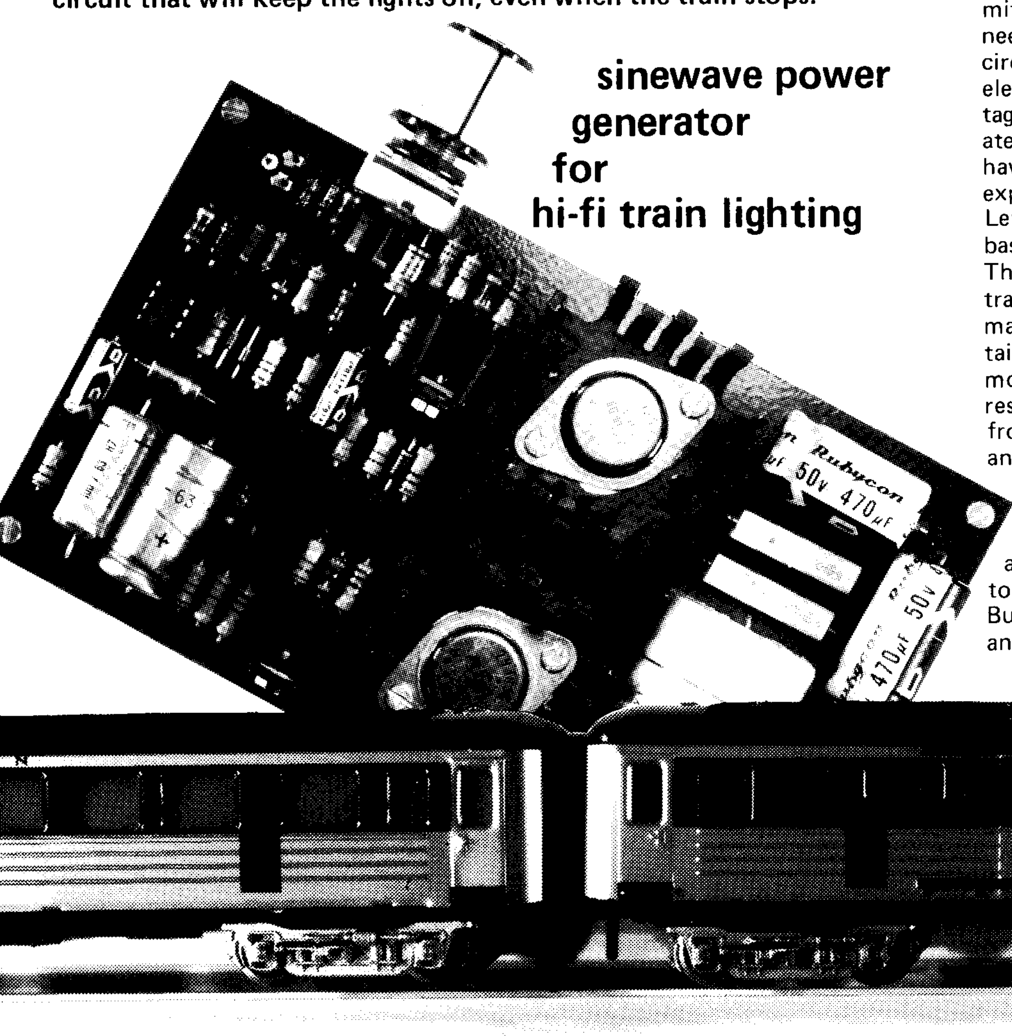
model train lighting

"Murder on the Orient Express!" The train enters a tunnel. The lights go out. A blood-curdling scream is heard and the famous detective Hercule Poirot has another assignment. Things are not usually so dramatic amongst model train enthusiasts and one cannot normally look into the tunnel of a model railway. But when the train stops and the internal lighting goes off, it is not very realistic. What we need is a circuit that will keep the lights on, even when the train stops.

sinewave power generator for hi-fi train lighting



What is actually involved? Well, the lighting for the railway itself can be provided quite simply by means of a "lighting transformer". Stations, houses and signals then become part of a realistic environment, for the railway. However, the bulbs in the carriages are powered from the "train transformer" via the rails. So, there is no problem with lighting as long as the train is travelling. But when the train stops, the lights go out because power is no longer applied. If the locomotive supply voltage is not constant the bulbs flicker. What we need is a method of operating the train lighting independently of the locomotive supply voltage.

A look at various solutions

One could, for example, construct a multiple rail system which would carry both the locomotive supply voltage and the lighting supply voltage; that would surely be too expensive. An overhead line plus one of the two rails could also be used for the lighting supply voltage. This method is less complicated, but the overhead line is usually employed for independent operation with two trains. The same applies to any third rail in the system. It is also possible to use dry batteries but this method must be ruled out because of the cost. Rechargeable NiCd batteries cannot be employed on account of their price, shape and weight. Furthermore, that method would require a bridge rectifier.
Half-wave operation is worth considering. A sinewave can be divided into two half-waves. The motor is activated for the duration of one half-wave and the lighting for the duration of the other. This method can be applied quite simply using properly rated diodes. It is a purely electrical solution without any mechanical modifications. The disadvantage is that half-wave operation requires four times the power output for normal operation. Moreover, this method only works for one direction of travel although it is possible to operate two trains independently in this way.

Our solution

A sinewave power generator. Admittedly, it is not new but no changes need to be made to the railway and the circuit can be constructed with simple electronic components. These are advantages that will particularly be appreciated by model constructors who have not had too much electronic experience.
Let us examine the situation on the basis of the block diagram in figure 1. The first item we notice is the "train transformer". We have used quotation marks because this transformer also contains a rectifier. This block powers the motor. The choke represents a negligible resistance for d.c. The bulbs are isolated from the d.c. supply by capacitors C2 and C3. The generator supplies the lighting voltage for the bulbs instead. The a.c. voltage is applied via blocking capacitor C1 to the tracks and from there to the bulbs via capacitors C2 and C3.
But what is the purpose of the choke and the capacitors? The choke presents

the a.c. voltage with a very high impedance so that the sinusoidal power is not lost in the low-impedance secondary side of the train transformer. Blocking capacitor C1 isolates the d.c. train voltage from the power generator. Only in this way is it possible to superimpose the a.c. voltage on the d.c. voltage for our purposes. One disadvantage should be pointed out, however. Although the motor represents a load for the a.c. voltage it is so small it can be discounted. Two questions that might be raised with respect to the power generator are: why a sinewave and why 20 kHz? Wouldn't a square-wave generator be much more efficient? The answer is yes, but the harmonics would cause severe interference to other equipment! We have chosen 20 kHz because the circuit and the locomotives start buzzing at lower frequencies and because this frequency allowed us to choose smaller values for the choke and capacitors. But we will go into this in more detail later.

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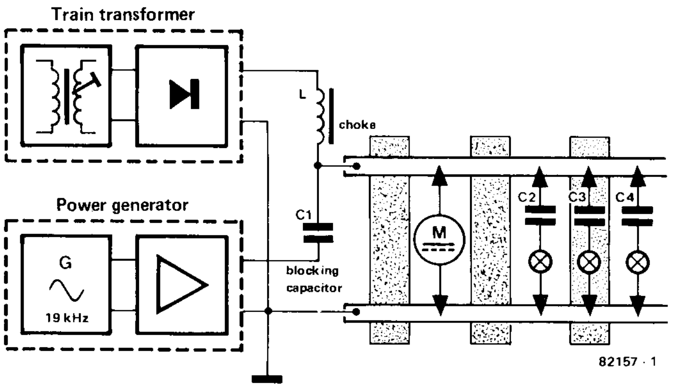


Figure 1. The a.c. output voltage of the power generator is applied to the tracks, superimposed on the a.c. voltage of the train transformer. The choke isolates the train transformer from the a.c. voltage and capacitor C1 isolates the power generator from the d.c. voltage. Capacitors C2, C3 etc. keep the d.c. voltage away from the bulb circuits. Apart from having to install the bulbs and capacitors in the carriages, no technical modification to the railway system is necessary.

The power generator

Before the system can be extended as shown in figure 1, we must first build the power generator and ensure that it is operating. First we shall have a look at the circuit.

Figure 2 mainly contains two functional parts: the sinewave generator using IC1 and the output stage consisting of T1 . . . T10. Choke L1 can also be seen, together with the power supply unit for the power generator with transformer, rectifier B1, and smoothing capacitor C14. A no-load d.c. voltage of 42 . . . 51 V is present at C14, depending on the transformer used.

The sinewave generator is configured as a Wien-bridge oscillator with IC1, D1, D2, C1, C2 forming a symmetrical power supply for the operational amplifier from the "asymmetric" operating voltage. This method also provides decoupling from the operating voltage of the output stage. R2, C3, C4, R5 are the generator components that determine the frequency. The oscillator frequency obtained purely by calculation is 19 kHz. The two germanium diodes provide coarse stabilisation of the output voltage. The gain (onset of oscillation) is adjusted with P1, and P2 is used to attenuate the amplitude of the generator (bulb brightness). The distortion factor of the sinewave oscillator is only 0.05%. It therefore emits practically no harmonics to cause distortion in the power generator.

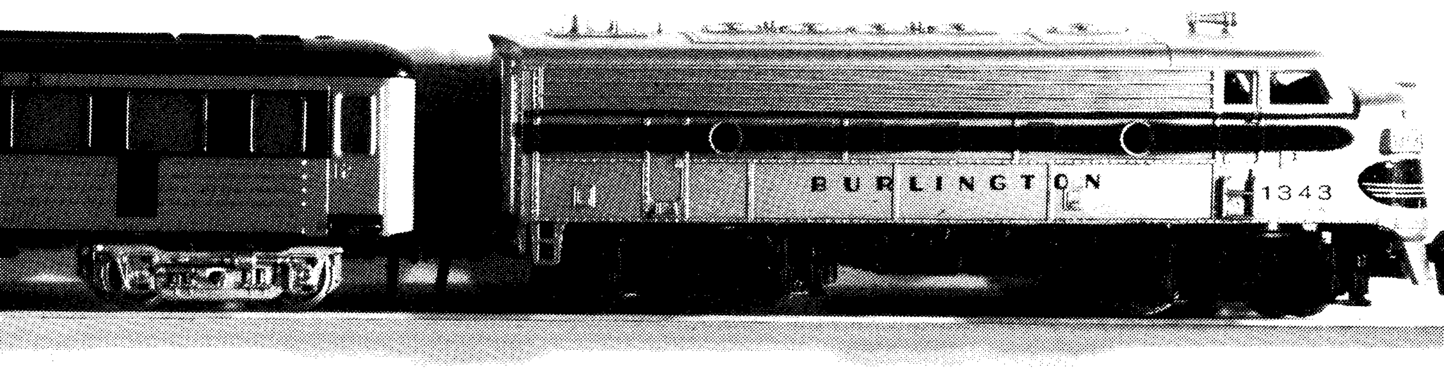
The next item is an old friend (as far as Elektor staff are concerned): EDWIN the output amplifier. This was first published way back in the seventies. In the meantime it has probably become the favourite and mostbuilt amplifier from the Elektor Laboratory. It is characterised by good reproducibility in construction, requires no alignment and the output transistors can now be procured at very low cost in most electronic component shops. The values of a few capacitors were reduced from those of the original circuit, because the amplifier is only needed to provide gain at 19 kHz. The output capacitor must be a bipolar type. Two polar electrolytic capacitors were connected back-to-back here. The output stage is shortcircuit-proof but not in continuous duty! We also thought that the finger-type heatsinks would be very practical for circuit constructors and they are quite adequate in this application. We shall discuss the assembly in more detail later.

Choosing the components

Before you pick up your soldering iron, here are a few useful comments concerning the components.

Choke L1: The choke must withstand a bulb current of about 2 A. With a total bulb power rating of 25 W maximum at 12 V the load current is 2 A. Suitable (mains) chokes must exhibit an inductance of 10 . . . 20 mH. The d.c. resistance at a frequency of 19 kHz is 1k2 . . . 2k4. The choke with its impedance of 3 . . . 6 ohms is practically a shortcircuit for mains frequency voltages. A mains choke from an old TV set is just as good as one of the new commercially available types. Coils from loudspeaker cross-over networks may also be employed if they meet the requirements.

Mains transformer: Using a transformer with a secondary voltage of 33 V, the output stage delivers about 25 W (at Urms = 12 V). This is where term hi-fi the scene. Hi-fi means "high fidelity" and here we are referring to realistic lighting in the train. The lighting voltage is adjusted so that the bulbs are operated at less than their rated voltages. In this way we achieve two things: the bulbs are not unrealistically bright (in keeping with our "hi-fi") and they last much longer than their rated service lives. For example, 14 V bulbs can be connected to the 12 Vrms output voltage or a 30 V transformer could be used to give an output voltage of 10 . . . 11 Vrms.



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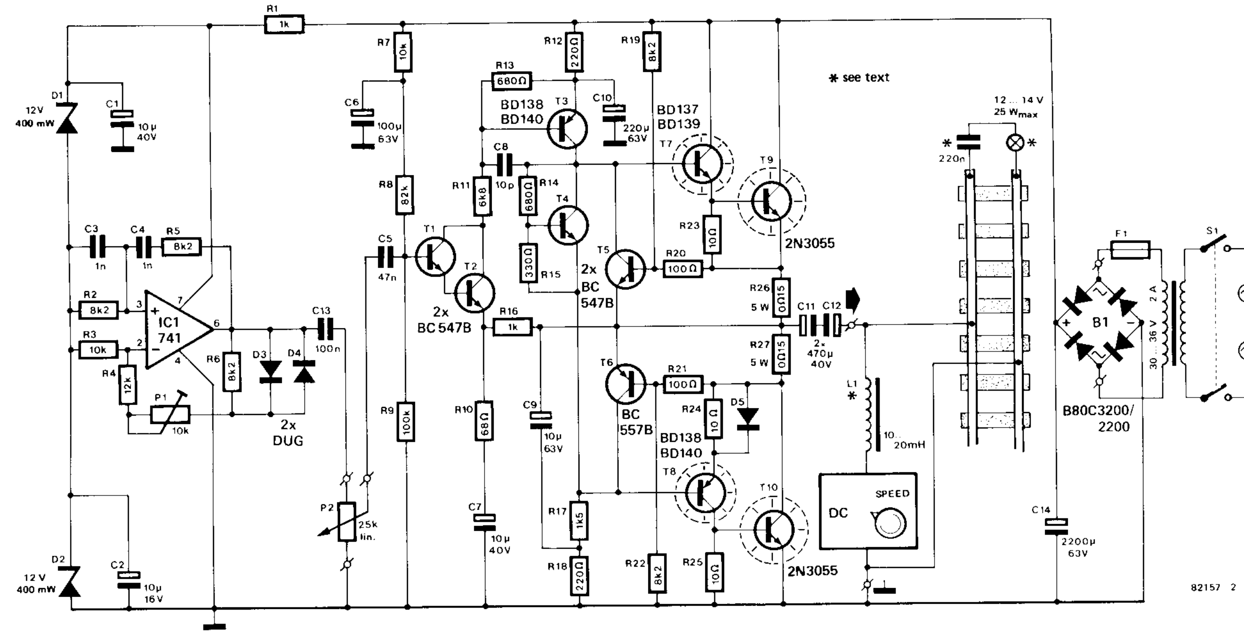

Figure 2. The circuit of the sinewave power generator consists of a Wien-bridge oscillator with IC1. Brightness of the train lighting is continuously variable with P2. The output capacitor must be a bipolar type because the rail voltage can be positive or negative (with respect to earth), depending on the direction of the travel.

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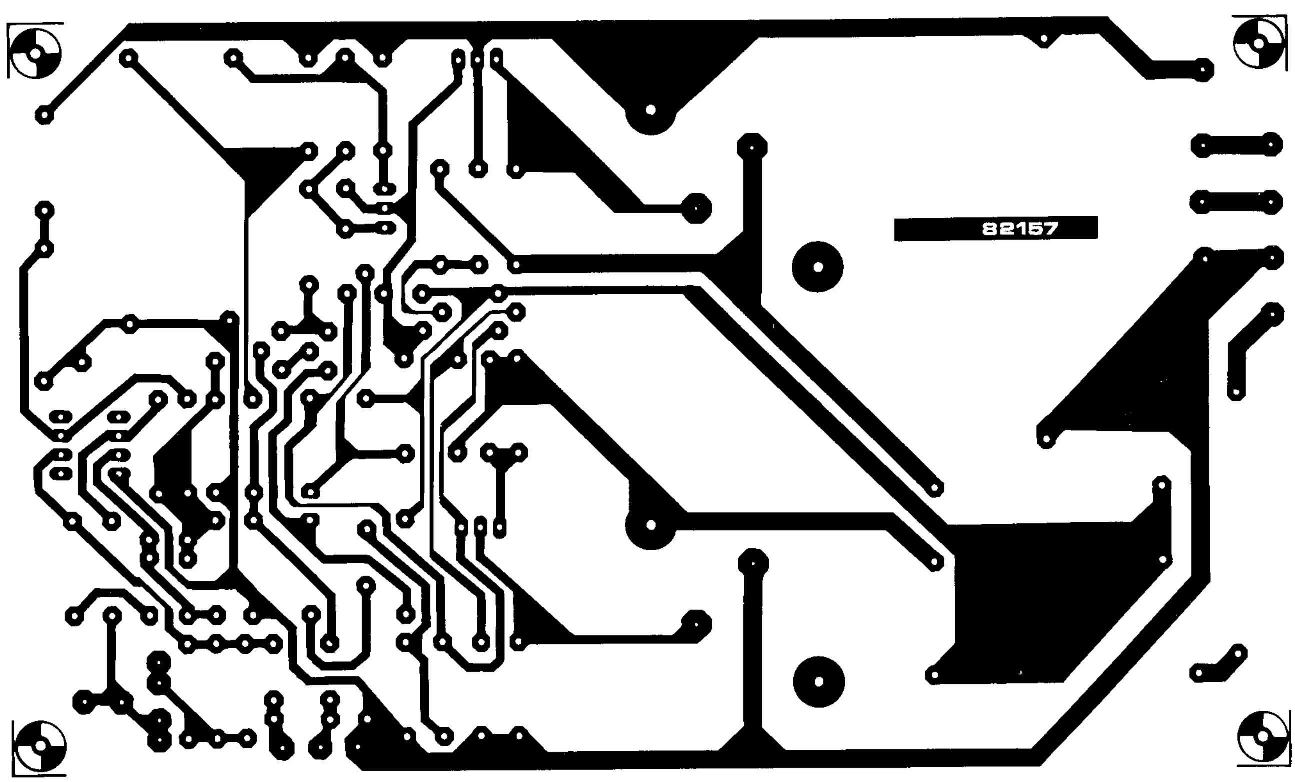


Figure 3. The printed circuit board for the power generator. All components are mounted on the board except for the mains transformer, fuse and mains switch. Since the output transistors are mounted on the printed circuit board with heatsinks (see text), the cover of the housing must allow sufficient ventilation.

In any case, the full output power of 25 W will never be required from the output stage. That would be sufficient to illuminate 25 carriages! The maximum output voltage will therefore be somewhat higher than indicated, on account of the lower load. Since the bulbs are operated at less than their rated voltage, their full power ratings are not reached either. This means that bulbs with a total power rating of more than 25 W can be connected.

Blocking capacitors: The capacitors in series with the bulbs are installed in the carriage together with the bulbs. A 220 nF capacitor is sufficient for a 12 V/50 mA bulb. If only one capacitor is connected in series with several bulbs of this type, its value must be increased proportionally. The exact voltage being dropped over a capacitor is not particularly critical, because the bulbs are being operated at less than their rated voltages. However, it is possible to arrange for "emergency lighting" in a sleeping car, for example, by selecting an appropriate value for the blocking capacitor. Those who would like to experiment can calculate the required series reactance according to the formula $X_C = \frac{1}{2 \cdot \pi \cdot f \cdot C}$. X_C should be at least 80% less than the bulb resistance (e.g. 240 Ω at 12 V/50 mA).

Parts list

Resistors:
R1,R16 = 1 k
R2,R5,R6,R19,R22 = 8k2
R3,R7 = 10 k
R4 = 12 k
R8 = 82 k
R9 = 100 k
R10 = 68 Ω
R11 = 6k8
R12,R18 = 220 Ω
R13,R14 = 680 Ω
R15 = 330 Ω
R17 = 1k5
R20,R21 = 100 Ω
R23 . . . R25 = 10 Ω
R26,R27 = 0,15 Ω/5 W
P1 = 10 k trimmer
P2 = 25 k lin. pot.

Capacitors:
C1,C7 = 10 μ/40 V
C2 = 10 μ/16 V
C3,C4 = 1 n
C5 = 47 n
C6 = 100 μ/63 V
C8 = 10 p
C9 = 10 μ/63 V
C10 = 220 μ/63 V
C11,C12 = 470 μ/40 V
C13 = 100 n
C14 = 2200 μ/63 V

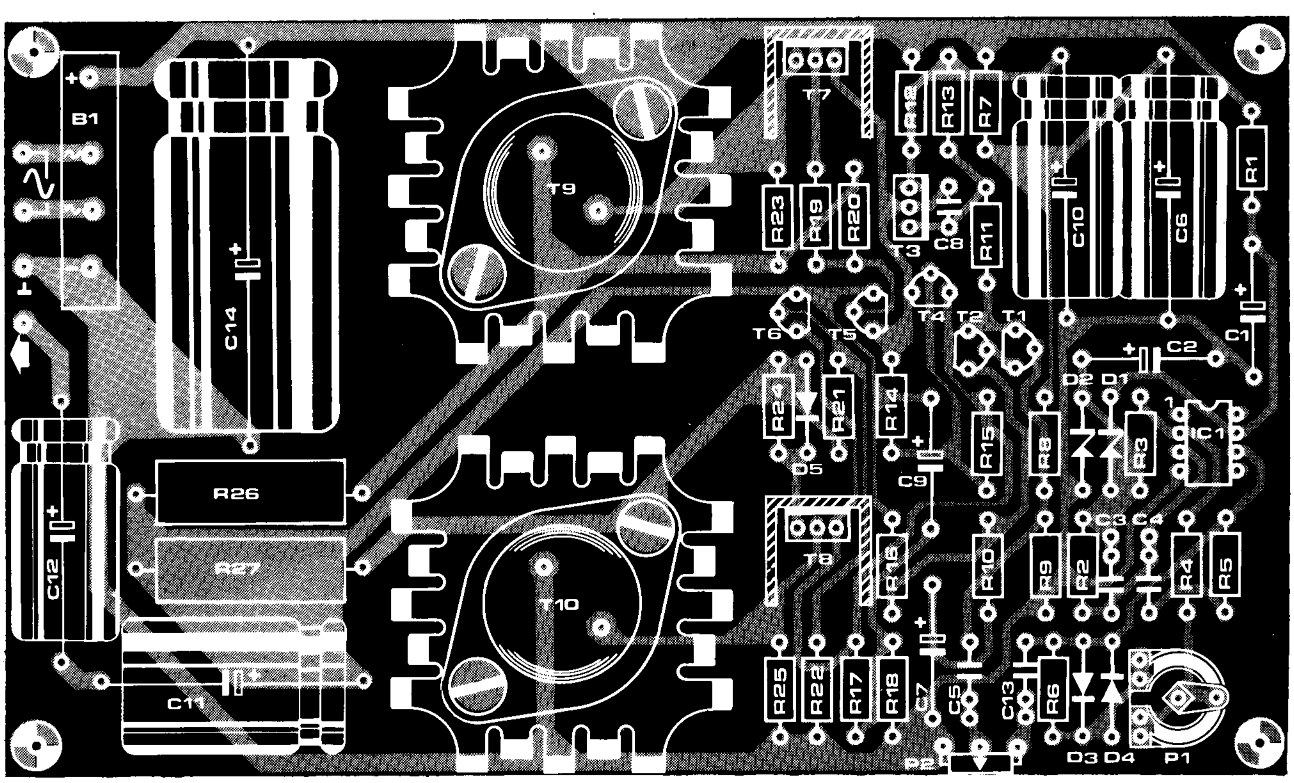
Semiconductors:
B1 = B80C3200/2200
D1,D2 = Z-Diode 12 V/0,4 W
D3,D4 = AA 119
D5 = 1N4001
T1,T2,T4,T5 = BC 547B
T3,T8 = BD 138 or BD 140
T6 = BC 557B
T7 = BD 137 or BD 139
T9,T10 = 2N3055
IC1 = 741

Miscellaneous:
L1 = (mains) choke 10 . . . 20 mH (see text)
Tr1 = mains transformer 30 . . . 36 V/2 A sec. (see text)
F1 = 2 A fuse, slow-blow with holder
S1 = double-pole mains switch

Construction and alignment

Construction of the sinewave power generator should present no problem using the ready made printed circuit board (figure 3).

T7 . . . T10 are fitted with heatsinks. In the case of T7 and T8 they are bracket-type heatsinks which are simply installed on the cooling surfaces of the transistors with M3 bolts. Do not forget the heat-conducting paste and ensure that there is no contact with any bare



wires. T9 and T10 are fitted on the printed circuit board together with heatsinks. Sleeving should be slipped over their pins to prevent any short-circuits. The contact surfaces for the collectors are first tinned on the solder-ing side. The transistors and heatsinks are then bolted to the printed circuit board. Use washers to keep them firmly in place. Remember the heat-conducting paste here too! Finally, the insulated terminals are soldered to the tracks.
Once the components have been fitted to the printed circuit board, the system can be expanded as shown by figure 1. Please observe the comments in the section entitled "Choosing the components". Ready-made lighting systems are available commercially, but it is cheaper to examine the mail-order advertisements for subminiature bulbs and order the required quantity. Chokes and other special components are usually cheaper from those sources too. It may also be necessary to replace plastic wheels by metal wheels which are mounted on the axles in an insulated manner. Your local model shop can advise you on this.
Once the circuit is completed in accordance with figures 1 and 2, switch S1 can be actuated for the first time with the hope that there will be no smell or smoke! Set P2 to maximum output and adjust P1 so that the bulbs are lit. The output voltage can be measured with a multimeter set to the a.c. range. It must not exceed 12 V. The setting can also be made by eye: rotate P1 so that the bulbs light up at the desired brightness. Those model constructors who own an oscilloscope can make "professional" adjustments. With the load connected, P1 is set to a point just before the "clipping" of the displayed sinewave, (with no limiting of the amplifier). Brightness of the bulbs can now be adjusted as desired with P2.
Another important comment: In this form the circuit is only suitable for d.c.-driven trains. A combination with pulse-controlled systems is possible.
If the lights should go out in the tunnel and a blood-curdling scream is heard: call Hercule Poirot!