APPLICATION NOTE

A broadband 150 W amplifier for band IV & V TV transmitters based on the BLV862

AN98014

Philips
Semiconductors

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CONTENTS

1 ABSTRACT

A broadband amplifier design is presented based on the BLV862, capable of operating in full band IV & V (470 – 860 MHz) with flat gain and high output power in class-AB. A single amplifier configuration is presented and characterized for aural and vision amplification. This amplifier is able to deliver 150 W CW power and up to 200 W peak-sync power at 1 dB compression point into a 50 W load. For combined vision and sound amplification two-tone and 3-tone performance is presented as well.

Two of these amplifiers have been combined with external quadarture hybrids to demonstrate the power capability of two BLV862. Results include 300 W CW power at 1 dB compression.

The circuit is a compact design on a PTFE-glass laminate with an ε_r = 2.55 and a thickness of 0.51 mm (20 mils).

2 INTRODUCTION

For application in TV-transmitter output stages a broadband high power amplifier design is described with the BLV862 transistor. The design objective based on a single BLV862 is given in Table 1

In the next sections some background on the BLV862 transistor and amplifier design is given. The tuning procedure used for this amplifier is described and its performance for aural and vision amplification presented. Because of the increasing interest for combined amplication of sound and vision also two and 3-tone performance is presented.

Finally full band performance data of two BLV862 amplifiers combined with quadrature hybrids is given.

Table 1 Electric characteristics (V_{CC} = 28 V; Icq = 800 mA)

	SYMBOL	VALUE	UNIT
Frequency band	B	470 – 860	MHz
Output power @ 1 – dB compression; note 1	P_{out}	>150	W
Power gain	G_P	>8	dB
Gain ripple	$G_{P\text{-ripple}}$	±0.5	dB
Efficiency	η	>45	%
Input Return loss	IRL	–8	dB

Note

1. $P_{OUT\text{-ref}}$ = 40 W (CW).

3 TRANSISTOR DESCRIPTION

3.1 Main properties of the BLV862

The BLV862 is a 150 W transistor incorporated in a gemini package SOT262B. A simplified outline of this package is shown in Fig.1. The emitter is connected to the flange and the collector leads are internally parallelled for DC because of the output matching applied. Therefore the collector currents cannot be measured separately.

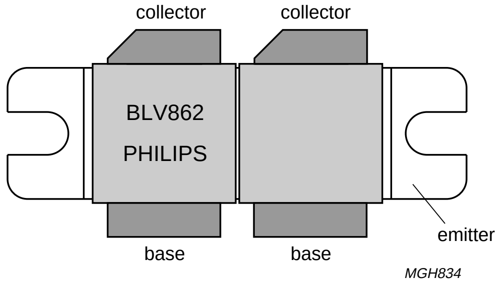

Fig.1 SOT262B package outline of the BLV862.

The active part of the BLV862 consists of four dies with a 6 µm emitter-pitch technology. It incorporates high value postillion emitter ballasting resistor for an optimum temperature profile in class-AB as well as class-A operation. Combined with gold metallization it offers a high degree of reliability and ruggedness. The main transistor data is summarized in Table 2.

Table 2 RF performance of BLV862

MODE OF OPERATION	f (MHz)	V_{CE} (V)	P_L (W)	G_P (dB)	Eff (%)	$G_{p\text{-comp.}}$ (dB)	$R_{thj\text{-}hs}$ (K/W)
Class-AB	860	28	150	>8 dB	>45%	<1 dB	<0.65

3.2 Internal matching

The BLV862 is internally matched to increase the useable bandwidth and to elevate the device terminal impedance. Figure 2 shows the equivalent circuit of one BLV862 section, with its matching circuitry. The input is pre-matched with two lowpass LC-sections to get low-Q transformation steps and high intermediate impedance level at the base terminals.

The output is post-matched with a collector-to-collector shunt inductor which is designed to resonate with the transistor output capacitance at the low end of the band. This results in an increased broadband capability and increased impedance level at the transistor output.

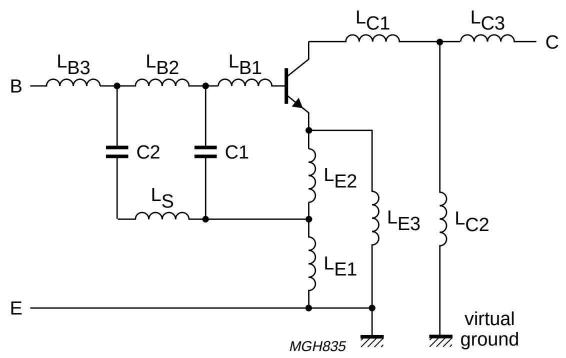

Fig.2 Internal circuit topology of one section of BLV862.

3.3 Gain and impedance data

The gain and impedance data are listed in the Table 3 and curves are given in “Appendix B”. This data has been measured in a fixture tuned for maximum gain at rated output power for each frequency. The impedance data given is from base-base and collector-collector.

Table 3 Conditions: V_{CC} = 28 V; I_{cq} = 800 mA; P_L = 150 W

f	G_P	Z_{IN} (Ω)		Z_L (Ω)	
MHz	dB	Re (Z_{IN})	Im (Z_{IN})	Re (Z_L)	Im (Z_L)
470	12.47	1.01	2.95	4.45	0.83
567	11.63	1.06	4.24	3.22	1.58
665	11.39	2.27	5.96	2.47	0.24
762	10.97	6.96	7.23	1.96	–0.63
860	10.83	6.68	–1.20	1.47	–0.62

4 AMPLIFIER DESIGN

The total description of the amplifier is given in“Appendix A1” to “Appendix A4”. The amplifiers input and output matching networks contain mixed microstrip-lumped elements networks to transform the terminal impedance levels to approx. 25 Ω balanced. The remaining transformation to 50 Ω unbalanced is obtained by 1 : 2 balun transformers. The baluns B_1 and B_2 are 25 Ω semi-rigid coax cables with an electrical length of 45° at 636 MHz, soldered over the whole length on top of microstrip lines L_2 and L_{19} of 1.8 mm width. To restore the balance in the circuit two stubs L_1 and L_{20} with the same length have been added. For low frequency stability enhancement the input balun stubs are connected to the point of symmetry by means of 0.5 Ω series resistors. To avoid input signal damping the stubs are decoupled to ground with 1 nF capacitors. The point of symmetry at the input and output balun is used to feed the base and collector from a single bias circuit. Large capacitors are added to these points to improve the amplifiers video response.

The PCB laminate utilized is PTFE-glass with an ε_r = 2.55 and a thickness of 0.51 mm. Specification of all components are given in “Appendix A4”.

4.1 Input network

The input network is designed for high gain match and flat overall gain versus frequency. This is achieved by a three section lowpass filter with and a series capacitor at 50 Ω input impedance level. Two variable capacitors are included for fine tuning of the matching @ 860 MHz and flatness adjustment of the gain. See circuit diagram in “Appendix A1”. The capacitor C7 is placed close to the base of the BLV862 to maintain low Q transformation.

4.2 Output network

The output network is designed for high output power and efficiency over the full bandwidth. RF dissipation in shunt capacitors is a critical factor in the design of the output network. To minimize the power loss in these components the loaded Q’s have been kept as low as possible. This is achieved with the use of a three-section semi-low pass network combined with stubs close to the collectors. The most critical component is the first shunt capacitor from the collectors. The current in this capacitor is at maximum level when operated at the high end of the band at a power level of 150 W (CW). To minimize the loss two high Q capacitors ATC180R are used in parallel. Experiments with lower Q capacitors ATC100B resulted in high losses leading to desoldering of the capacitors at full power level.

4.3 Biascircuit

The class-AB bias circuit used is shown in Fig.3. This circuit has a very low power consumption allowing the use of low power SMD chip resistors. Two NPN transistors BD139 are used. T2 is chosen to operate in the reverse mode in order to have its lower collector to base diode voltage to track the base-emitter voltage of the BLV862. R7 mainly compensates for the difference between these two values. T2, T3 and BLV862 have been mounted on the same heatsink to have good temperature compensation. R8 is incorporated to protect T3 in case of short circuit in the BLV862. For large variations in base currents the V_{BE} level of the BLV862 will show small variations due to this resistor and R2//R3 and R4//R5, see “Appendix A1”. No adverse effect will results from this. Capacitor C18 bypass any RF leakage to T2. The bias circuit is fully integrated on the amplifier board, see “Appendix A2”.

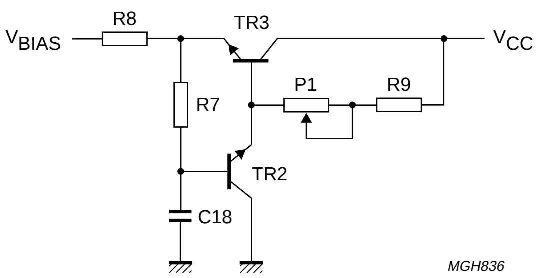

Fig.3 Class-AB biascircuit.

5 PERFORMANCE OF A SINGLE AMPLIFIER CONFIGURATION

The amplifier tuning is done under class-A small-signal conditions and characterized under large signal class-AB conditions from 470 – 860 MHz. The conditions used are:

Table 4 Test conditions

	SMALL SIGNAL	LARGE SIGNAL
Class of operation	A	AB
Collector-emitter voltage	28 V	28 V
Quiescent current (Icq)	2.5 A	0.8 A
Source/Load impedance	50 Ω	50 Ω
Heatsink temperature	25 °C	25 °C

5.1 Small Signal Response

Tuning the amplifier under small-signal class-A conditions to obtain optimum large signal performance was found to be a very suitable and save technique for the BLV862. The best small-signal response was determined experimentally. The S_{11}, S_{22} and S_{21} response resulting in optimum large signal performance is given in “Appendix C1”. The input is tuned for maximum gain and a flat respons over the whole frequency band (470 – 860 MHz). The output is tuned to get at least 10 dB returnloss over the band.

5.2 Large Signal Response

After the small-signal class-A tuning the amplifier was biased into class-AB and large signal measurements were done. Gain, efficiency, input return loss and compression was determined versus frequency at a power level of 150 W (CW). The data is summarized in “Appendix C2”.

The gain level is 8.5 dB on average with a ripple of ±0.5 dB. Efficiency over the whole band is above the 50% level. The minimum efficiency occurs at 762 MHz. See “Appendix C2”. The gain compression at the lower and higher end of the band is about 1 dB while at the centre this is 0.5 dB referenced to a 40 W output power level. The input return loss is up to 3.5 dB at the lower end and 8.5 dB at the upper end of the frequency range.

5.3 3 dB Input Overdrive Capability Test

An input overdrive test has been performed on the amplifier to test its capability to withstand 3 dB overdrive. P_{OUT} vs P_{IN} measurements have been done from zero to 3 dB above its normal drive level for 150 W power output. The amplifier has proven to withstand a drive level of 46 W for several minutes without degradation of the transistor. The power level associated with this level was 200 W. “Appendix E” presents the recorded data.

5.4 Amplitude and Phase Transfer Characteristic

A power sweep measurement has been performed using a network analyzer to determine the input/output transfer characteristics of the amplifier. The linearity of the amplifier is described in terms of the input/output amplitude transfer function known as AM-AM conversion or differential gain and the input/output phase transfer function known as AM-PM conversion or ICPM (incidental carrier phase modulation). The total setup for power sweep is reflected on “Appendix G1”. the sweep range of the network analyzer was set for –10 dBm to +14 dBm.

“Appendix G2” shows the power sweep output from the network analyzer in a multiple sweep format to show the effect of various bias levels in class-AB. Any deviation from a straight line is a measure of non-linearity in the amplifier. Slight gain variations are to be expected at turn on. Important points for observation are the 1 dB gain compression point and the phase deviation at 1 dB gain compression referenced to the maximum phase in the linear gain region. The phase shift is about 6° at the 1 –dB compression point for 800 mA bias level. The stop between sweep power level was measured at 165 W and coincides with the 1 dB compression point.

5.5 Intermodulation

Because of the increasing interest for combined carrier options we have determined the linear performance of the amplifier for 2-tone and 3-tone operation. IMD has been measured at 860 MHz for different tone levels. Since the bias level dependency was found not to be very strong only results at 800 mA are presented.

Two tone and three tone IMD-measurement have been performed as defined in Fig.4. For two tone performance two carriers have been chosen which represents the vision and sideband carriers. Three tone measurement is done with an additional carrier which represents the sound carrier. The different tone systems used are listed below.

Table 5 Survey of used tone systems for intermodulation measurements

SYSTEM	AMPLITUDE VISION	AMPLITUDE SIDEBAND	AMPLITUDE SOUND	UNIT
A	–8	–16	–10	dB
B	–5	–17	–10	dB
C	–3	–20	–10	dB
Tones	855.25	859.68	860.75	MHz

IMD-performance is depicted as a function of the output peak-sync power (P_{SYNC}) in “Appendix D1” and “Appendix D2”.

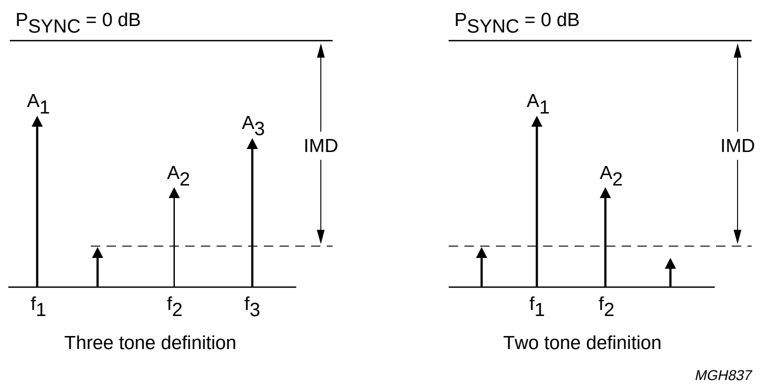

Fig.4 Definition for IMD-measurement.

5.6 TV-measurements

The amplifier is also characterized with a PAL composite TV signal (without soundcarrier) according CCIR standard G. The TV test setup used, is depicted in “Appendix F1”. The following important characteristics have been measured in channel 69:

- Differential gain (level dependence of gain)
- Differential phase (level dependence of phase)
- Sync compression
- Peak output power @ 1 dB compression.

5.6.1 DIFFERENTIAL GAIN

Differential gain is present if chrominance gain is dependent on luminance level. These amplitude errors are a result of the systems inability to uniform process the high-frequency chrominance signal at all luminance levels. Differential gain is expressed in percentage of the chrominance gain at blanking levels. Differential gain is expressed in percentage of the chrominance gain at blanking level. The input video waveform used for differential gain evaluation is a modulated staircase with 10% rest carrier as given in “Appendix F2”.

“Appendix F2” and “Appendix F3” depicts the differential gains in channel 69 at a peak-sync power level of 150 W for several bias levels.

5.6.2 DIFFERENTIAL PHASE

Differential phase is present if a signals chrominance phase is affected by luminance level. This phase distortion is a result of a systems inability to uniform process the high-frequency chrominance information at all luminance levels. The amount of differential phase distortion is expressed in degrees. Differential phase data for the same conditions are also given in “Appendix F2” and “Appendix F3”.

5.6.3 SYNC COMPRESSION VS PEAK-SYNC POWER

One effect produced by non-linearity above the blanking level is compression of the sync pulse. This effect is compensated in transmitters by making the sync pulses correspondingly greater before amplification.

The degree of this so called sync-stretching required, depends on the sync compression due to the non-linearity in the amplifier.

Evaluation of the sync compression is done using a input video waveform at black level, see “Appendix F4”. The sync power is calculated by from the measured average output power and the sync-to-bar ratio after demodulation. The sync-to-bar ratio is measured with the video waveform on line 18 containing a 100% white-bar. With this available ratio the sync amplitude can be calculated referenced to a 1 V sync-to-bar top level. The sync content is then normalized to a 1.11 V RF amplitude. An undistorted signal corresponds to 27% sync content.

The sync power can then also be determined from the obtained sync level. The formula and definitions used for this calculation are given below (1) and in Fig.5. The output sync pulse content versus Psync power is presented in “Appendix F4”.

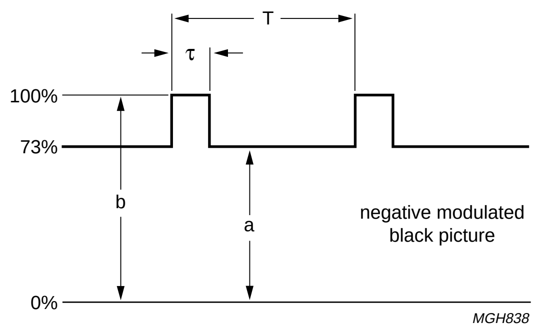

Fig.5 Composite video signal with black level for determining sync-peak power.

$$P_{RMS} = \frac{U_{RMS}^2}{R} = \frac{\left(\sqrt{\frac{1}{T}\int_0^{\tau} b^2 \cdot dt + \frac{1}{T}\int_{\tau}^{T} a^2 \cdot dt}\right)}{R} = \frac{\frac{\tau}{T} \cdot b^2 + \left(1 - \frac{\tau}{T}\right) \cdot a^2}{R} \quad ; \quad P_{SYNC} = \frac{b^2}{R} \quad \Bigg\} \; k = \frac{P_{SYNC}}{P_{RMS}} = \frac{1}{\frac{\tau}{T} + \left(1 - \frac{\tau}{T}\right) \cdot \left(\frac{a}{b}\right)^2} \qquad (1)$$

If there is no compression (a = 73% and b = 100%) then k = 0.567 and sync-power corresponds to $P_{SYNC} = P_{RMS}/0.567$. If there is a maximum sync-compression, which means that a = b, then k = 1 and as a result P_{SYNC} will be equal to P_{RMS}. In practice the allowable sync compression is bound to a maximum since sync-stretching is limited.

5.6.4 PEAK OUTPUT POWER AT 1 dB COMPRESSION

“Appendix F4” shows the gain versus Psync power for channel 69. The input video signal is at black level. The 1 dB compression point is approximately 190 W Psync.

6 DUAL AMPLIFIER CONFIGURATION

Two single amplifiers were combined using external quadrature couplers as depicted in Fig.6. Broadband CW measurements has been performed to test the capability of the combined BLV862 amplifiers. The conditions for each amplifier are listed in “Performance of a single amplifier configuration”.

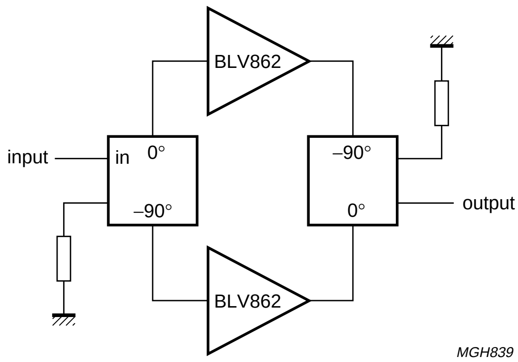

Fig.6 Dual amplifier configuration of BLV862.

6.1 Small Signal Response

The small signal plots in class-A of the combined amplifiers are given in “Appendix H1”. Only a gain loss of 0.5 dB has been observed. On the otherhand the input and output is now perfectly matched. The gain-ripple is still acceptable which is approximately ±1 dB.

6.2 Large Signal Response

The large signal gain in class-AB is above 7 dB and 300 W. Gain compression at different frequencies has been determined. At a loadpower of 300 W the gain compression is about ±1 dB over the whole frequency range. See “Appendix H2”.

Efficiency of the combined amplifiers is within the specifications which is >45%. As mentioned before. at 762 MHz the efficiency reaches its lowest value, but still >45%. See “Appendix H2”.

7 CONCLUSIONS

A complete TV transmitter amplifier has been designed and characterized based on the BLV862, capable of operating in full band IV & V with flat gain and high output power in class-AB. With one BLV862 it is possible to generate 150 W CW power at 1 dB compression with a gain of >8 dB and an efficiency of >45%. Two amplifiers combined with quadrature couplers have shown to deliver 300 W CW power at 1 dB compression with >7 dB gain and 45% efficiency.

TV-measurements have been performed showing a 1 dB compression point close to 200 W Psync from one BLV862. The prototype has been reproduced five times with very good repeatability.

8 REFERENCES

1. TEKTRONIX: “Television measurements – PAL systems”
2. Rhode & Schwarz Sound and Broadcasting: “Rigs and Recipes how to measure and monitor...”.

9 APPENDIX

- A1: Schematic diagram of the BLV862 amplifier
- A2: Component layout of the BLV862 amplifier and Layout of the BLV862 amplifier
- A4: List of components
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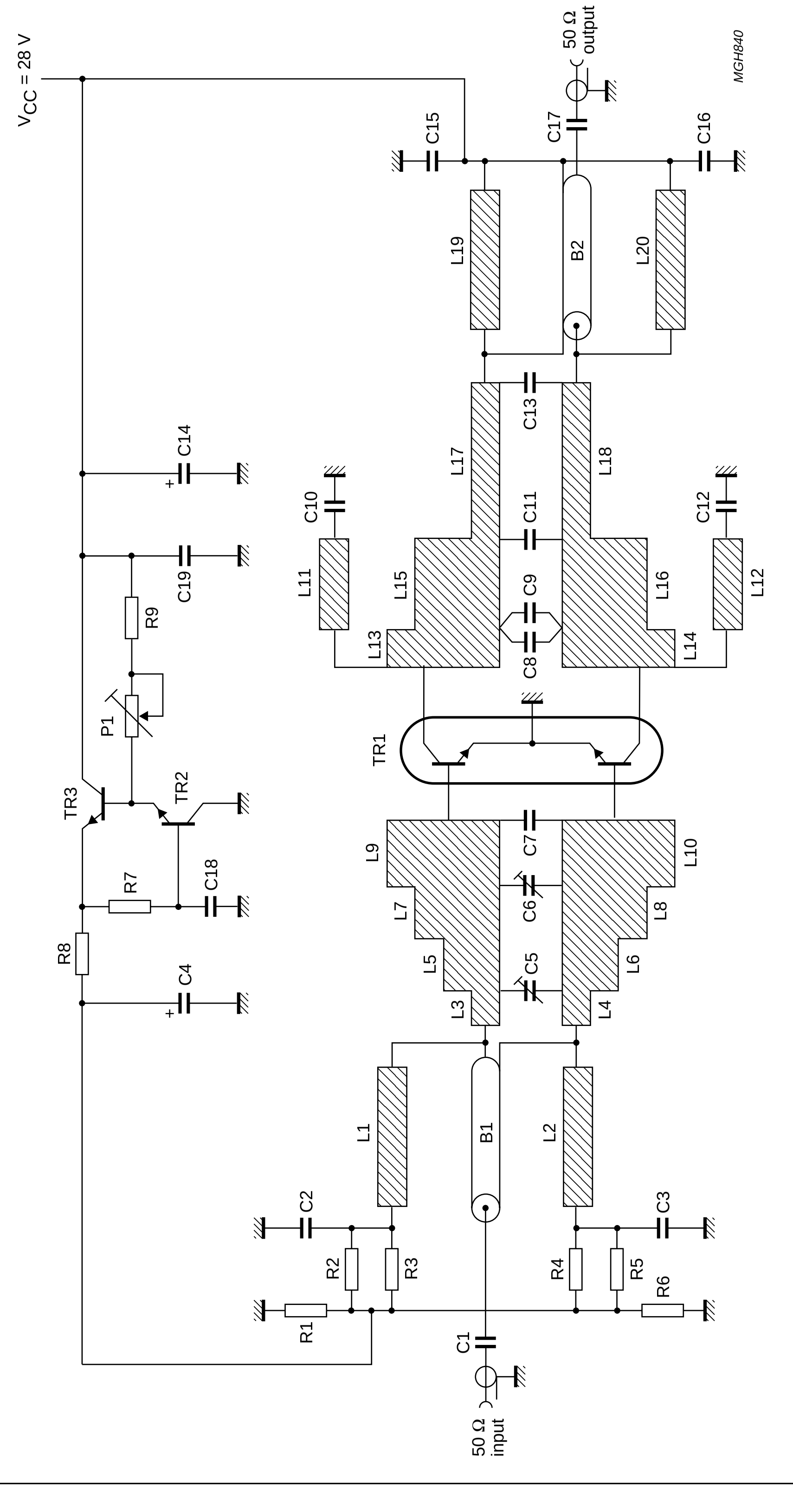

Fig.7 Schematic diagram of the BLV862 amplifier.

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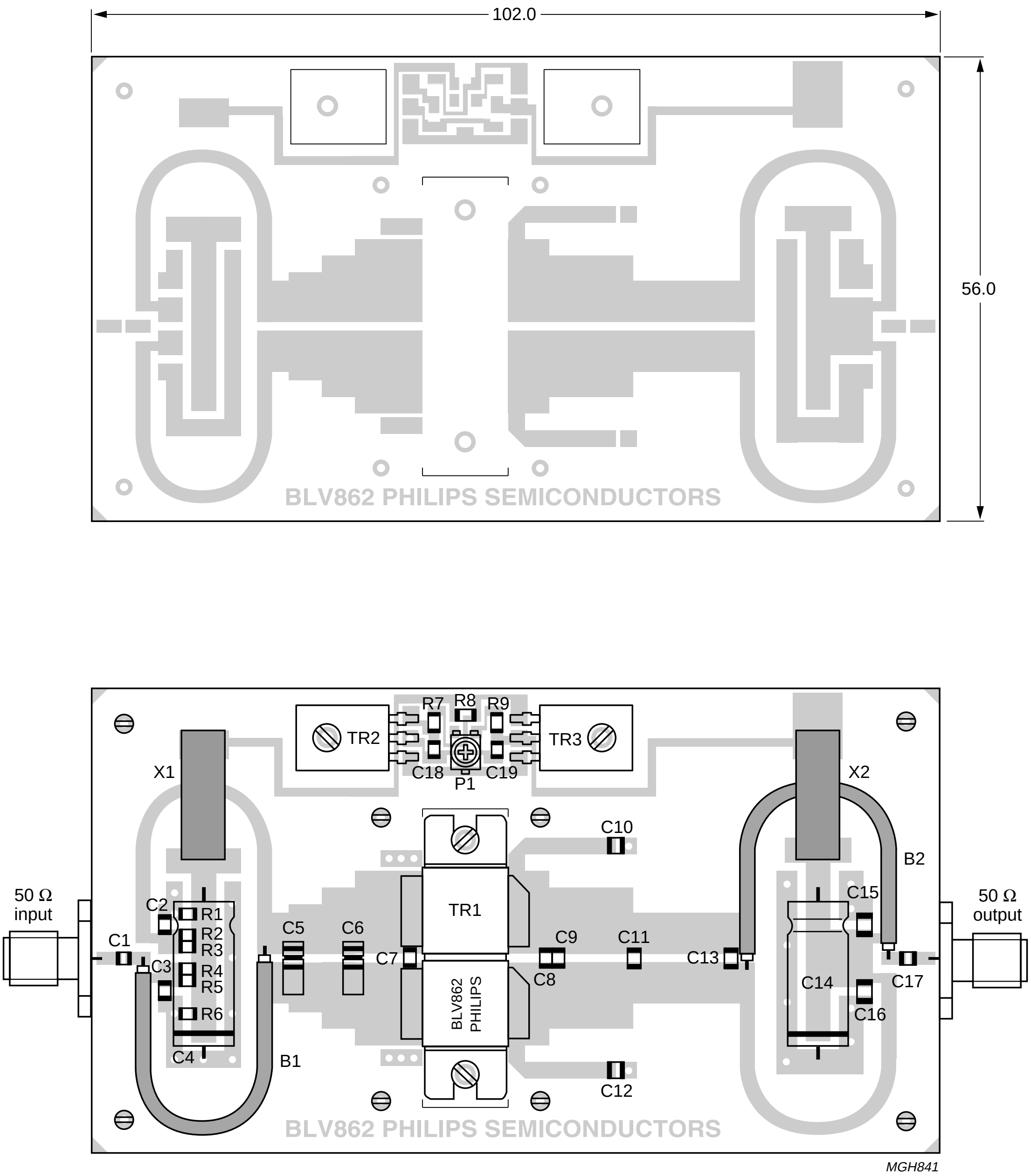

Fig.8 Component layout of the BLV862 amplifier.

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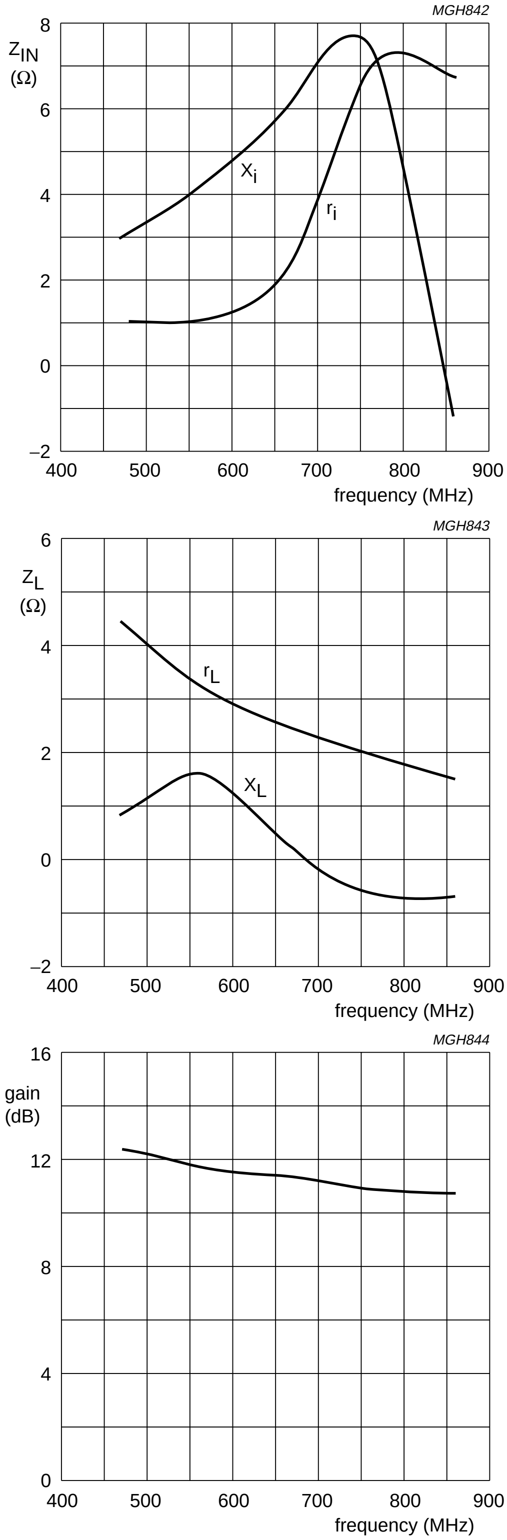
List of components

COMPONENT	DESCRIPTION	VALUE	DIMENSIONS	CATALOGUE NO.
C1	Multilayer ceramic chip capacitor; note 1	10 pF		
C2, C3	Multilayer ceramic chip capacitor	1 nF		222285247102
C4	Solid aluminium capacitor	220 µF/16 V		222203135221
C5, C6	Multilayer ceramic chip capacitor; note 2 + Tekelec trimmer	6.8 pF/0.6 – 4.5 pF		
C7	Multilayer ceramic chip capacitor; note 2	13 pF		
C8, C9	Multilayer ceramic chip capacitor; note 3	10 pF		
C10 C12	Multilayer ceramic chip capacitor; note 1	100 pF		
C11	Multilayer ceramic chip capacitor; note 2	8.2 pF		
C13	Multilayer ceramic chip capacitor; note 2	3.9 pF		
C14	Solid aluminium capacitor	100 µF/40 V		222203137101
C15, C16	Multilayer ceramic chip capacitor	100 nF		222285247104
C17	Multilayer ceramic chip capacitor; note 1	22 pF		
C18	Multilayer ceramic chip capacitor; note 1	100 pF		
C19	Multilayer ceramic chip capacitor	15 nF		222285247153
R1, R6	SMD resistor	100 Ω	805	212211803881
R2, R3, R4, R5, R8	SMD resistor	1 Ω	805	212211804562
R7	SMD resistor	47 Ω	805	212211804598
R9	SMD resistor	1.2 kΩ	805	212211804579
P1	Potentiometer	5 kΩ		
T1	NPN push-pull RF-transistor	BLV862		934038450112
T2, T3	NPN transistor	BD139		933091220112
B1	Semi rigid coax balun UT70-25	Z = 25 ±1.5 Ω	47.0 mm	
B2	Semi rigid coax balun UT70-25	Z = 25 ±1.5 Ω	48.7 mm	
X1, X2	Copper ribbon hairpin			
L1, L2	Stripline; note 4		47.0 × 1.8 mm	
L3, L4	Stripline; note 4		2 × 5 mm	
L5, L6	Stripline; note 4		4 × 6 mm	
L7, L8	Stripline; note 4		4 × 8 mm	
L9, L10	Stripline; note 4		8.1 × 10 mm	
L11, L12	Stripline; note 4		15 × 2 mm	
L13, L14	Stripline; note 4		5 × 10 mm	
L15, L16	Stripline; note 4		10 × 8 mm	
L17, L18	Stripline; note 4		12.9 × 5 mm	
L19, L20	Stripline; note 4		48.7 × 1.8 mm	

Notes

1. American Technical Ceramics type 100A or capacitor of same quality.
2. American Technical Ceramics type 100B or capacitor of same quality.
3. American Technical Ceramics type 180R or capacitor of same quality.
4. The striplines are on a double copper-clad PCB: PTFE-glass material (TLX8) from Taconic (epsilon of 2.55).

13 APPENDIX B



V_{CC} = 28 V; I_{cq} = 800 mA;
P_{OUT} = 150 W; T_{hs} = 25 °C.

Fig.9 Gain and input-output impedance of two sections.

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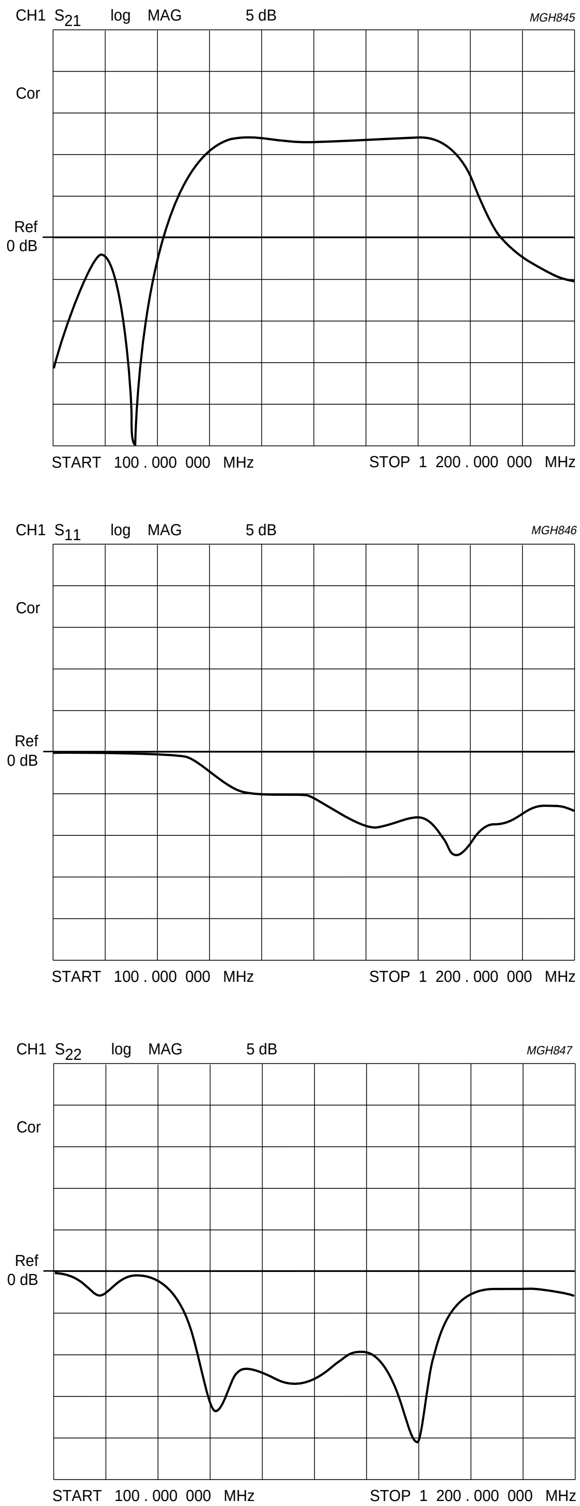

V_{CC} = 28 V; I_{cq} = 2.5 A; T_{hs} = 25 °C.

Fig.10 Small signal respons of the BLV862 amplifier in class-AB operation.

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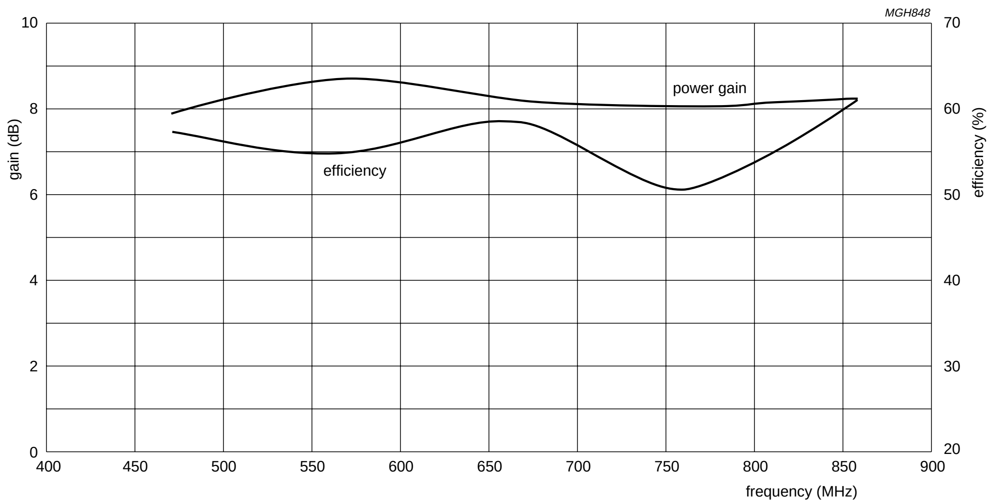
FREQ (MHz)	P_{OUT} (W)	PIN-F (W)	PIN-R (W)	Ic (A)	Gp (dB)	EFF (%)	IRL (dB)	COMP. (dB)
470	150	24.40	11.00	9.31	7.89	57.54	–3.46	–1.05
567	150	20.04	7.20	9.77	8.74	54.83	–4.45	–0.47
665	150	22.50	6.40	9.12	8.24	58.74	–5.46	–0.54
762	150	23.00	3.65	10.55	8.14	50.78	–7.99	–0.56
860	150	22.20	3.14	8.75	8.30	61.22	–8.49	–0.86



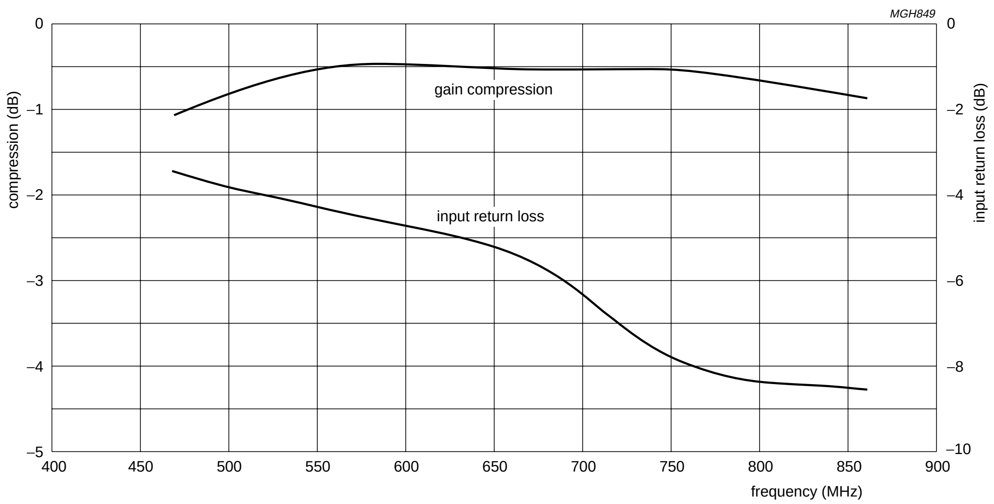


Fig.11 CW results of the BLV862 amplifier.

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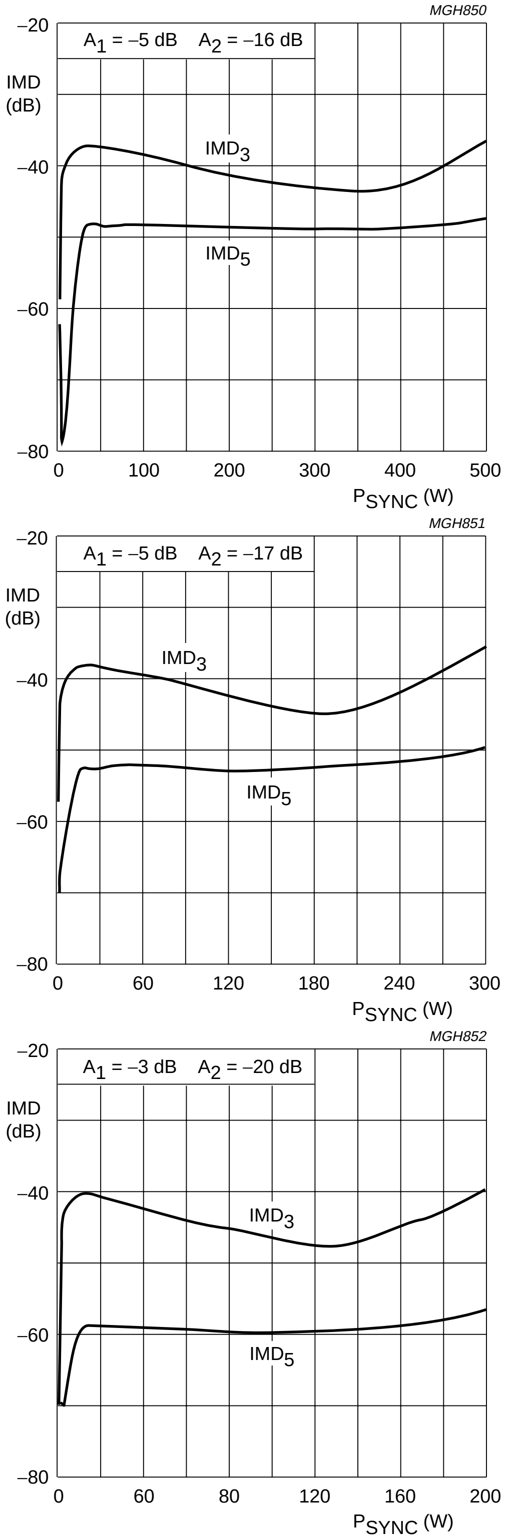

V_{CC} = 28 V; I_{cq} = 800 mA; T_{hs} = 25 °C.

Fig.12 Two tone intermodulation in class-AB.

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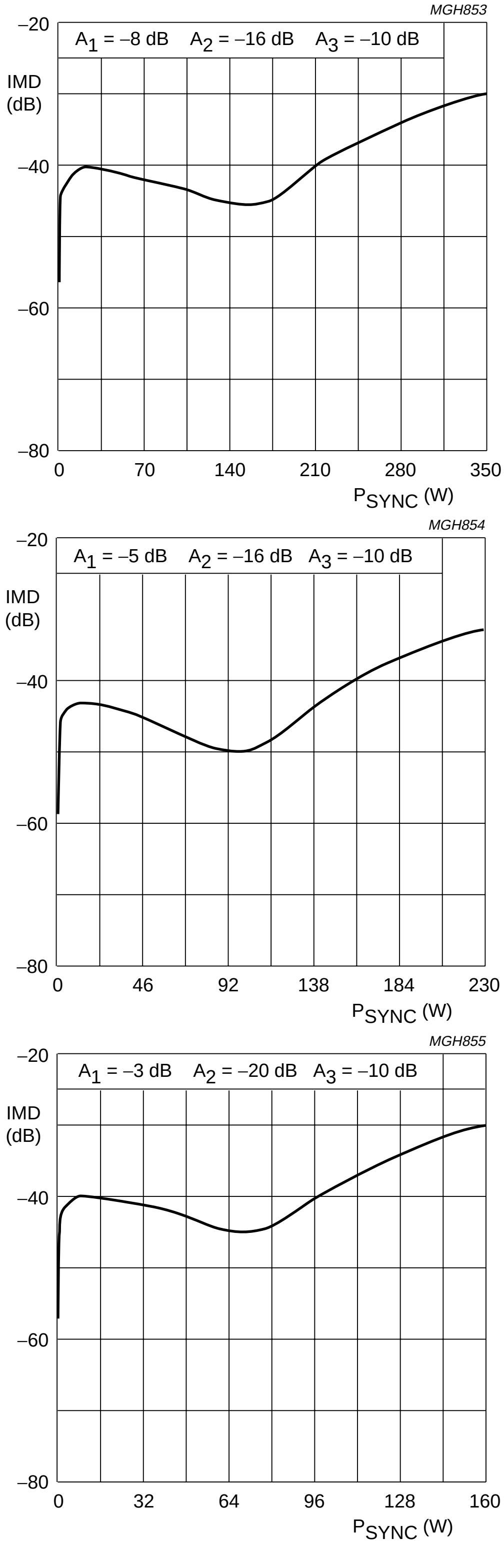

V_{CC} = 28 V; I_{cq} = 800 mA; T_{hs} = 25 °C.

Fig.13 Three tone intermodulation in class-AB.

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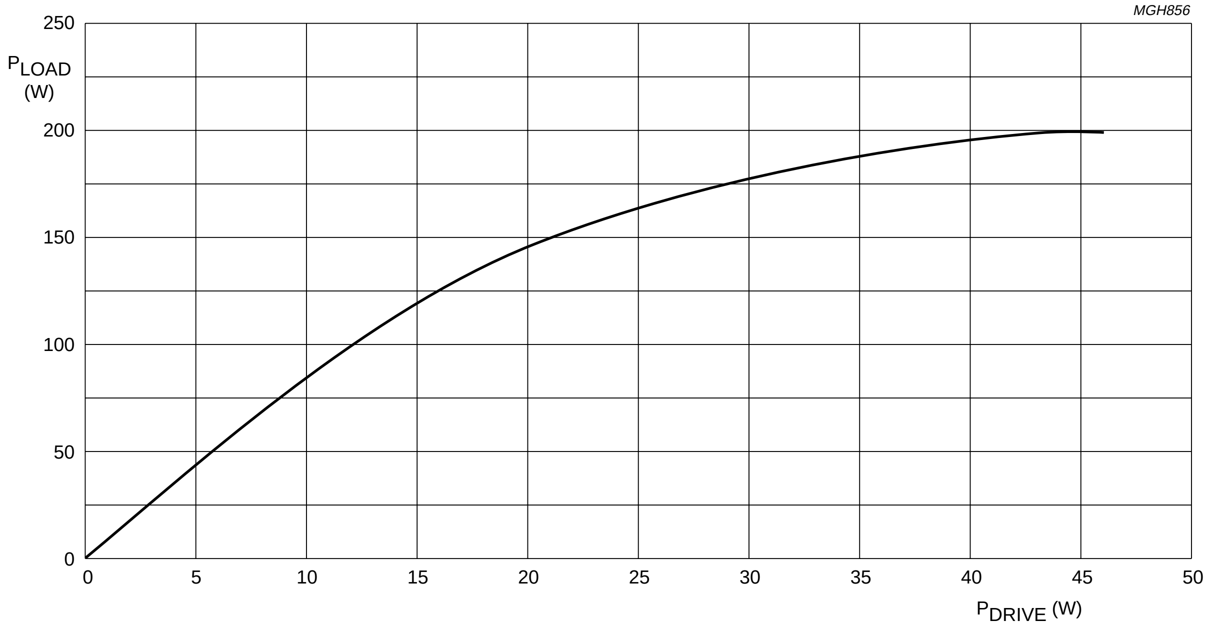
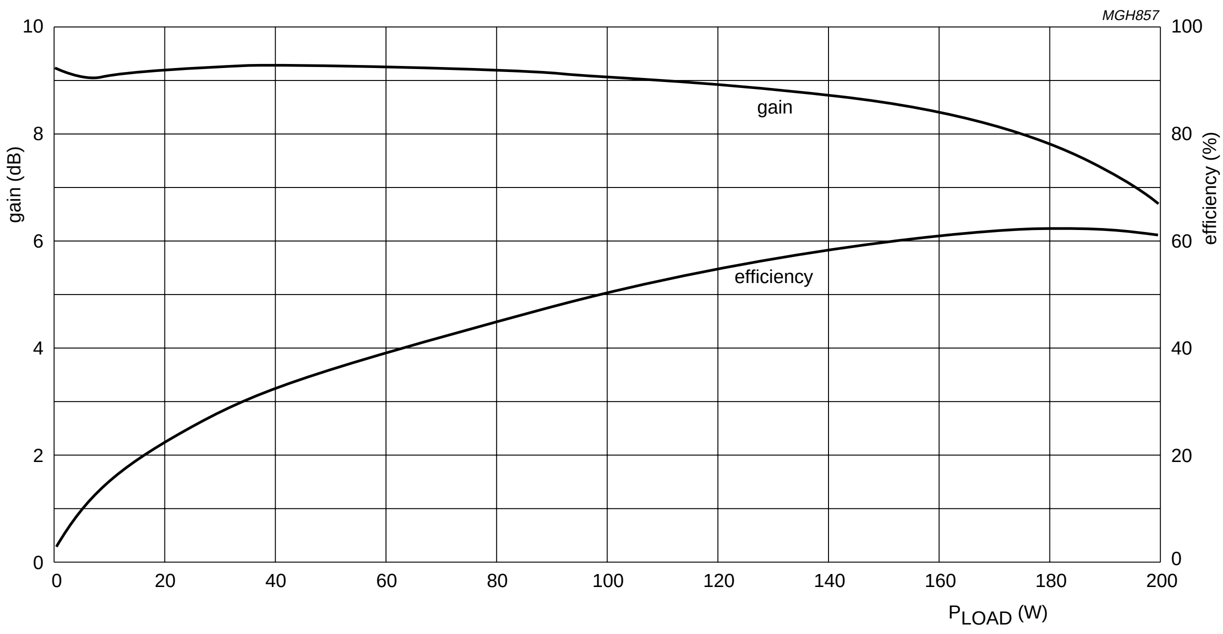


a. Loadpower vs. input power.



b. Gain and efficiency vs. loadpower.

V_{CC} = 28 V; I_{cq} = 800 mA; freq. = 860 MHz; T_{hs} = 25 °C.

Fig.14 3 dB input overdrive capability test.

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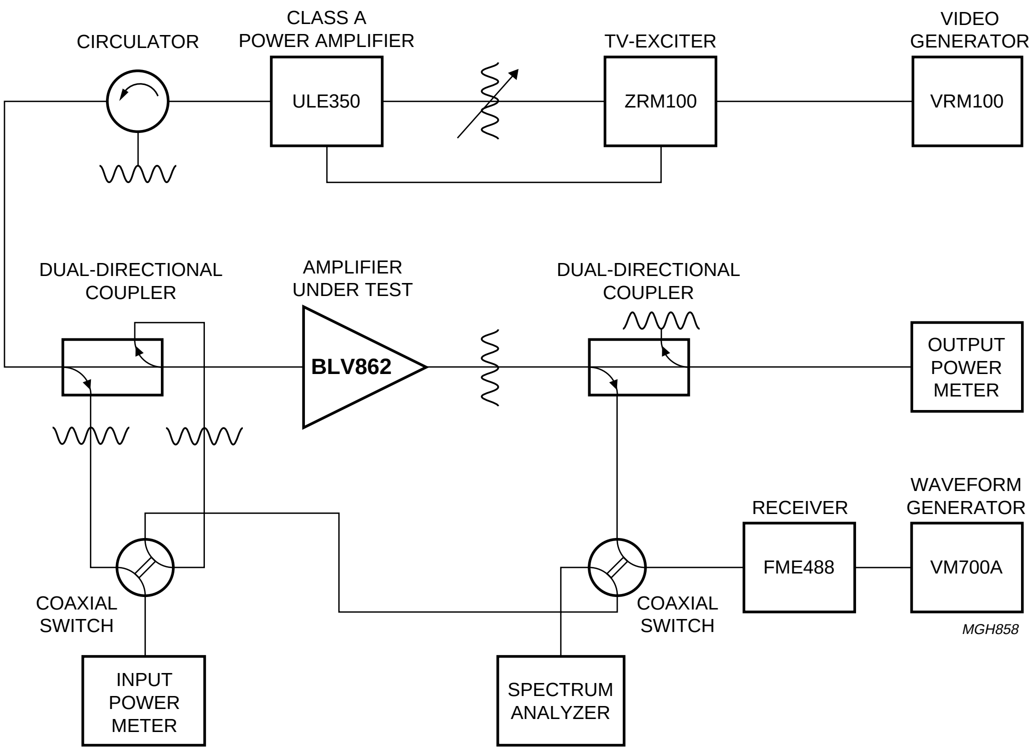
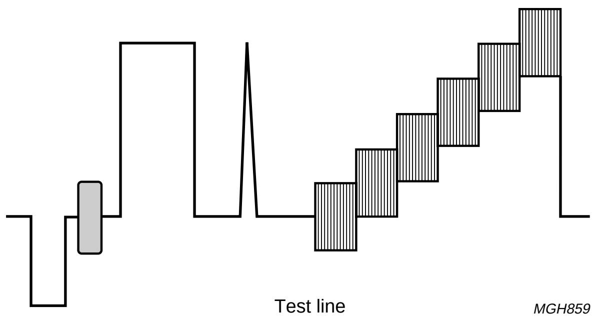
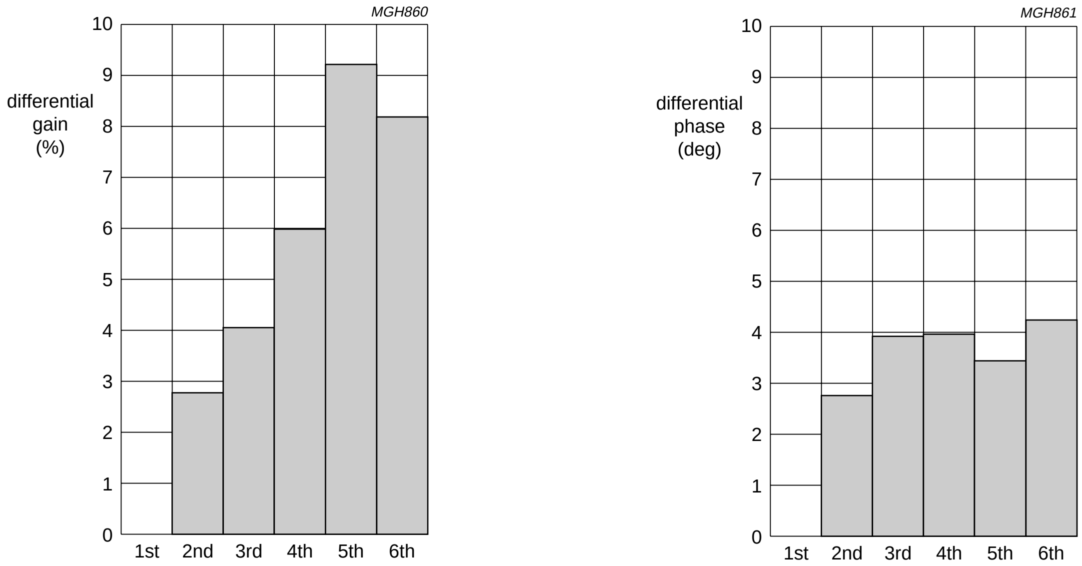


Fig.15 TV measurement setup.

20 APPENDIX F2



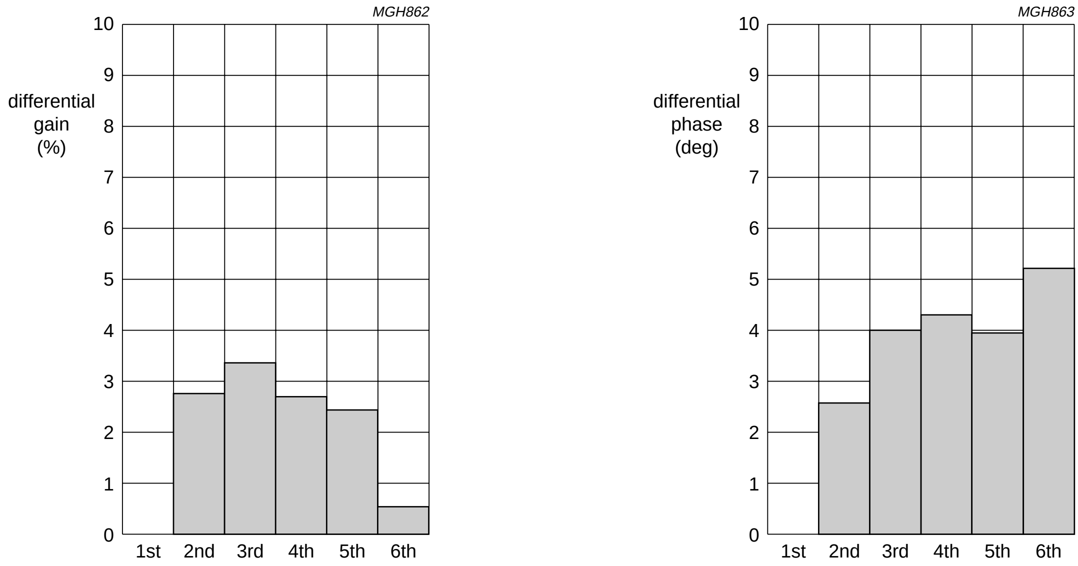
Channel 69; $P_{o,sync}$ = 150 W; 10% residual carrier; V_{CC} = 28 V; T_{hs} = 25 °C; Picture content: colour bar.



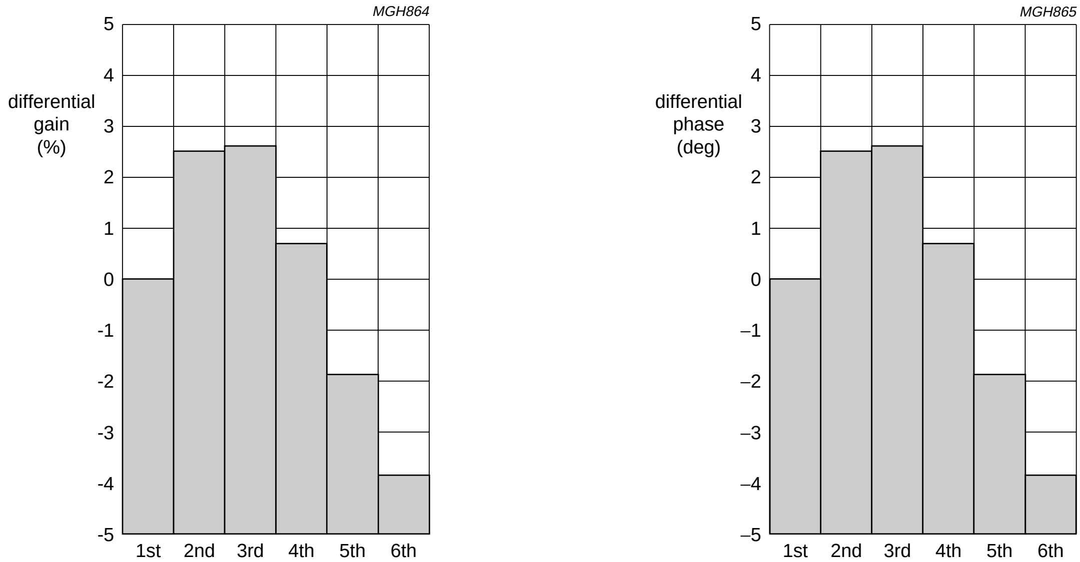
I_{cq} = 800 mA.

Fig.16 Differential Gain and Phase.

21 APPENDIX F3



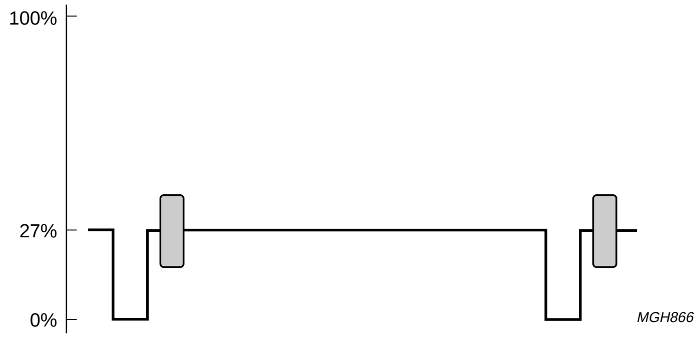
Icq 300 mA.



Icq 150 mA.

Fig.17 Differential Gain and Phase.

22 APPENDIX F4



Test conditions: channel 69; black level; V_{CC} = 28 V; I_{cq} = 800 mA; T_{hs} = 25 °C.

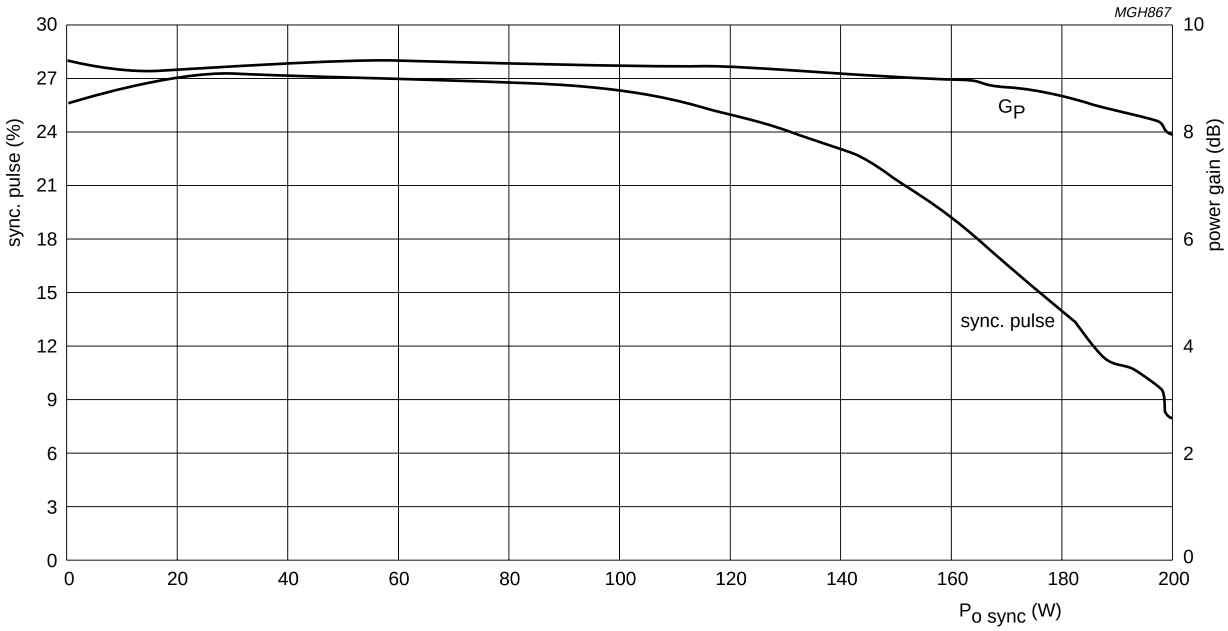


Fig.18 Sync compression vs. peak-sync power.

23 APPENDIX G1

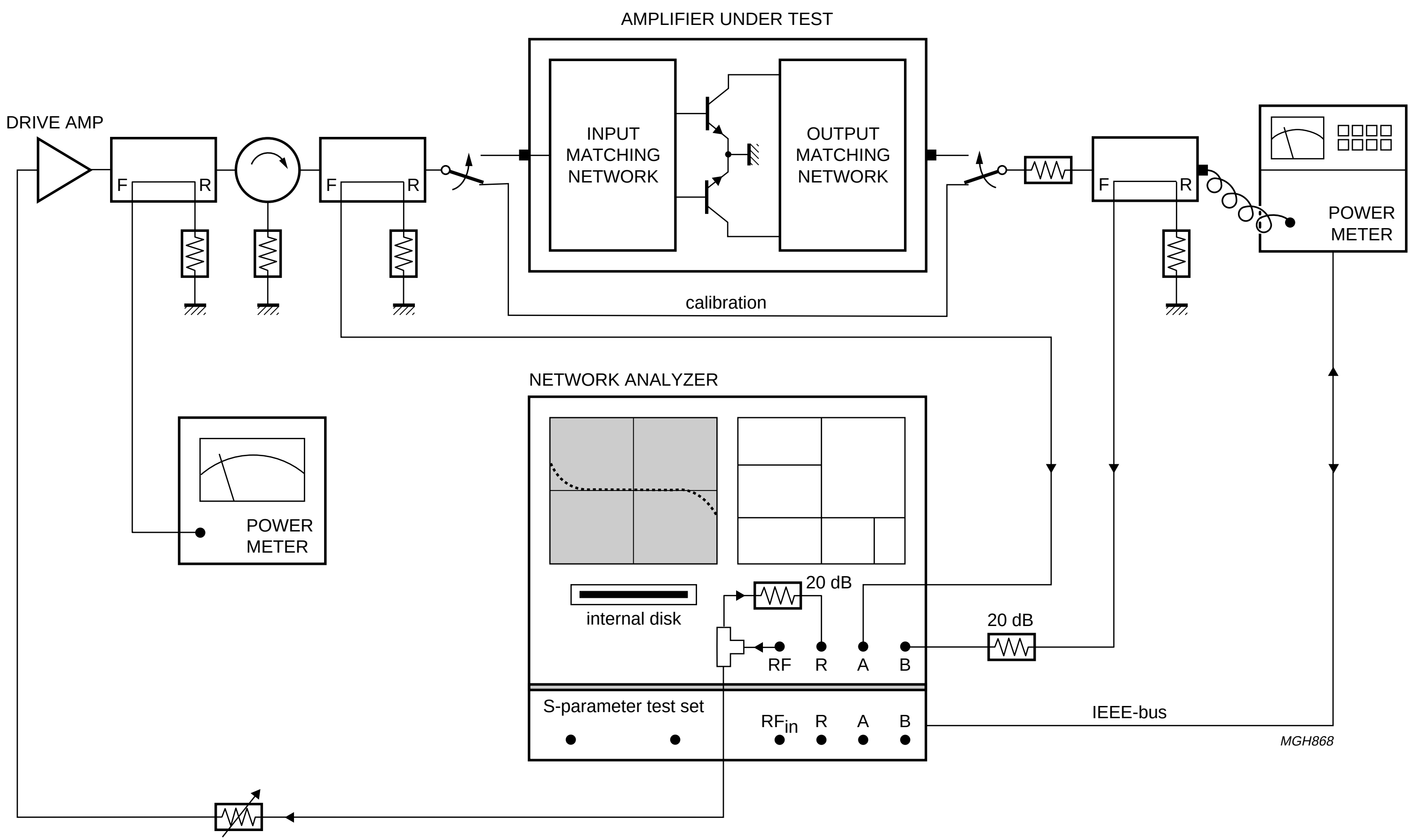


Fig.19 Setup for phase linearity measurement.

24 APPENDIX G2

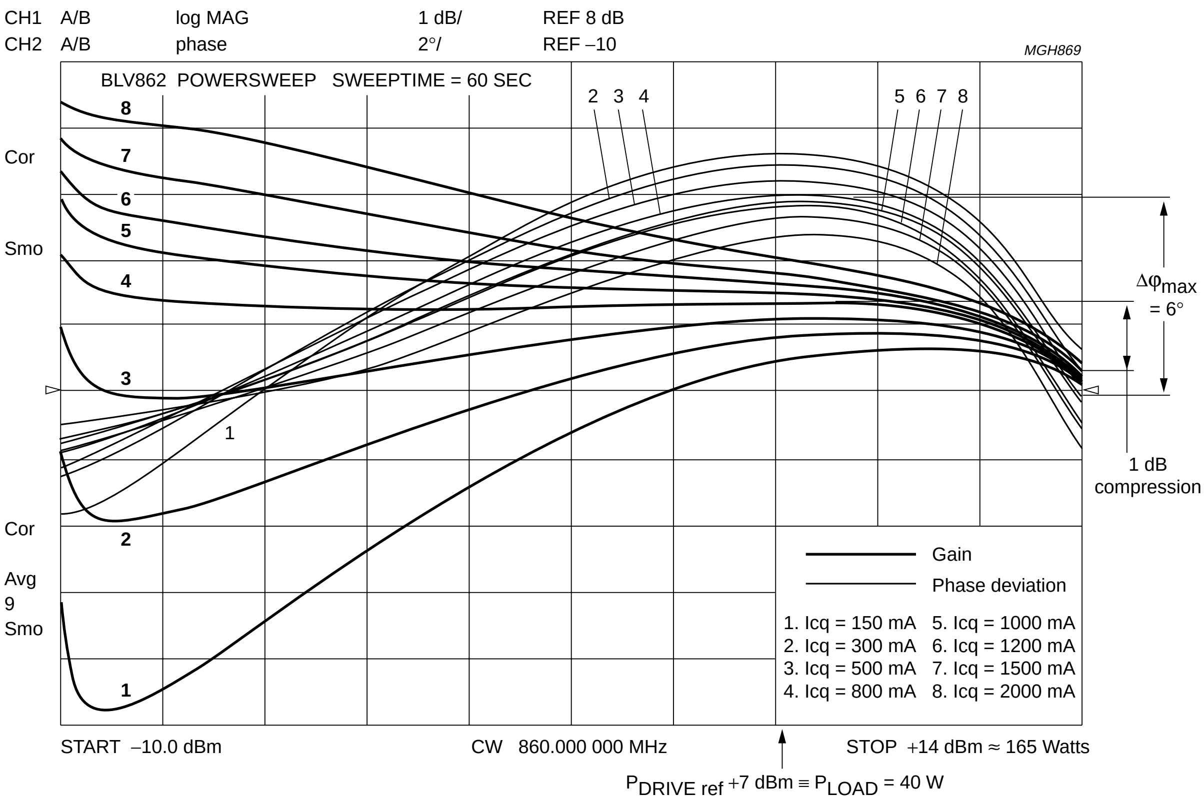
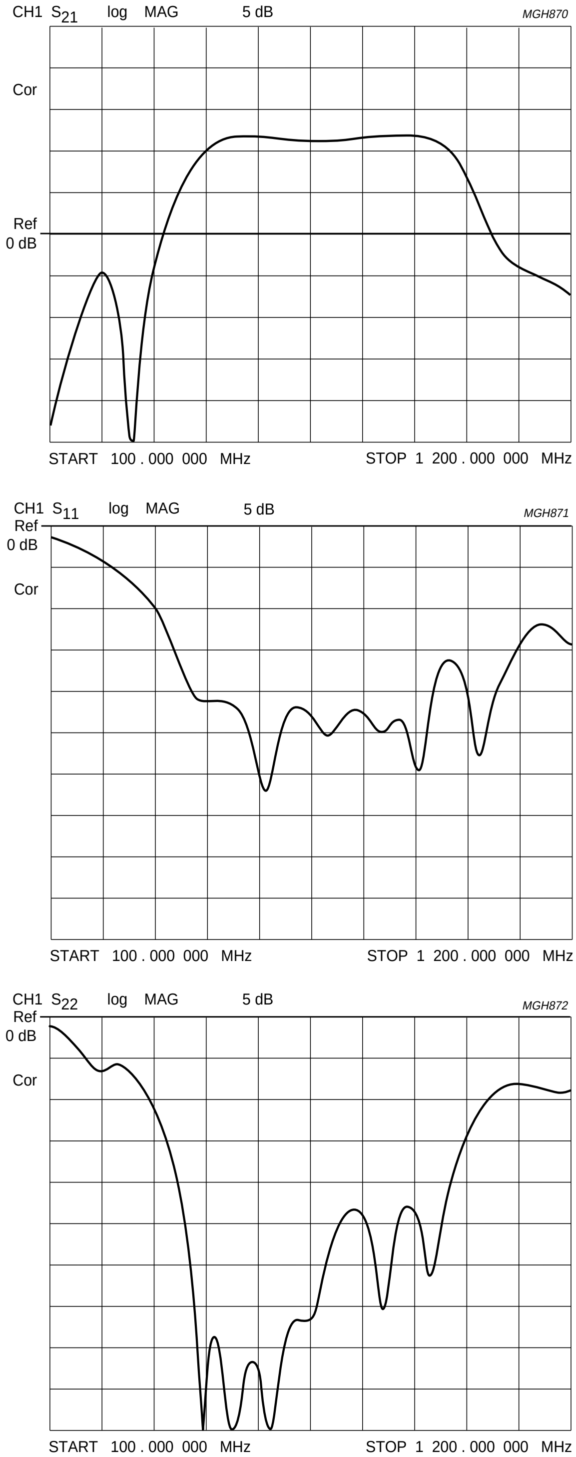


Fig.20 Gain and Phase deviation.

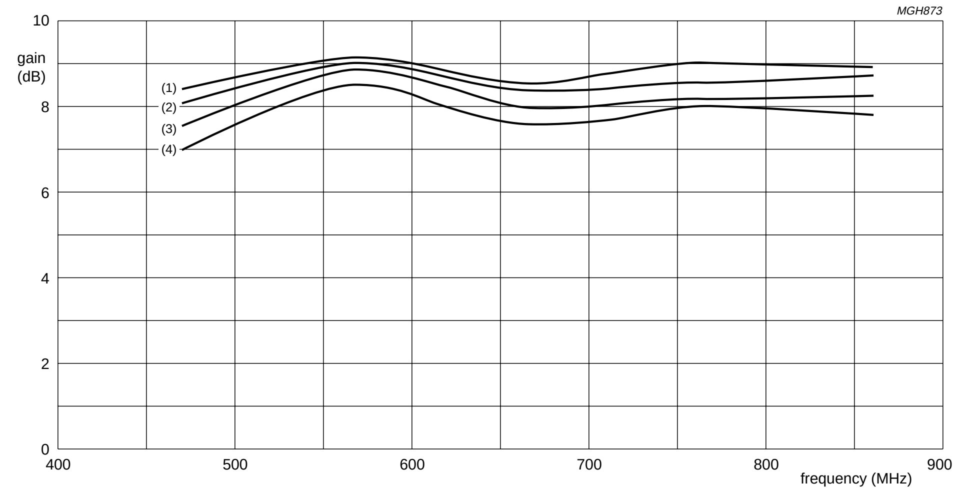
25 APPENDIX H1



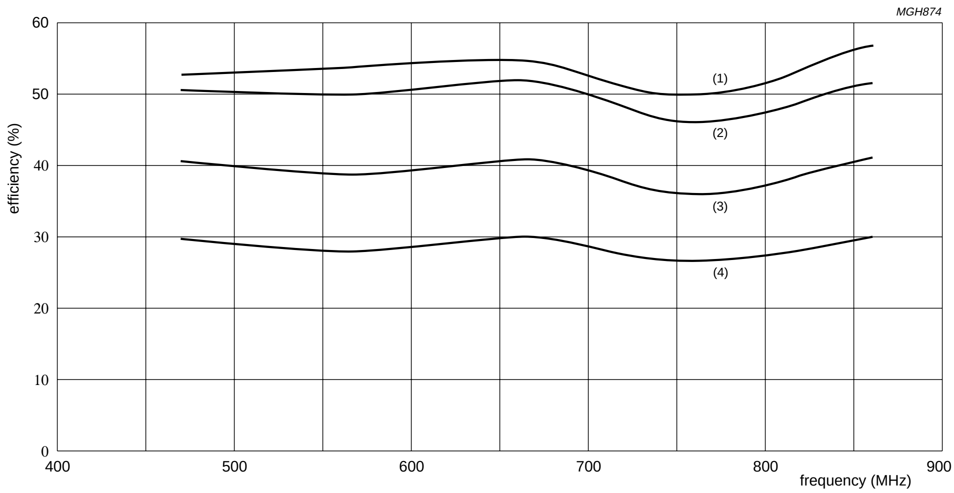
V_{CC} = 28 V; I_{cq} = 2.5 A (each amplifier); T_{hs} = 25 °C.

Fig.21 Small signal respons of two BLV862 amplifiers in class-AB combined with quadrature hybrids.

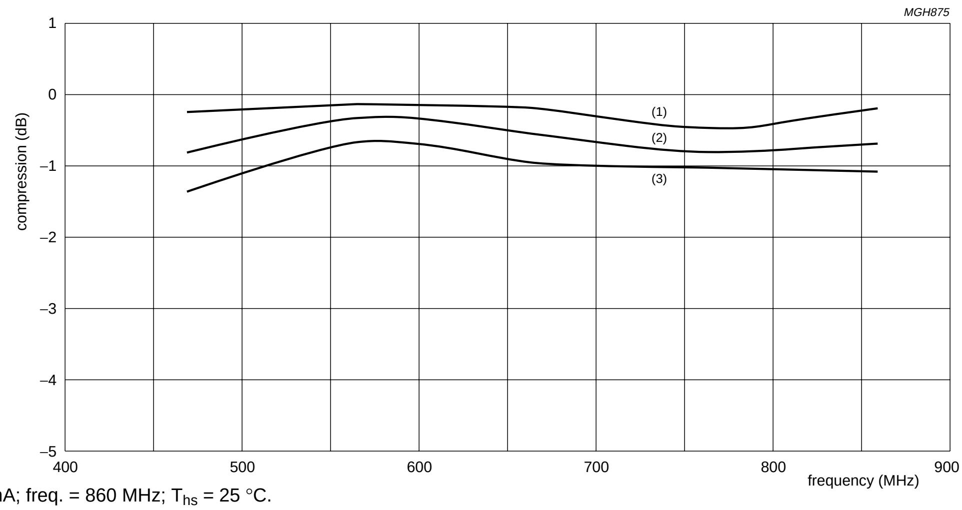
26 APPENDIX H2



(1) P_L = 80 W.
(2) P_L = 150 W.
(3) P_L = 250 W.
(4) P_L = 300 W.



(1) P_L = 80 W.
(2) P_L = 150 W.
(3) P_L = 250 W.
(4) P_L = 300 W.



(1) P_L = 150 W.
(2) P_L = 250 W.
(3) P_L = 300 W.

V_{CC} = 28 V; I_{cq} = 800 mA; freq. = 860 MHz; T_{hs} = 25 °C.

Fig.22 RF performance of two BLV862 amplifiers combined with 3 dB quadrature hybrids.

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