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Active subwoofer

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Satellite loudspeakers are not a seperate cetegory of sound reproducing aquipment; any loudspaaker whose bess performance should be improved could be classified es a satellite. So-called bookcase loudspeeker are invariably setellites, baceuse their modest dimensions prohibit proper reproduction of frequencies below ebout 100 Hz.

Tha erticle follows on the Active subwoofer end deals with the satellite loudspeakers that complement the subwoofer to give complete coverage of the audio spectrum.

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Video in decline?

Now the semiconductor markets are beginning to show signs of a slow revival, it seems to be the turn of video revenues (and therefore profits) to start declining. The reason for this is that some forty per cent of households in the industrialized world already have a VCR (video cassette recorder).

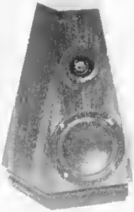
To retain their share of the consequently declining market, the 20-odd Japanese (and some other Asian) manufacturers have become engaged in a price war that is hotting up.

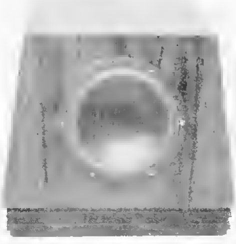
What they are all hoping for is a miraculous expansion of the market, or a new market. But that is pie in the sky, because market observers believe that such an expansion or new market will only occur if a technically new, yet lasting and exciting, equipment is introduced. Moreover, such equipment must be relatively inexpensive, easy to operate, and offer a high degree of standardization.

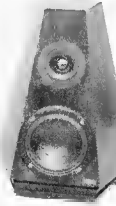
The only equipment that seems to meet most of these requirements is Sony's new 8 mm video system. But since this is not compatible with the 100-odd million half-inch VCRs already in use, it has a long, hard slog ahead of it.

In the mean time, the video market is likely to go on declining at an increasing rate. As guarded estimates suggest that nearly a fifth of Japanese electronics sales consists of VCRs and their components, some sectors of the Japanese industry are in for a leaner time than they have experienced for years. The question is: what are they going to do about it?

The subwoofer described in this article can be used to extend any existing loudspeaker system. It has been designed to obtain a frequency response within ±1 dB over the frequency range 30-100 Hz with an enclosure volume of only 85 litres.







ACTIVE SUBWOOFER

The faithful reproduction of very low audio frequencies in normal living rooms poses a number of problems. The first is that the lowest frequency f, that can be reproduced depends on the length, l, of the room:

$$f = c/2l \text{ [Hz]}$$

where c is the velocity of sound waves in metres per second at normal atmospheric pressure and at 20 °C.

In a 6-metre long room, therefore, the lowest frequency that can be reproduced without distortion is about 28 Hz. In practice, other problems, such as the vibrating of doors, windows, cupboards, glassware, and so on, become evident long before this frequency has been reached.

A more important problem concerns the dimensions of the enclosure. For a reasonably faithful reproduction at 30 Hz and full volume, the enclosure should normally have a volume of not less than 100 litres, and preferably about 200 litres. Two such large boxes required for a stereo installation are often unacceptable in a normal living room.

Fortunately, there is an alternative which offers much the same bass performance and has a much more modest space requirement. It uses only one enclosure for the low frequencies, even in stereo operation. For the middle and high frequencies, one loudspeaker system per channel remains required.

The alternative solution is made possible by the human ear having virtually no sense of direction at frequencies below about 200 Hz. This means that if frequencies below, say, 100 Hz, are reproduced by one central subwoofer, and the remainder of the audio spectrum by so-called satellite loudspeakers, there is no discernible impairment of the stereo effect. Note that the satellite speakers can be kept small

Technical characteristics

System:	active closed box
Net volume	85 litres
Crossover network	electronic, 24 dB octave, Bessel filter
Frequency range:	30-100 Hz (see Fig. 1b)
Recommended amplifier output	50-100 W
Maximum sound pressure	>100 dB (50-100 Hz)
Sensitivity	87.5 dB (1 watt at 1 metre)

The system has been provided with a presettable output power limiter.

because they are required to reproduce frequencies above 100 Hz only. The design and construction of these satellite loudspeakers will be described in this issue

Table 1 shows some types of loudspeaker system and their most important characteristics. It is clear that the closed box generally offers the best performance, were it not for its inability to reproduce very low audio frequencies when its volume is modest to small. The bass reflex and transmission-line types are superior in this respect, but these suffer from an inferior frequency response characteristic and a much worse step response. The horn and transmission-line types are, furthermore, rather difficult to build.

This leaves, in practical terms, the active closed box. The properties of this type depend to a large extent on its specific design, which can be approached from different directions. The questions that immediately crop up are: "how low should the −3 dB point be?", and "what are the acceptable dimensions of the enclosure?". The lower the frequency at the −3 dB point for a certain volume, or the smaller the dimensions for a given −3 dB point, the more electronic correction will be necessary.

Table 1. Some prominent types of loudspeaker system and their most important properties.

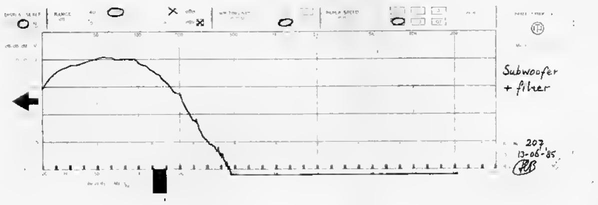
Type of system	Dimensions	Sensitivity	Step response	Characteristic	Lower −3 dB point
Horn	very large	very high	reasonable	very irregular	fairly high
Bass reflex	large	high	reasonable	irregular	low
Transmission line	large	low	poor	irregular	low
Closed box	large	fair	good	tapering	high
Active closed box	small	reasonable*	good*	smooth*	low*

* Depends to a large extent on the system set-up.

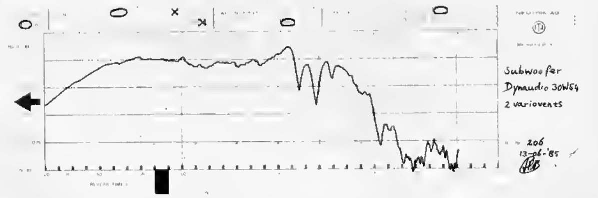
Fig. 1a Frequency response characteristic of the Dynaudio 30W54 drive unit in an 80-litre closed box without any filtering

Fig. 1b Frequency response characteristic of the Dynaudio 30W54 drive unit in an 80-litre closed box with electronic crossover network and correction filter

1a



1b



But this correcting cannot be taken too far, otherwise the sensitivity as well as the step response will suffer; also, distortion will increase and power handling will be reduced.
The present system was designed to give a reasonable performance without any electronic help first, and then some electronic circuits were added to extend the frequency range downwards.
The frequency response of the subwoofer in an 80 l enclosure is given in fig 1: 1b clearly shows the effect of the added filters, particularly the lowering of the −3 dB point from about 50 Hz to 30 Hz.

Set-up

The system is arranged as shown schematically in Fig 2, and is seen to consist of the loudspeaker in its enclosure, an output amplifier, and an electronic circuit. The output amplifier will not be discussed here, because any good type may be used, as long as it is capable of delivering at least 50 W into 8 ohms. The enclosure is simple to build as described under *Construction*. The loudspeaker used in the prototype was a Dynaudio (Denmark) type 30W54 —see Fig. 3. This is a robust 300 mm drive unit on a light metal frame with high peak power handling capability, good step response, and a suitable frequency response (see Fig. 1a).
The electronic circuit consists of two parts: the filters and the output limiter. There are three filters a steep-skirted anti-rumble type with its change-over point at 20 Hz; a correction filter for the very low audio frequencies from 50 Hz downwards; and a crossover filter with change-over point at 100 Hz and a slope of 24 dB/octave. The combination of these filters results in the frequency response shown in Fig. 1b.
The output limiter is, strictly speaking, not essential but very useful, particularly where full volume is used habitually. It has been added to allow for the decreasing power handling capability of the drive unit below 50 Hz. The coming into operation of the limiter is indicated by the lighting of an LED.

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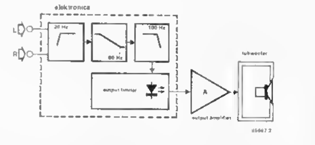


Subwoofer and satellite speakers

In principle, the subwoofer can be used as an addition to any loudspeaker system that has unsatisfactory performance at low frequencies. If, however, a new loudspeaker system is planned, the design of the satellite speakers should take account of the subwoofer. These units need reproduce frequencies above 100 Hz only, so that the volume of their enclosures can be kept to about 10 litres.

The various units should be interconnected as shown in Fig. 4. The simplest and least expensive way is shown in Fig. 4a: the subwoofer system, including the output amplifier and filters is simply connected to the loudspeaker terminals of the existing amplifier. Capacitors C form a 6 dB filter to protect the satellite speakers high low frequency output power. The necessary level matching between the subwoofer and the satellite speakers may be effected with a preset on the filter PCB.
Where the pre-amplifier an output amplifier are separate units, interconnections may be made as illustrated in Fig. 4b. In this way, each loudspeaker has its own output amplifier, so that filtering can take place between the pre-amplifier and the output amplifiers. The set-up in Fig. 4b is preferable to that in Fig. 4a.
The question may be asked why the satellite speakers are filtered at only 6 dB/octave from 100 Hz, whereas the subwoofer has a skirt roll-off of 24 dB/octave. The answer is that the satellite speakers (in a closed box) have an inherent fall-off of about 12 dB/octave. Together with the additional filtering, this works out at 18 dB/octave, which is ample in this combination.
The value of capacitors C is determined from

$$C = 10^6/2\pi Z f_t \quad [\mu F]$$

where Z is either the impedance of the satellite speaker (Fig. 4a), or the

3

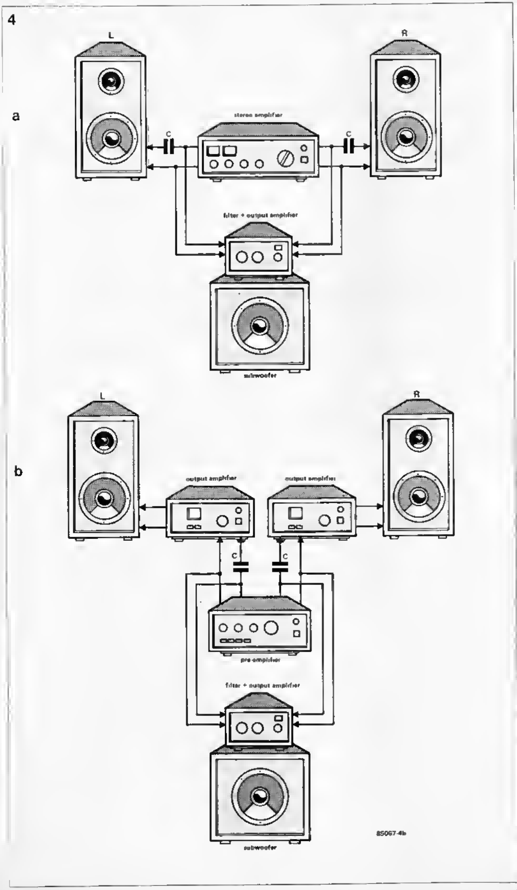


Fig. 4. Two different arrangements for using the sub woofer system with a pair of satellite loudspeakers. The set-up in 4b is preferred.

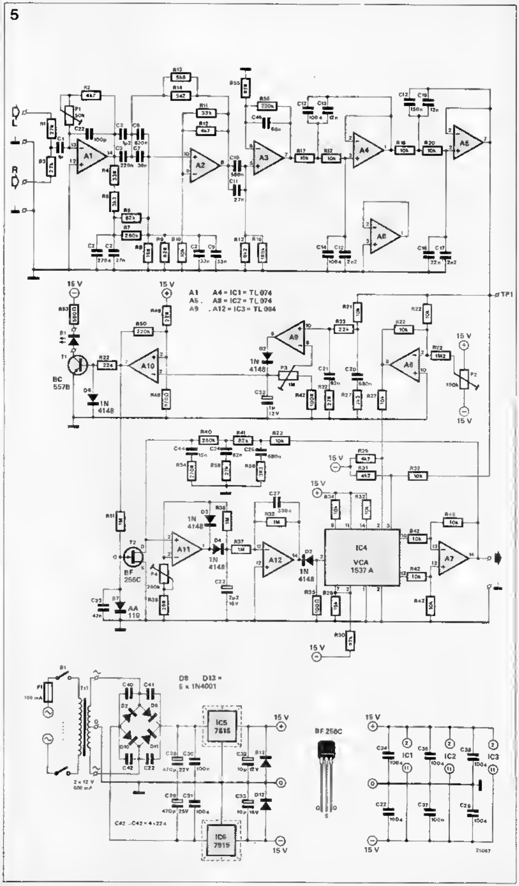
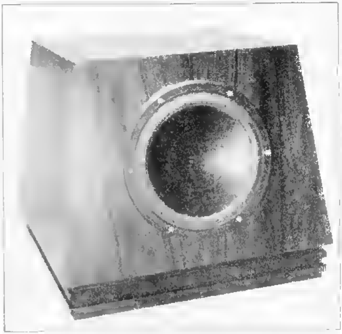


Fig 5 The circuit diagram of the three filters and output power limiter. Diode D. should be mounted so that it can be seen from the outside since it serves as overload indicator.

input impedance of the relevant output amplifier (Fig. 4b) in ohms, and f_c is the roll-off frequency in hertz.

If, therefore, in Fig. 4a the satellite speaker impedance is 8 ohms, and the roll-off frequency is 100 Hz, the series capacitor should have a value of 200 μF. It is recommended to shunt such large bipolar electrolytic capacitors by a foil capacitor of 1 μF, which improves the properties of the filter

Since the input impedance of the output amplifiers in Fig 4b is considerably higher than the loudspeaker impedance, the value of the filter capacitor is much smaller For instance, an input impedance of, say, 20 k gives a value of C=80 nF (use 68 nF or 0.01 μF)



Electronic circuits

The circuit diagram of the three filters and the active output limiter is given in Fig 5

After the two input signals have been summed in amplifier A_1, they are applied to a complex rumble filter formed by A_2. This elliptical or Cauer (high-pass) filter provides an attenuation of 0 dB at 25 Hz, −3 dB at 20 Hz, and 40 dB at 10 Hz. Note that some resistors and capacitors are connected in parallel to obviate the need for non-standard 1 per cent components.

The rumble filter is followed by the correction filter, which, covering a range of only 3-6 dB, is a fairly simple circuit. It is formed by A_3 and the frequency-determining components are R_{56} and C46 .

The third filter is the actual crossover network and is constructed around A_4 and A_5. It is a fourth-order Bessel type which provides an even phase shift and very good step response.

The remainder of the circuit is the active output power limiter The filtered signal at pin 7 of A_5 is applied to a metering circuit formed by A_8 and A_{16}. Network R_{21}-R_{22}-R_{23}-R_{57}-C_{20}-C_{21} ensures that the input to A_8 is large at low frequencies (against which the system needs protection) and small at high frequencies. The rectified signal is compared in A_{10} with a reference voltage. If the signal becomes too large, the comparator toggles, T_1 is switched on, and D_1 lights. At the same time, T_2 is switched off and the control loop of attenuator IC_4 is actuated

The voltage-controlled attenuator (VCA) was described in *Design Ideas* in the February 1986 issue of *Elektor India* Opamps A_6 and A_7 provide buffering of the input and output of the VCA respectively.

The buffered signal at pin 14 of A_7 is passed via low-pass filter R_{40}-R_{41}-R_{42}-R_{54}-R_{58}-R_{59}-C_{24}-C_{26}-C_{44} to active rectifier A_{11}. This low-pass filter serves to adapt the control characteristics to the frequency-dependent power curve of the loudspeaker Note that the signal is passed to A_{11} only when T2 is switched off. The output of the rectifier is applied to the control input of the VCA via integrator A_{12}.

As long as the signal level at pin 6 of A_{10} remains below that of the reference voltage at pin 5, T_2 remains on. The control loop of the attenuator is then inactive and the VCA merely passes all signals applied to it This arrangement ensures effective limiting of the output signal.

The power supply is a fairly standard circuit. Diodes D_{12} and D_{13} prevent a temporary reversal of the supply voltages on switch-off the ICs cannot then accidentally be put into an undefined state.

Construction (electronic circuits)

It is best to complete the electronic part first on the PCB shown in Fig 6. Most if this work is pretty straightforward, except for the heat sink of regulators IC_5 and IC_6. This should be made from a 25×100 mm strip of 1 mm thick tin or tinned copper. Bend this lengthwise into an L of 70×30 mm. Drill two holes in a suitable position in the short leg to receive the ICs. Place the heat sink onto the PCB along the indicated fat line and solder it in place with the aid of two pins mounted as shown. The regulators are then fitted to the heat sink. the 7815 without, and the 7915 with, insulating washers.

If the arrangement of Fig 4b is used, the values of resistors R_1 and R_2 should be as shown in the parts list. With the set-up of Fig 4a, their value should be increased to about 560 k. Some trial and error may be necessary to find the correct value that gives a satisfactory control range of P_1.

The (mono) output amplifier required should, as already stated, be rated at not less than 50 W for satisfactory performance. Together with the filter PCB and mains transformer, it can then be fitted in a suitable case

Connections between the filter board and output amplifier should be made in screened audio cable The amplifier and subwoofer drive unit may be interconnected by any twin cable with a cross-sectional core diameter of 2.5 mm² for lengths up to 7 metres

Construction (enclosure)

The enclosure is, simply, a rectangular box that must be really solid and have a net volume of about 85 litres. A suitable construction is shown in Fig 7 but it should be noted that the dimensions stated may be varied by ±30 per cent, as long as the net volume remains about 85

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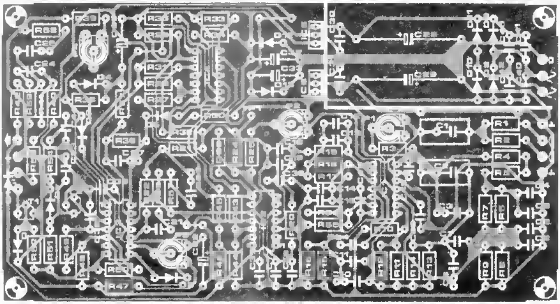

Parts list

Resistors

R_1,R_2;R_{23};R_{59} = 27 k
R_3,R_{12},R_{29},R_{31} = 4k7
R_4,R_{11} = 33 k
R_5,R_{57},R_{58} = 3k3
R_6,R_9,R_{22},R_{41} = 82 k
R_7,R_{40} – 680 k
R_8,R_{28} = 15 k
R_{10},R_{17} R_{21},R_{24},R_{26},
R_{27},R_{32} R_{34},
R_{42} R_{46} · 10 k
R_{13},R_{14} = 5k6
R_{15} 8k2
R_{16} 180 k
R_{25} = 1M5
R_{30},R_{56} – 47 k
R_{35} 100 Ω
R_{36} R_{38} R_{51} = 1 M
R_{39} = 39 k
R_{47} 100 k
R_{48} = 470 Ω
R_{49},R_{52} = 22 k
R_{53} = 560 Ω
R_{54} = 270 k
R_{55} = 220 k
P_1 = 50 k preset
P_2 = 100 k preset
P_3 = 1 M preset
P_4 = 250 k preset

Capacitors:

C_1 = 1 μ metal foil plastic or polystyrene
C_2 = 1μ5 metal foil plastic or polystyrene
C_3 – 220 n
C_4 – 270 n
C_5 = 27 n
C_6 – 820 n
C_7 – 39 n
C_8 C_9 = 33 n
C_{10} = 560 n
C_{11}·C_{12};C_{24} = 82 n
C_{12} C_{14},C_{30},C_{31}
C_{34} C_{39} = 100 n
C_{13} – 18 n
C_{15} – 6n8
C_{16} = 56 n
C_{17} 5n6
C_{18} 150 n
C_{19} – 12 n
C_{20},C_{26} = 680 n
C_{22} 1 μ;16 V
C_{23} – 47 n
C_{25} = 2μ2,16 V
C_{27} 330n
C_{28},C_{29} 470 μ,25 V
C_{32} C_{33} · 10 μ,16 V
C_{40} C_{43} 22 n
C_{44} 15 n
C_{45} = 100 p
C_{46} = 68 n

Semiconductors

D_1 – LED, red
D_2 D_6 = 1N4148
D_7 = AA119
D_8 D_{13} – 1N4001
T_1 = BC557B
T_2 – BF256C
IC_1,IC_2 TL074
IC_3 = TL084
IC_4 = 1537A (Aphex)
IC_5 7815
IC_6 7915

Miscellaneous

F_1 – fuse 100 mA, delayed action
Tr_1 mains transformer, secondary 2 × 15 V at 500 mA
S_1 = mains on/off switch
Enclosure as per Fig 7
Damping material
Drive unit Dynaudio 30W54
2 variovents of 110 mm dia
Terminals as required
Loudspeaker grille cloth as required
Rubber feet 4 or 6 as required
Wood glue as required
Wood screws and nails as required

litres. The holes for the two acoustic resistors (variovents) in the back of the enclosure should, however, always have a diameter of 110 mm. These units attenuate the resonance peak of the drive unit and contribute, therefore, in a real sense to the performance of this relatively small enclosure.
The material should preferably be 22 mm plywood. All edges should be provided with 45 × 45 mm reinforcing battens. Moreover, a 45 × 45 mm cross-piece at the centre of the box will further prevent any panel resonance.
It is best to start with gluing the battens to the panels, followed by the gluing together of the four side panels. Provided the holes for the drive unit and the variovents have been sawn, the front and back panels can then be glued into place. One of these may be screwed, instead of glued, into place, but suitable tape should then be used to seal the gap. This tape should also be used around the frame of the

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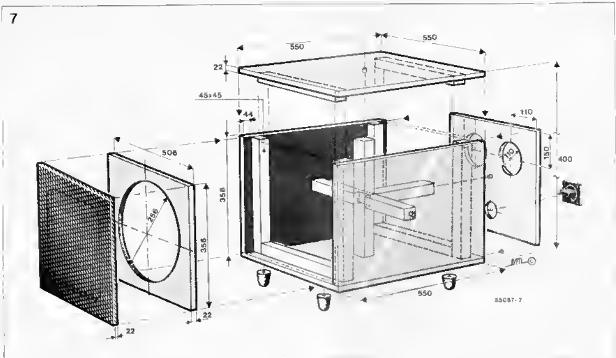

drive unit to ensure an airtight construction.

Panel resonance can further be prevented by gluing strips of rubber-backed floor covering at the inside of all but the front panels and then covering these panels with 30 mm thick rock-wool.

The photograph on the previous page shows an enclosure of around 85 litres of which the dimensions vary from those shown in Fig. 7.

Setting the limiter

To set the limiter, a digital multimeter and a 50 Hz test generator are required. Fig. 8 shows how such a simple test generator may be built.

- Set all potentiometers to the centre of their travel
- Connect inputs L and R to earth.
- Connect the multimeter (set to a DC mV range) to the output and adjust P_2 for a reading of exactly 0 V
- Disconnect the L and R inputs from earth and apply a 50 Hz signal to one of them.
- Connect the output to the (mono) power amplifier but do not yet connect the drive unit.
- Turn P_3 fully clockwise (i.e. towards C_{21}).
- Set the multimeter to the 20 V or 50 V AC range and connect it to the output of the amplifier
- Increase the input signal gradually until the meter reads 12 V r.m.s. (i.e. the maximum allowable voltage across the drive unit at 50 Hz). Adjust P_3 so that D_1 just lights
- When the input signal is increased, the VCA should limit the output voltage, and this is achieved by adjusting P_4 so that the multimeter reading remains 12 V r.m.s. for any further increase of the input level.
- Preset P_1 is used to adjust the sound pressure of the subwoofer relative to the satellite loudspeakers.

Some practical points

It is advisable not to place the enclosure direct onto the floor, but to provide it with four or six rubber feet. This acoustic decoupling prevents any tendency to boom.

As regards the location of the subwoofer, this is best determined by trial and error, because it is impossible to give strict guide lines for every type of living room. It is, of course, wise to place it initially somewhere between the satellite speakers. It is, however, recommended to place it, if at all possible, about 110 cm (4 ft) in front of the satellite speakers. In any case, do not place it direct against a wall or in a corner

F[illegible] the construction of the enclos[illegible] The dimensions may vary by [illegible] to ±30 per cent but care should be taken that the net volume remains about 8[illegible] litres. The diameter of the vanovents must be 110 mm

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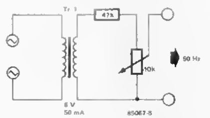

Fig. 8. If an audio tone generator is not available, this simple to build 50 Hz generator will do nicely

talk funny?

ring modulator, chopper and frequency modulator

Deliberate electronic distortion of speech and music signals can give fascinating results. Professional musicians use extremely expensive equipment to obtain their very own weird and wonderful 'sound'. For electronics enthusiasts, it is much more fun to get the same sort of results from very simple circuits. Which is what this article is about: getting effective effects using a single IC, the 2206.

One of the best known and most impressive distorters for audio signals is the ring modulator. Normally speaking, a ring modulator circuit has two inputs one for the audio signal (speech, for instance) and one for a 'carrier' The weirdest effects are obtained when the carrier frequency is within or just above the audio range; using different carrier shapes (sinewave, squarewave or triangular waveform) can produce different effects

The circuit can be drastically simplified by using a 2206. This IC contains a suitable generator for the 'carrier', and a multiplier circuit that is ideally suited for use as a ring modulator. The internal block diagram is shown in figure 1.

The oscillator (VCO) is already connected internally to the multiplier. This means that, basically, applying an audio signal to the other multiplier input (pin 1) will produce a 'ring-modulated' output at pin 2. Simplicity itself!

Obviously, a few other components are needed in a practical circuit Not many, though, as shown in figure 2. A single capacitor, C4 (C_{ext} in figure 1), determines the frequency range of the VCO. With the value given, the 1M potentiometer (P1; R_{ext} in figure 1) can be used to set any frequency between approximately 10 Hz and 10 kHz The waveshape is selected by means of S1 switch closed for sinewave, switch opened for triangle.

The audio input signal is fed to the modulation input via C1. A voltage divider circuit (R1, P2, R2) sets two DC bias levels: the voltage across C2 provides the basic internal DC reference, and P2 is used to adjust the operating point of the multiplier This adjustment is important: it determines the 'carrier level' (the output from the oscillator)

Tabla

Technical data for the complete circuit (figure 3).

Functions

Ring modulator
Chopper
Frequency modulator

Frequency range of VCO:

Low range 1 Hz . . . 300 Hz
High range 100 Hz . . . 20 kHz

Frequency modulation:

± 30% frequency swing for 1V top-top modulation signal.

Impedances

Input 30 k
Output 2 k

Signal levels:

Input, nominal 1 V_{tt} (350 mV RMS)
maximum 8 V_{tt} (2.8 V RMS)
Output, maximum 10 V_{tt} (3.5 V RMS)

Supply

12 V, stabilised, 30 mA max

1

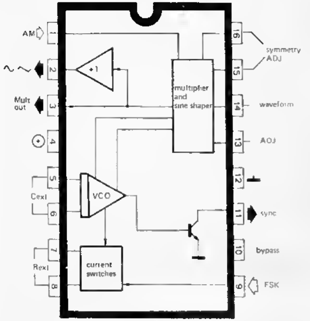

Figure 1. Internal block diagram of the 2206. This IC is a complete function generator, containing a VCO and a multiplier. The latter is ideally suited for use as a ring modulator.

2

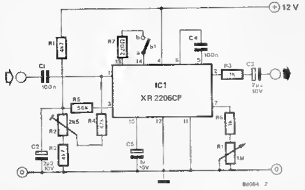

Figure 2. A simple circuit, using the 2206 as a ring modulator

present in the final audio output. The easiest way is to short the audio input and then adjust P2 for zero audio output. Only then is the circuit operating as a true ring modulator. If P2 is incorrectly set, the oscillator frequency will appear at the output, amplitude modulated by the input (speech) signal. This can give interesting effects, but it isn't really the intention!

A stabilised supply must be used, otherwise the DC settings may drift. This would mean regular re-adjustment of P2 — which is rather a nuisance.

Chopping and frequency modulation

The circuit can be extended, as shown in figure 3. Only a few additional components are needed to really use the IC to the full. Apart from adding the 'chopper' and 'frequency modulator' features, a useful linear frequency scale for the oscillator control is obtained as an additional bonus.

The basic ring modulator circuit is virtually identical to the circuit given in figure 2. The main difference is that the multiplier bias adjustment is improved: P3 is used for initial coarse adjustment, with P2 in the mid position; then P2 is used to tune out the last traces of the carrier.

The chopper circuit makes use of a squarewave output available at pin 11. To be more precise, this is the collector of an internal switching transistor (see figure 1). With S5 in position 'chopper', this point is connected to the signal output. When the transistor is turned on, the output is shorted; since the transistor is turned on and off periodically by the internal oscillator, the chopper frequency is determined by the setting of P5 (the VCO frequency control). Switch S2 can be used to select the audio signal before or after the ring modulator; note, however, that in the latter case the 'carrier' frequency for the ring modulator and the chopper

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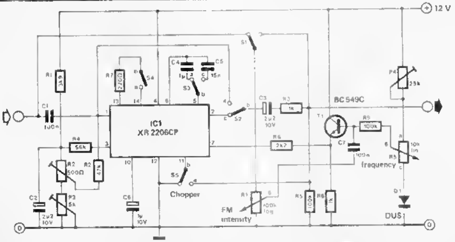
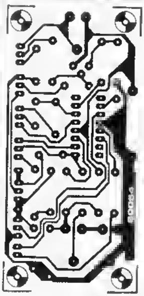
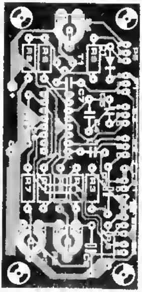


Figure 3. The simple circuit given in figure 2 can be extended as shown here. The 2206 is now used to the full: the input signal can be ring modulated and/or frequency modulated and/or chopped.





Parts list

Resistors:
R1 = 3k9
R2 = 47 k
R3,R8 = 1 k
R4 = 56 k
R5 = 100 k
R6 = 2k2
R7 = 220 Ω
R9 = 100 k
P1 = 100 k log
P2 = 470 Ω (500 Ω) preset
P3 = 4k7 (5 k) preset
P4 = 47 k (50 k) preset
P5 = 10 k lin

Capacitors
C1,C7 = 100 n
C2,C3 = 2μ2/10 V
C4 = 1 μ (not elco)
C5 = 15 n
C6 = 1 μ/10 V

Semiconductors:
IC1 = XR2206CP
T1 = BC109C, BC549C, or equ
D1 = DUS

Switches:
S1,S2,S3,S5 = single-pole changeover
S4 = single-pole, make

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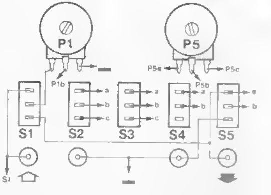

Figure 5. Wiring diagram for the front panel controls. The small arrows indicate connections to the corresponding points on the board

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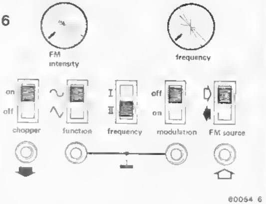

Figure 6. A suggested front panel layout

frequency are identical — they are both derived from the same VCO.

The main reason for modifying the frequency control circuit for the VCO is to obtain a linear voltage control point. The frequency of the VCO varies linearly with the voltage at the base of T1; this voltage is determined by the setting of P5, but a frequency modulation signal can be superimposed via C7. P1 sets the modulation level; S1 is used to select either the audio input signal or the output signal.

The frequency control range is set by P4. The procedure is as follows. Turn P5 right up (lowest frequency) and set P4 to maximum resistance. C5 is switched into circuit via S3 and P2 is offset so that the oscillator signal appears at the output. P4 is now slowly turned down until the oscillator stops, and then turned back until it starts again reliably. This is the optimum setting. Once again, it depends on the supply voltage — so the latter must be stabilised.

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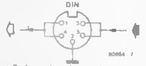


Figure 7. A combined in- and output can be wired as shown here

A simple supply using a 78L12, say, is adequate.

A basic printed circuit board layout for the circuit itself is given in figure 4, and the two sides of the front panel with the controls are shown in figures 5 and 6. Finally, a suggestion for a combined in- and output connection is shown in figure 7. All of these drawings are included as suggestions only, the final design may be modified according to personal taste.

How funny does it sound?

Sound effects are always difficult to describe — you've got to hear them. The ring modulator 'sound' is perhaps the best known: all kinds of additional frequencies are added to the original signal, without any harmonic relationship. If really sharp dissonances are what you want, the 2206 ring modulator is just the trick!

The effect can be 'improved' by switching from sinewave to triangle: if you're not careful, you end up with a completely scrambled signal. On the other hand, using a low-frequency sinewave produces a more 'pleasant' sound — the ring modulator adds an interesting rhythmic effect to the original.

The chopper facility can be useful on its own, producing a kind of 'robot' or 'computer' sound. When used in combination with the ring modulator, the most weird results can be obtained. In the same way, combining frequency modulation with the ring modulator can be interesting: low modulation levels produce a kind of vibrato effect, and high modulation levels — well. Try it!

electronic maze

Whether they are formed by garden hedges or walls, galleries of mirrors or simply lines on paper, mazes have always proven a popular pastime for all ages. The 'electronic maze' described in this article provides an extra 'twist' to the problem of finding the correct path through the maze.

D. Neubert

The problem in most mazes is simply to find the way out, with no account being taken of the number of false steps made. Part of the novelty of this electronic labyrinth is that it counts the number of incorrect steps made. The maximum number of errors permitted can be preset to 10, 20, 40 or even 80. If the hapless victim has failed to find his way out of the maze before reaching the preset limit, an audio tone sounds to indicate that he has lost. The number of steps taken to escape from the labyrinth is indicated on a digital display so that successful contenders can compare their scores, the one with the lowest score obviously winning.

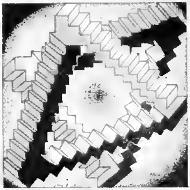
The maze itself consists of a matrix of drawing pins or furniture tacks on the playing board. All pins that lie along the correct path are linked and connected to positive supply, whilst other pins are grounded. The path through the maze is traced using a probe wired to the input of the error counter. So long as the correct path is followed the counter input will remain high, but whenever a false step is taken the counter input will receive a low-going pulse and will advance.

Complete circuit

The major part of the maze circuit consists of a two decade counter, which is shown in figure 1. The probe, which can be a 'banana' plug or may be made from an old ballpoint pen, is connected to the input of Schmitt trigger N2. So long as the probe input is high or floating (not grounded) the input of N2 will remain high. If the probe is grounded the input of N2 will be pulled low. The output of N1 will then go low, clocking the counter IC4. The filter network R4/C2 connected at the input of N2 helps suppress noise generated by 'contact bounce' between the probe and the drawing pins. This bounce could cause the counter to advance several counts for only one wrong step.

When the counter reaches a predetermined number, selected by S1, the appropriate output of the second decade counter (IC3) will go high. The oscillator constructed around N4 will then produce an audio tone to indicate that the conteslant has lost. This tone is amplified to loudspeaker level by T1 and T2. The volume can be adjusted by changing the value of resistor R3. The counter is reset to zero at the start of the game by a pushbutton switch, S2.

Two 7447 BCD-to-seven-segment decoders (IC1 and IC2) drive the seven-segment displays which indicate the number of errors made.



Multiple exits

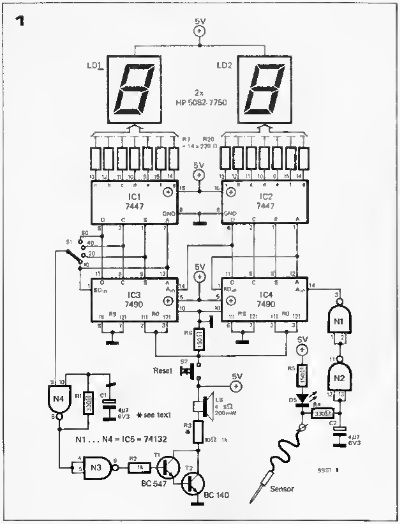
A maze with only a single path would quickly lose its entertainment value. This can be avoided by providing multiple exits from the maze. To achieve this, several paths are provided to exit points around the periphery of the maze. However, these are not permanently wired to positive supply, but each path is linked to positive supply only when it is in use, and all other paths are grounded. Light-emitting diodes mounted around the edge of the playing board indicate which exit is being aimed for.

The switching circuit used to select the paths of a four-exit maze is shown in figure 2. When exit D1 is selected, for example, then output D1 of the switching circuit is high. All points in the path leading to exit D1 only are linked to output D1. Provision is also made for connecting points that are common to two paths. For example, output A is high when output D1 is high and when output D4 is high (see table 1). Any points common to both these paths should be linked to output A. Output B performs a similar function for outputs D2 and D3. It is important that any points common to two paths should be linked to A or B and not back to any of the D outputs, as this would mean that one of the outputs would be trying to pull these points low while the other was trying to pull them high.

Provision is not made for connecting points that are common to three or more paths. Such points should be avoided when drawing the maze, but if any such points are unavoidable they should be treated as 'dead' points and left floating.

Constructing the maze

The construction of a 14 x 14 point maze is illustrated in figure 3. To con-



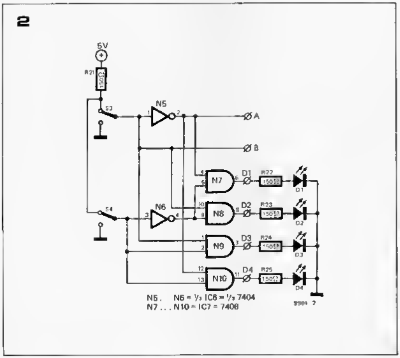


Figure 1. Circuit of the counter and audible warning oscillator, which forms the major part of the maze electronics.

Figure 2. This gating circuit provides four different exits from the maze by taking the required path high and all other paths low.

Figure 3. A typical layout for a 14 x 14 maze, with the four exits at the corners.

Figure 4. Mains power supply for the maze circuit.

Table 1. This table illustrates the four possible combinations of S3 and S4, and the state of the outputs that define which path through the maze is active.

struct the maze a sheet of squared (e.g. graph) paper is glued to a playing board made of suitable material such as strong card (Bristol board) or thin plywood. Drawing pins or furniture tacks are then pushed through the paper and the baseboard to form a matrix. It is important that the spacing between the heads of the tacks should be such that it is not possible to move the probe from one to the next without breaking contact.

On the underside of the board all tacks which form part of a path through the maze should be linked together and connected to the appropriate points (D1 to

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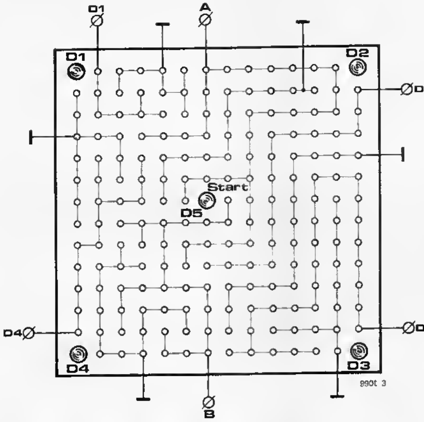

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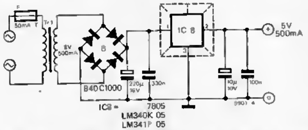


Table 1.

S3	S4	D1	D2	D3	D4	A	B
0	0	1	0	0	0	1	0
1	0	0	1	0	0	0	1
1	1	0	0	1	0	0	1
0	1	0	0	0	1	1	0

D4, A or B). Points not forming part of any path are permanent blind alleys and should be connected to ground.

How to play the game

A maze usually is nothing more than a complicated pattern of lines drawn on paper, and there is normally only one correct way through the maze with a large number of blind alleys leading off from the main path.

However, if 'walls' are drawn for this electronic maze it becomes a fairly simple task to find the proper way out. The game becomes much more interesting (or frustrating) if no lines are drawn, so that the path must be found in true 'hit or miss' fashion by the player. LED D5 indicates each false step, and the player must remember each step taken – otherwise the 'wrong step counter' will quickly reach the maximum permitted setting!

An alternative possibility is to construct a truly complicated maze, including lengthy and involved blind alleys, and draw in the walls alongside the rows and columns of the matrix. In this case the 'wrong step indicator' D5 and displays LD1 and LD2 should obviously not be visible to the player, as he would then be aware that he was wandering off the correct path.

Power supply

A suitable power supply circuit for the maze is given in figure 4. Care should be taken to ensure the electrical safety of the circuit, especially if it is to be used by children. All mains wiring should be extremely well insulated from the low-voltage circuits.

RF CIRCUIT DESIGN

Third in the series, this article discusses aspects of good VHF preamplifier design, before proposing a practical circuit that enables reception of FM broadcast signals hitherto lost in noise.

VHF PREAMPLIFIER

Some of the important aspects in aerial amplifier design have already been covered in *Elektor India* April 1986 issue, along with the prerequisites for successful VHF filter realization. While the points discussed in that article remain fully valid, the present article aims to look at the most important technical characteristic of any VHF preamplifier stage: its noise figure.

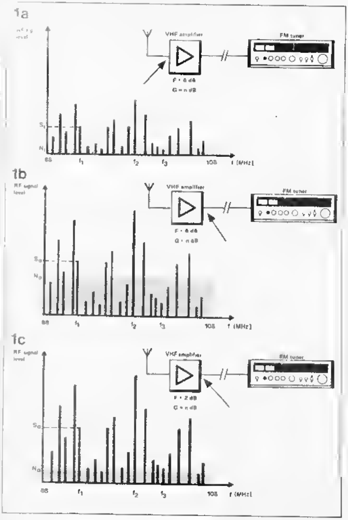
While many of today's FM tuners have very sophisticated tuning control systems and excellent stereo demodulation, the design of up-to-date RF amplification and first mixer sections often deplorably lags behind. Since it is certainly not advisable to embark upon a complete reshuffle of the proprietary RF parts in the receiver front end, an add-on preamplifier stage of good design may prove helpful in updating the receiver performance to a considerable degree. Moreover, as the above mentioned article already pointed out, a VHF aerial booster should not be mounted in the receiver, but at the other end of the downlead coax cable at the one and only place where it is effective; direct at the aerial connections (masthead mounting).

Noise

There are a number of basic considerations to go with design and construction of an RF preamplifier stage, if this is to operate in the very high frequency (VHF) range, generally referred to as 50... 300 MHz. A section of this band is of special interest for this article, namely the FM broadcast band which extends from 88 to 108 MHz; while being quite crowded with local stations in most built-up areas, only few stations may be received in rural districts. This is due to the straight line propagation characteristics of the RF waves at these frequencies, which makes it impossible to receive over-the-horizon stations, except during special weather conditions.

A typical daytime FM-band spectrum (= survey of signal strengths within a certain frequency band) may look very much as sketched in Fig 1a; there are a number of very strong transmissions, as well as relatively weak and also nearly invisible (i.e. inaudible) ones, sometimes quite close to one another. This spectrum is purely hypothetical, however, since it is a representation of relative signal strengths at the aerial connections, i.e. without noise caused by any active electronic device. Obviously, the spectrum analyser itself would feature a certain amount of self-generated noise, but this has been disregarded for the sake of clarity. The low noise level N_i in Fig 1a is, however, present at any

Fig 1 Representation of FM band spectrum analyses showing that the noise factor of the preamplifier stage determines to a large extent the number of stations that can be made audible in the FM receiver



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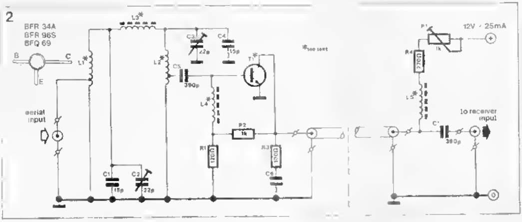


VHF aerial, since this picks up a certain amount of atmospheric noise; the nature of this effect would lead us into theoretical physics, which is beyond the scope of this article. Spectrum analysis of the preamplifier output signal (Fig. 1b) reveals that while all signals have been amplified, a certain amount of additional noise is introduced by the aerial booster, to the effect that some signals have got lost underneath the noise threshold N_o and are, therefore, inaudible in the receiver. Since the amplifier noise output is not caused by amplification of the atmospheric noise level N_i (compare the signal levels of f_3 in Fig. 1a and 1b), level N_o must needs be generated by the amplifier itself, clearly, this is an undesirable effect. If we consider the effective signal strengths of, for instance, the transmission at f_1 in Fig. 1a as opposed to Fig 1b, the total **noise factor** of the amplifier stage may be defined as the overall ratio of the output signal/noise ratio to the input signal/noise ratio, or

$$F=(S_o/N_o)/(S_i/N_i) \qquad (1)$$

the **noise figure** may be calculated from F using

$$F_{dB}=10\log_{10}F \qquad (2)$$

Clearly, S_o/N_o for f_1 is worse (lower) than the original S_i/N_i and this arises from the extra amount of noise generated by the amplifier. Were this device ideal, then

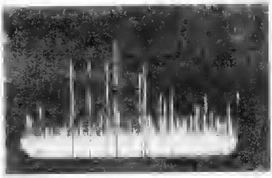
$$S_o/N_o=S_i/N_i \text{ or } F=1, \text{ or } F_{dB}=0\text{dB} \qquad (3)$$

Unfortunately, no electronic device has been developed as yet for use in the ideal preamplifier, nor will it ever be developed, due to some basic laws of physics. However, modern SHF transistors are now readily available with noise figures as low as 1.5 dB at 1000 MHz, while Gallium Arsenide (Ga-As) FETs have been designed to achieve 2.8 dB at 12 GHz; however, the cost and circuit design complexity of these devices puts them well beyond the reach of the average home constructor.

The importance of a low preamplifier noise figure is evident after a comparison of Figures 1b and 1c; while its signal gain (amplification factor) is still ndB, the amplifier of Fig 1c has a noise figure improved by 4 dB, which enables reception of signals that were inaudible with the F=6 dB amplifier of Fig 1b. We may, therefore, establish the general rule that reception is improved with a lower preamplifier noise figure. Thus, designing for low noise should be a high priority issue.

So far, only the active device in the preamplifier has been held responsible for the noise addition, but it should be pointed out that this device can only attain its minimum noise contribution when supported by passive components that ensure thermal stability and low signal insertion loss at the amplifier input. It will stand to reason that any mismatch at the booster input will adversely affect (i.e. increase) the transistor noise figure as given in the manufacturer's data sheets.

No preamplifier stage, however low its noise figure, will be capable of reception improvement if the signals at the target frequency have been considerably attenuated before being applied to the first active device, either by download cable losses or a severe mismatch at the booster input. As the above mentioned article pointed out, however, the preamplifier input necessarily consists of a low-loss filter, which serves the dual function of an out-of-band signal attenuator and signal source to transistor input impedance transformer (source matching). It should be fairly obvious by now that the actual gain of the booster is far less important than its noise figure, if the former is some 10 dB higher than the downlead cable attenuation, adequate results are usually obtained; a gain of 15...20 dB is common for a single-transistor preamplifier stage.



Practical circuit

The circuit diagram of the present VHF preamplifier is shown in Fig. 2. The RF signal at the input is passed to the base of T_1 by a capacitance-tuned, inductive top-coupled, low insertion loss and source matching bandpass input filter with a −2 dB bandwidth of 20 MHz (88...108 MHz). This is quite a mouthful for a basically simple filter that performs the functions outlined above. Note the taps on L_1 and L_2 to obtain impedance matching of the cable and the transistor respectively. Any of the listed transistor types may be used in the circuit, but the Type BFQ69 is preferable because of its extremely low noise figure. Since this transistor has been introduced only quite recently, however, it may prove difficult to get hold of.

The amplifier is fed by the receiver power supply over the downlead coax cable, the parts to the right of the dotted line are, therefore, mounted in the FM tuner. Decoupling parts L_5 and C_7 ensure that no RF signal is lost in the power supply. The amplifier bias setting is effected with P_1; depending on the transistor in use, this preset may be adjusted to find the right compromise between

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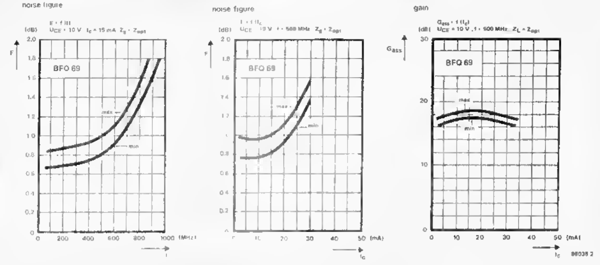

Fig 3 Curves showing the characteristics of the new BFQ69 transistor. Note that the curves in Figures 3b and 3c refer to a test frequency of 500 MHz and not to the design frequency of the present preamplifier (Siemens)

optimum noise figure (low current) or maximum amplification with acceptable intermodulation response (high current). For further details on the bias setting of RF preamplifier transistors, refer to *Elektor Electronics (UK)*, February 1980 issue. Fig. 3 shows three curves relevant to the novel BFQ69, a collector current of 15 mA appears to be suitable for a minimum noise figure of about 1 dB, which will bring the total noise figure of the present design in the 1 . . 2 dB range with a Type BFQ69 fitted and the filter tuned to optimum input matching. However the Types BFR34A and BFR96S will also ensure a noise figure that is usually far better than the average FM tuner specification in this respect

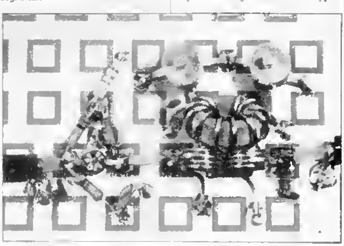

Fig 4 This RF design is also fitted on the universal prototyping board 85000 available through the Readers Services

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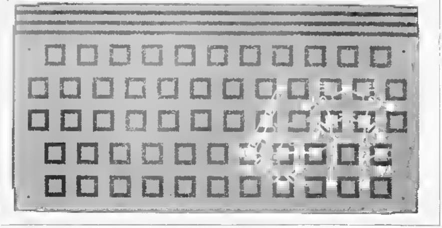


The coils and chokes for the present design are wound as follows:

L_1 = 4 turns 20SWG (ϕ 1 mm) enamelled wire, close wound on dia 6 mm, tap at 1.5 turns from earth.

L_2 = identical to L_1, but tap at 2.5 turns from earth.

L_3 = 11 turns 20SWG enamelled wire on toroid core Type T50-12 (Amidon).

L_4; L_5 = 4.5 turns 30SWG (ϕ 0.3 mm) enamelled wire through 3x3 mm ferrite bead

For more information on inductor calculations and specifications, refer to last month's issue of *Elektor Electronics*.

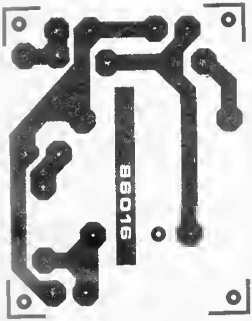
Construction and alignment

The present amplifier is fitted on the universal RF board 85000 as shown in Fig 4; not shown are the bias setting parts, since these are mounted in the receiver. After completion, the unit may be tested by tuning the receiver to a weak transmission at about 95 MHz and adjusting C_1 and C_2 for optimum reception. The collector current setting should be fairly uncritical, its precise effect on the amplifier performance can only be judged when a very stable and yet sufficiently weak transmission is being received and the input filter has already been correctly tuned. Finally, the preamplifier may be fitted in a suitable water-resistant case for masthead mounting, equipped with suitable coaxial sockets, and fixed to the aerial mast.

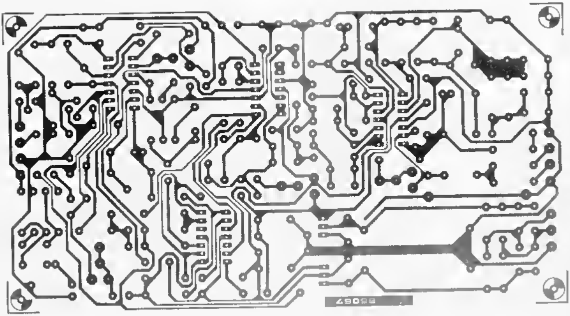
JB;JB

PCB track patterns for
Subwoofer & Satellite loudspeaker

Satellite loudspeakers



Subwoofer



REAL-TIME CLOCK

A good many highly interesting computer applications will no doubt have been cancelled for lack of a programmable time keeping device. This article, however, offers a truly up-to-date RTC extension board to program dates with data!

With the presentation of the universal I/O bus in the June 1985 issue of *Elektor India* the peripheral handling capabilities of the popular C64 computer, as well as other personal micros, have been considerably enhanced, since the I/O bus board allows a number of extension boards to be inserted in a neat and versatile arrangement.
The present design enables the user to program real-time software drivers without the need for critical and cumbersome machine language wait loops. Time and data can now be read from and written to I/O addresses, in the very same manner as customary with peripheral control ports; the time updating process is autonomously controlled by a dedicated low-power chip: the Type ICM 7170 manufactured by Intersil.
In order to be useful for many owners of personal micros currently on the market, the present add-on RTC board has been designed to operate in both 6502- and Z80-based systems equipped with Elektor's universal I/O bus. However, there is one important restriction for use with the Z80 processor: since the I/O bus was originally intended for the 65XX series of microprocessors as used in Commodore machines, no bus line is left over for the Z80 $\overline{NMI}$ or $\overline{INT}$ input; this means that the alarm and periodic interrupt facilities offered by the RTC chip can not be put to use in conjunction with the Zilog CPU. None the less, the time and calendar features of the ICM7170 will also be fully functional with the Z80.

Inside the RTC chip

Since the real-time clock controller (RTC) Type ICM7170 is an all-CMOS device with extremely low power consumption, it may conveniently be operated from a back-up battery to keep the internal oscillator and counter sections working when the computer supply voltage is off, or when a mains failure occurs.
The main features of the RTC chip in the proposed circuit may be summarized as follows:

- full compatibility with 8-bit microprocessor types that have either a fully decoded or multiplexed address bus;
- time registers supply binary coded data to simplify software;
- faultless RTC register-to-CPU data transfer thanks to intermediary buffer section;
- calendar with automatic leap year correction;
- chip switches automatically to back-up supply;
- chip access time less than 300 ns;
- software selection of one of four crystal frequencies;
- data buffering after any read of 10 millisecond register (1/100th part of a second);
- programmable alarm with memory function;
- CPU interrupt requests generated by alarm section or by one of six selectable periodic signals;
- 2 μA typical standby current at 3V and oscillator frequency of 32 kHz

The internal organization of the ICM7170 RTC controller is shown in Fig 1. The chip has a low-power Pierce-type CMOS oscillator which only requires two external capacitors and a quartz crystal to obtain an accurate frequency standard for the present RTC extension board. One of the capacitors is an adjustable type for precise alignment of the crystal frequency, which is divided down to 4 kHz by a programmable prescaler section. By virtue of this prescaler, four crystal frequencies may be used with the on-chip oscil-

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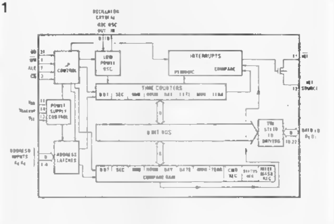


Fig. 1 Internal organization of the Type ICM7170 chip, an all CMOS and microprocessor compatible real-time clock (RTC) controller

Table 1

COMMAND REGISTER ADDRESS (10001b, 11h) WRITE–ONLY							
D7	D6	D5	D4	D3	D2	D1	D0
n/a	n/a	Test	Int	Run	12/24	Freq	Freq

Table 1. RTC command register organization

Table 2

D1	D0	CRYSTAL FREQUENCY	D2	24/12 HOUR FORMAT	D3	RUN/STOP	D4	INTERRUPT ENABLE	D5	TEST BIT
0	0	32.768kHz	0	12 hour mode	0	Stop	0	Interrupt disabled	0	Normal Mode
0	1	1 048576MHz	1	24 hour mode	1	Run	1	interrupt enable	1	Test Mode
1	0	2 097152MHz								
1	1	4 194304MHz								

Table 2. Programming functions of bits D_0 ... D_5 in the command register at address 11_{hex}

Table 3

ADRESS						FUNCTION	DATA								VALUE
A4	A3	A2	A1	A0	HEX		D7	D6	D5	D4	D3	D2	D1	D0	
0	0	0	0	0	00	Counter 1/100 seconds		–					–	–	0–99
0	0	0	0	1	01	Counter hours	–	–	–			–	–	–	0–23
						12 Hour Mode	–	–			–	–	–	–	1–12
0	0	0	1	0	02	Counter minutes	–	–			–	–	–	–	0–59
0	0	0	1	1	03	Counter seconds	–	–	–		–		–	–	0–59
0	0	1	0	0	04	Counter month	–	–			–	–	–	–	1–12
0	0	1	0	1	05	Counter date	–	–				–	–	–	1–31
0	0	1	1	0	06	Counter year	–	–	–			–	–	–	0–99
0	0	1	1	1	07	Counter day of week	–	–	–		–	–	–	–	0–6
0	1	0	0	0	08	RAM 1/100 seconds	M	–	–	–	–	–	–	–	0–99
0	1	0	0	1	09	RAM hours	–	M	–		–	–	–	–	0–23
						12 hour Mode	*	M					–	–	1–12
0	1	0	1	0	0A	RAM minutes	M	–					–	–	0–59
0	1	0	1	1	0B	RAM seconds	M						–	–	0–59
0	1	1	0	0	0C	RAM month	M	–				–	–	–	1–12
0	1	1	0	1	0D	RAM date	M	–	–	–		–	–	–	1–31
0	1	1	1	0	0E	RAM year	M	–			–	–	–	–	0–99
0	1	1	1	1	0F	Ram-day of week	M	–			–	–	–	–	0–6
1	0	0	0	0	10	Interrupt Status and Mask Register	+	–			–	–	–	–	
1	0	0	0	1	11	Command register	–	–	–	–	–	–	–	–	

Table 3. Address organization for the RTC counter sections and their RAM counterparts

Notes

\+ = not present in interrupt-mask register, MSB in interrupt-status register.
– = not used.
* = AM/PM in 12-hour indication mode; (AM = 0, PM = 1).
M = alarm time is compared with corresponding counter time when this bit is programmed low (0)

Note that addresses 10010 up to and including 11111 (i.e. 12_{hex} ... $1F_{hex}$) are not used by the RTC chip.

Table 4.

INTERRUPT MASK REGISTER ADDRESS (10000b, 10h) WRITE-ONLY							
D7	D6	D5	D4	D3	D2	D1	D0
n/a	Day	Hour	Min	Sec	1/10 sec	1/100 sec	Alarm

INTERRUPT STATUS REGISTER ADDRESS (10000b, 10h) READ–ONLY							
D7	D6	D5	D4	D3	D2	D1	D0
Int	Day	Hour	Min	Sec.	1/10 sec.	1/100 sec	Alarm

Table 4. Organization of the internal RTC interrupt mask and interrupt status registers at address 10_{hex}

lator: 4.194304 MHz, 2.097152 MHz, 1.048576 MHz, or 32.786 kHz. As can be seen from Tables 1 and 2, two bits, D_0 and D_1 in the RTC command register at address 11_{hex} (10001_2) select the appropriate prescale divisor for the crystal in use. Databit D_2 allows selection between 12- or 24-hour mode operation.

The 4 kHz signal is next divided down to 100 Hz for use as a central clock input to the ripple counter stages. The time and calendar data are available from eight sequentially arranged and programmable counter sections: 10 milliseconds, seconds minutes, hours, day of the week, date, month, and year. The information is binary coded and basically consists of eight bits per section, as can be seen from Table 3. However, since a maximum indication of 31 is sufficient for the date counter, 59 for the seconds counter, and so on, eight bits are never required (2^8 = 256); the unused ones are kept logic low (0) during a read, while they are not observed ('don't care') in the case of a write operation. Also inside the chip is a 51-bit RAM memory area to hold the alarm time and date as programmed by the user; these registers are loaded in exactly the same way as the updated counter sections. When set to the alarm mode, the RTC chip will generate an interrupt request signal when the current (updated) time matches the preprogrammed alarm time, i.e. the updated counter sections are constantly compared on a byte-by-byte basis to their RAM counterparts after every counter step. If a certain counter section is to be ignored in this continuous comparison, the user may set the M (mask) bit in the relevant RAM byte, which will prevent an interrupt from being generated if the updated counter contents match those of the corresponding alarm register.

The RTC chip interrupt request output may be programmed to supply any one of the following periodic

2

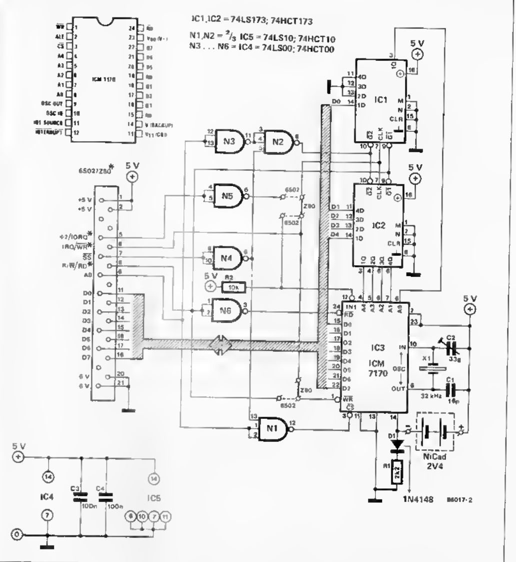


Fig. 2. By virtue of the high number of functional sections contained in IC_3 the final circuit of the RTC extension board is fairly simple. Note that it is not possible to use the RTC chip interrupt facilities in Z80-based systems, since this would require an additional bus line.

digital signals: 100 Hz, 10 Hz, 1 pulse/second, 1 pulse/minute, 1 pulse/hour, or 1 pulse/day. Provision has been made for both simultaneous and independent interrupt operation of the alarm and periodic signal circuitry.

Both the alarm and periodic interrupts are under the control of the interrupt-mask register (IMR) and interrupt-status register (ISR), the bit assignments of which are shown in Table 4. Selection of the desired interrupt signal is effected by setting the relevant bit in the IMR. By reading ISR, the CPU is informed about the nature of the interrupt request; ISR is automatically cleared by the falling edge of the CPU read pulse.

Whatever the source of the interrupt request signal, it may or may not be passed to the 6502 $\overline{IRQ}$ line depending on the logic level of the interrupt enable bit in the RTC command register (see Table 1). This bit controls an on-chip output FET which has its drain connected to the $\overline{INT}$ terminal (pin 12) and its source to the INTERRUPT-SOURCE terminal (pin 11). This arrangement allows the $\overline{INT}$ output to be used in an existing WIRED-OR interrupt request bus configuration, together with other devices that may supply interrupts to the CPU. If an interrupt is generated by the RTC chip, the $\overline{INT}$ output will be at near interrupt-source potential, since the FET is switched on internally; this may occur both in the stand-by and in the power-down (battery back-up) mode.

If, as in the proposed circuit, the RTC supply voltage is connected to the V_{dd} and V_{ss} terminals, and the interrupt-source connection also to V_{ss}, the $\overline{INT}$ output can only be active (i.e. logic low with respect to V_{ss}) in the presence of a sufficiently high chip supply voltage; that is, when the computer has been switched on (RTC fully operational). In case the user wishes to pass interrupts in the power-down mode only, pin 11 should be connected to the negative terminal of the battery at the V_{backup} pin. This arrangement may be useful to activate a computer wake-up circuit after a predetermined time has elapsed since system power-down.

When the voltage between the V_{backup} and V_{ss} terminals drops below 1 V, the RTC chip switches to the power-down mode with only the internal clock and interrupt sections active; all other functions are disabled to ensure minimum power consumption from the back-up battery. Chip terminals $A_0 \ldots A_4$, $D_0 \ldots D_7$, ALE, $\overline{WR}$, $\overline{RD}$, and $\overline{CS}$ are internally connected to V_{dd} with a single 50 kΩ resistor. In case a battery back-up supply voltage can be dispensed with, V_{dd} may be connected to V_{backup}.

Practical circuit

The proposed circuit of the real-time clock extension board for the universal I/O bus is shown in Fig. 2. Note that very few components are required to make a functional unit with the ICM7170 RTC chip in a 6502- or Z80-based system. To select between these two types of microprocessor, the user need merely fit the appropriate wire links; connection to the I/O bus is through a standard 21-way PCB connector.

The ready-made PCB for this project is fitted with the necessary parts as shown in the mounting plan of Fig. 3. Note that the battery is an integral part of the completed RTC board; it may be charged from the computer +5V supply by means of D_1 and R_1.

Since it was considered a waste of available I/O address space to reserve 17 memory locations or I/O channels for the RTC registers, IC_1 and IC_2 latch the RTC register number which must be supplied as a databyte with a POKE or OUT instruction to an address within the slot that has a ∅ for address line A_0; the contents of the RTC chip registers are next read from or written to an address within the same slot with A_0 high (1). Since every slot offers four I/O addresses (see the article on the universal bus, *Elektor Electronics*, June 1985), both the latch and the RTC chip appear two times within the slot occupied by the present extension board. Finally, Z80 programmers are referred to the first article in the series on MSX extensions in the February 1986 issue of *Elektor India* to find details on modification of the universal I/O bus as required for this CPU.

Setting up

As can be seen from Table 1, the real-time clock may be stopped and started by programming bit D_3 in the command register; this bit controls the 100 Hz clock input to the counter sections. To stop the clock in order to synchronize it with an available time standard, D_3 must be set low (∅). The desired start time for the RTC is next loaded into the time registers, the correct data is also supplied, and the RTC may be started at the desired time by setting D_3 again (1).

To enable the CPU to read glitch-free and therefore absolutely stable time data from the RTC chip, time register data are passed through a buffer section before being transferred to the CPU databus during a read cycle. However, this buffer is only loaded when the 10 ms register is read, and programmers are advised to start any time reading from the RTC chip with a read of this latching register to ensure that time data are stable and accurate.

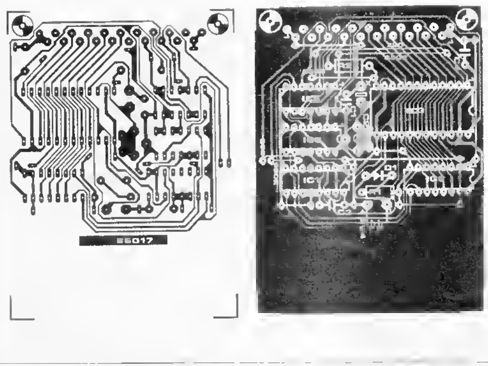
The command register comprises a TEST bit (D_5) to apply the internal 100 Hz signal to the seconds counter; this will cause the clock to run a hundred times faster than normal, which may be useful for test purposes.

It will be evident that the accuracy of the present RTC board depends solely on crystal stability and correct frequency setting of the oscillator. Outlined below is a preferred alignment method using a period counter such as the one featured in *Elektor India* February 1985. To prevent the RTC $\overline{INT}$ output from actually generating an interrupt pulse in the computer during the alignment session, temporarily disconnect the wire at pin 12 of IC_3.

First, write all zeros to the IMR. Next, load the command register with decimal values 24 or 28 (18 or 1C hexadecimal respectively) to run the clock in either the 12- or 24-hour mode with interrupts enabled. Now set D_3 in the IMR to generate periodic interrupts with a frequency of 1 Hz. Adjust capacitor C_2 for an indication of exactly 1.000 second on the period counter which should be connected to the RTC chip $\overline{INT}$ output (pin 12). For this measurement, the period counter should be set to trigger on the falling edge of the digital input signal. Reset ISR by

Fig. 3. Component mounting plan for the RTC extension. Note the on-board NiCd battery and the wire links to accommodate either the 6502 or the Z80 processor in the host computer.

3



Parts list

Resistors
R_1 = 2k2
R_2 = 10k

Capacitors
C_1 = 18p
C_2 = 10 33p trimmer
C_3;C_4 = 100n

Semiconductors:
D_1 = 1N4148
IC_1,IC_2 = 74HC(T)/LS173
IC_3 = ICM7170 (Intersil)
IC_4 = 74HC(T)/LS00
IC_5 = 74HC(T)/LS10

Miscellaneous
X_1 = 32 768 kHz quartz crystal (subminiature type)
21 way DIN41617 connector, angled connections
NiCd battery 2.4V or two 1.2V cells connected in series
PCB 86017

```
5 CLS:PRINT"**** MSX REAL-TIME CLOCK ****"
7 OUT 113,17:OUT 112,4:REM STOP CLOCK
9 REM GO GET TIME&DATE INFO
10  N=0:U$="SYNCHRO":GOSUB 1000
20 CLS: PRINT "SET ";U$;"DATE =";A(N+5);"-";A(N+4);"-";A(N+6)
30 PRINT "SET ";U$;"TIME =";A(N+1);":";A(N+2);":";A(N+3);"*";10*A(N)
40 PRINT "IF CORRECT PRESS [Y]":INPUT Q$:IF Q$="Y" OR Q$="y" THEN 60
50 GOTO 7
55 REM GO LOAD RTC
60 N=0:GOSUB 2000
70 CLS:PRINT"HIT ANY KEY TO START CLOCK"
75 IF INKEY$="" THEN GOTO 75
80 CLS
84 REM READY TO START CLOCK
85 OUT 113,17:OUT 112,12
90 OUT 113,0:A=INP(112):REM 10MS LATCH
100 OUT 113,3:S=INP(112)
110 OUT 113,2:M=INP(112)
120 OUT 113,1:H=INP(112)
130 LOCATE0,0:PRINT"TIME=";H":";M;":";S
140 IF INKEY$="" THEN GOTO 90
150 END:REM OPTION HERE FOR RETURN
1000 REM GET TIME AND DATE
1010 INPUT"YEAR = 19";A(N+6)
1020 INPUT"MONTH = (1-12)";A(N+4)
1030 INPUT"DATE = (1-31)";A(N+5)
1040 INPUT"DAY OF THE WEEK = (0-6)";A(N+7)
1050 INPUT "HOURS = (0-23)";A(N+1)
1060 INPUT "MINUTES = (0-59)";A(N+2)
1070 INPUT "SECONDS = (0-59)";A(N+3)
1080 INPUT "10 MILLI-SECONDS = (0-99)";A(N)
1090 RETURN
2000 REM LOAD RTC REGISTERS
2005 FOR N=N TO N+7
2010 OUT 113,N:REM POINT LATCH
2020 OUT 112,A(N):REM LOAD RTC
2030 NEXT N
2040 RETURN
```

Listing 1. The essentials of MSX real-time clock programming. Although the present RTC hardware does not support interrupts with the Z80, provision has been made to set the RTC alarm function. For this purpose, the subroutines at lines 1000 and 2000 may be called with N=8 and U$="ALARM". Note that the register latch is at OUT 113, the RTC proper at INP/OUT 112.

reading it; this will also deactivate the $\overline{INT}$ output (logic 1). The outlined method should be programmed as an instruction loop to obtain maximum clock accuracy.

Where a period counter is not readily available, use may be made of another time reference signal with known accuracy, such as the BBC time signals on radio and TV. Obviously, this method costs more time and requires a good deal of patience before the target accuracy is reached.

RTC programming

Hardware needs software support and vice versa. To complete this article, two sample programs are offered to guide in further programming explorations, which will, no doubt, lead to more complex and sophisticated time-keeping software once the basics of RTC control have been mastered.

Programmers should be well aware of the essential difference in I/O mapping between the Commodore type of computer and Z80-based micros, such as the MSX series. Generally speaking, the former use memory locations for I/O byte transfer, the latter have 256 I/O channels available which are under control of IN and OUT instructions, whereas the 65XX-based computers work with PEEKs and POKES for this purpose. However, the basic method of RTC control remains the same for both computer types: first the internal RTC register is specified with an appropriate instruction, then data may be read from or written to that register by addressing the RTC proper.

MSX users may key in the program of Listing 1 which displays a digital clock in the top left-hand corner of the screen. Obviously, the screen formatting and graphics features of this computer type allow the user to 'brush up' this little program to his heart's content. Note that line 100 reads the 10 ms register before the actual time reading is performed in a loop. Experienced programmers may have a go at writing a routine that prints time and date on every printer sheet prior to a listing or any other draft copy. Note that, once the clock has been synchronized, time display is simply effected with GOTO 90. However, some provision will have to be made to exit the time display loop and resume the main program.

The sample program listed for the Commodore 64 and 128 model computers is somewhat lengthier than the MSX version, and, therefore, offers more programming functions; among these are selection of video polarity and word-based input of days and months — see Listing 2.

HS:GS

```
10 REM * COMMODORE 64 REAL-TIME CLOCK CONTROL *
20 DIM A$(12),B$(7)
30 RESTORE
40 FOR Q=1 TO 12:READ A$(Q):NEXT Q
50 DATA "JANUARY","FEBRUARY","MARCH","APRIL","MAY","JUNE","JULY","AUGUST"
60 DATA "SEPTEMBER","OCTOBER","NOVEMBER","DECEMBER"
70 FOR Q=1 TO 7: READ B$(Q): NEXT Q
80 DATA "MONDAY","TUESDAY","WEDNESDAY","THURSDAY","FRIDAY","SATURDAY","SUNDAY"
90 PRINT CHR$(147):PRINT:PRINT"--COMMODORE 64 REAL-TIME CLOCK CONTROL--"
100 PRINT:PRINT:PRINT:
110 INPUT"CLOCK SETTING (Y/N)";V$
120 IF V$="N" THEN 365
130 PRINTCHR$(147)
140 REM CLOCK SETTING
150 INPUT " ENTER HOURS ";H:PRINT:PRINT
160 INPUT " ENTER MINUTES ";M:PRINT:PRINT
170 INPUT " ENTER SECONDS ";S:PRINT:PRINT
180 INPUT " ENTER MONTH ";M$:PRINT:PRINT
190 FOR Q=1 TO 12: IF M$=A$(Q) THEN R=Q
200 NEXT Q
210 INPUT " ENTER DATE ";D:PRINT:PRINT
220 INPUT " ENTER YEAR ";F:PRINT:PRINT
230 F1=INT(F/100):F2=INT(F1/10):F3=F1-10*F2:Y=F-F1*100
240 INPUT " ENTER DAY OF THE WEEK ";W$:PRINT:PRINT
250 FOR Q=1 TO 7:IF W$=B$(Q) THEN E=Q
260 NEXT Q
270 INPUT " PRINT MODE (NORMAL/REVERSE) ";P$: IF P$="R" THEN C=128
280 POKE 56832,17:POKE 56833,4:REM 24 HOURS-MODE SELECT
290 POKE 56832,1:POKE 56833,H:REM SET HOUR
300 POKE 56832,2:POKE 56833,M:REM SET MINUTES
310 POKE 56832,3:POKE 56833,S:REM SET SECONDS
320 POKE 56832,4:POKE 56833,R:REM SET MONTH
330 POKE 56832,5:POKE 56833,D:REM SET DATE
340 POKE 56832,6:POKE 56833,Y:REM SET YEAR
350 POKE 56832,7:POKE 56833,E:REM SET DAY OF THE WEEK
360 POKE 56832,17:POKE 56833,12:REM ACTIVATE CLOCK
365 PRINT CHR$(147)
370 POKE 56832,0:REM PUT TIME IN LATCH
380 POKE 56832,1:H=PEEK(56833):REM READ HOUR
390 POKE 56832,2:M=PEEK(56833):REM READ MINUTES
400 POKE 56832,3:S=PEEK(56833):REM READ SECONDS
410 DH=INT(H/10):UH=H-DH*10+C:DH=DH+C:REM PRINT HELP HOURS
420 DM=INT(M/10):UM=M-DM*10+C:DM=DM+C:REM PRINT HELP MINUTES
430 DS=INT(S/10):US=S-DS*10+C:DS=DS+C:REM PRINT HELP SECONDS
440 POKE 56832,4:R=PEEK(56833):REM READ MONTH
450 POKE 56832,5:D=PEEK(56833):REM READ DATE
460 DD=INT(D/10):UD=D-DD*10:REM PRINT HELP DATE
470 POKE 56832,8:Y=PEEK(56833):REM READ YEAR
480 DY=INT(Y/10):UY=Y-DY*10:REM PRINT HELP YEAR
490 POKE 56832,7:E=PEEK(56833):REM READ DAY OF THE WEEK
500 KL=54272:REM PRINT TIME WITH COLOUR HELP
510 POKE1051,DH+48:POKE1051+KL,14
520 POKE1052,UH+48:POKE1052+KL,14
530 POKE1053,58+C:POKE1053+KL,14
540 POKE1054,DM+48:POKE1054+KL,14
550 POKE1055,UM+48:POKE1055+KL,14
560 POKE1056,58+C:POKE1056+KL,14
570 POKE1057,DS+48:POKE1057+KL,14
580 POKE1058,US+48:POKE1058+KL,14
590 PRINT:PRINT TAB(27);B$(E)
600 POKE1171,DD+48:POKE1171+KL,14
610 POKE1172,UD+48:POKE1172+KL,14
620 PRINTTAB(30);A$(R)
630 PRINT "";:REM CURSOR 3 LINES UP
640 POKE1211,49:POKE1211+KL,14
650 POKE1212,57:POKE1212+KL,14
660 POKE1213,DY+48:POKE1213+KL,14
670 POKE1214,UY+48:POKE1214+KL,14
680 GOTO 370
```

Listing 2. Commodore 64 and 128 users may enter this BASIC program, intended as a guide to further experiments with the real-time clock board as described in this article. Note the PEEK and POKE instructions to access the RTC registers at locations 56832_{10} (RTC) and 56833_{10} (latch)

junior computer

The cost and complexity of home computers is a serious deterrent to the newcomer to computer operating and programming. We know of meny reeders who would like to 'build their own' but who lack the necessary technicel knowledge. The Junior Computer hes been designed (for just this reason) as an ettempt to 'open the door' to those readers who need a push in the right direction.
It should be emphasized that, elthough simple to construct, the Junior Computer is not a 'toy' but a fully workable computer system with the capability for future expension. It has been designed for use by emateurs or experts.
The purpose of this erticle is to give e generel description of the operetion of the Junior Computer. It has been decided to publish e more detailed description in book form.
The arrival of 'The Junior Computer' Books 1 and 2 on the market will be ennounced shortly. This, however, is e preview intended to give the reader en idee of whet the computer entails.

There are meny raeders who would like to know mora about home computers but who may not be technically minded or who consider them too complicated to understend. These two reesons, coupled with cost, tend to prevent many people from 'taking the plunge'. To help overcome these problems we have designed the Junior Computer (JC). Do not be misled by the term 'Junior' – this computer provides the first step to understanding large and powerful systems. When fully expanded the Junior Computer can work with higher level languages. It uses a simplified method of operation and has the edvantage of various expansion possibilities.

The heart of the JC occupies no more than a single printed circuit board which should dispel any fears produced by large end complicated systems. The intention of this article is to encourege readers to take the intitial steps towerds constructing and operating their own personal computer. Extensive and precise deteils will not be dealt with here but will be published in depth in book form – the Junior Computer Books 1 and 2. We can however whet the appetite and set the balt rolling. Specific deta concerning the computar are given in Table 1, this is intended for reeders who are already familiar with computers.

Block diagram

The fundamental features of the Junior Computer are shown in the simplified block diagram of figure 1. The heart of any computer system is the CPU, or central processing unit. In this perticuler case it is a 6502 microprocessor, a 40 pin chip that you cen hold in the palm of your hand – but shouldn't! Its purpose is to control communications between the various units inside the computer in eccordance with the instructions of the program. A clock generetor (oscilletor) serves as e 'pacemeker' for the processor.

A certain amount of memory is raquired by tha microprocessor to store programs end date. In the JC it consists of two sections. The first one for storing permenent deta and the monitor programe The monitor program conteins a number of routines which perform such chores as program loeding, debugging and genaral housekeeping. The second section of memory is used for storing temporary data and progrem instructions

Tha block marked I/O (input/output) maintains contact between the computer and the outside world including the keyboerd and display. In the circuit tha I/O appears es the PIA, or peripheral interface adepter. It takes cere of the data transfer in two directions end can (temporarily) store date. The operator communicates with the computer via the keyboard end display.

Computers are not as 'intelligent' as some television programmes would hava us believa In fect, they marely carry out (programmed) instructions in a certein (programmable) order. Thera ere three sets of parallel interconnactions (called buses) which carry tha various date and control signals. First of all there is the dete bus to consider. It is made up of a number of lines along which date travels from block to block. The processor must also be able to indicate the memory location where date is to be stored or removed. This is performed by the second bus, the adress bus. Last, but by no means least, is the control bus which ensures that the CPU is eble to control the internel status, for instence the nature and direction of datatrensfer and the progress of successive programs sections.

This then very briefly covers the various blocks, their functions and their interconnections. We can now move on to look et the circuit in greater detail.

Circuit diagram

The circuit diagram of the entire Junior Computer (except for the power supply) is shown in figure 2. Now that the block diagram has been examined, each section should be easily recognisable. The 6502 microprocessor is IC1. Below it is clock generator formed by N1, R1, D1, C1 and the 1 MHz crystal. The system uses a two-phase clock, shown in the circuit diagram as signals Ø1 end Ø2. The memory is constituted by IC2, IC4, IC5 and part of IC3. The monitor program is stored in IC2, which is en EPROM (Erasable Programmable Read-Only-Memory). This is the basic program in the computer (not to be confused with BASIC – a high level computer language). The RAMs (Rendom Access Memory) IC4 and IC5 serve as user memory and together have a capacity of 1024 bytes.

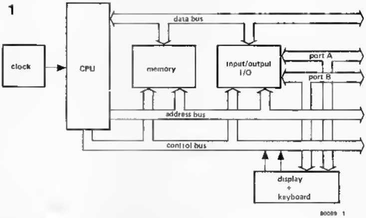


Figure 1. Block diagram of the Junior Computer.

In the PIA, IC3, there are another 128 bytes of RAM. The PIA constitutes a data buffer which controls all the data transfer passing in either direction between the computer and ports A and B. The port lines are fed out to a 31 pin connector. IC3 also contains a programmable interval timer.

The displays (Dp1 ... Dp6) and keys (S1 ... S23) are at the bottom of the circuit diagram. Of these keys, sixteen are for the purpose of entering data and addresses in hexadecimal form and the remaining seven have various control functions. Data to the displays and from the keyboard is transferred across seven lines from port A. The information on the displays is controlled by the software in the monitor program, which also ensures that key function signals are recognized. IC7 multiplexes the displays and periodically checks the state of the rows of keys to see which one, if any, is being depressed. With the aid of switch S24 the display may be switched off.

The display may be used in two different ways. Usually, the four left hand displays will indicate an address and the two right hand ones will indicate the data in the address location concerned. As a second possibility, the two left hand displays can show the (hexadecimal code of an instruction while the others display the address of the data corresponding to this instruction. This makes program entry much easier.

The address decoder, IC6, provides chip select signels for each of the various memory blocks. These appear as K7, K6 and KØ for the EPROM, PIA and the RAMs respectively. The other five selection signals are available externally for memory expansion. The RAMs also require a R/W (read/write) signal. This is made available via gate N6 and is generated by a combination of the R/W signal in the 6502 and the Ø2 clock pulse (Ø2 = dete bus enable). Another control signal is the reset signal RES, which places the microprocessor and the PIA in the correct initial condition for the monitor program. A reset is generated when key RST (S1) is pressed and half of a 556 timer (IC8) is used to suppress any contact bounce this key might produce. duce.

1

Photo 1. The completed Junior Computer looks like this. The keyboard and display can be cleerly seen, the microprocessor and other components being on the other side of the printed circuit board.

2

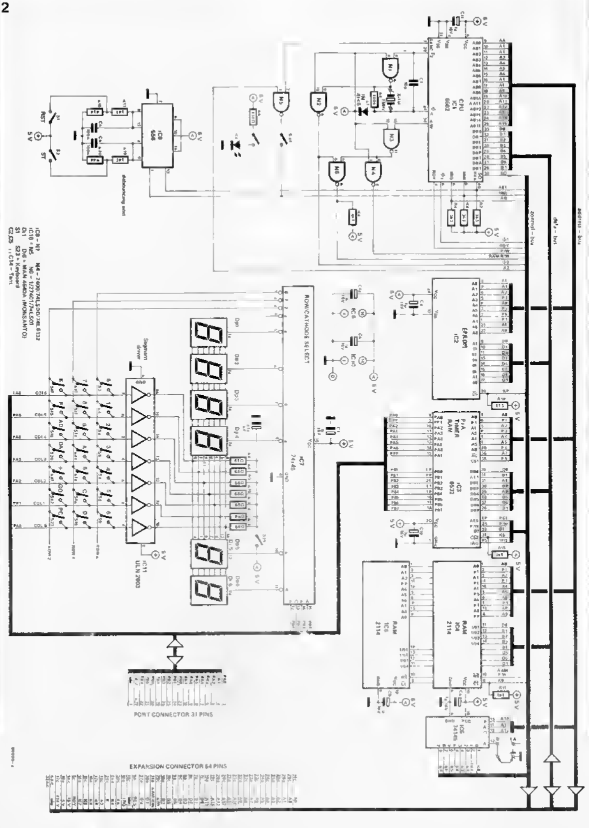


Figure 2. The circuit diagram of the Junior Computer.

Tebla 1

General information on the Junior Computar

- single board computer
- programmable In mechine lenguaga (haxedecimal)
- microprocassor type 6502
- 1 MHz crystel
- 1024 bytaa of monitor in EPROM
- PIA type 6532 with two I/O ports,128 bytes of RAM and a programmeble Interval timer
- aix dlgit seven segmant display
- hexadecimel kayboard with 23 keys: 16 'alpha' keys and 7 double function control kaya

Control keys (normal mode)

+	: Increment address on display by ona
DA	: enter data
AD	: enter address
PC	: call up contanta of current program counter position
GO	: start program from address on display
ST	: interrupt program by way of NMI
RST	: call up monitor
STEP	: step by step run through programe

Control keys (editor mode via ST)

insert	: insert program step before address shown on display
input	: insert progrem step after address shown on display
skip	: jump to next op-code
saarch	: search for a certain labal
delete	: delete row of characters on display

Possibilities

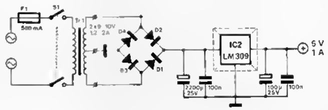
dabugging	: all internal ragisters may be shown on display
hax editor	: lebal identifiction with hexadacimal figures JMP. JSR, branch instructions operata with label
hex assembler	: convarsion of label numbers into displacemant velues for real address
brench	: calculate address offset for jump instructions

Applications

- can ba used as a basis for many expansions
- can be used as a 6502 CPU card
- educational computer for beginners
- can be expanded with:
  elaktarminel
  cassatta Interface
  video Interface
  matrix printar
  assemblar
  disassemblar
  editor

3

D1 . = 1N4004



There are two ways in which a program bieng run can be interrupted by means of the NMI (non-maskable interrupt). The first one is provided by the STOP key S2 (which uses the other half of IC8 for contact bounce suppression) and the second is provided by the STEP switch S24 when this is in the 'ON' position. When the output of N5 then changes from high to low, the IRQ (interrupt request) connection ceuses the program being run to be interrupted, for instance by programming the interval timer in IC3. Also present on the control bus are the two clock signals Ø1 and Ø2 which control the PIA and the RAM R/W signals. These determine the direction of data transfer. Finally, lines RDY, SO and EX provide possibilities for future expansion.
All the address, data and control signals are fed to a 64 pin expansion connector which, as its name suggests, is meant for the purpose of expanding the system futher at a later stage. Figure 3 shows the power supply for the Junior Computer. This produces +5V for all the ICs and the displays.

A few remarks

Before work is begun on the construction of the Junior Computer, two more espects have yet to be considered. The entire system is built up on three printed circuit boards of which one is double sided with plated through holes. It is advisable to check all the through connections with an ohmmeter to make sure that both sides of the circuit are well connected. This will avoid problems, for after soldering it is very difficult to trace eny breaks.

How to build the Junior Computer

Construction of the Junior Computer is not difficult by any stendards. If it is assembled carefully (paying particular attention to solder connections) end the instructions are followed to the letter, very little can go wrong. The three sections of the JC are each constructed on a separate printed circuit board: the main board (including keyboard) the display board and the power supply. Detailed instructions for construction will be given in Book 1.

The 6502 (CPU) is available from M/s Semiconductor Complex Ltd See page No. 5.11

SATELLITE LOUDSPEAKERS

This article deals with the satellite loudspeakers that complement the subwoofer featured elsewhere in this issue, to give complete coverage of the audio spectrum. These satellite are, however, also perfectly suitable for independent use.

Satellite loudspeakers are not a separate category of sound reproducing equipment; any loudspeaker whose bass performance should be improved could be classified as a satellite. So-called bookcase speakers are invariably satellites, because their modest dimensions prohibit proper reproduction of frequencies below about 100 Hz.

If you are planning a new loudspeaker system, you could do worse than to opt for a subwoofer-satellites system. It is then, of course, best right from the start to design the satellites for optimum performance with the subwoofer and vice versa. It is on this basis that the present article has come about: the results are very satisfactory, indeed.

Even those who are not terribly interested in the subwoofer will find that the bass performance of the satellite speakers (−3 dB point at 65 Hz) is perfectly adequate for their requirements

Although the design of a loudspeaker enclosure is never an easy task. the one proposed here presents the constructor with relatively few difficulties. This is, of course, largely due to there being no need of paying much attention to the bass reproduction. A response down to 100 Hz would be perfectly adequate; true, an octave further down would be very nice, but is, in this case, not necessary.

This immediately removes the problem of choosing the right shape and size of enclosure and deciding how many "ways" the system should have. The enclosure decided on is a normal closed box while it was felt that a two-way system would be perfectly acceptable, provided that the chosen drive units would allow this. The latter aspect also requires less arithmetic and fewer measurements than, e.g., a three-way system.

These considerations have resulted in a very satisfactory practical realization, both as regards the enclosure and the number of drive units. As a bonus, the bass performance measured is considerable better than that aimed at. In short, the proposed design is compact, easy to build, not expensive, and, even without a subwoofer, gives an excellent overall performance.

The drive units

As said, the design is based on two drive units Since the majority of

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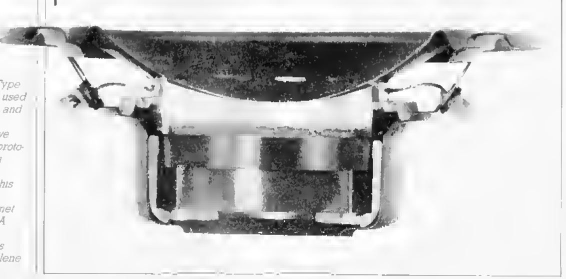

Fig 1 The Dynaudio Type 17W75 was used as the bass and middle frequency drive unit in the prototype system Noteworthy aspects of this unit are the centre magnet and the PHA (phase homogenous area) propylene cone

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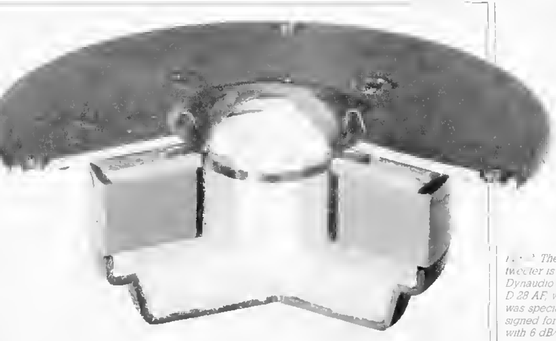

Fig. 2 The tweeter is a Dynaudio Type D 28 AF, which was specially designed for use with 6 dB/octave cross-over filters

middle-frequency units are not really satisfactory above about 2000 to 2500 Hz, which causes problems in the choice of tweeter. Dynaudio units were used for the prototypes. These units did not only meet the requirements for the present design better than most; they also offer the advantage of an excellent match with the subwoofer (which also uses a Dynaudio drive unit). The units are the Type 17W75, a 170 mm bass and middle-frequency unit, and the Type D-28 AF tweeter.

The 17W75, shown in Fig. 1, is a drive unit with a relatively large voice coil (75 mm) in hexacoil technique, which, in conjunction with the unusual shape of the one-piece cone, gives an ideal transfer of the acceleration force from the coil to the PHA (phase homogeneous area) cone. Another advantage of the big voice coil is the short rise time (fast transient response) of 50 µs. Very low distortion and excellent phase characteristics are a result of the total concave shape of the cone.

The D-28 AF, shown in Fig 2, is a 28 mm soft dome tweeter. The voice coil is coupled with the aid of ferro fluid. The unit has a noteworthy fast transient response (short rise time) of 12 µs. It offers the great advantage of having been designed specifically for use with 6 dB/octave filters: not many dome tweeters have!

Cross-over filter

Cross-over filters (or networks) are, unfortunately, necessary, because there is not a drive unit that can reproduce the entire audio range satisfactorily. As long as these filters are not to steep-skirted, they do not cause too much harm, but with increasing skirt steepness the flaws they introduce become more and more serious. Steep-skirted filters have particularly bad transient response characteristics.

The design of a cross-over network should therefore be based on 6 dB/octave slopes, provided the drive units used allow this. This is so in the present design as can be seen from the diagram in Fig 3. Strictly speaking, this circuit contains only two true filter components: L_1 and C2. The remainder of the components perform the correcting functions that are always necessary for good filter operation. Network R_1-C_1 serves to counteract the impedance of the 17W75, which increases with rising frequency. This carefully designed network ensures that the overall impedance of the drive unit remains constant above its resonance frequency. Only because of this can the filter perform as required.

Resistive divider R_2-R_3 serves a twofold function. In the first place, it ensures level matching of the tweeter, whose efficiency is somewhat higher than that of the 17W75. Then, the value of R_2 may be varied between zero ohms and 2.2 ohms without the necessity of changing the value of C. A value of 0 ohms corresponds to a 0.5 dB correction for the tweeter, while 2.2 ohms gives a −1.5 dB correction. Moreover, R_3 smoothes out a small uneveness in the tweeter characteristic: its value must, therefore, not be changed under any circumstances.

The characteristic in Fig 4 represents the output voltage of the filter, measured across the two drive units. Note that the cross-over point only appears to be at −5 dB, it is actually at the customary −3 dB. The characteristic of the 17W75 has a slight peak at the cross-over frequency, and this has been corrected by a slightly earlier action of the filter. Acoustically, everything is, therefore, as it should be.

Construction of the filter should not give any difficulties if the PCB (Type 86016) shown in Fig 5 is used. Note, however, that L_1 should be fastened with glue or a brass/nylon bolt, a

Fig 3 The 6 dB/octave cross-over network is typified by its simplicity

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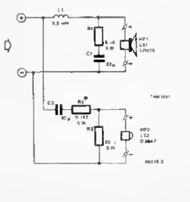

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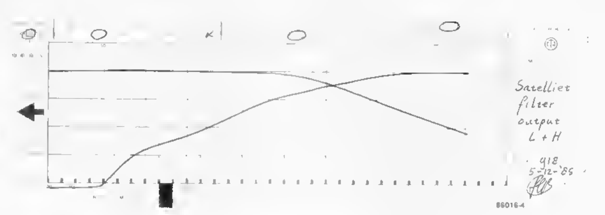
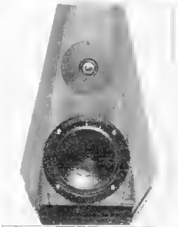


4 Character... curve of the ...utput voltage of ...e cross-over ...ter measured ... in the drive ...s connected



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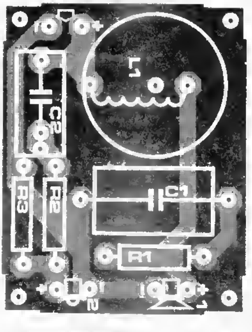


5 The ...ted-circuit ...ard for the ...ss over network (Type 86016 – available through our Readers' Services)

Parts list

L1 0.5 mH air cored inductor, wire diameter 1 mm
C1 – 22 µ bipolar electrolytic or polyester
C2 – 10 µ polyester
R1 5 Ω,5 W
R2 0 47 Ω 5 W
R1 – 22 Ω;5 W
Dynaudio Type 17W75 drive unit
Dynaudio Type D-28 AF drive unit
chip board or plywood, 18 mm thick as required (see Fig 6)
about 0 25 m² rubber backed floor covering
about 0 25 m² rock wool
1 variovent; 110 mm, (Dynaudio)
connector terminals as required
wood glue, screws, and nails as required

steel fastening would affect the value of the inductor. Also, observe correct polarity when the drive units are connected to the board. The PCB may be conveniently mounted —on spacers— on the bottom lid or against the back panel of the enclosure.

The enclosure

According to the manufacturer's data, the 17W75 is best housed in a 10 to 15 litre closed box, which has been provided with a so-called variovent (acoustic resistance). Although theoretical considerations point to a somewhat larger volume, in practice the manufacturer's recommendations proved to be correct. In a damped closed box of exactly 10 litres volume, the bass performance of the 17W75 was surprisingly good. The difference between a box with, and one without, a variovent is slight The variovent only serves to attenuate the resonance peak, and this results in a somewhat more rigid performance at low frequencies.

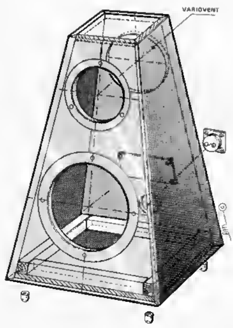
Although some photographs accompanying this article show a beautifully styled pentagonal, pyramid-shaped prototype enclosure (courtesy Dynaudio), the proposed enclosure has been kept rather simpler. Note, however, that the pentagonal enclosure is available from Dynaudio as a kit: it is acoustically excellent, but quite difficult to build. Our own proposal, shown in Fig. 6, offers similar advantages as the Dynaudio design: no parallel side panels; leaning backwards, upward tapering front panel; but does not demand the craft of a furniture maker.

The material is 18 mm fine-chip board; plywood may, of course, also be used, but is rather more expensive The front, back and side panels have exactly the same dimensions. If these are sawn very carefully, all four can be glued together in one go. The bottom and top lid must be sawn very carefully to ensure a good, tight fit onto the leaning vertical panels The top lid may be glued in place, but the bottom panel is best fitted with screws and sealing tape so that access is possible at a later stage, if required Next, the holes for the drive units, the variovent, and the connector terminals should be cut. The variovent should be glued into

Technical characteristics

System	passive, two way
Enclosure	closed box
Net volume	about 10 litres
Cross over filter	6 dB/octave, cross-over point at about 2500 Hz
Frequency range	−3 dB points at 60 Hz and 20 kHz
Amplifier rating	30-100 watts
Sensitivity	89 dB

6a



place, while the drive units should be screwed on. Afterwards, the gap between the rim of the drive units and the front panel should be sealed with suitable tape.

The beste place to fit the cross-over filter is at the back panel between the variovent and the connector terminals.

Panel resonance is further prevented by gluing strips of rubber-backed floor covering at the inside of all panels and then covering these with 30 mm thick rock-wool. If this material is amply cut, the strips will be push-fitt, obviating the need for gluing them into place.

The finish of the exterior of the enclosure is left to your own taste and preference.

Performance

It is, of course, easy (and tempting) for a designer to sing his own praises, so the performance of the system can be gauged from the measured impedance and frequency response characteristics illustrated in Figures 7 and 8 respectively. The smooth impedance curve should not present any problems to a good output amplifier. The frequency response curve was measured with $R_2 = 0.47$ ohms. When this is increased to 2.2 ohms, the characteristic shifts down by about 2 dB above 2 kHz. Response at low frequencies was ascertained by close-proximity (20 mm) measure-

6b

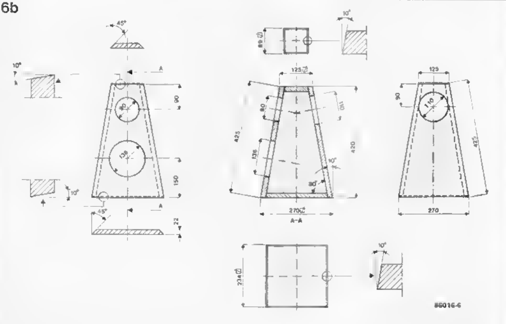


Fig 6 Construction details of the proposed enclosure The material may be 18 mm plywood or good quality chip board

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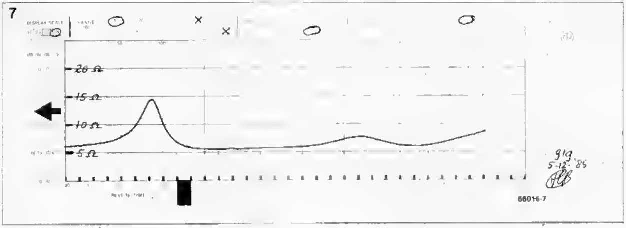

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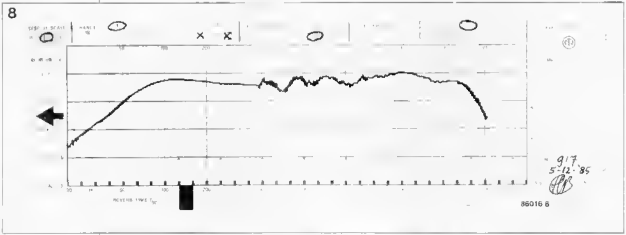
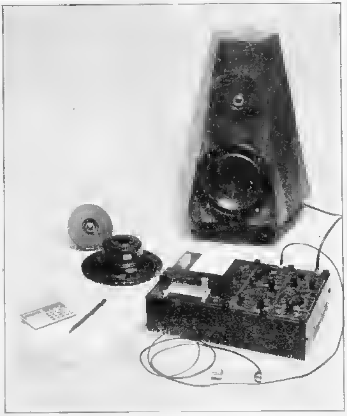


Fig 7. Characteristic impedance curve of the completed satellite system

Fig 8. Frequency response curve of the completed satellite system



ments. The acoustics of the test room has such an effect that measurements at greater distances give no meaningful information as to the behaviour of the system at low frequencies. For measurements at middle and high frequencies, the test microphone was placed at a distance of about 2 metres at roughly the height of the acoustic centre of the enclosure

Digi-Course II

Chapter 6

We have seen so far how divider and counter circuit can be constructed using cascaded Flipflops.

In this chapter, we shall see another practical application of the cascaded Flipflops; the 'Shift Register'

1

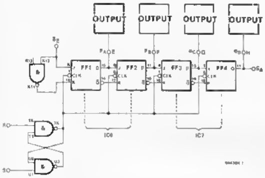


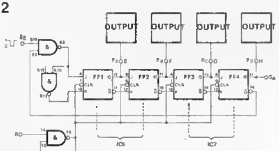
Figure 1 shows a cascade of four Flipflops connected in such a way that the outputs Q and $\overline{Q}$ of each Flipflop are connected to the inputs J and K of the next Flipflop. The clock inputs of all four Flipflops are connected together. A 'NAND' gate inverter is inserted at the input of the first Flipflop so that the possibility of having J/K = 1/1 or 0/0 is eliminated. The state of input SE is thus taken as a single input to the cascade and travels to the next Flipflop on occurance of a clock pulse at the clock input. If we sent the in put SE = "1" at the first clock pulse and then reset it to "0" before the second clock pulse, we can observe that this "1" will travel to the next Flipflop on every subsequent clock pulse. On the fifth clock pulse the "1" gets out of the last Flipflop and as the output of the last Flipflop is floating, it is lost from the cascade.

The clock pulses are generated by alternately connecting the R and S inputs to the ground line. The NAND gate Flipflop consisting of gates T and U switches states on each transition and the clock is "debounced".

As the circuit described in Figure 1 is used to shift the data at the input forward to the next Flipflop on every clock pulse, it is called a 'Shift Register'. For proper functioning of the circuit, all unused inputs of IC 6 and IC 7 must be connected to "1".

Figure 2 shows how we can prevent the "1" from getting lost on the fifth pulse.

2



Here the $\overline{Q}$ output of the last Flipflop is connected back to the input of the first Flipflop, through the OR gate obtained by using a NAND gate. A NAND gate functions as an OR gate with inverted inputs. In the circuit of figure 2, SE must always be held at "1" and taken to "0" only at the first clock pulse, so that a "1" is entered into the Shift Register. At the fifth pulse when QD switches from "1" to "0", $\overline{Q}$D switches from "0" to "1" and this "0" being shifted out of the FF 4 appears at the input Sg of the NAND gate S. This in turn appears as a "1" at the output pin S8 and enters Flipflop FF 1 on the fifth clock pulse. This "1" again travels through the cascade for next four clock pulses, and appears at the QA output of FF 1 on the 9th clock pulse. This operation continues as long as we provide the clock pulses. This modified circuit is called the Ring Counter.

As the Flipflops can assume any state when power is switched on for the first time, we must initially Reset all the Flipflops to "0" before starting the clock pulses, otherwise the initial condition of the Flipflops will keep on rotating through the Ring-Counter.

The circuit of figure 2 has only four Flipflops, and can count only four clock pulses. If we want to construct a Decimal Ring Counter we need 10 Flipflops. This will have its feedback line which activates after every 10 pulses. Another Decimal Ring Counter can be operated from this feedback pulse used as a clock pulse. Practically, such circuit are not constructed using individual Flipflop ICs. Fully integrated Shift Register or Ring Counter ICs are available for these applications.

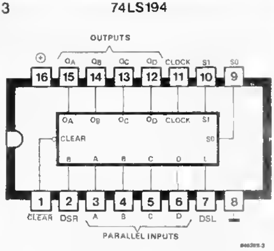
Shift registers are often used in Computer Technology, and rather than entering 1 bit, a series of bits is entered. For example, a bit sequence of 1001 can be entered into a Shift Register using clear and preset inputs and shifted out bit by bit. This will represent a serial transmission of the binary number 1001 (Decimal 9).

If the sequence 1001 is entered bit by bit into a shift register on 4 clock pulses, we have the combination 1001 at the outputs Q_A, Q_B, Q_C and Q_D at the end of the fourth clock pulse, thus representing a serial input of the binary number 1001 into the 4 bit Shift Register, which gives a parallel output 1001 at the end of the 4th Clock pulse.

In the first case when we set the 4 Flipflop outputs to 1001 before giving the clock pulses, it can be described as parallel input/serial output operation. In the second case, where we had all Flipflops set to zero, and entered the sequence 1001 bit by bit at every clock pulse, it can be described as serial input/parallel output operation.

Data transmission between two devices can either be serial or parallel. Serial transmission requires only two lines, one data line and one ground line. Parallel transmission requires one line for each bit and an additional ground line. For 8 bit data transmission in parallel mode, we would thus require a 9 core cable. However, as the parallel transmission can take place in one shot, it takes much less time than in case of serial transmission. An 8 bit data to be transmitted serially will require minimum 8 clock pulses, whereas if it is transmitted parallely it will take only one clock pulse (almost 8 times faster!)

3



You can try the serial and parallel data transmission using two Digilex Boards. The internal block diagram of a 4 bit Shift Register IC 74 LS194 is shown in Figure 3.

This particular IC can operate as Shift Left or Shift Right Register. The direction of Shift is decided by the combination at the inputs S0 and S1 a 01 combination gives Shift Left and a 10 combination gives a Shift Right operation. A 11 combination allows parallel entry of data. The Clock input is blocked by the 00 combination. CLEAR input is used to reset all the outputs to ''0'.

Pins DSR and DSL are used as the data input pins during Shift Right and Shift Left operations.

Mini Amplifier

A small amplifier circuit is described here for the readers who are always looking for a practical project. The description 'Mini' does not apply to the performance of the amplifier, it applies to the size, and number of components required.

A full fledged amplifier generally consists of two main stages, a pre amplifier to amplify the signal coming from the signal source like a Tuner, Cassette-player or a record player, and the power amplifier which amplifies the signal further and delivers the driving power to the loud speaker.

The circuit's presented here takes care of the second function. It raises the signal level coming from the pre amplifier and delivers the driving power to the loudspeaker. It can give a maximum of 10 Watts to a suitable loudspeaker. It is built around a single IC and a few additional passive components.

The Circuit

The main component of the circuit illustrated in figure 2 is the amplifier IC TDA 2003 (which can also be substituted by another IC TDA 2002 without affecting the performance).

It is a compact integrated low frequency amplifier suitable for output capacities upto 10 Watts.

Only a few passive components (resistors and capacitors) are necessary to complete the amplifier circuit.

The input signal is given to the IC through capacitor C1. This is amplified by the IC and is available at the output pin 4. The gain of the amplifier is decided by the ratio of resistances R1

1

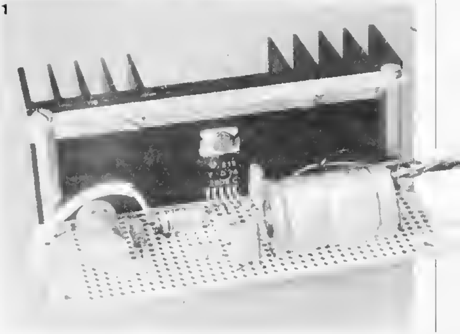


Figure 1
Fully assembled 'Mini Amplifier'

and R2 This is equal to 100 in the present circuit, with the selected values of R1 and R2 as 220Ω and 2.2Ω respectively. The bandwidth of the amplifier is decided by the RC combination R4 and C7. With the selected values of 47Ω for R4 and 100nF for C7 the bandwidth available is 33KHz If the input signal is within this range, the amplifier works without any loss of amplification. However, for signals with frequencies above 33KHz, the amplification falls rapidly

The output signal available at pin 4 of the IC is supplied to the loudspeaker through the capacitor C4. The impedance of the loudspeaker finally decides the output power. If the supply voltage is 18 volts, the output power available from a 2Ω loudspeaker is full 10 Watts A 4Ω loudspeaker gives 6 Watts and an 8Ω loudspeaker delivers just 1 5 Watts

The RC combination R3, C5 is connected accross the loudspeaker to avoid unstable operation of the entire circuit

The no load current drawn by the amplifier is about 50 mA It draws about 500 mA when delivering 6 Watts power through a 4Ω loudspeaker and can go upto 1A when delivering 10 Watts through a 2Ω loudspeaker The input signal being a 1 KHz sine wave and the supply voltage at 18 V

If the power amplifier is used in a car radio or cassette player the power supply can be directly taken from the car battery Though the maximum specified supply voltage is 18 Volts, the amplifier can be operted from lower voltages

A battery eliminator circuit is also presented here in gifure 3 for those who want to operate the amplifier from mains supply

It is a simple battery eliminator circuit with a 12V/1.5A transformer, a bridge rectifier consisting of 4 diodes of the type 1N 4002 and an electrolytic filter capacitor of 1000 uF/25 V This gives a no load voltage of about 16V The supply voltage to the IC should not be more than 18V in any case. Though the IC can tolerate upto 28V without any damange, the performence of the amplifier is affected beyond 18V and the volume drops to zero.

Construction

The component layout of the circuit on a size 1 SELEX PCB is shown in figure 4 The layout is very simple and everything except the loudspeaker and the battery eliminator fits on the PCB

The assembly should be carried out in the usual sequence - jumper wires, resistors, capacitors and then finally the semiconductors. The fully assembled PCB is shown in photograph 1, which clearly shows the construction details It also shows how the heatsink is fitted to the PCB and the IC cooling fin the cooling fin of the IC is internally connected to pin 3 which is externally connected to the ground line No mica washers are therefore necessary between the IC and the heat sink. Care should be taken while mounting the heatsink that the mounting screws on the PCB do not short the heat sink with any other tracks, because the heat sink is connected to the ground line through pin 3 of the IC There should be a gap of about 2 to 3 mm between heat sink and the PCB

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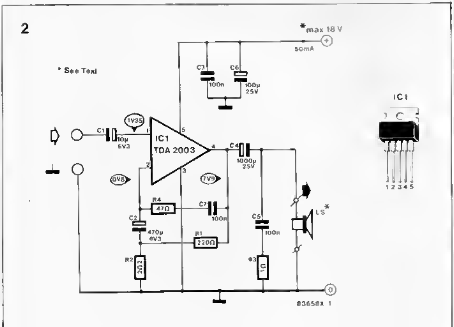

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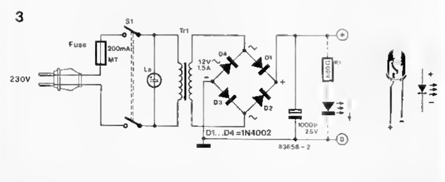

Figure 2
Complete Circuit diagram of the Mini Amplifier.

Figure 3
Simple battery eliminator circuit for use with the Mini-Amplifier

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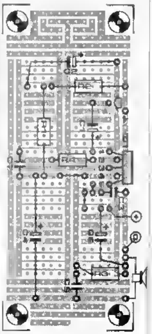

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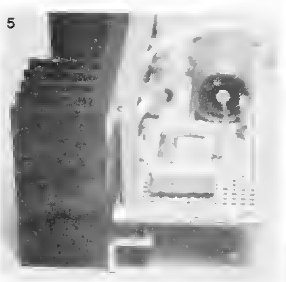

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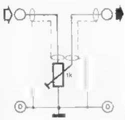


Figure 4
Component layout on SELEX PCB, which accomodates everything except the loudspeaker and battery eliminator

Figure 5
2 to 3 mm airgap available between the heat sink and the PCB

Figure 6
Volume control to be provided in case of connection to high output pre amplifiers

Component List :

R1 = 220Ω
R2 - 2.2Ω
R3 1Ω
R4 - 47Ω
C1 = 10μF/6.3V
C1 = 470μF/6.3V
C1 = 470μF
C3 100nF C2
C4 1000nF/25V
C5 - 100 nF
C6 = 100 μF/25V
C7 - 100 nF
IC1 TDA 2003/TDA 2002
LS - 2Ω 10W Loudspeaker
LS 4Ω 4W Loudspeaker
LS 8Ω 3W Loudspeaker

Other parts

1 SELEX PCB Size 1
1 Suitable heatsink
Aluminium angle and spacers for mounting heatsink

The battery eliminator circuit must be constructed separately as it has no space on the main PCB. The output of the battery eliminator must be connected through a cable to the amplifier PCB at the terminals marked + ad O

Testing

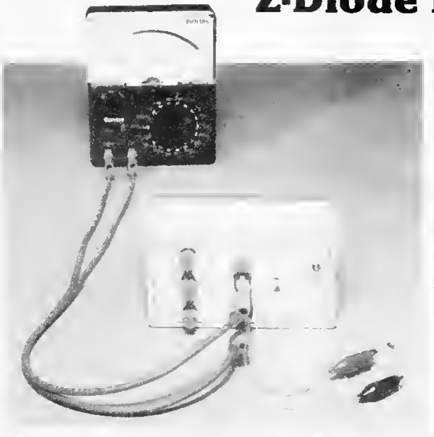
When the assembly is complete, the first test can be carried out. The input is connected to the ground line, and a suitable loudspeaker is connected at the output. A multimeter is inserted in the supply line to measure the no load current. The measuring range is set to 100 mA. As soon as the supply is switched on, the meter should read about 50 mA, and the loudspeaker must not make any sound (Because the input is connected to the ground line.) If one or both of these indications are not there, immediately switch the power off. Check the PCB for faulty connections or short circuits if any.

If the first test is passed, then remove the multimeter from the supply line and connect the output of the eliminator directly to the amplifier PCB. Now you can check all the DC voltages marketed in the circuit diagram of figure 2. If these are all as per the specified values, you are ready to operate your amplifier. The short circuit between the input and ground can now be removed and the input can be connected to the output of a preamplifier.

If an 18V supply is used and the loudspeaker has an impedance of 2Ω then the preamplifier output required to drive the amplifier at full load is about 45 mV. A 50 mA signal is required if the loudspeaker has an impedance of 4Ω or 8Ω. If you expect the preamplifier to deliver a higher output signal, then a potentiometer must be used in the input circuit as shown in figure 6. The connection between the preamplifier and the power amplifier must be through a shielded cable, with the shield connected to the ground and the core connected to the signal. This precaution reduces the hum pick ups by the amplifier.

It is generally very difficult to obtain 2Ω loudspeakers and a simple solution to this problem is to use two 4Ω loudspeakers in parallel.

Z-Diode Tester



Right at the beginning, let us make it clear why we have called it a Z-Diode Tester and not a Zener Diode Tester as you might be expecting. A little bit of hair splitting is necessary to understand this. To be very precise, Zener Diodes are available only for the voltages between 2.7 and 5V. Only these are the genuine Zener Diodes, based on the effect inverted by Mrs. Zener! The so-called Zener Diodes available for higher voltages are really 'Avalanche-Diodes' which are based on the Avalanche effect. Zener Diodes for voltages less than 2.7 V are also not true Zener diodes but they are just the combinations of two or three ordinary silicon diodes in series packaged in a single glass body.

Precisely for this reason, we have not used the name Zener Diode Tester. The name Z Diode is used to cover all the three types of diodes.

The Z-Diode teter described here can be used for all types of Z-diodes, as well as for ordinary diodes. The tester can be used to test a Z-diode and find out if it can function, how well it can function and how high is the Z-Voltage.

Normally the Z-voltage is marked on the body itself. For example, "4 V 7" or "5 V 6" means a Z-Voltage of 4.7V or 5.6V. However, there are some Z-Diodes which have code numbers only and no Z-Voltage markings. In case of these diodes, one must either consult the manufacturers data book or use the Z-Diode Tester to find out more about the diode.

Sometimes when using components removed from old circuit boards, one may come across a diode with illegible markings. In such a case, firstly we want to find out if it is a Z-Diode at all, and if it is, then we must find out the Z-Voltage.

How well a Z-Diode functions depends upon its V-I characterisistics. The V-I characteristics if ab udeak Z-Diode and a practical Z-Diode are shown in figure 2a and 2b. In case of an ideal Z-Diode, the diode is non conducting till the voltage reaches the Z-Voltage value. As soon as the Z-Voltage is reached, current flows through the diode and the diode behaves like a short circuit. The voltage remains clamped at the Z-Voltage value and remains independent of the amount of current flowig through the diode. The characteristic curve goes up vertically towards infinity. If we operate such a diode with a series resistance as show in figure 3, the voltage across the diode remains clamped at the Z-Voltage and only current changes with change in UB. This property is very useful in designing stabilised power supplies.

A practicel Z-Diode does not function as effectively as an ideal Z-Diode. The characteristic curve of a practical Z-Diode is shown in fugure 2b.

1

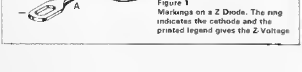
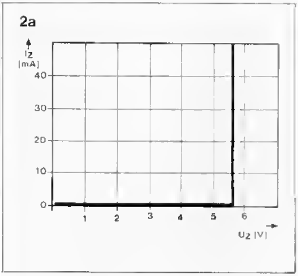


Figure 1
Markings on a Z Diode. The ring indicates the cathode and the printed legend gives the Z-Voltage



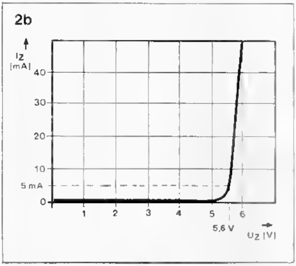
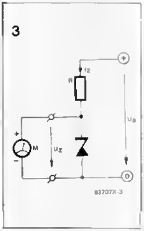


Figure 2a:
Characteristic curve of an ideal Z-Diode. Voltage across diode remains constant independent of current after it breaks down at the Z Voltage.

Figure 2b
Characteristic curve of a practical Z-Diode The voltage slightly increases with current

Figure 3.
Principle of operation of the Z Diode Tester



The curve does not rise vertically upwards, but does so at an angle. Due to this slightly slanted curve, the voltage across the Z-Diode does not remain fully independent of the diode current. How well the Z-Diode functions can be seen from how steeply the curve rises. The Z-Diode tester described here has a facility to measure the Z-Voltage at seven different currents flowing through the Z-Diode.

The Circuit

The principle of our Z-Diode Tester is similar to the circuit shown in figure 3. A DC voltage, a series resistance and a Z diode. When the voltage is more than the Z-Voltage, a current flows through the circuit. Value of the current is decided by the series resistance and the Z Voltage of the diode.

With a 9 V DC supply, a resistance of 1K and a Z-Voltage of 4.7V, the voltage across the resistor is 4.3V and current flowing through the circuit is 4.3 mA.

Now if we replace the Z-diode by another one with a Z-Voltage of 6.8V, then the voltage across the resistance is only 2.2V and the current through the circuit is only 2.2 mA.

From the above observations, we can draw a conclusion that just a series resistance is not enough if we want to test different Z-diodes at the same current. We need a constant current source for this, preferably one with different current settings available.

Figure 4 shows the practical circuit of the Z-Diode Tester with a constant current source and three switches to set the constant current value. Transistors T1 and T2 together function as a constant current source. These are connected in such a way that the colletor current of T1 always remains constant and depends on the resistance across the Base-Emitter of transistor T2; which can be varied in seven steps by setting the switches S1, S2 and S3 in different combinations.

To understand the functioning of the circuit, assume that switch S1 is closed. With the power supply connected across ⊕ and ⊖ various currents will flow in the circuit.

The collector current of T1 also flows through the Z-Diode and through the resistance R1. However, as the resistance R1 is directly connected between the base and emitter of transistor T2, voltage across R1 cannot exceed 0.6V which is the Base-Emitter voltage of T2. When voltage across R1 tries to cross 0.6V, T2 goes into conduction and its collector current flowing through R4 increases. With increased current through R4, the voltage on the base of T1 reduces. A drop in base voltage of T1 means a drop in its collector current, which is nothing but the Z-Diode current. These two actions balance each other in such a way that voltage across R1 in not allowed to rise beyond 0.6V and in affect the collector current which is also the Z-Diode current remains constant.

By changing the switch settings in various combinations, we can obtain seven different values of the diode current for our tester. The three switches give three independent settings, three combinations of two switches closed simultaneously and one combination where all three are closed simultaneously. When more than one switches are closed simultaneously it results into a parallel combination of resistances. Table 1 gives all the seven combinations, and the values of currents produced by them with a 24 V power supply.

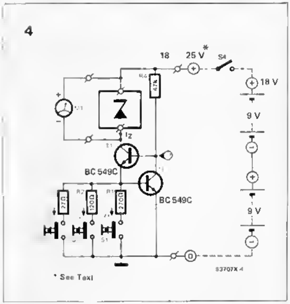
Table 1

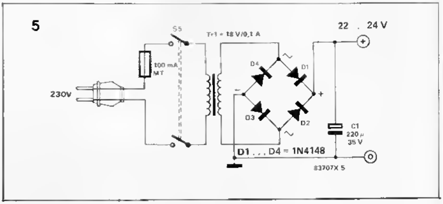
Switches closed	I_Z bei U_B = 24 V in mA
S1	2,22
S2	5
S3	21,3
S1 + S2	7,2
S1 + S3	23,5
S2 + S3	26
S1 + S2 + S3	28,4

With the power supply voltage of 24 V, Z-Diodes for voltages upto 21 volts can be tested It is easier to obtain a supply voltage of 18 V rather than 24V, by connecting two 9V battery packs in series With en 18 V supply, Z-Diodes for volteges upto 15V can be tested The currents shown in table 1 will be slightly reduced with an 18V supply Even otherwise, the currents will deviate by +10% due to tolerances in resistance values and transistor characteristics, Practical application of the Z-Diode Tester is not affected by this deviation If need for testing Z-Diodes for voltages above 15V is expected, a 24V supply must be made available One such circuit for a 24V battery eliminator is given in figure 5

Figure 4
The practical design of the Z-Diode Tester. A constant current source is incorporated.

Figure 5
This simple battery eliminator circuit can be used to provide a 24V supply voltage to the Z Diode Tester.





Construction

The circuit of the Z-Diode Tester is so simple to construct, it cen be easily essembled on e size 1 SELEX PCB including two 9V bettery pecks.

The component layout is shown in figure 6. It occupies just helf the area on the PC8, and if you are good et soldering, probebly nothing cen go wrong!

Deteils of the prototype mounted in a plastic cabinet are shown in the photograph which appears at the end of this description The front panel leyout cen be seen in the photograph at the beginning of this article

The switch appearing in the top right hand corner is the ON/OFF switch which connects or disconnects the power supply Two small wires with crocodile clips are provided for connecting the Z-Diode under test, red for the cathode and black for the enode of the Z-diode. The symbol of the Z-Diode is also painted on the front panel between the two connecting wires Two banana sockets are provided for connecting the multimeter leads, the colours chosen are again red for plus and black for minus. On the left handside of the panel, there are three push button switches S1 S2 and S3.

Once the assembly is complete, the functioning of the Z Diode Tester can be checked es follows

1) Check the supply voltege.
2) Connect the two crocodile clips togetner end check the voltage on the bese of transistor T1 to be 1 2V and that on the base of trensistor T2 to be about 0 6V At least one of the three push buttons must be pressed during this measurement
3) Connect the two crocodile clips to the leads of a multimeter and keep the multimeter in the 50 mA measuring range. Press the push buttons es per combinations shown in table 1 and check the current flowing through the collector of transistor T1 The meesured current should agree with the values given in table 1 with a maximum deviation of + 10% for a 24V power supply If an 18V power supply is given using two 9V battery packs, the current values may be e little less than those indicated in table 1

If all the above tests are passed - your Z-Diode Tester is in perfect working order

Testing with the Tester.

If you have used two 9V battery packs as the power supply of your Z-Diode Tester, it will be suitable for testing Z-Diodes from 1.5 to 15V and the normal silicon diodes like 1N4148, 1N4001 etc. (With a supply voltage of 24V, you can test Z-Diodes upto 21 V.)

For testing, the Z-Diode is connected with the two crocodile clips and the multimeter is connected through the banana plugs. The measuring range to be set on the multimeter is 20V D.C. Switch S2 is now pressed and you can directly read theZ-Voltage on the multimeter. Switch S2 is used because it gives approximately 5 mA current through the Z-Diode, and the rated Z-Voltage is generally specified at 5 mA operating current. This is true for almost all 0.4W Z-Diodes. In case of 1 W Z-Diodes, keep all three switches pressed to give the maximum test current of about 28 mA when measuring the Z-Voltage.

The find out how well the Z-Diode functions, measure the Z-Voltage at every switch combination of table 1. The varioation in Z-Voltage with increase in current will tell you how steeply the characteristic curve rises. A 5.6V/0.4W Z Diode may give a variation of about 0.2V in the Z-Voltage over the current renge of 5mA to 28mA. The smaller this variation, the better is the Z-Diode.

If during the test, the multimeter shows a Z Voltage comparable to the supply voltage itself, this can mean the following:

1. The Z-Voltage is beyond the measuring renge of our tester.
2. The Z-Diode is open.
3. This is not a Z-Diode but it may be just an ordinary germanium or silicon diode.

Now if the diode polarity is reversed and switch S2 is closed, the voltage measured by the multimeter should be about 0.6 to 0.7V for Germanium and 0.2 to 0.4V for silicon diodes. If this voltage is less than 0.2 volts, it means that the diode is short circuited.

In case of a good Z-Diode which showed the Z-Voltage equel to the supply voltage, it should show a voltage of about 0.7 when its polarity is reversed.

A good diode (other than a Z Diode) will always show the Z-Voltage to be almost equal to the supply voltage when connected in the blocking direction.

Component List

R1 = 270Ω
R2 - 120Ω
R3   27Ω
R4   47KΩ
T1   BC 549 C
T2   BC 549 C

S1 ... S3 S.P.S.T. Push button Switches

S4 ON/OFF Toggle Switch

Other parts

2 wires with crocodile clips
2 wires with banana plugs at both ends
1 SELEX PCB Size 1
2 9V miniature batteries
2 Connecting clips for batteries
1 Plastic casing and suitable assembly material

Components for Battery Eliminator

Tr 1 Mains transformer 18V/0.1A
Si - 100mA slow blow fuse
S5 = DPST Mains Switch
D1 ... D4 - 1N4148
C1 220µF/35V

Other parts for Battery Eliminator

1 Mains cord
1 Fuse holder

1 Suitable enclosure and other assembly material.

Figure 6
The component layout of the Z-Diode Tester on a SELEX PCB Size 1

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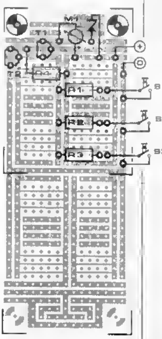

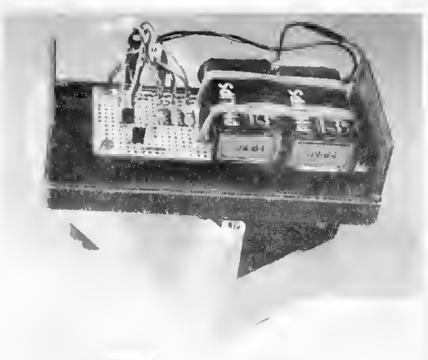

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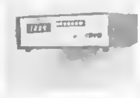

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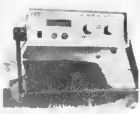

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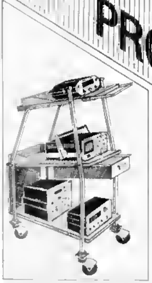

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The description of Panel Flush Mounting is given in March issue of Elektor India. This issue we are describing Table Top style of the same.

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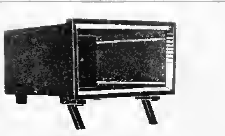

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Modular in construction, the system comprises power components, control switchgear and PCB rack fitted in standard cubicles. It incorporates safe guards like electronic overcurrent trip under voltage trip overvoltage trip, etc. It is designed to suit 3 phase 415V 50Hz AC supply line

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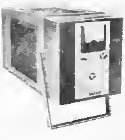

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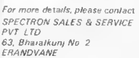

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The prepaid rate for classified advertisement is Rs. 2.00 per word (minimum 24 words). Semi Display panels of 3 cms by 1 column. Rs 150.00 per panel. All cheques, money orders, etc. to be made payable to Elektor Electronics Pvt. Ltd. Advertisements, together with remittence, should be sent to The Classified Advertisement Manager. For outstation cheques please add Rs. 2.50

CORRECTIONS

MSX Extensions — 3 (April 1986)

The caption to Fig. 5 should have read: "For slot signal functions see Infocard 121
Note that further information on the connector is given in Inforcard 122 in this issue (p 81)

RF Circuit Design — 2 (April 1986)

The value of f in Fig 4b should read 65 0 MHz, not 65 0 Hz

Active subwoofer

In this issue

Owing to a printers error, Figures 1a and 1b have been interchanged
The end of paragraph 2 on should read (use 68 nF or 0 1 μF)

Advertisers Index

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