SILENT A-B SWITCH

Speakers may be A-B tested using this simple modification to our tone-burst generator

WHEN evaluating speaker systems in A-B listening tests, the first few seconds of listening convey the truest impression of sound quality. Listening for longer than a few seconds not only fails to give further information, but may well give a false indication. For this reason it is usual to switch rapidly between the reference speaker and the speaker under test. This is generally done by using the amplifier's A/B speaker selector switch, or by wiring a change-over relay in the speaker wiring.

Whilst such switching methods are simple and reliable they have one major drawback. That is that switching may take place at any point in the waveform and as a consequence switching transients may be introduced which tend to mask the subtle differences for which one is listening. Hence a method of switching at zero-crossing points would be of great value.

When the ETI Tone-Burst Generator was constructed it was realised that it contained all the circuitry needed to performance this switching task and that it could be modified to do so very simply.

The switching must be done at low level and hence the unit is used at the input of a stereo power amplifier. The reference speaker and the speaker under test are each connected to one channel of the amplifier and the silent switch switches the input to the amplifiers as required. Thus the arrangement is mono only but this is all that is required to assess the transient response and performance of a speaker in comparison to a reference speaker.

CONSTRUCTION

The ETI 124 Tone-burst Generator should first be constructed, as detailed last month, except that the wiring to SW3 is changed as detailed in Fig. 1 and 2 of this article. The dual phono socket and the phone socket are then mounted on one side of the box. If a metal box is used make sure that the phono socket is insulated from the case of the box as it is at a potential of six volts. The switch, SW6, should be mounted in a small pill container or similar housing and fitted with a three-core cable that is terminated at the other end by a stereo phone jack. Note that the common of the switch should be connected to the common of the jack but that the other wires may be wired to either of the remaining contacts.

USING THE SWITCH.

The audio switch requires a reasonably high level of signal to ensure correct zero-crossing switching. There are two suitable points in a conventional amplifier. The first position is between the tape-in and tape-out sockets but the second and preferable position is between the pre and main amplifiers provided that the main amplifier has a volume control that is independent of the preamplifier.

HOW IT WORKS – ETI 124 AB

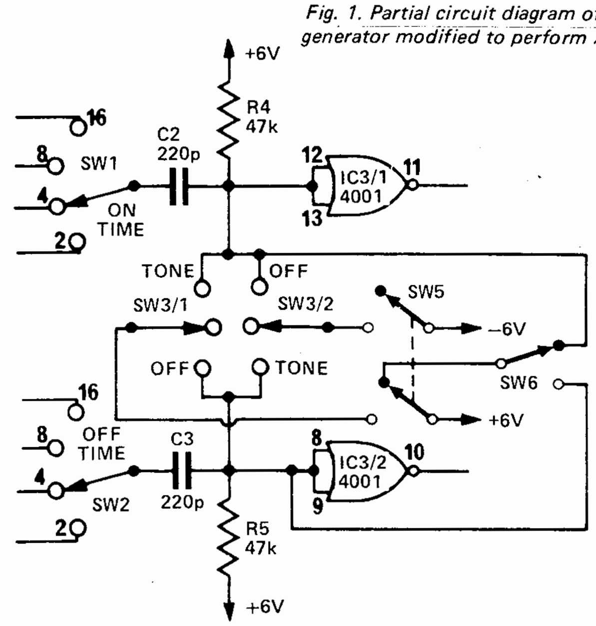
As this unit is based on the operation of the tone-burst generator ETI 124 described last month, that article should be thoroughly read first. Only the changes necessary to that unit are detailed in this article.

Whilst an A-B switch would be a little simpler if designed specifically for that purpose, the modifications required to the tone-burst generator are so simple that we thought it not worth while to design a special circuit.

To make the generator act as an A-B switch it is necessary to disable the existing mode switch. We do this by plugging in an external control switch, SW6, via a stereo phone socket. The phone socket has two change-over contacts fitted which are used to disconnect the plus and minus six volts supplies from SW3 when the jack is inserted. One of the phono contacts also disconnects the plus six volts from the common of the socket when the jack is removed. As the common of the socket is required to be at plus six volts the phono socket must be insulated from the front panel which is at 0 volts.

The control switch, SW6, effectively shorts either R4 or R5 thus stopping the pulses from C2 or C3 triggering the flip-flop. When the switch is actuated there is a delay until the number of cycles as set by the front panel switch have occurred and then, at the next zero crossing, the change-over occurs. The delay is necessary to ensure that any contact bounce of the SW6 contacts does not cause unwanted switching of the circuit.

Fig. 1. Partial circuit diagram of the tone-burst generator modified to perform AB switching.



124 AB

SILENT A-B SWITCH

To connect the unit for AB testing apply a single input, from the preamplifier (switched to mono), to the normal input socket of the generator. The normal output socket of the generator is not used but the two phono output sockets are connected back to the left and right channel inputs of the main amplifier. When SW6 is operated the mono input will be silently switched between right and left channel speakers.

If using the tape sockets the monitor switch should be in the 'monitor' position and the balance control should be adjusted so that the levels from the two speakers are apparently the same. Make sure that the tone controls are in the flat position, as they can cause phase shifts which prevent the switching occuring at the zero-crossing point.

If the pre and main amplifier terminals are used the preamplifier volume should be adjusted to about half way and separate volume controls used to balance for the difference in efficiencies of the two speakers. If the main amplifier does not have separate volume controls then external ones must be added if balance is to be achieved. In this case the tone controls may be used if required without upsetting the crossover point.

Change over may be effected by using either a toggle switch or a push button. The tone-burst generator controls should be set for eight cycles on and off as this position will effectively remove any contact bounce. ●

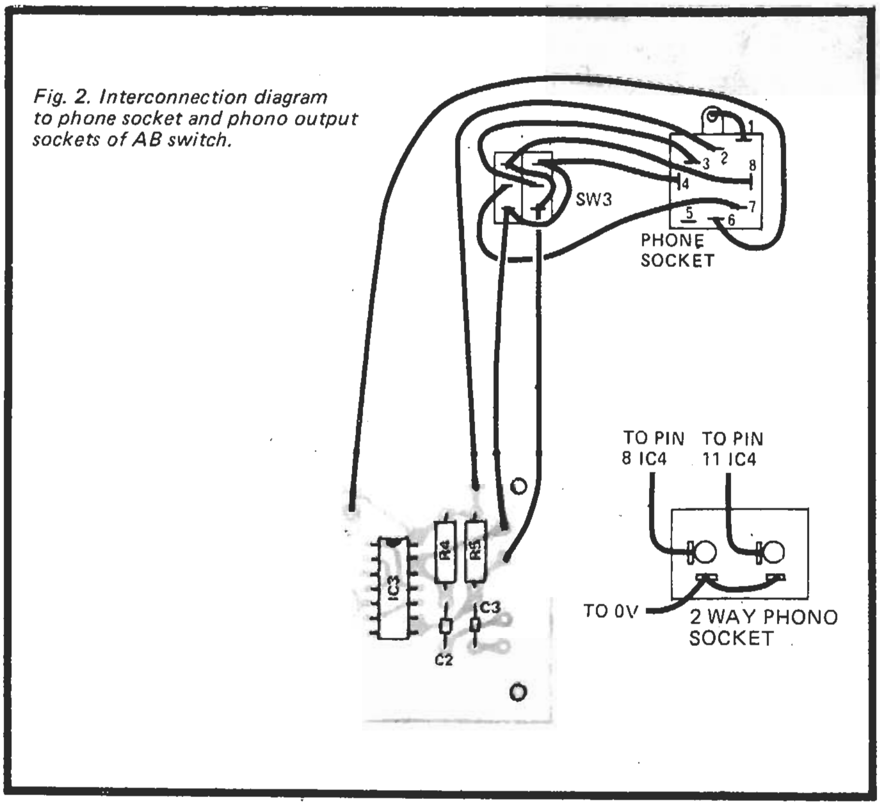


Fig. 2. Interconnection diagram to phone socket and phono output sockets of AB switch.

Silent switch for stereo-pair comparisons

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Design and printed circuit construction details are given for an f.e.t. electronic switch designed to meet stringent requirements.

During the course of a project the need arose for a silent switch with the following specification: an on/off ratio greater than 70dB; a switching time as fast as possible without introducing any audible transients; remote control switching facility by means of a single, mechanically silent on/off switch; output clipping level not less than +10dBm into 600 ohms; overall unity gain into 600 ohms; an input impedance greater than 50kΩ over the frequency range 30Hz to 15kHz; output impedance of 600 ohms ±2% over the above frequency range; amplitude/frequency response ±0.2dB over the above frequency range; hum and noise not greater than −70dBm over a 15kHz bandwidth and a total harmonic distortion not greater than 0.5% and void of high order harmonics.

A preliminary survey showed that a unit satisfying the above requirements was not readily available on the market and, therefore, one had to be designed. However, before the actual design procedure which was adopted is outlined, a brief study of the underlying requirements may serve as a useful introduction.

When a programme is switched by mechanical means, transients of two different kinds are transmitted through the system. The first type is caused by the rapid change in the d.c. at the point of switching which of course leads to an audible thump. The second and less objectionable variety is the result of terminating an a.c. signal when its waveform is not passing through zero.

In order to eliminate transients caused by changes in d.c. levels, either the signal carrying part of the circuit must be electrically isolated from the switching section, or measures must be taken to ensure that the d.c. biasing potentials remain unchanged at the instant of switching.

In the past, the majority of transient free switches employed a light-sensitive resistance as the signal carrying element, and the luminance of a lamp to control the degree of attenuation required. The main disadvantage of light-operated switches is that they are not fast enough, because an incandescent lamp has a decaying luminance after the current through it has been stopped. In fact, the decay rate is inversely proportional to the normal standing current through the lamp; even with low current lamps the decay time is too long. Up to now, such switches have, in addition, suffered from poor on/off ratios whenever small size, low current and hence low power lamps have been used. It should be pointed out that in recent years light emitting diodes have also been used instead of incandescent lamps.

The other group of silent switches or electronic attenuators often used may be conveniently classified under the heading of d.c. modulators. Such circuits are essentially amplitude modulators under various disguises. The programme signal is injected into the otherwise carrier input and a d.c. potential is used instead of the modulation signal to control the amplitude of the programme. Basically, these circuits make excellent electronic attenuators over a finite range, and with additional refinements high on/off ratio switches can be designed. Unfortunately, the use of the above technique to achieve the desired specification would have resulted in a fairly complex circuit unless integrated circuits were employed. Furthermore, during the designing stages (two years ago) the author could not find any i.c. modulator or attenuator that would meet the requirements. Therefore, the only feasible alternative was to use an f.e.t. as a voltage controlled resistor which in fact constitutes the basis of the present design.

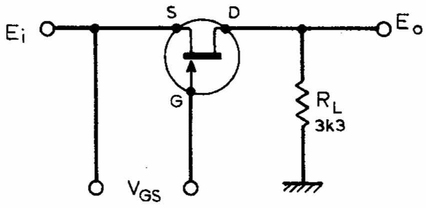

Fig. 1. An f.e.t. used as a voltage controlled resistor.

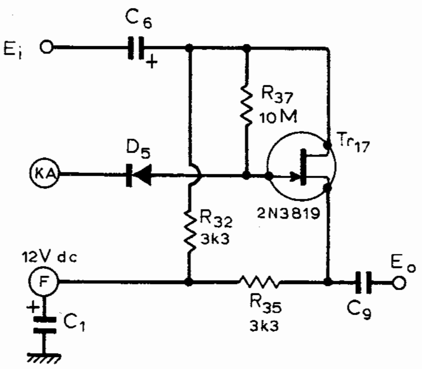

Fig. 2. Biasing arrangement for a symmetrical junction f.e.t.

If an f.e.t. is biased near the origin of its output characteristics, the channel behaves like a pure resistance whose value is a function of the gate voltage. In other words, the device becomes a voltage controlled resistor. With suitable circuit arrangements, this property can be put to use as the basis of a transient free switch.

Essentially, an f.e.t. is used in conjunction with a resistance to form a voltage controlled potential divider shown in Fig. 1. When the f.e.t. is conducting, V_{GS} is zero and the channel resistance, r_{DS}, is a minimum and therefore:

$$\frac{E_o\,(on)}{E_i}=\frac{R_L}{R_L+r_{DS}\,min.}$$

If V_{GS} is greater or equal to the pinch-off voltage of the f.e.t, r_{DS} becomes a maximum and thus:

$$\frac{E_o\,(off)}{E_i}=\frac{R_L}{R_L+r_{DS}\,max.}$$

For a 2N3819 junction f.e.t., r_{DS} (min) and r_{DS} (max) are of the order of 100Ω and 10MΩ respectively. If R_L is set at 3.3kΩ, an on/off ratio of 70dB is achieved for the voltage controlled potential divider.

Let us now consider the biasing arrangement for the f.e.t. If the device is biased at the origin of the output characteristics, the a.c. signal will swing symmetrically about that point, implying that the output characteristics of the f.e.t. must be symmetrical about the origin over the working range required. A symmetrical junction f.e.t. fulfils this requirement for small excursions about the origin of its characteristics.

Fig. 2 shows the basis of the biasing arrangement for a symmetrical junction f.e.t. The source and drain are both held at 12V through R_{32} and R_{35} because the drain current is zero. When point KA is open circuited or at 12V, V_{GS} becomes zero because the current through R_{37} is zero, and the f.e.t. is switched on. The function of D_5 is to protect the gate against excessive forward bias. Taking KA to a voltage greater than the pinch-off voltage of the device, switches the f.e.t. off. In the actual circuit, point KA is in fact taken to earth.

So far as signal transmission is concerned, point F should ideally be at a.c. earth. In practice, the resistive path between F and true earth must be very small in comparison to R_{32} at the lowest frequency of interest, because the two form a potential divider between the input and true earth, and hence a fraction of the a.c. signal always present at the input leaks through to the output via R_{35} thus reducing the on/off ratio. In the actual circuit, a 5000μF capacitor couples F to earth giving a theoretical leakage factor of about −70dB at 40Hz.

Using a single f.e.t., signals of the order of −30dBm can be passed without exceeding the distortion limit when the device is conducting. For larger swings, the incremental value of the channel resistance will no longer be the same as its d.c. resistance. In other words, the channel resistance will change during the actual a.c. cycle which of course leads to distortion. The effect can be minimized by using two complementary f.e.ts in parallel so that the change in the channel resistance of one is compensated by the other hence reducing changes in the total resistance during the a.c. cycle. The complementary changes in resistance is due to the fact while one f.e.t. is forward biased, the other is reversed biased and the incremental value of the channel resistances are in the opposite sense for the two biasing

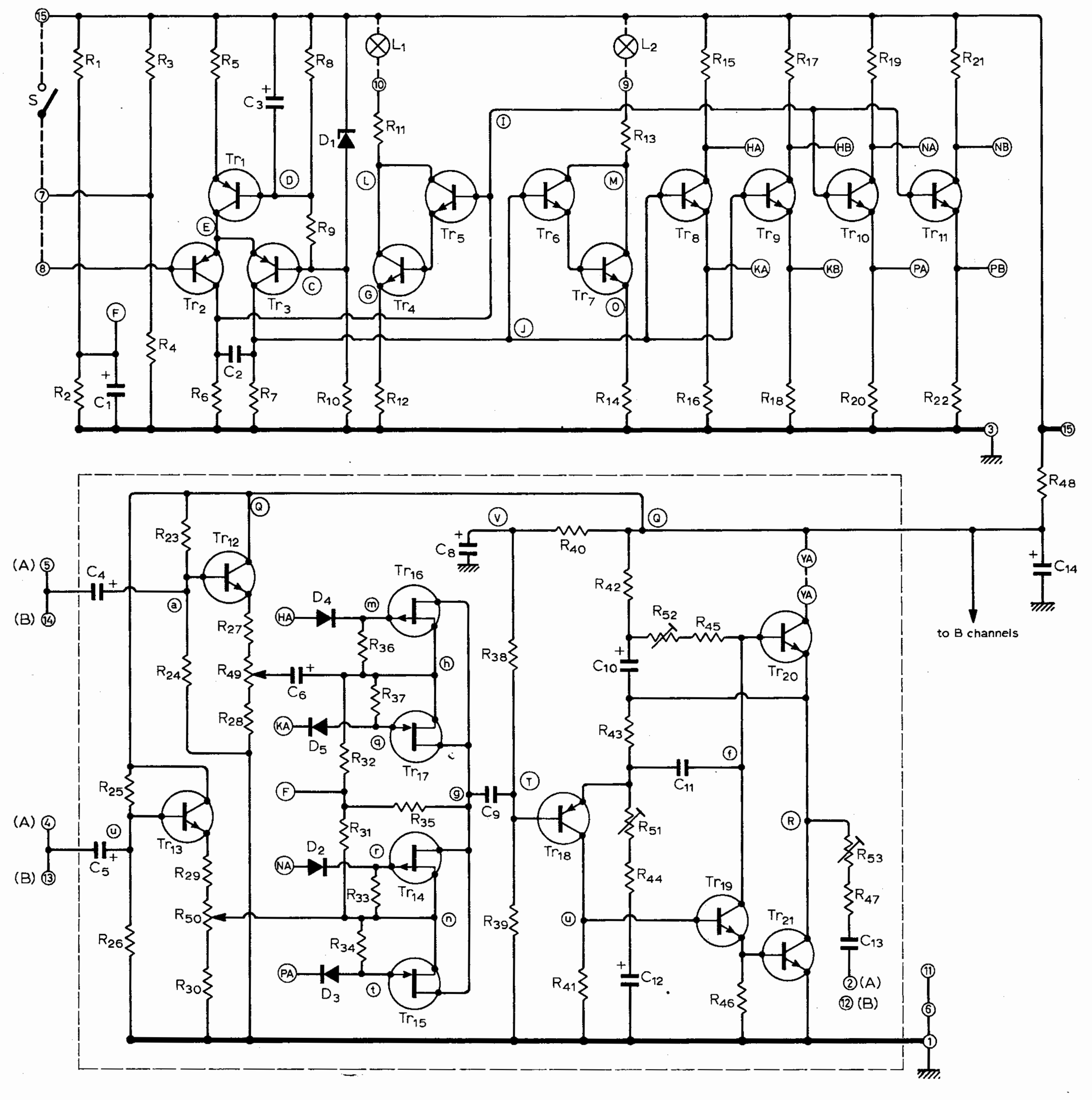

Fig. 3. Complete circuit for one channel of a stereo pair. Parts enclosed in the broken line are repeated for the B channels. Points marked with identical letters are connected together. Circled numbers refer to pin connections and operating voltages as shown in the table of voltages.

modes. The use of a complementary pair of f.e.ts was found to increase the signal handling capability by some 20dB.

Fig. 3 shows the complete circuit of the stereo silent switch. Transistors Tr_{14} and Tr_{15} form the switching elements for the A channel of a stereo pair, while Tr_{16} and Tr_{17} serve the A channel of a second stereo pair. The circuit for the B channels is identical to that enclosed by the broken lines. Resistances R_{31}, R_{32} and R_{35} maintain the drains and sources of the four f.e.ts at about 12V. Resistor R_{35} also acts as the a.c. load for both A channels. When points HA and KA are at about 12V, f.e.ts Tr_{16} and Tr_{17} are switched on, and the signal present at their sources is developed across R_{35}. When point HA is at 24V and KA is at zero volts, V_{GS} for both Tr_{16} and Tr_{17} becomes greater than their corresponding pinch-off voltages and, therefore, they are both switched off. Furthermore, at any given time if Tr_{16} and Tr_{17} are conducting, Tr_{14} and Tr_{15} will be cut off and vice versa. Therefore, the signal developed across R_{35} is either that belonging to the A channel of one stereo pair or the corresponding signal of the other stereo pair. The advantage of this arrangement is that only one subsequent amplifier (consisting of Tr_{18} to Tr_{21}) is required for two independent channels. However, the required d.c. switching for f.e.ts Tr_{16} and Tr_{17} is done by means of the phase splitter Tr_8 which itself is driven by the differential amplifier consisting of transistors Tr_1, Tr_2 and Tr_3. When Tr_{16} and Tr_{17} are on, Tr_{14} and Tr_{15} should be off and, therefore, points NA and PA are driven by the phase splitter Tr_{10} which is in turn driven in opposition to Tr_8 by the differential amplifier.

The remaining a.c. carrying part of the circuit is fairly straightforward. The two input signals present on the bases of transistors Tr_{12} and Tr_{13} are attenuated by 20dB before entering the switching elements in order to reduce harmonic distortion. The switching mode ensures that only one of the two input signals appears across R_{35}. The amplifier that follows the switching elements compensates for the initial 20dB attenuation and therefore maintains the overall unity gain required. The amplifier proper is of the class A push-pull variety, the operation of which has been explained frequently in the literature.

The d.c. switching and indicating section was designed to operate by means of a single on/off switch S, which could also be paralleled with a second on/off switch to facilitate remote control switching. The differential output state of the amplifier Tr_1 to Tr_3 is governed by switch S, provided the base of Tr_2 is connected to the junction of R_3 and R_4. This corresponds to linking pins 7 and 8 on the printed circuit board. Alternatively, the switching could be done by an external d.c. signal of about 4–5 volts negative with respect to the 24V supply rail. In that case, the switching voltage should be applied directly to the base of Tr_2 with pins 7 and 8 isolated from each other. The magnitude of this switching voltage was chosen with t.t.l. compatibility in mind.

Lamps L_1 and L_2 are indicators for the two stereo-pair programmes. When S is open, L_1 lights and signals present at input pins 4 and 13 pass through to the output pins 2 and 12 respectively. Conversely, the closed position of the switch corresponds to L_2 lighting and the signals at pins 5 and 14 appearing at output pins 2 and 12 respectively.

Finally, the 1μF capacitor C_2 is used to reduce the change-over speed at the output of the differential amplifier. In this way, transients otherwise generated by rapid switching of the a.c. signals are subjectively eliminated. Note that this capacitor alone determines the switching speed of the complete unit.

Component list

Resistors: 1/8W, ± 2% unless otherwise stated.

R_1 & R_2	10kΩ	R_{23}	150kΩ	R_{39}	560kΩ ± 5%
R_3	30kΩ	R_{24}	330kΩ ± 5%	R_{40}	220kΩ
R_4	82kΩ	R_{25}	150kΩ	R_{41}	27kΩ
R_5	1.5kΩ	R_{26}	330kΩ ± 5%	R_{42}	100kΩ
R_6 & R_7	15kΩ	R_{27}	4.7kΩ	R_{43}	47kΩ
R_8	10kΩ	R_{28}	680Ω	R_{44}	2.2kΩ
R_9	5.6kΩ	R_{29}	4.7kΩ	R_{45}	18kΩ
R_{10}	3.9kΩ	R_{30}	680Ω	R_{46}	100kΩ
R_{11}	¼W, 160Ω ± 5%	R_{31} & R_{32}	3.3kΩ	R_{47}	560Ω
R_{12}	1W, 270Ω ± 5%	R_{33} & R_{34}	10MΩ ± 10%	R_{48}	27Ω
R_{13}	¼W, 160Ω ± 5%	R_{35}	3.3kΩ	R_{49} & R_{50}	470Ω ± 10%
R_{14}	1W, 270Ω ± 5%	R_{36} & R_{37}	10MΩ ± 10%	R_{51}	1kΩ ± 10%
R_{15}–R_{22}	120kΩ	R_{38}	680kΩ ± 5%	R_{52}	100kΩ ± 10%
				R_{53}	100Ω ± 10%

Capacitors:

C_1	5000μF/12V	C_6 & C_7	50μF/12V	C_{11}	33pF
C_2	1μF	C_8	4μF/25V	C_{12}	50μF/12V
C_3	30μF/6V	C_9	1μF	C_{13}	100μF/25V
C_4 & C_5	4μF/25V	C_{10}	10μF/12V	C_{14}	500μF/25V

Semiconductors:

D_1	BZY88, C3V3	Tr_5 & Tr_6	2N930	Tr_{16}	2N3820
D_2–D_5	1N916	Tr_7	2N2219A	Tr_{17}	2N3819
		Tr_8–Tr_{13}	2N930	Tr_{18}	2N3702
Tr_1–Tr_3	2N3702	Tr_{14}	2N3820	Tr_{19}–Tr_{21}	2N930
Tr_4	2N2219A	Tr_{15}	2N3819		

Lamps

L_1 & L_2 6V, 40mA

Construction

All components of the stereo silent switch except the two lamps and switch S are mounted on a printed circuit board shown in Fig. 4. The corresponding component layout is outlined in Fig. 5 which is immediately followed by relevant explanatory notes and the line-up procedure.

During assembly, it should be observed that the capacitor C_2 is not in physical contact with the resistor R_{12} because the latter generates a certain amount of heat.

The length of the wires connecting switch S to the circuit are not critical. In fact, the circuit operates satisfactorily with remote control wires ten meters long. However, should the casing of switch S chosen be connected to any one of its pins, measures must be taken to eliminate the possibility of an inadvertent contact between the casing of that switch and earth. Otherwise, either a short circuit is created across the d.c. supply line, or a 21V reverse bias will be imposed across the base to emitter junction of Tr_3.

Operating voltages

Point	S open		S closed
1, 3, 6 & 11		0 Volts	
7	17.6		24.0
8	17.6		24.0
9	24.0		17.8
10	17.8		24.0
15		24.0	
C		20.8	
D		21.9	
E	18.3		21.4
F		11.8	
G	10.7		0
HA & HB	23.7		12.4
I	11.9		0
J	0		11.9
KA & KB	0.14		11.4
L	11.4		24.0
M	24.0		11.4
NA & NB	12.4		23.7
O	0		10.7
PA & PB	11.4		0.14
Q		23.0	
R		11.5	
T		8.8	
U		1.14	
V		19.4	
a		14.8	
f		12.1	
g		11.8	
h		11.8	
m	23.4		12.3
n		11.8	
q	0.43		10
r	12.3		23.4
t	10		0.43
u		14.7	

Performance tests

Objectively, the unit meets the required specification initially outlined. Total harmonic distortion, for example, is in fact less than 0.2% from 30Hz to 15kHz for an output level of +10dBm into 600Ω. The distortion is predominantly second harmonic and its magnitude decreases with reduction in the output level.

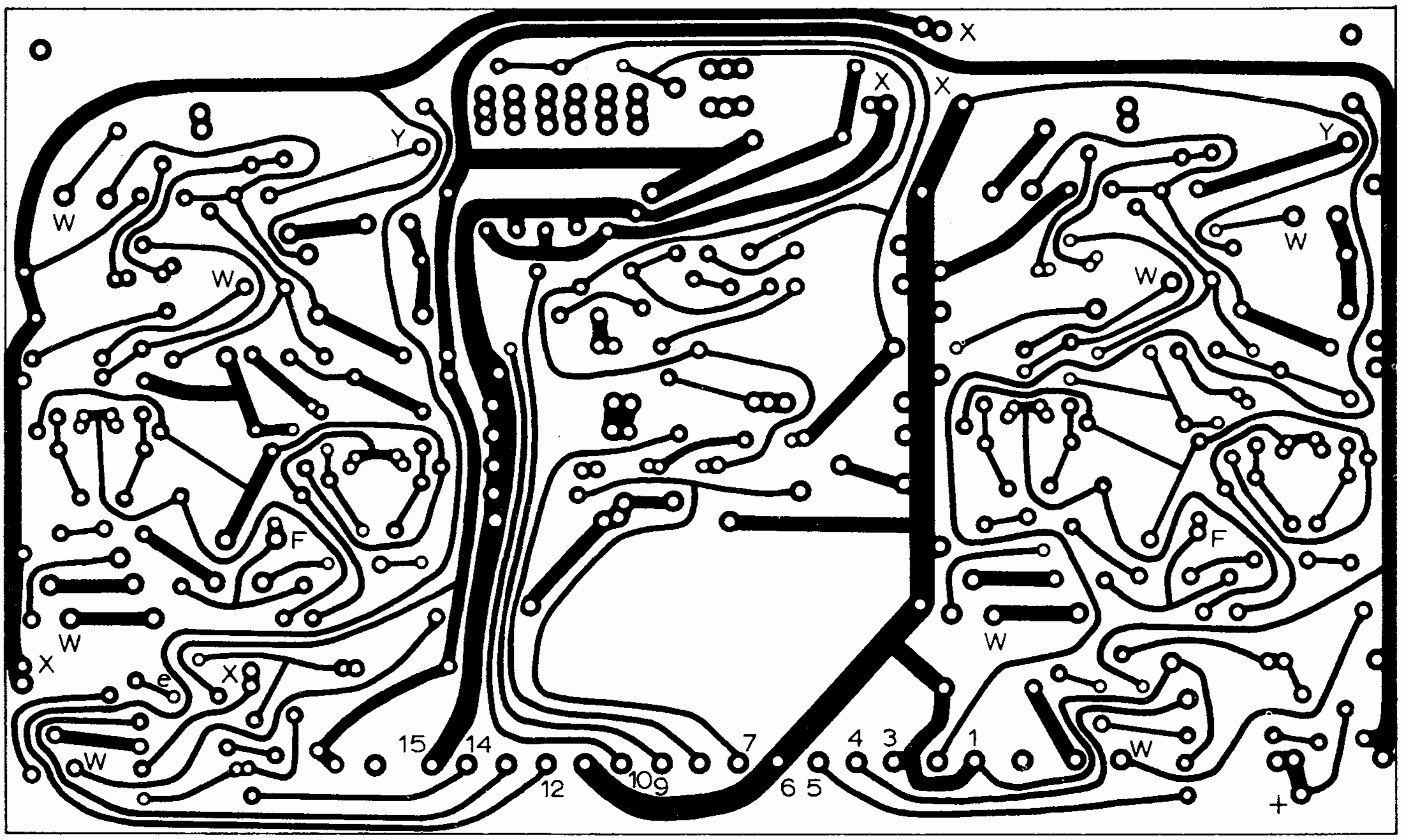

Fig. 4. Printed circuit layout of silent switch.

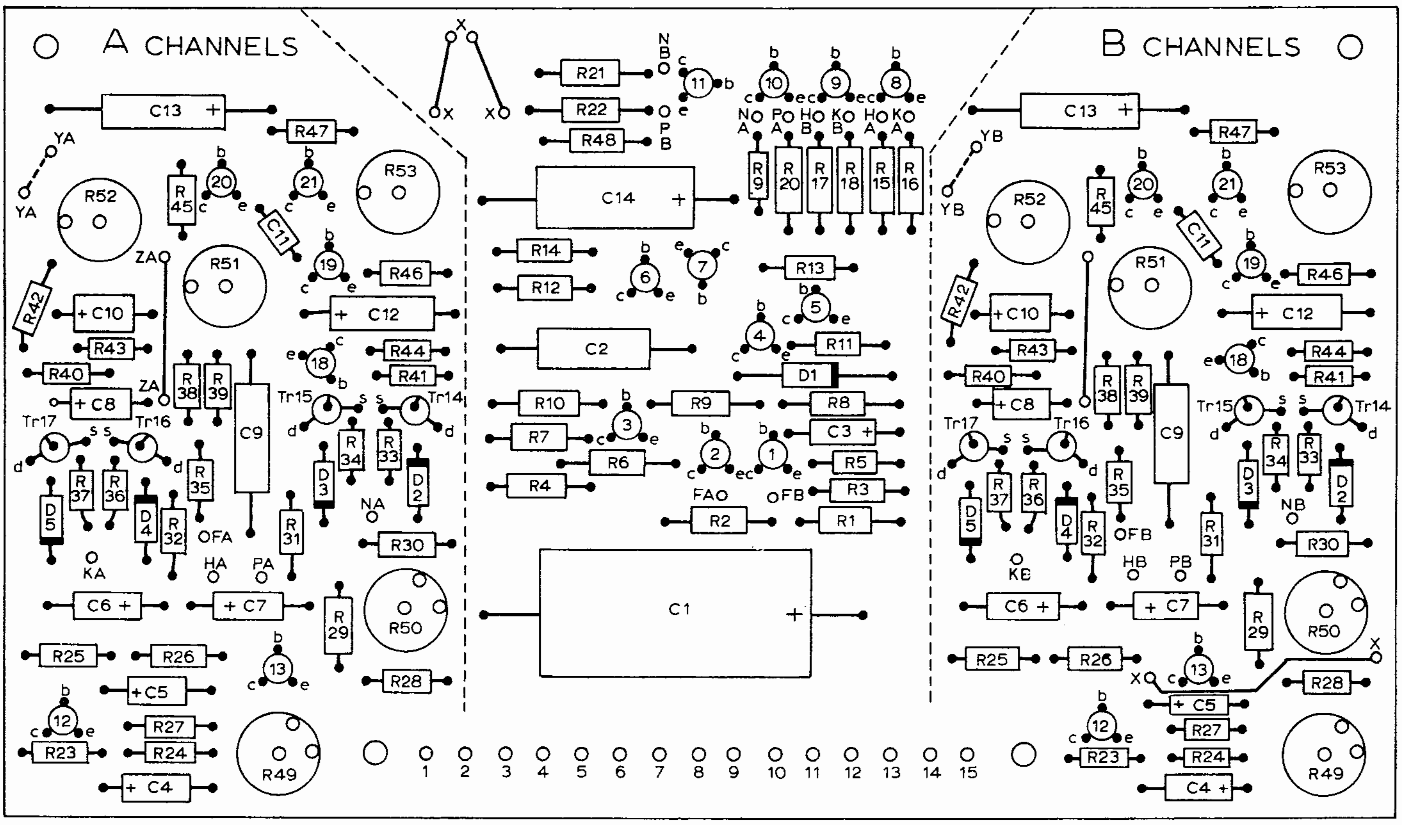

Fig. 5. Printed circuit component layout.

The d.c. switching and indicating section components are placed in the middle of the board. Components belonging to the signal carrying parts of the circuit are positioned to the left and right of the board for the A and B channels respectively.

External Connections. Connect points marked X to each other as indicated. DO NOT connect points Y at this stage. Connect the following:
HA to HA, KA to KA, NA to NA, PA to PA, FA to FA, ZA to ZA, etc.

Line-up Procedure. With no signal applied, connect an ammeter between points YA. Adjust R_2 so that the ammeter reads 12mA. Remove the ammeter and connect points YA together. Set R_{53} to obtain an output impedance of 600Ω. Terminate the output (pin 2) with a 600Ω load. Apply a 1kHz, −10dBm signal (via a 100μF capacitor with its positive end connected to the circuit) to either end of C_9. Adjust R_{51} to obtain +10dBm at the output. Connect pins 7 and 8 together. Apply a 1kHz, +10dBm signal to pin 4 (the input). Adjust R_{50} so that the output is at +10dBm. Apply a 1kHz, +10dBm signal to pin 5. Close switch *S* (see circuit diagram). Adjust R_{49} so that the output is also at + dBm.

Repeat the same procedure for the B channels.

Pins 1 to 15 are laid out for connection to a Painton 15 pole plug type 73/10/1501/10.

Tr_{20} and Tr_{21} should be matched.

The switching speed of the unit was measured in terms of a parameter called parameter implies "Fade-in" as well as time taken for the output level of the switch to change by 60dB. Note that the parameter implies "Fade-in" as well as "Fade-out". This mode of measurement was adopted in preference to the other criteria generally used because it is subjectively meaningful and compatible with the properties of human hearing as well as other parameters in acoustical engineering. The justification generally accepted is that a 60dB reduction in the sound pressure level of a programme makes it inaudible under average conditions. A figure of 25ms ± 20% was obtained as the Fade-Time of the silent switch.

Subjectively, the switching was found to be free from transients for all programme materials including pure tone. Nevertheless, in order to investigate the subjective detectability of the actual transition, the same programme was fed to both inputs and the switch was operated so as to create a momentary interruption. The degree of the impairment caused by the transition was then judged by a few observers experienced in sound quality evaluations. It was found that the detectability of the transition was dependent on the programme used and the relative instant at which the switch was actuated. For speech and music if the change-over was made during the momentary silences of the programme, then the transition was not noticeable. However, if switching was done during the existence of a continuous passage, then the interruption was found to be noticeable but quite acceptable. The same judgment was also passed when continuous signals such as pink noise or pure tone were used.

Two units were manufactured, both of which were in continual daily use for about 14 months with satisfactory performance. The few problems encountered during this period were minor ones and their corresponding remedies have already been mentioned.

It is perhaps worth mentioning that during the designing stages, attempts were made to add electronic fading facility to the unit. Unfortunately, it was found that using f.e.ts as the fading element, realization of a unit capable of low distortion performance during an entire fade, in addition to high on/off and signal to noise ratios, was not really possible. However, the author has since designed a four-channel modulation type electronic fader, the details of which will hopefully be published soon!

Acknowledgement

The above paper presents an engineering aspect of a Ph.D. project financed by the University of Surrey but carried out at the BBC Research Department. I would like to thank both bodies for making this rather unusual but most productive arrangement possible.