The HARMONAPHONE

By M.P.R. HAMER

A simple electronic device for augmenting, in an unusual way, the sounds of guitars and many other instruments with magnetic pick-ups or microphones. Gives "fuzz" and "subs".

THE colouring of the sound of a fundamental tone from a musical instrument depends on the number of harmonic overtones present, besides the fundamental, and the range over which these harmonics are spread. It is very rare for a note from a musical instrument to contain many sub-harmonics—frequencies lower than the fundamental note. Several electronic devices which are on sale to the general public produce changes in the sound of a note by artificial means; a treble booster, for example, can amplify the harmonics at higher frequencies to a greater degree than the lower ones, but this has the effect of reducing the fundamental tone to give the sound more "force".

On a large number of modern records, however, engineers often dub a piano or organ, playing along with a guitar in order to give the guitar a greater body of sound.

The "Harmonaphone" provides a simple means of augmenting the sound of a single instrument, without the use of additional instruments.

OPERATION

The "Harmonaphone" adds sub-harmonics f_1 and f_2 on to any note which is fed into it. The output of the device is controlled by the mixer unit, in which the relative volumes of the direct signal (f), sub-harmonics f_1 and f_2 and a square wave signal of the fundamental frequency, can be adjusted to give a wide range of different effects. The square wave signal produces the standard "fuzz" effect.

It will be found that a rather unpleasant sound is produced if more than one note is fed into the input at the same time. A foot-switch is therefore included to switch the Harmonaphone "in" and "out". This means that, with a guitar, for example, chords should only be played with the Harmonaphone switched out, and the Harmonaphone switched in for guitar "breaks" by means of the foot-switch.

The Harmonaphone has one input into which is plugged the magnetic or acoustic pick-up fitted to a guitar or similar instrument, or microphone placed in front of an instrument (e.g. oboe, flute, clarinet).

CIRCUIT FUNCTION

The input signal is fed into a pre-amplifier, which is connected to the input of a Schmitt trigger (see Fig. 1). This is turned on by the one edge of the "sine-wave" input, and off by the other edge (Fig. 2).

The two switching voltages are made distinctly different by the different values of the collector resistors in the triggering circuit. The reason for giving the trigger such a large hysteresis is that the input signal often contains harmonics of quite large amplitude, superimposed on the fundamental, and these can cause double triggering if the trigger has a small hysteresis.

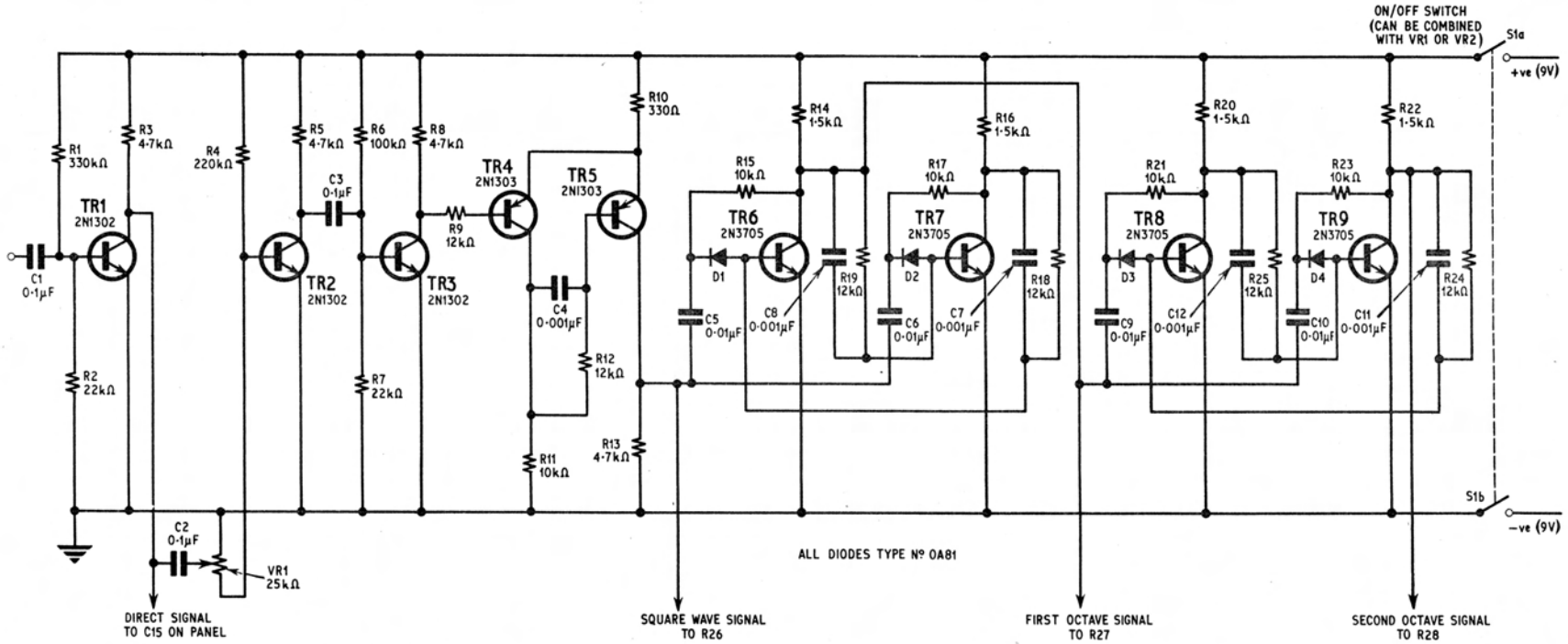


Fig. 1. Circuit diagram of the amplifier, squarer, and dividers (refer also to Figs. 3 and 4)

COMPONENTS . . .

Resistors

Pre-amp		*Trigger*		*Divider 1*		*Divider 2*		*Mixer*	
R1	330kΩ	R9	12kΩ	R14	1·5kΩ	R20	1·5kΩ	R26	33kΩ
R2	22kΩ	R10	330Ω	R15	10kΩ	R21	10kΩ	R27	33kΩ
R3	4·7kΩ	R11	10kΩ	R16	1·5kΩ	R22	1·5kΩ	R28	33kΩ
R4	220kΩ	R12	12kΩ	R17	10kΩ	R23	10kΩ	R29	100kΩ
R5	4·7kΩ	R13	4·7kΩ	R18	12kΩ	R24	12kΩ	R30	100kΩ
R6	100kΩ			R19	12kΩ	R25	12kΩ	R31	100kΩ
R7	22kΩ								
R8	4·7kΩ								

R32 Resistor to reduce relay battery consumption. Find maximum possible value by experiment (see text)

All ±10%, ½W carbon

Capacitors

Pre-amp		*Trigger*		*Divider 1*		*Divider 2*		*Mixer*	
C1	0·1μF	C4	0·001μF	C5	0·01μF	C9	0·01μF	C13	0·05μF
C2	0·1μF			C6	0·01μF	C10	0·01μF	C14	0·1μF
C3	0·1μF			C7	0·001μF	C11	0·001μF	C15	0·05μF
				C8	0·001μF	C12	0·001μF		

All capacitors can be paper, polyester or polystyrene types

Transistors

Pre-amp
TR1, TR2, TR3 } *2N1302*

Trigger
TR4, TR5 } *2N1303*

Divider 2
TR8, TR9 } *2N3705*

Divider 1
TR6, TR7 } *2N3705*

Diodes

D1, D2, D3, D4 OA81 (4 off)

Potentiometers

VR1 25kΩ Linear
VR2*, VR3, VR4, VR5 100kΩ Linear carbon
* One potentiometer (VR2) to have built in switch S1, unless a separate on/off switch is used

Miscellaneous

S2 Footswitch single-pole push button push on, push off
RLA 9V relay, two-pole, two-way (see text)
Two-pin socket or two single sockets
Standard jack socket
Standard jack plug
Printed circuit board 4in × 2½in
Metal case (see text), knobs

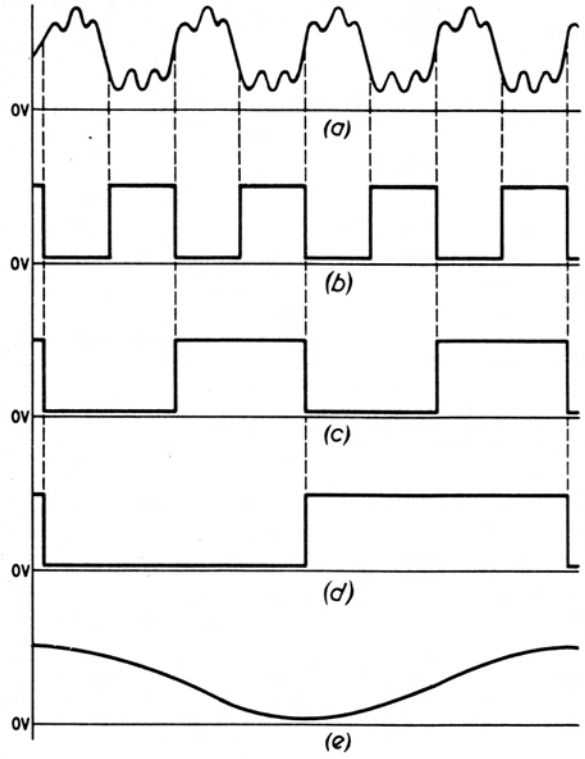


Fig. 2. Waveforms, based on the fundamental tone, appearing at different parts of the circuit
(a) Input signal
(b) Output of Schmitt trigger (TR5 collector)
(c) Output of first divider (TR6 collector)
(d) Output of second divider (TR9 collector)
(e) Output after being fed through RC filter in mixer

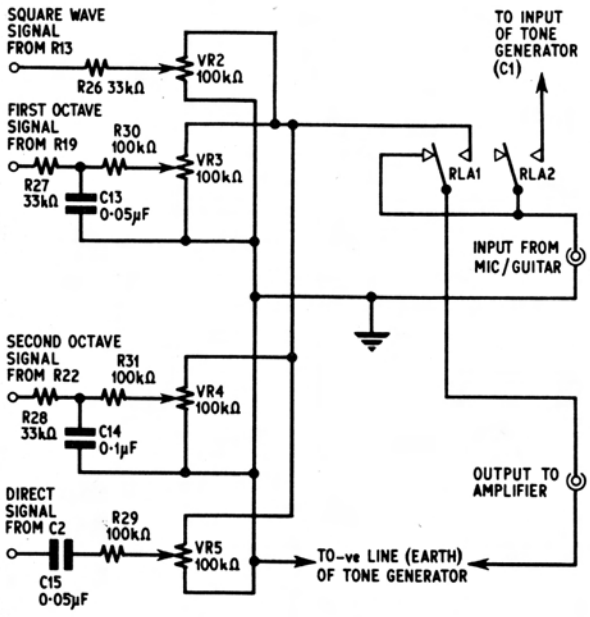


Fig. 3. Mixer and filter circuit with relay contact, input, and output connections

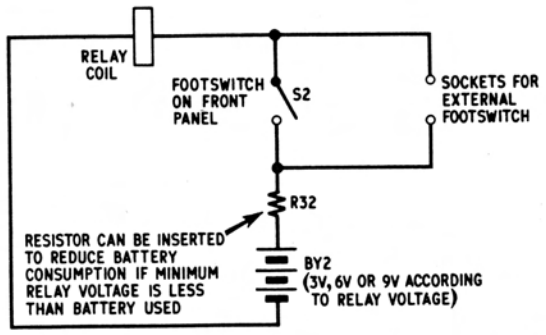


Fig. 4. Independent relay circuit. The relay can be any type with two or more changeover sets. Battery voltage and R32 depend on the relay

A potentiometer (VR1) is included to adjust the amplitude of the signal fed into the Schmitt trigger. This is adjusted so that the device works for the quietest notes, but is not sensitive to background noise. The output of the trigger, which is a square-wave of the same frequency as the input note, besides being used for the "fuzz" effect, is fed into two bistable frequency dividers in series. The output of each of these is taken from the collectors of one transistor in each divider.

In the mixer (Fig. 3) the square-wave signals from these dividers are passed through RC filters to produce sine wave signals. These two signals, and the square wave for the "fuzz" effect, are each fed to one of three potentiometers, which are used to vary the combination of signals in the output. The total signal generated by the device is then added to the original signal, which is taken from the collector of TR1, and whose volume is controlled by a fourth potentiometer. The final signal is fed via the output lead to a power amplifier.

COMPONENT NOTES

The pre-amplifier has three transistors, each having its emitter grounded, so as to give maximum gain. If the transistors used have low gains, or the input signal from the microphone or pick-up is very weak, it may be necessary to double the first stage of the pre-amplifier. This is mentioned later.

The gain of the pre-amplifier should be such that the device will oscillate through internal feedback with VR1 turned to the maximum sensitivity position. *PNP* transistors may be used in place of *npn*, and vice versa, provided that the battery connections and diodes are reversed. The printed board may also have to be altered.

The battery voltage for the device is given as 9V, but this is far from critical. A separate battery is used to operate a relay, switching the device "in" and "out". The relay is operated by a footswitch, which can be either on the front panel of the Harmonaphone, or in a remote position. The battery voltage for the relay is chosen according to the relay used and a resistor can be included to reduce the relay current if a convenient battery delivers too high a voltage (see Fig. 4).

The transistors used in the trigger and dividers need not be of particularly good quality, as they are only used for switching. Therefore, if substitutes are used for those suggested, a great deal of expense is not necessary.

The transistors in the pre-amplifier, however, should be of reasonable quality. The diodes can be of almost any type and component values in the dividers are not critical.

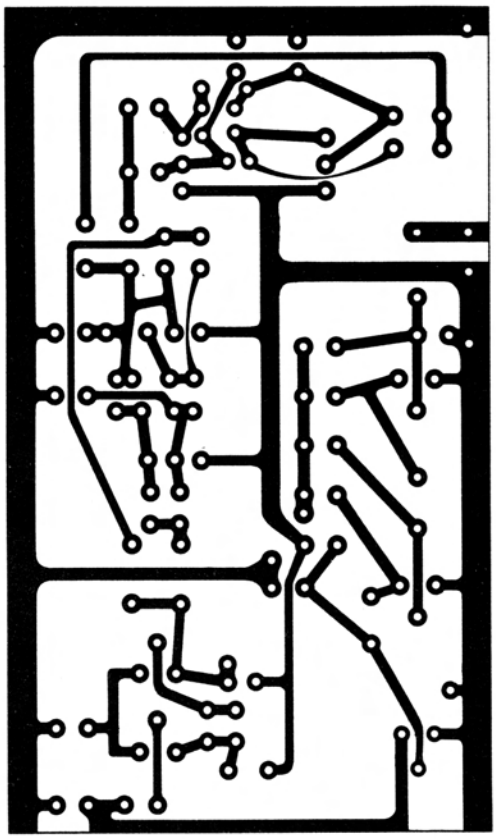


Fig. 5a. Full size printed circuit pattern on the back of the board

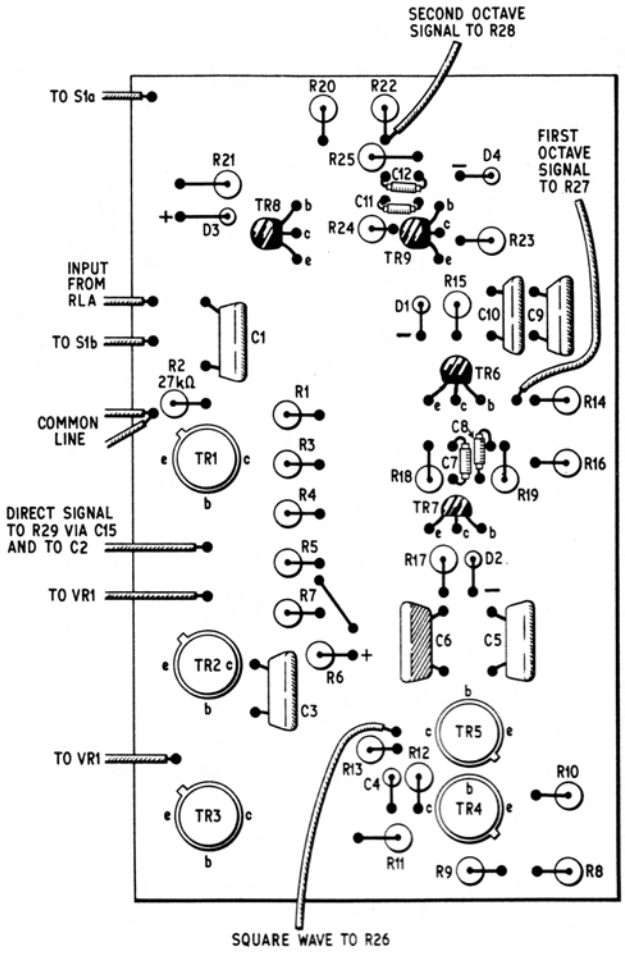


Fig. 5b. Layout of components with transistor connections and leads to mixer

If the device is not housed in a metal case, it is advisable to use screened wire for some of the longer leads, especially in the input circuit.

CONSTRUCTION AND TESTING

As the circuit is fairly complex, a printed circuit board for the tone generator will greatly reduce the size and complexity of the device. The complete layout for such a board is shown in Fig. 5. All resistors are mounted vertically and transistor connections are planned for 2N1302, 2N1303, and 2N3705 transistors, as stated in the component list. Equivalent transistors may, of course, be used, but the 2N3705 was chosen because it is a small transistor, adequate for use in the divider circuits. In the prototype the printed circuit board was 4in × 2½in and is shown full size.

The printed circuit board should be constructed, wired, and checked. When an input signal, say from a signal generator, is connected to the input, a square wave signal should appear on TR5 output when VR1 is adjusted to a suitable setting. At the same time, square wave signals one and two octaves lower should appear on TR6 collector and TR9 collector respectively. Care should be taken in connecting the battery, as each side has to be connected at two different points on the board and confusion can easily occur.

Once the tone generator is complete and tested, the construction of a box for the device can be started. A suggested layout for the front panel is shown, as viewed from behind (Fig. 6). The mixer circuit is wired in the box, the tags on the potentiometers providing supports for the components. Both a footswitch and sockets for an external footswitch are shown in the diagram.

If extra contacts are available on the relay, these can be used to switch on the tone generator, in order to reduce battery consumption. This is, however, perhaps an unnecessary precaution and has the disadvantage that the footswitch may accidentally be left in the on position. The use of a separate on/off switch is therefore advisable. This can be combined with a potentiometer, for example, VR2.

If the battery provides a larger than necessary voltage for the relay, a resistor should be included to reduce battery consumption. The value of this must be found by experiment. When a suitable value has been found for a new battery, it should be checked with an old one

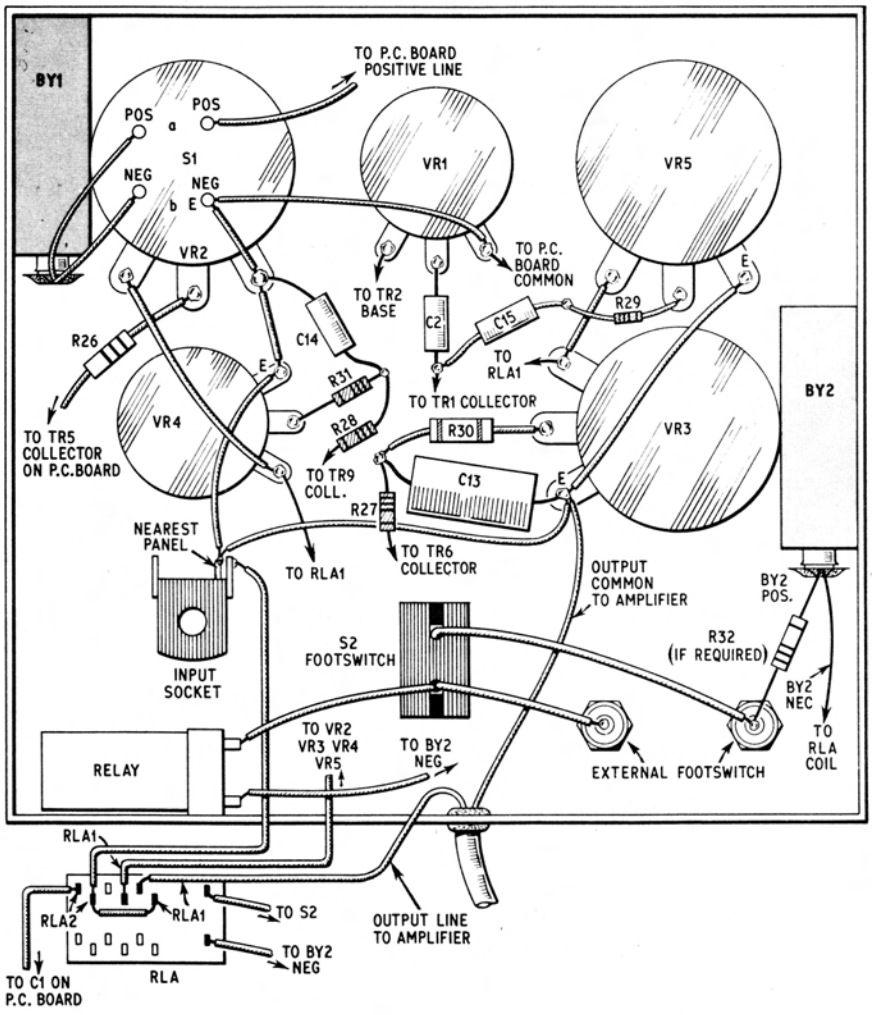


Fig. 6. Layout and wiring of the mixer and relay circuits inside the box. Connections to the printed circuit board are also shown

and reduced if necessary. The actual relay type is not important so long as it has at least two sets of change-over contacts.

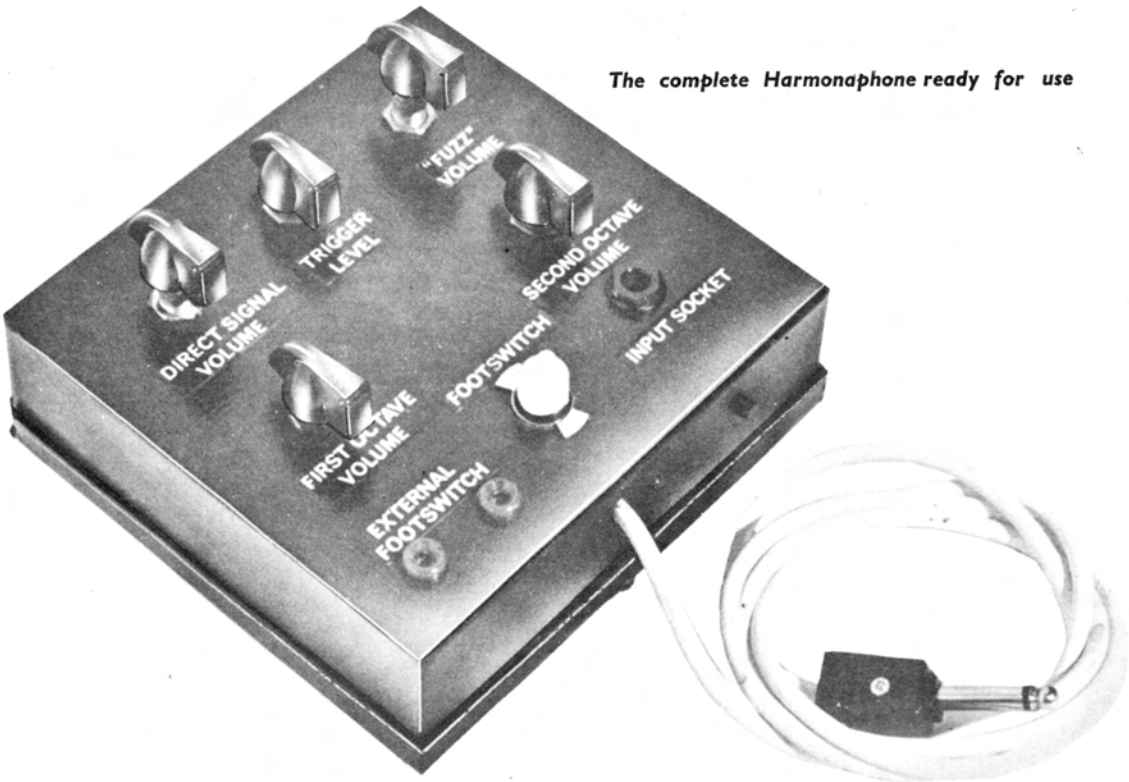
Two jack sockets can be mounted on the panel for output and input, or one socket for input and a lead (screened pair) with a jack plug for the output. The leads to the printed circuit board need not be screened if the box is metallic and connected to the earth line.

The board should be mounted in a manner that gives easy access to the back of the panel for alterations or repairs and for this the wires to the board should be long enough to enable the board to be withdrawn a few inches out of the box. If the top of the board faces upwards, it should be checked that none of the components touches the clips on the batteries or the components of the mixer unit or, indeed, the case.

The prototype fitted easily into a metal box, about 6in × 6in × 2in. The front panel was the top face of the box and a hinged lid formed the base of the Harmonaphone. The lid was fastened by one screw, so that the batteries could be replaced easily. None of the wiring under the front panel (the mixer unit) filled the box to a greater depth than the potentiometers on to which the wiring was attached. The potentiometers were mounted so that they formed ready-made battery retainers with the walls of the box (see Fig. 6). The relay was bolted to the side of the box.

The printed circuit board (tone generator) was insulated from the metal base of the box by means of padding, which also protected it against damage. It was found unnecessary to mount the board rigidly in the box. Instead a square piece of foam rubber, about $\frac{1}{4}$in thick, was layed over the wiring of the front panel; the printed circuit board was sandwiched between this and the felt padding, which was glued to the lid of the box. Hence the board was both insulated from the wiring of the front panel and the metal box, and was cushioned against blows on the box itself. Also, of course, this arrangement makes access to both the board and front panel wiring very easy.

If one wishes to mount the board on rigid supports, the wiring in the box should be carefully planned and insulated, to ensure that none of it can touch the printed circuit board. Also, provision must be made for bolts or nuts fastening the board to these supports, possibly by making the board slightly larger. The supports



The complete Harmonaphone ready for use

could be fixed to the front panel, but preferably to the lid, so that access to both the board and panel wiring is possible when the lid is lifted. In this case the wires to the board are best made a little longer.

If it is found that the gain of the pre-amplifier is not adequate, either because the transistors used have poor gains, or the pick-up used with the Harmonaphone has a very low output, an additional stage of the pre-amp can easily be added to the wiring on the back of the control panel.

An additional 2N1302 can be supported by soldering its emitter lead to any point connected to earth (negative), either on a potentiometer or the input socket. The original input line is then connected to its collector which is connected through a 4·7 kilohm resistor to the positive supply.

A 22 kilohm resistor is connected between emitter and base, which is connected to the input socket via a 0·1μF capacitor and through a 330 kilohm resistor to the positive supply line. This doubling of the first stage of the pre-amp should, however, be unnecessary if high gain transistors are used. A high gain 2N2926 could be tried.

Finally, rubber feet can be glued on to the base of the Harmonaphone case to prevent it sliding across the floor when the footswitch is used.

SETTING UP

In setting up the device, the pick-up or microphone is plugged into the input, and the output of the device into the amplifier. The amplifier volume is adjusted to the desired level. The on/off switch is then switched on and the foot-switch put in the "on" position.

The "fuzz" volume (VR2) is turned up slightly, then the sensitivity control (VR1) is turned up, while the instrument is being played, until suitable triggering is obtained. Then the "fuzz" volume is turned off, and the direct signal volume (VR5) adjusted to give the required direct signal volume, this being of the same order as that when the foot-switch is off. Then the three other volumes ("fuzz", first octave, and second octave) are adjusted to give the desired sound.

The best results are obtained with instruments which produce the purest notes. If the harmonics are too strong, the Schmitt trigger may seem unable to "make up its mind" which signal it is responding to. The result is a yodelling sound, as the output changes from one octave to another.

In this case a filter can be put in the input. This will depend on the type of guitar and pick-up and is a matter of experiment. Often a bass-booster or treble-booster, included between the pick-up and Harmonaphone input, will eliminate many unwanted harmonics. If it is intended for use with one instrument only, then the filters found to produce the best input signal can be built into the Harmonaphone.

USE OF THE HARMONAPHONE

In small groups and bands the Harmonaphone provides an excellent means of producing a "full" sound. It may even be used to provide bass when the group is lacking a bass guitar or double bass, but does have an ordinary guitar. Also, it has the advantage that the output sound has only a slight dependence on the input sound. Consequently, even a very simple wind instrument, such as a recorder, may be used to produce a church organ sound if the amplifier, into which the Harmonaphone is plugged, has reasonable echo or reverberation facilities. ★