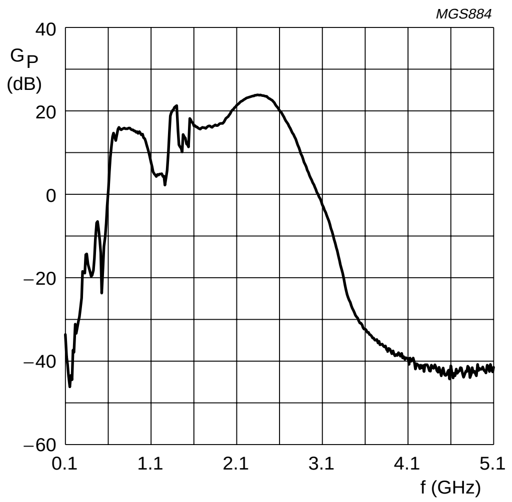

Fig.7 Power gain as a function of the frequency, wideband measurement.

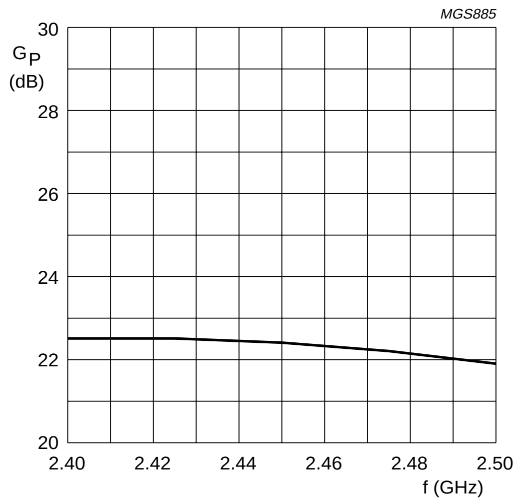

Fig.8 Power gain as a function of the frequency, narrow band measurement.

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