APPLICATION NOTE

Combining units for a 1 kW wideband HF amplifier

AN98032

Philips
Semiconductors

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Combining units for a 1 kW wideband HF amplifier

CONTENTS

1 SUMMARY

Based on Philips 4C6 ferrite toroids, input and output combining units are described for combining four 300 W PEP linear wideband amplifiers to produce at least 1 kW PEP in the HF band (1.6 – 30 MHz) with an intermodulation distortion of less than –30 dB.

2 INTRODUCTION

For long-range communication, the HF band from 1.6 – 30 MHz is used. As the modulation method is mainly SSB, linear amplifiers are required with output powers of 1 kW PEP in many cases. However, the best power amplifiers obtainable only have output powers of 300 to 400 W PEP. For example, Report AN98030 describes a push-pull amplifier using two BLW96 bipolar transistors delivering 400 W PEP, while Report NCO8703 describes a push-pull amplifier using two BLF177 MOS transistors delivering 300 W PEP. So four of these amplifiers are required to achieve powers of 1 kW PEP.

This report describes suitable combining units for both the input and output of such amplifiers to achieve the power mentioned above.

3 CIRCUIT DESCRIPTION

All transformers and hybrids used in the combiners are transmission line types as described in report ECO6907. Extensive use is made of Ferroxcube toroids, size: $36 \times 23 \times 15$ mm^3, material: 4C6. Part no.: 4322 020 91090.

3.1 The input power divider

Figs 1 and 2 show the block diagram and circuit diagram of the divider. It consists of four transformers wound on ferrite toroids, each transformer using one 4C6 toroid.

The input transformer provides a 4:1 impedance transformation from 50 Ω unbalanced input to 12.5 Ω unbalanced output. It consists of 7 turns of two parallel 50 Ω cables (3 mm ext. dia.) wound on the toroid.

The second transformer consists of 7 turns of two parallel 50 Ω cables (3 mm ext. dia.) wound on one toroid with the connections arranged as a hybrid to give a transformation from 12.5 Ω to two 25 Ω unbalanced in-phase outputs.

The third and fourth transformers are identical and consist of 8 turns of 50 Ω coaxial cable (3 mm ext. dia.) wound on the toroid with the connections arranged as a hybrid to give a transformation from 25 Ω to two 50 Ω unbalanced in-phase outputs.

Out-of-balance (or power dumping) resistors of 100 Ω are connected across the two 50 Ω output ports of each output transformer, and a 50 Ω resistor is connected across the two 25 Ω output ports of the intermediate hybrid transformer.

Although ideal transmission line transformers operate over a very wide band, in practice, there are inevitable performance degradations due to stray capacitance, stray leakage inductances etc. caused by the construction of such a system. In addition, the relatively large ballast resistors and their connecting leads (stray inductances) must be compensated by capacitors to obtain a near constant impedance throughout the band (1.6 – 30 MHz).

It was found experimentally, using a Hewlett Packard vector impedance meter, that satisfactory impedance compensation could be obtained by using three capacitors (120 pF, 80 pF and 80 pF) connected between the 12.5 Ω terminal and earth and each of the two 25 Ω impedance terminals to earth. The final result gave a maximum VSWR of 1.3 at the input port with all other ports terminated with 50 Ω wideband loads. Figure 3 shows the measured VSWR throughout the band.

The rating of the hybrid resistors is sufficient for fail-safe operation of the system under the worst fault conditions for continuous CW operation without forced air cooling of the resistors.

3.2 The output power combiner

Figs 4 and 5 show the block diagram and a circuit diagram of the combiner. Like the input power divider, it consists of four transformers wound on ferrite toroids.

One pair of amplifiers is coupled through 50 Ω ports to a common 25 Ω port (as is the other pair). Each transformer is wound with 5 turns of PTFE dielectric coaxial cable (2.5 mm ext. dia.) on a stacked core of two toroids, the connections arranged as a hybrid transformer from 50 Ω plus 50 Ω to 25 Ω. Out-of-balance (or power dumping) resistors of 100 Ω are connected across the two 50 Ω ports of each hybrid transformer.

A third hybrid transformer couples the two 25 Ω outputs to combine the power from these two sources to an impedance of 12.5 Ω. This transformer is wound with 3 turns of two 50 Ω PTFE dielectric coaxial cables (4.0 mm ext. dia.) on a stack of four toroids, the connections being arranged as a hybrid transformer from 25 Ω plus 25 Ω to 12.5 Ω. An out-of-balance (or power dumping) resistor of 50 Ω is connected across the two 25 Ω inputs.

The fourth transformer is a 1:4 impedance transformer which transforms the combined output at 12.5 Ω impedance to the 50 Ω load impedance. This transformer is wound with 4 turns of two parallel 50 Ω PTFE dielectric coaxial cables (4.0 mm ext. dia.) on a stack of five toroids, the connections are arranged for a 1:4 impedance transformer (unbalanced).

To compensate the stray influences (leakage inductance and capacitance etc.) it was found experimentally, using a vector impedance meter, that satisfactory compensation could be obtained using five capacitors connected at the points shown in the circuit of Fig.5. The final result (Fig.6) shows a maximum VSWR of 1.16 on any input port with all other ports terminated with 50 Ω wideband loads.

The rating of the hybrid resistors is sufficient for short-term fault conditions with two-tone signals without forced air cooling. With suitable forced air cooling, continuous CW operation under the most severe fault condition (two units inoperative) is possible.

A parts list for the input and output combiner units is given in Chapter 5.

4 MEASURED RESULTS

The practical performance of the units described was tested with four push-pull amplifiers each using two BLX15 bipolar transistors. The results concerning intermodulation are shown in the graphs of Fig.7 for a total output power of 1 kW PEP. All intermodulation products remained below –30 dB. Note, the BLX15 is no longer in Philips' product program and has been superseded by the BLW96 which has a maximum output power of 200 W PEP (at $d_3 \leq -30$ dB).

To keep the power loss in the hybrid resistors as low as possible, it is desirable to use amplifiers having roughly the same power gain. In the case of bipolar transistors, eight devices should be chosen from the same h_{FE} group, while for MOS transistors, devices should be chosen from the same $V_{GS(th)}$ group.

5 PARTS LIST

Table 1 Input power divider

4	4C6 Ferroxcube toroids (Philips); 36 × 23 × 15 mm; part no.: 4322 020 91090
1	50 Ω resistor, Electrosil type H35, 30 W
2	100 Ω resistor, Electrosil type H33, 15 W
	Miniature 50 Ω coaxial cable windings; external dia. approx. 3 mm (from any suitable manufacturer)
2	82 pF tubular ceramic (or ceramic plate) capacitors (low ε_r)
1	120 pF tubular ceramic (or ceramic plate) capacitor (low ε_r)

Table 2 Output power combiner

13	4C6 Ferroxcube toroids (Philips); 36 × 23 × 15 mm; part no.: 4322 020 91090
2	100 Ω resistors in parallel, Electrosil type H37
2	100 Ω resistors, Electrosil type H37
	50 Ω PTFE dielectric insulated coaxial cable; external dia. approx. 4 mm (from any suitable manufacturer)
2	33 pF ceramic block capacitors (ATC)
2	68 pF ceramic block capacitors (ATC)
1	120 pF ceramic block capacitors (ATC)

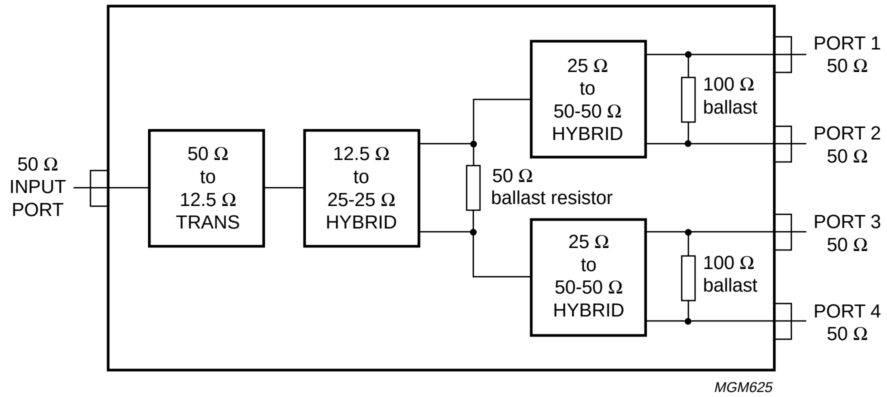

Fig.1 Block schematic of the input power divider.

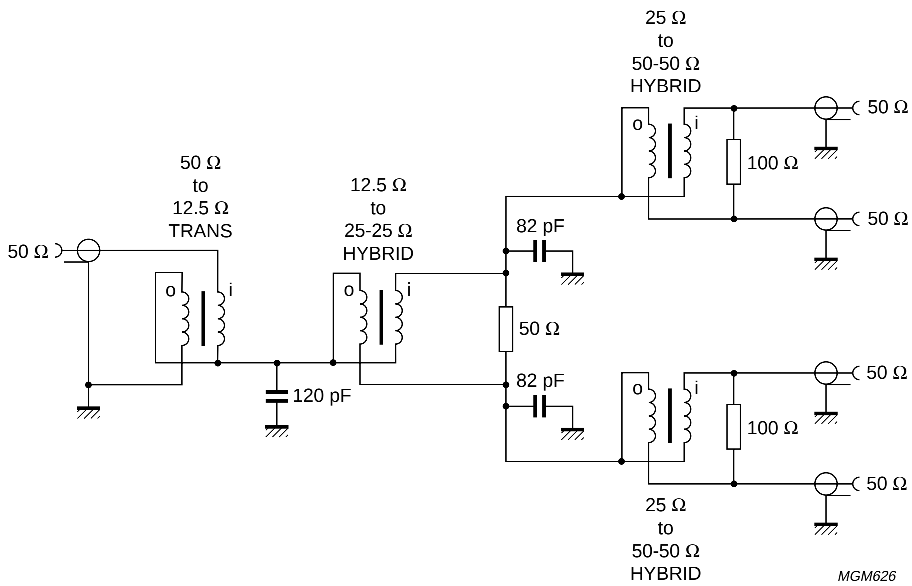

Fig.2 Circuit diagram of the input power divider.

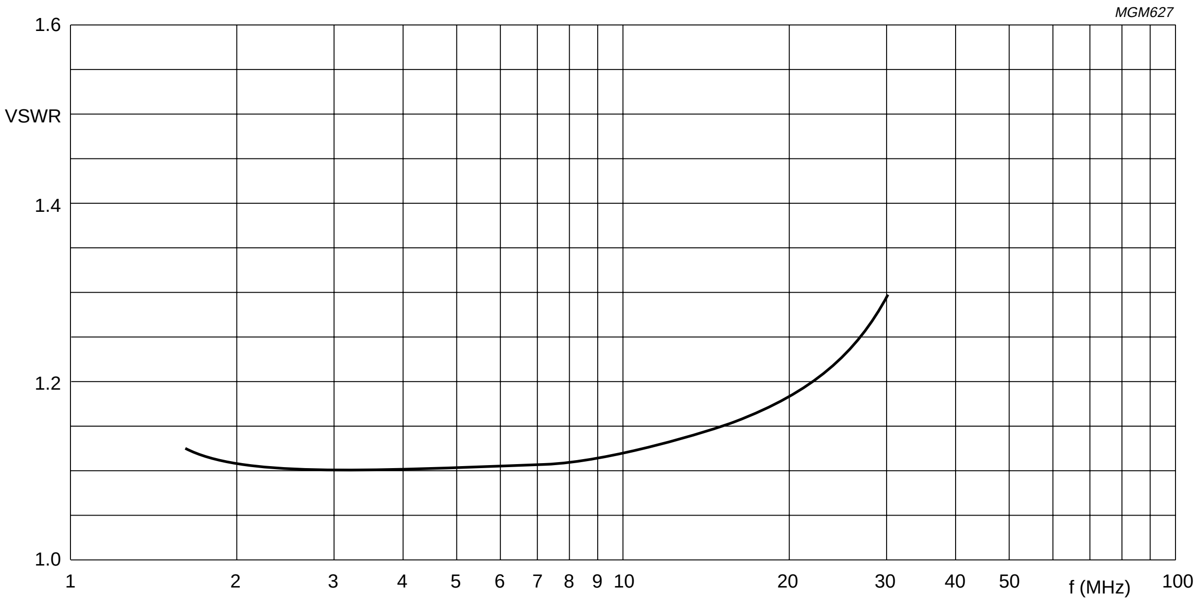

Fig.3 Input VSWR of the hybrid coupler with all output ports loaded by 50 Ω.

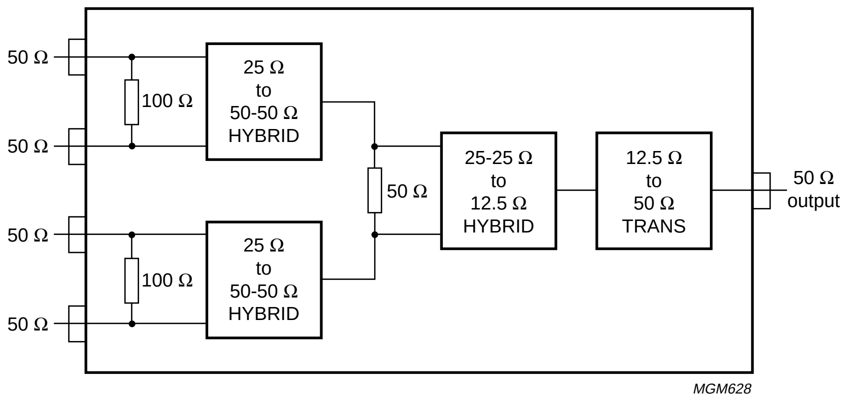

Fig.4 Block schematic of the output power combiner.

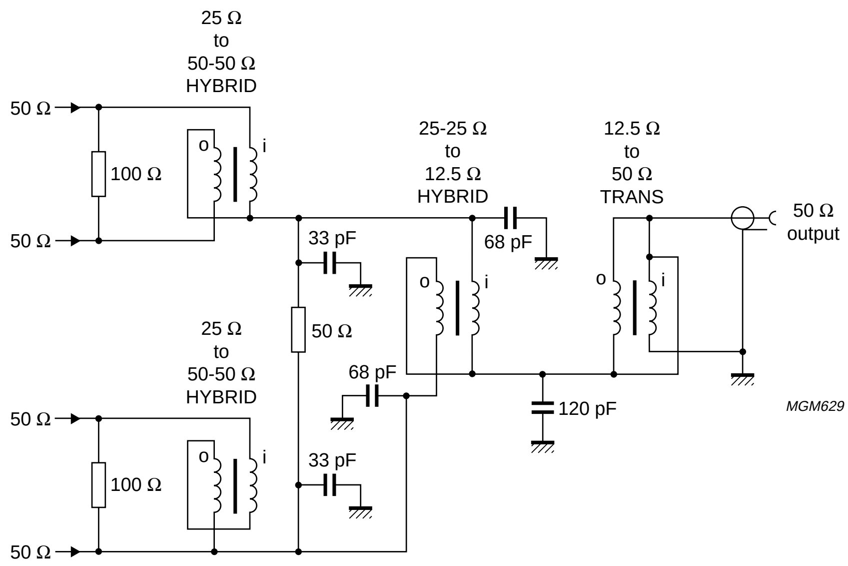

Fig.5 Circuit diagram of the output power combiner.

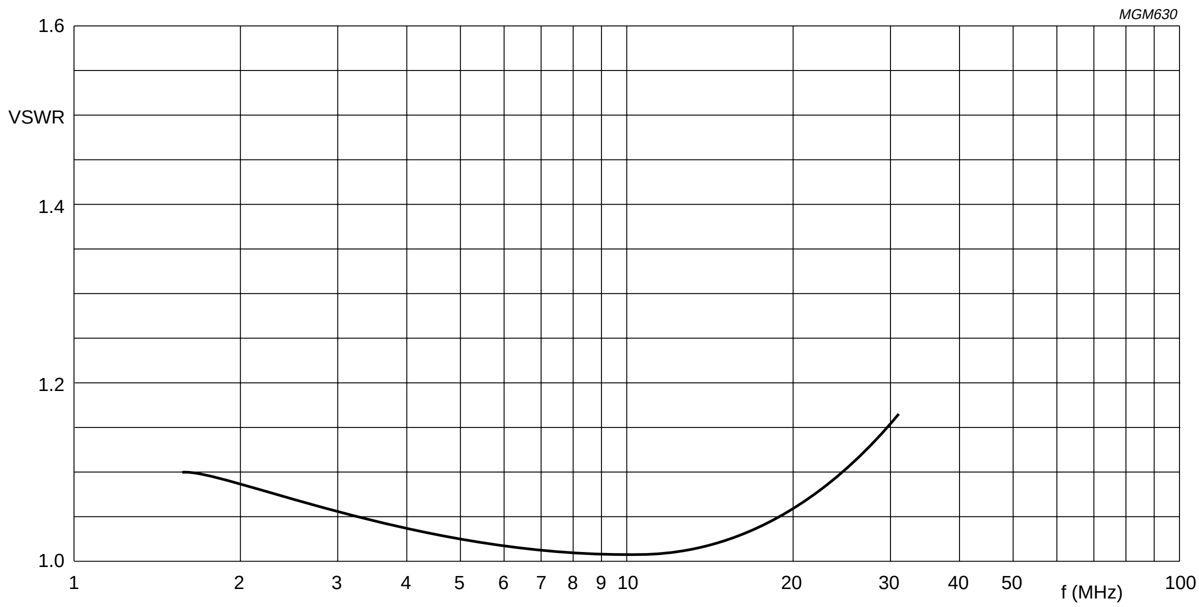

Fig.6 VSWR of any 50 Ω input port with all other ports terminated by 50 Ω.

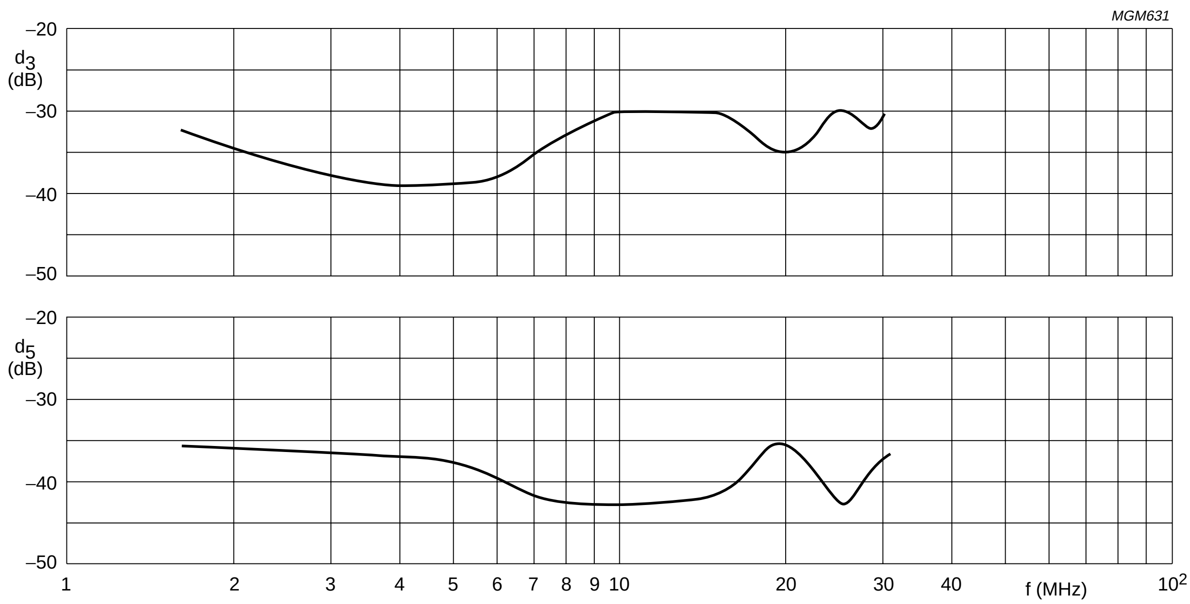

Fig.7 Intermodulation distortion (d_3 and d_5) of the four 300 W amplifiers coupled with hybrid couplers and driven to 1 kW PEP.

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