elektornado

The Elektornado is a high-fidelity amplifier offering extremely good performance at moderate cost. The use of an IC for the input and driver stages reduces component count and allows an extremely compact construction. Two amplifier channels can be accommodated on a single (small) printed circuit board either as a 2 x 50 W stereo amplifier or a 100 W mono bridge amplifier.

There has been much debate in hi-fi circles about the necessity for high amplifier output powers, with some maintaining that a high output power is an absolute necessity for undistorted handling of programme peaks, and others maintaining that high-power amplifiers are just a status symbol. Be that as it may, there is no doubt that for many applications such as disco work, or situations where extremely inefficient loudspeakers are being used, a high power output is a definite advantage. With its choice of 50 W or 100 W maximum output power, the Elektornado should certainly satisfy most requirements.

A high output power either entails the use of a high supply voltage or the use of a bridge output stage. A bridge configuration was chosen for the Elektornado for several reasons:

1. It allows relatively inexpensive output devices to be used and avoids the necessity for expensive high-voltage (> 60 V) devices.
2. Each half of a bridge amplifier can be used as an independent, lower power amplifier.

A bridge configuration entails the construction of two virtually complete amplifiers for each channel, so some way had to be found of reducing component count. Fortunately, the input and driver stages of the amplifier can be replaced by a single IC which has recently been introduced, the LM 391. In the past, integrated circuits have not been very suitable for hi-fi applications due to limitations of bandwidth, distortion, noise and operating voltage. The LM 391, however, suffers from none of these disadvantages.

The circuit

The complete circuit of one channel of the amplifier, including the equivalent internal circuit of the LM 391, is shown in figure 1. The IC replaces all the input and pre-driver stages of the amplifier, the only parts of the circuit using discrete transistors being the driver and output stages.

The input stage of the IC consists of a differential amplifier (T_G, T_H) and a current mirror (T_O, T_P), which forms the collector loads for the differential stage. The signal from the collector of T_H is fed to a cascode stage (T_O, T_N), which has a very high gain, and thence to the output stages of the IC.

The driver and output stages of the amplifier consist of two discrete transistor pairs T1/T3 and T2/T4, the quiescent current of the output stage being set by the collector/emitter voltage of transistor T_K, which is varied by adjusting the base bias by means of P1.

To avoid distortion caused by slew-rate limiting (slope overload), care has been taken in the design of the feedback and compensation networks, and additional protection is provided in the form of an input filter R15/C11, which limits the slew-rate of the input signal. However, this does not have a detrimental effect on the normal frequency response, which begins to roll off at about 30 kHz.

The closed-loop gain of the amplifier is determined by the feedback network R5, R1 and C1. At frequencies where the reactance of C1 is small the gain is given by:

$$A_V = \frac{U_{out}}{U_{in}} = 1 + \frac{R_5}{R_1} \approx 22.$$

At low frequencies the increased reactance of C1 in series with R1 causes the gain to roll off to unity for DC signals. Amongst other things this avoids any DC offset problems which might result from a high DC gain. With the component values shown the voltage gain is approximately 20 (26 dB), which means that the input sensitivity for full output voltage swing is about 1 volt. This should make the circuit suitable for use with most modern preamps.

Table 1 measured with ± 30 V supply.

Maximum output power:	
stereo	2 x 45 W into 4 ohms
	2 x 50 W into 8 ohms
mono (bridge)	100 W into 8 ohms (4 ohm load not recommended as current limiting occurs at 45 W)
Frequency response:	
	6 Hz to 30 kHz (–3 dB)
Total harmonic distortion:	
	0.1% 40 Hz < f < 10 kHz
(see also figure 6)	

Circuit protection

Several protection circuits are incorporated into the design to prevent damage to the output transistors under various fault conditions.

Inductor L1, which is wound on R18, protects the output stage when operating into capacitive loads.

Diodes D1 and D2 provide brute-force protection against any transients that might be produced by an inductive load by clamping the maximum output voltage excursion to ± U_b.

A number of sophisticated protection circuits exist within the IC itself. Should

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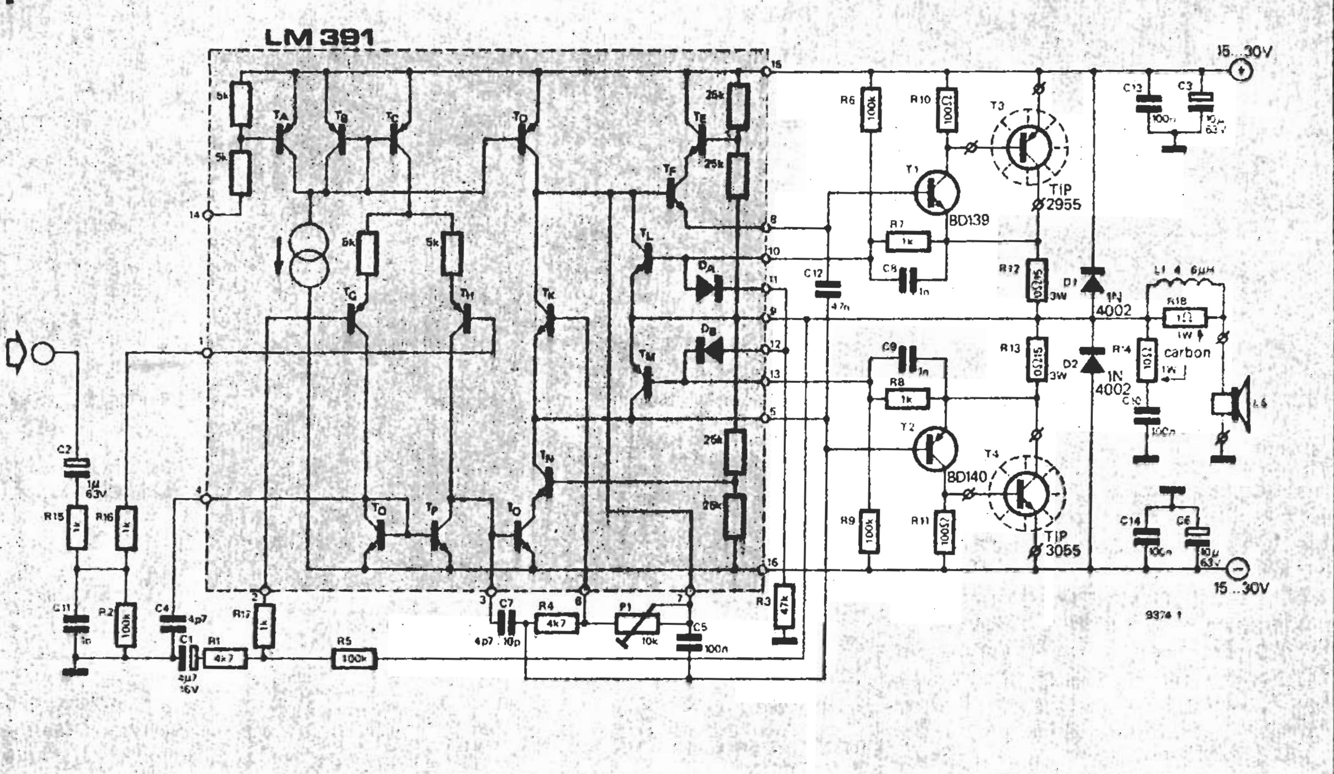

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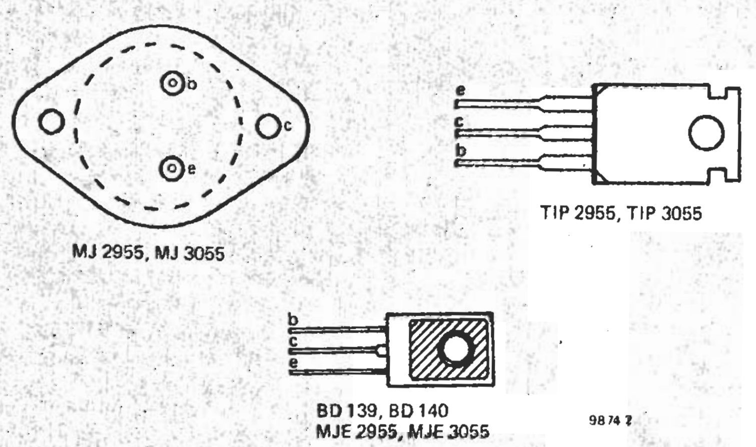

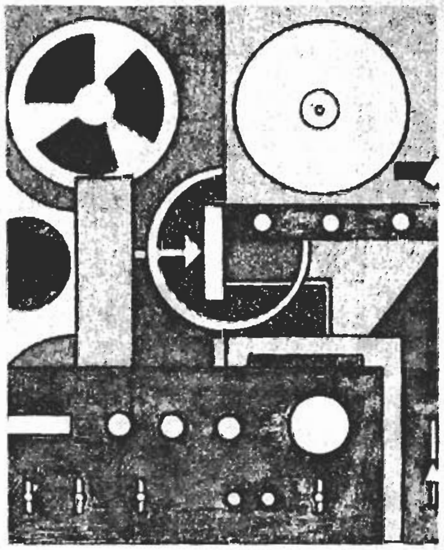

the output current of the amplifier rise above about 4 amps peak the voltage dropped across R12 or R13 will cause transistors T_L or T_M to turn on, thus limiting the output current.

Thermal protection of the output transistors may also be provided as an optional extra if desired. A negative temperature coefficient thermistor, which is in thermal contact with the output transistor heatsink, may be connected between pin 14 of the IC and ground. Current will flow through this thermistor via the two base resistors of T_A. As the temperature increases and the resistance of the thermistor falls this current will increase until the voltage drop across the 5 k resistor is sufficient to turn on T_A. This will shut down current sources T_B, T_C and T_D and cut off the drive to the output stage.

A resistor may need to be included in series with the thermistor to limit the maximum current out of pin 14 to 1 mA, and the thermistor value should be chosen such that the current out of pin 14 will be about 100 μA at the desired cutoff temperature.

Two-channel amplifier

Figure 3 shows the complete circuit of a two-channel amplifier. In this case, for simplicity, the internal circuit of the LM 391 is not shown. With a ± 30V supply each channel of the amplifier will deliver 50 W into an 8 ohm load, or 45 W into a 4 ohm load. By connecting a resistor, R_X, between the output of one channel and the inverting input of the other channel (non-inverting input grounded) the two channels can be made to function as a mono bridge amplifier, with the loudspeaker connected as shown dotted. Note that in this configuration both ends of the loudspeaker are floating!

Theoretically, the maximum output power that can be obtained in the bridge mode is four times that obtained in the normal configuration. However, this would place great stress upon the output transistors and would require much more massive heatsinks and an extremely 'beefy' power supply. The maximum output power into an 8 ohm load in the bridge configuration is therefore restricted to 100 W by current limiting. Operation into a 4 ohm load in the bridge configuration is not recommended as current limiting will restrict the maximum output power to about 45 W.

Printed circuit board

The printed circuit board and component layout for the Elektornado are given in figure 4, and it will be seen that

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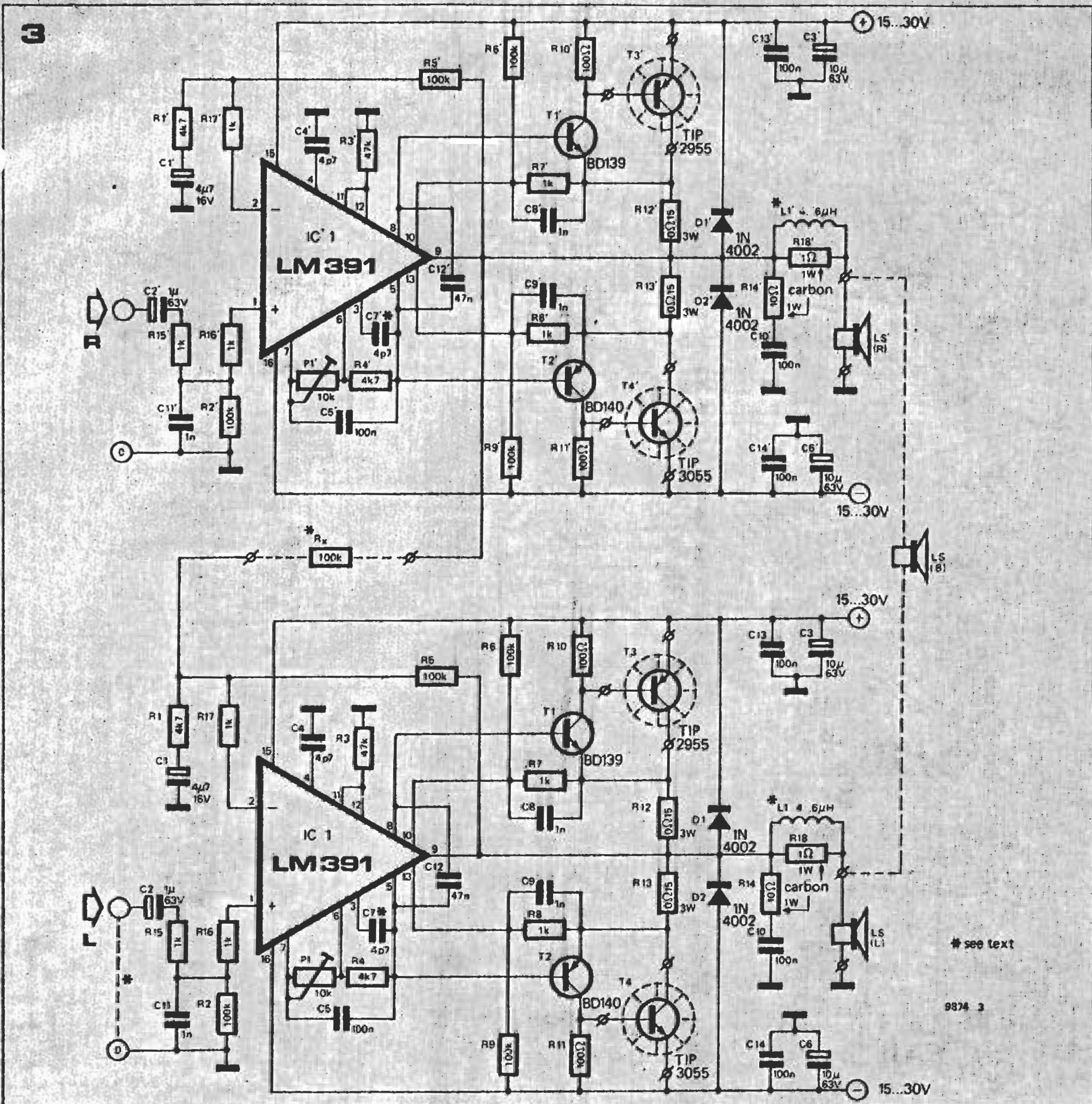


two identical channels are mounted on a single board to facilitate operation in the bridge mode. If this configuration is required then R_X is soldered into place and the input of the left channel is grounded. If the 2 x 50 W stereo version is required then R_X is omitted.

L1 consists of 20 turns of 0.9 mm (20 SWG) enamelled copper wire, wound on the body of resistor R18.

The driver and output transistors are, of course, mounted external to the board on heatsinks, which should have a thermal resistance of less than 1.5°C per watt and should be mounted with the fins running vertically to give a chimney effect which will aid cooling. Painting the heatsinks matt black also improves cooling.

Wiring

To avoid problems of instability, earth loops etc. the wiring layout shown in figure 5 should be followed. For clarity the driver and output transistors are not shown in this diagram. A simple, unstabilised power supply between ± 15 V and ± 30 V is quite adequate for the amplifier, although the maximum output power will only be obtained with the higher supply voltage. Care should be taken to ensure that the off-load voltage of the power supply is no greater than ± 30 V, otherwise there is a danger of damaging the IC or output transistors. The 2 x 20 V RMS secondary rating of the transformer should be considered as an absolute maximum, as this will allow for a +10% variation in mains voltage.

Setting quiescent current

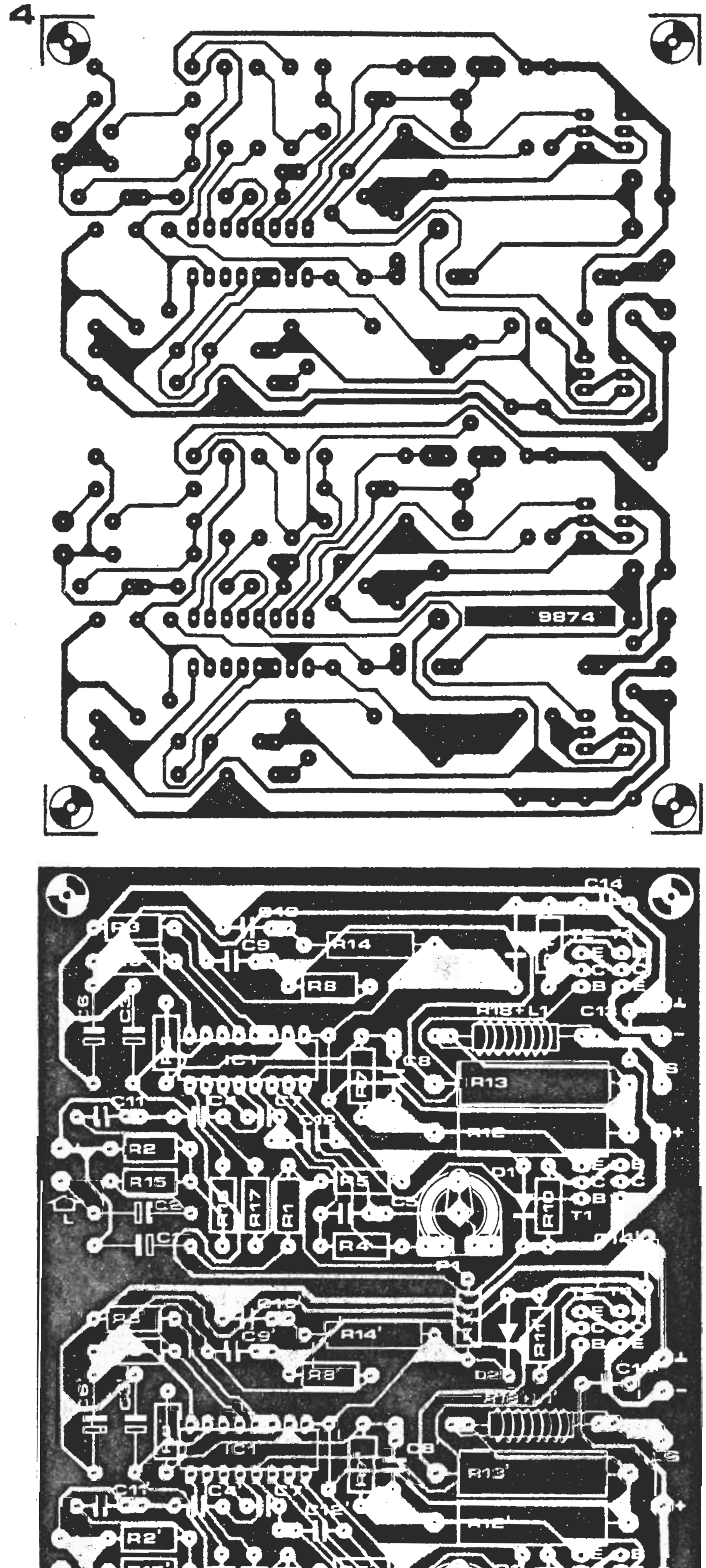
Before applying power to the amplifier P1 and P1' should be turned fully to the

Figure 1. Circuit of one channel of the Elektornado, showing the internal circuit of the LM 391 IC.

Figure 2. Pinning of the driver and output transistors (all bottom view).

Figure 3. Complete circuit of the 50 W per channel/100 W mono amplifier.

Table 1. Principal specifications of the Elektornado amplifier.



Parts list to figure 5.

Resistors:

R1,R1',R4,R4' = 4k7
R2,R2',R5,R5',
R6,R6',R9,R9',R_x = 100 k
R3,R3' = 47 k
R7,R7',R8,R8',R15,R15',
R16,R16',R17,R17' = 1 k
R10,R10',R11,R11' = 100 Ω
R12,R12',R13,R13' = 0.15 Ω/3 W
R14,R14' = 10 Ω/1 W (carbon film resistor)
R18,R18' = 1 Ω/1 W (carbon film resistor)
P1,P1' = 10 k preset

Capacitors:

C1,C1' = 4µ7/16 V
C2,C2' = 1 µ/63 V
C3,C3',C6,C6' = 10 µ/63 V
C4,C4',C7,C7' = 4p7
C5,C5',C10,C10',C13,C13',
C14,C14' = 100 n
C8,C8',C9,C9',C11,C11' = 1 n
C12,C12' = 47 n

Semiconductors:

IC1,IC1' = LM 391-60 or LM 391-80
T1,T1' = BD 139
T2,T2' = BD 140
T3,T3' = TIP 2955 or MJE 2955
T4,T4' = TIP 3055 or MJE 3055
D1,D1',D2,D2' = 1N4002

Figure 4. Printed circuit board and component layout for the Elektornado (EPS 9874).

Figure 5. Wiring diagram for the Elektornado (driver and output transistors not shown). Figure 5a: stereo version; figure 5b: bridge version.

Figure 6. Total harmonic distortion versus frequency graph for the Elektornado.

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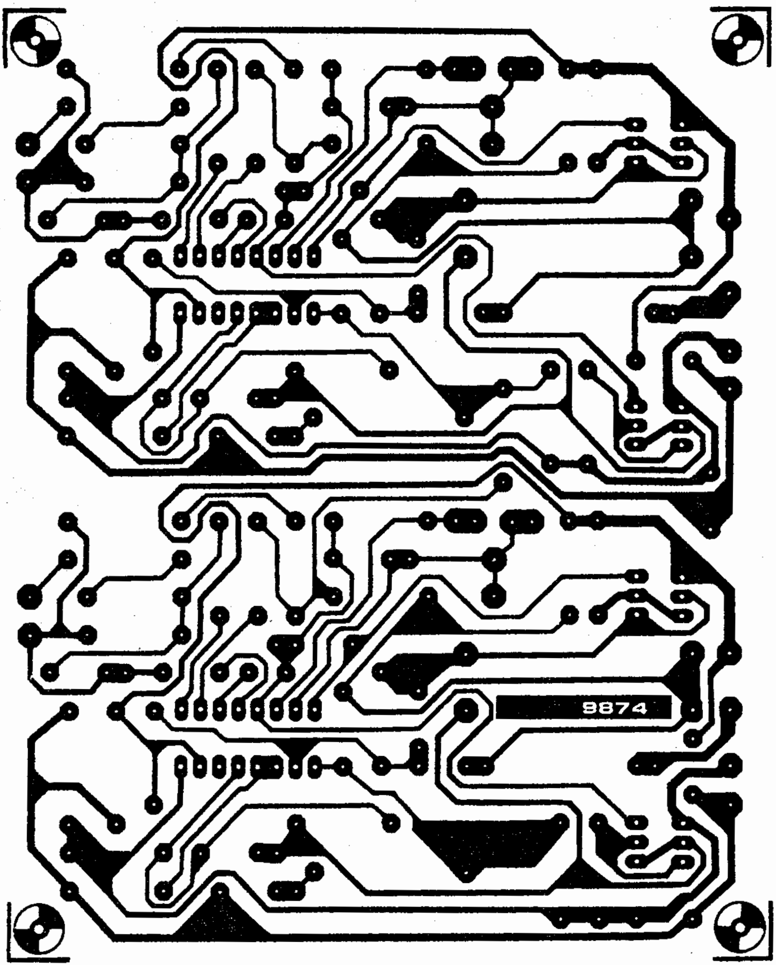

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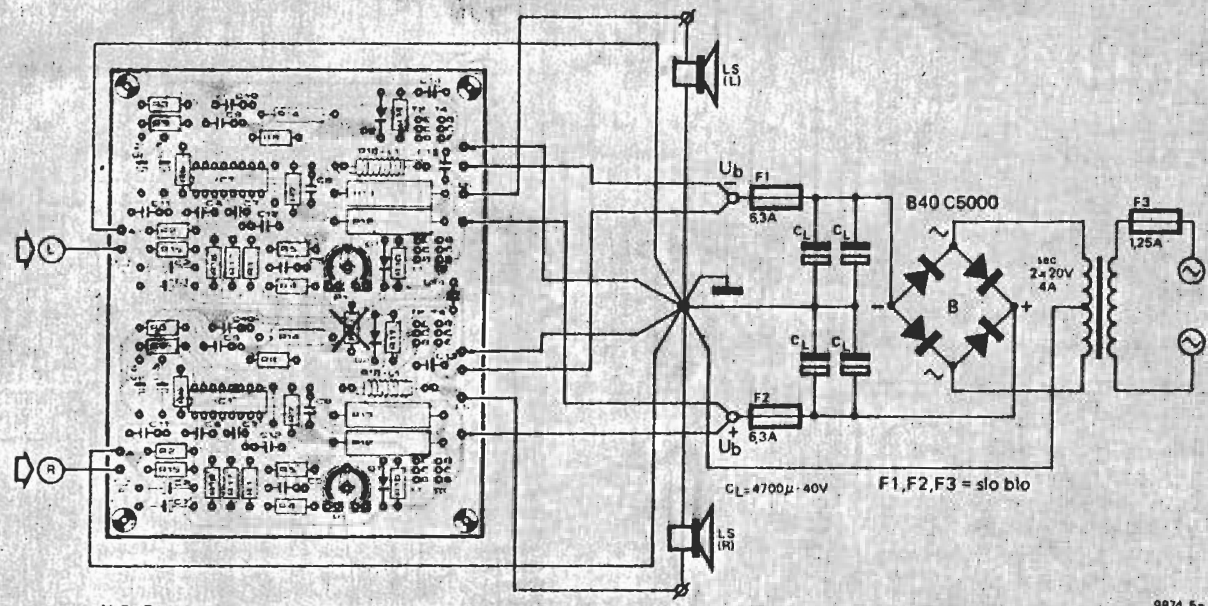
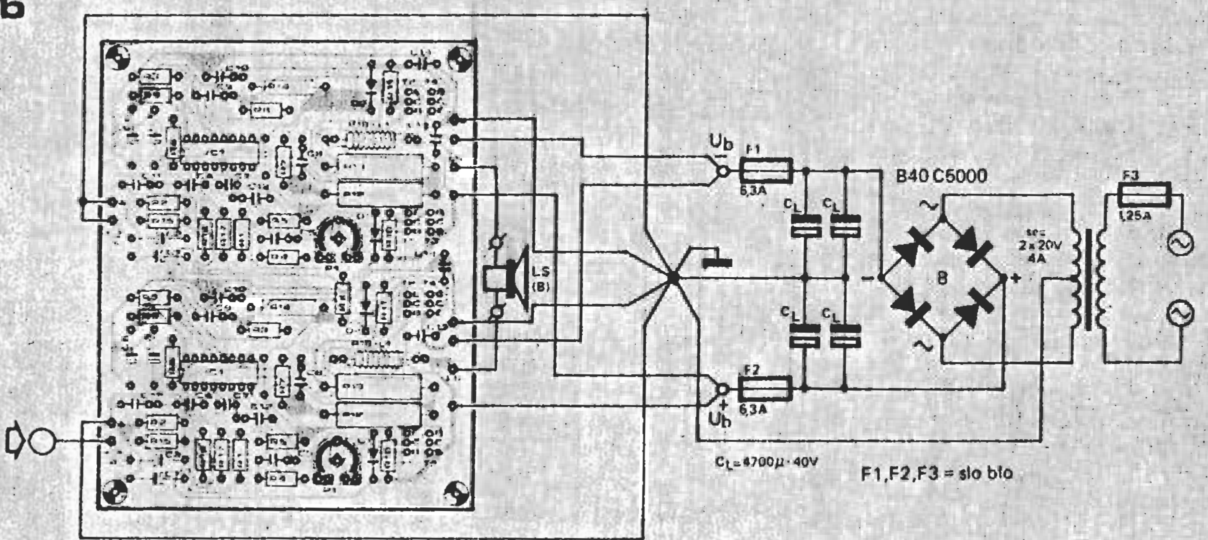


N.B. For clarity, the output transistors are not shown.

5b



N.B. For clarity, the output transistors are not shown.

left.

A multimeter set to the 100 mA range is then connected in the positive or negative supply lead to the left channel, and P1 is adjusted to give a current of between 50 and 100 mA. The procedure is then repeated for the right channel.

If the amplifier should exhibit any tendency to instability (this may manifest itself as an excessively large and uncontrollable quiescent current) this can be cured by increasing the values of C4 and C7, keeping them of equal value.

Conclusion

The specifications of the Elektornado can safely be called excellent. As can be seen from figure 6 the harmonic distor-

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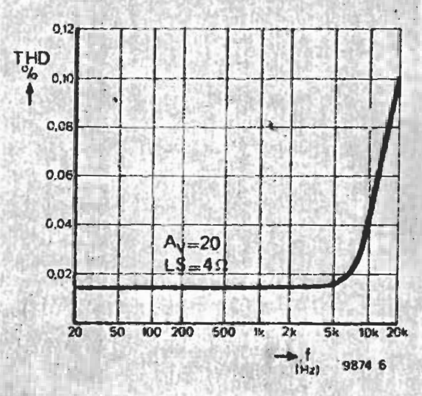

tion is below 0.1% over the entire audio spectrum, and over the important mid-band frequencies is less than 0.02%. Other important parameters of the amplifier are listed in table 1.

As mentioned previously, the input sensitivity for full output is 1 V RMS, which should be suitable for most preamplifiers. However, if this sensitivity is insufficient the gain of the amplifier may be increased simply by changing the values of R1 and R5 (decreasing R1 and/or increasing R5).

The high output power and excellent specifications of the Elektornado, together with its versatility, should ensure that it will prove the right answer for a great number of amplifier applications.