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IN ELECTRONICS & ELECTRO-MUSIC

MARCH 1981
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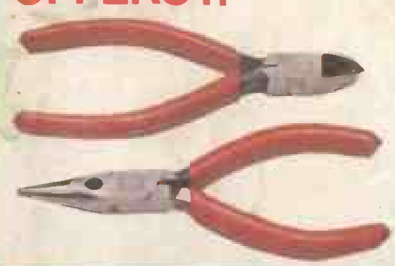

FIRST ISSUE

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First Issue — 100 Pages for the Electronics and Music Hobbyist!

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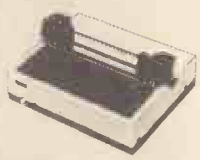

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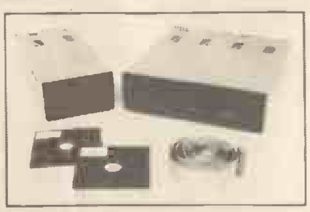

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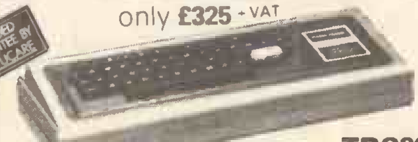

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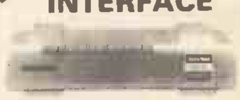

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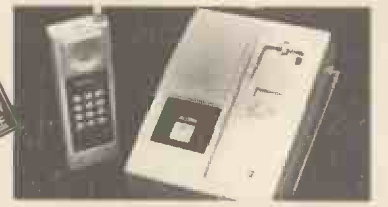

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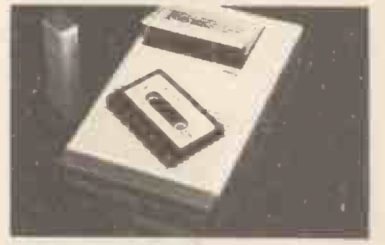

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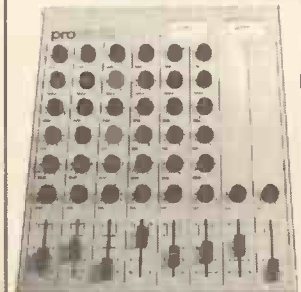

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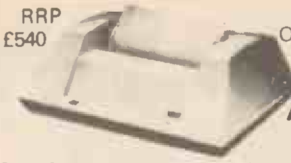

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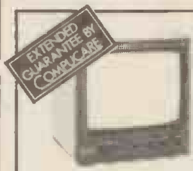

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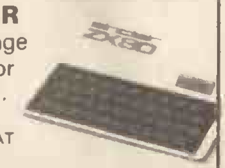

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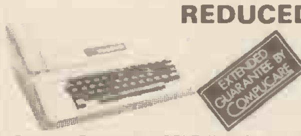

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Why Electronics & Music Maker? Because there is a huge public who need to be informed about today's electronic and electro-music developments. This is largely achieved by practical building projects submitted by leading authors in electronics who also have a special interest in music. In addition, there will be features, news and new-style reviews that will directly link for the first time commercial electro-music to the hobbyist market.

Electro - music defines the whole field of musically orientated electronic equipment. Its range includes Hi-Fi, car sound systems, micro - computers, electronic

by Mike Beecher, Editor
Electronics & Music Maker.

musical instruments and sound processors. Thus Electronics & Music Maker has a vast market in D-I-Y Electronics, musicians at all levels, audiophiles, teachers and students plus anyone involved in electronics, computing and the music industry.

Music today depends to a great extent on electronics — for instrument design from the electronic organ to the sophisticated micro-based synthesizer, and for sound recording and reproduction — there can be no more important time for launching our magazine.

In schools and colleges, the enormous potential of computers, electronic musical instruments and other new electronic aids is more than evident. Pupils try out these educational tools with an eagerness that urges the teacher to acquire more knowledge. Electronics & Music Maker's editorial policy will be authoritative in its information to education.

Boosted sales of electronics magazines when featuring musical building projects confirm a need for Electronics & Music Maker. The lack of practical information in leading music magazines equally points to the need for an electronics and music publication, and these cost-sensitive economic times lead many people to the do-it-yourself periodical.

For the layman, Electronics & Music Maker gives the chance to enter the exciting world of electro-music, with regular features introducing the beginner to electronics along with practical step-by-step constructional projects that have been thoroughly tested and are not only enjoyable, but useful to build. Important aspects such as where to buy components, ready-made circuit boards and clear descriptions in both electronic and musical terms will be provided.

For the musician, Electronics & Music Maker enables a vital updating of electronic music developments, particularly in terms of practical projects, reviews in our electro-music studio, proven and tested projects from our technical lab, and also encourages readers to contribute their ideas and experiences of electronic music making, whether for home, school, disco, stage or studio.

For the electronic hobbyist, Electronics & Music Maker offers practical projects and features for home, workshop, vehicle, education, computer and making music.

Above all, the editorial policy of the magazine will be to present an informative publication that brings together the 3 main areas of leisure interest for the future — electronics, computing and music.

Mike Beecher

Letters

Send to: Reader's Letters, Electronics & Music Maker
282 London Road, Westcliff-on-Sea, Essex SS0 7JG.

Dear Editor,

We have read with interest Electronics & Music Maker, and would advise you that we feel there is scope for this magazine, especially in the future of music using electronic and micro computer techniques. Obviously Roland, as a company which is in the forefront of electronic music, will very much look forward to seeing a magazine of this nature on the market, and we will do our best to give you all the technical assistance that we can.

In the meantime, we wish you every success.

Yours sincerely
F. R. Mead
Sales Director

Brodr Jorgensen (UK) Ltd.

Dear Editor,

Vero Electronics would like to take the opportunity of wishing you every success with Electronics and Music Maker.

Having had the opportunity to preview the publication we look forward with great interest to the educational and project features. These are areas on which Vero Electronics have laid particular emphasis for many years and we are pleased to be associated with the first edition of your new magazine.

Best wishes for a successful launch,

John Burns,
Commercial Sales Manager
Vero Electronics Ltd.

Essex County Council

After a period of successful teaching in this Authority and elsewhere, Mike Beecher now seeks to promulgate through this publication those lessons which he himself learnt in the classroom and beyond.

This self-styled 'Electro-Musical' approach combines sound modern educational practice with the practice of modern sounds in education.

We wish him every success in this exciting new venture at a time of innovation and experiment in the teaching of music.

Eric Stapleton
Senior Inspector for Music (Essex)

I would like to wish your new magazine every success, and I am sure your entry into the technical music and electronics market will further stimulate the growth of synthesis as a medium for music. We look forward to the greater understanding of science in music which we feel will be the continuing theme in 1981 and 1982.

Yours sincerely
Jim Wilmer
Marketing Manager
Rose, Morris & Co Ltd

There has long been a need for this particular type of magazine. It should be welcomed by all those interested in the creative use of technology in education and by the professional and amateur musician.

Desmond Briscoe
BBC Radiophonic Workshop

THE MATINÉE ORGAN

PART 1 OF A SERIES SHOWING YOU HOW TO BUILD A COMPLETE ELECTRONIC ORGAN AND SAVE YOURSELF HUNDREDS OF POUNDS

In the early part of this century almost every home had a piano, but the advent of recorded music and hi-fi turned most people away from making their own music and thousands of pianos were scrapped. Today we are witnessing a renaissance in home music making, brought about by the arrival at an affordable price of the easy-to-play home entertainment organ.

Home entertainment organs are now available in the shops at prices ranging from a few hundred pounds to several thousand pounds. A careful study, however, shows that ready-made organs selling in the £700 to £1,000 price range are a "best buy" for home entertainment.

Organs priced at under £700 are rather basic and although on the face of it, ideal for the beginner, their limited range can soon restrict the more ambitious player. Organs priced at over £1,000 have extra facilities, but apart from orchestral voicing, string and brass chorales, the extra features have a limited usefulness and unless you are a highly proficient musician they are not worth the extra price. Certainly, if you can afford it, orchestral voicing, string and brass chorales are worth having, but they are still rather expensive.

The organs in our "best buy" price range have four main features: two manuals, a 13-note pedalboard, a rhythm unit and a simplified chord playing facility commonly known as single finger chording. Table 1 shows how the Matinee compares with twelve of the most popular ready-made organs in the shops at the moment. Naturally it was not possible to compare every switch and facility, and all the organs in the survey did have other features which are either shared by the Matinee or restricted to a particular manufacturer. The Matinee too has some features not found on the other organs in the survey as a close examination of the specification will show.

You will see from Table 1 that the Matinee compares very favourably with the commercial organs and the fact that it has drawbar voicing, more than overcomes any apparent deficiency in upper manual voices, because having all the voices on drawbars allows an almost infinite variation of sound, greatly surpassing anything possible with fixed volume stops.

The one stand-out feature on Table 1 is of course the price, but none of the saving is due to a lack of quality or to inferior circuits.

The organ sounds every bit as good as the commercial organs and it looks as good as well. Ready - made punched and printed front panels are available and a complete cabinet of equal quality to those found on the other organs in the survey is included in the price. For those who wish to build their own cabinet, we shall publish full cutting and construction details in the last part of this series and this could save you another £70 or £80 as the price for everything except the cabinet is only £299.95.

Some of the price saving certainly comes from the fact that you have to build the organ yourself, but much of the saving is the result of a major technological advance in integrated circuits designed for electronic organs.

In 1978, a young graduate from the University of Bologna in Italy, Mr Giuseppe Ravaglia joined SGS-Ates, a company that was already actively involved in the design of integrated circuits for the electro-music scene. Mr Ravaglia has the rare distinction of having not only a degree in electronic engineering, but also of having studied music theory at the Muncipal School of Music. Since he joined SGS-Ates, he has been working at their headquarters near Milan in Italy on the development of microprocessor controlled organs with programmable voicing and specification.

The first step towards this goal was to integrate on one chip what might be considered the heart of an organ — the tone generation and gating system. By late 1979 he and the team of SGS Digital IC's Applications Group had a working breadboard of such a system. It consisted of over 300 CMOS integrated circuits and yet by mid-1980 every part of this had been condensed onto one integrated circuit chip measuring less than two tenths of a millimetre square. They called their baby, the M108.

Not a very exciting name, but definitely a very exciting chip. To fully appreciate their achievement, it is necessary to look briefly at the way the silicon chip has been advancing on the electronic organ over the past few years.

During the 1960's, an organ with an integrated circuit in it would have been a rarity, but by the late 60's the first IC specifically designed for electronic organs was on the market. It was a top octave synthesiser IC that allowed the twelve musical notes of the top octave of an organ to be generated from one very high frequency. In earlier years electronic organs had to have separate generators for each note in

PARTS LIST

Resistors - all 5% ⅓W carbon unless specified

R368, 371-2, 374, 380	10k	5 off	(M10K)
R369, 375-6	4k7	3 off	(M4K7)
R370	68k		(M68K)
R373. 377, 381	1k	3 off	(M1K0)
R378	100k		(M100K)
R382	47R		(M47R)
R383	47k		(M47K)
RV28, 30	22k Drawbar 1in., red	2 off	(BR41U)
RV29	220k Hor. S-min preset		(WR62S)
RV31	1k Hor. S-min preset		(WR55K)
RV32	22k Hor. S-min preset		(WR59P)
Capacitors			
C122	1uF carbonate		(WW53H)
C123	10uF 25V axial elect.		(FB22Y)
C124, 205	100nF min. disc ceramic	2 off	(YR75S)
C125	33uF 16V axial elect.		(FB35Q)
C126	22uF 10V axial elect.		(FB29G)
C127	100pF ceramic		(WX56L)
C128	100nF carbonate		(WW41U)
C203	3n3 polystyrene		(BX62S)
Semiconductors			
IC35	1458C		(QH46A)
IC36	4001BE		(QX01B)
IC37	4013BE		(QX07H)
TR36-38	BC548	3 off	(QB73Q)
TR39	BSX20		(QF32K)
D133-136, 138	1N4148	5 off	(QL80B)
D137	6V8 400mV zener diode		(QH10L)
Miscellaneous			
S20, 21	Tablet rocker, red	2 off	(BH51F)
S31	Latchswitch, 4-pole		(FH68Y)
S36	Switched swell pedal		(XY89W)

All parts will be available as a complete kit from Maplin Electronic Supplies Ltd in mid-April (when Part 3 is published).

Table 1. Comparison Chart

MODEL	MATINEE	BALDWIN SKYLINE 245	CRUMAR MOD 905	FARFISA AMBASSADOR	GEM 327L	HAMMOND 124JM3	KAWAI E150	LOWREY FIESTA	SOLINA C117	TECHNICS SXU30	VISCOUNT CABARET	WELSON GRAN FIESTA DELUXE	YAMAHA B35N
PRICE	399	725	875	695	750	995	965	855	799	975	819	930	899
KEYBOARD SIZE (NOTES)	49	44	44	44	44	44	44	37	44	44	44	44	44
13-NOTE PEDAL BOARD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DRAW BAR VOICING	✓												✓
ORGAN VOICES UPPER	7	9	5	6	6	7	9	6	12	7	9	6	8
ORGAN VOICES LOWER	5	5	2	4	4	3	4	3	5	3	3	4	3
ORGAN VOICES PEDALS	2	2	2	2	2	1	2	1	4	2	2	2	2
BASS GUITAR PEDALS	✓	✓		✓									
FOOTAGES UPPER	3	3	5	3	3	4	4	3	3	4	3	3	3
FOOTAGES LOWER	3	1	2	2	1	1	1	1	2	1	1	1	1
FOOTAGES PEDALS	2	2	2	2	2	1	2	1	3	2	2	2	2
PRESET STOPS (INCLUDING PERCUSSION)	5	2	2	4	8	5	5	3	1	4	7	6	4
UPPER MANUAL SUSTAIN	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
LOWER MANUAL SUSTAIN	✓											✓	
PEDAL SUSTAIN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
VIBRATO	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
DELAY VIBRATO	✓	✓		✓	✓		✓			✓	✓		✓
ROTOR SOUND	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓
REVERB	✓	✓	✓		✓	✓	✓		✓		✓		
WAH WAH	✓											✓	✓
GLIDE	✓	✓		✓	✓			✓		✓		✓	
REPEAT	✓				✓	✓	✓		✓		✓	✓	
RHYTHMS	30	12	15	15	8	8	10	10	14	12	8	8	12
SINGLE FINGER CHORD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MEMORY	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 2. The Equal Tempered Scale

	Octave 1 (C1 to B1)	Octave 2 (C2 to B2)	Octave 3 (C3 to B3)	Octave 4 (C4 to B4)	Octave 5 (C5 to B5)	Octave 6 (C6 to B6)	Octave 7 (C7 to B7)
C	32.7	65.4	130.8	261.6	523.3	1046.5	2093
C#	34.6	69.3	138.6	277.2	554.4	1108.7	2217.5
D	36.7	73.4	146.8	293.7	587.3	1174.7	2349.3
D#	38.9	77.8	155.6	311.1	622.3	1244.5	2489.7
E	41.2	82.4	164.8	329.6	659.3	1318.5	2637
F	43.7	87.3	174.6	349.2	698.5	1396.9	2793.8
F#	46.2	92.5	185	370	740	1480	2960
G	49	98	196	392	784	1568	3136
G#	51.9	103.8	207.7	415.3	830.6	1661.2	3322.4
A	55	110	220	440	880	1760	3520
A#	58.3	116.5	233.1	466.2	932.3	1864.7	3729.3
B	61.7	123.5	246.9	493.9	987.8	1975.5	3951.1

Pedalboard
16ft and C2
8ft and C3
Lower Manual (Accompaniment)
16ft and C5
8ft and C6
4ft and C7
Upper Manual (Solo)
16ft and C6
8ft and C7
4ft and C8 (4186Hz)

RANGES: All frequencies in Hz. Scale based on A=440Hz.

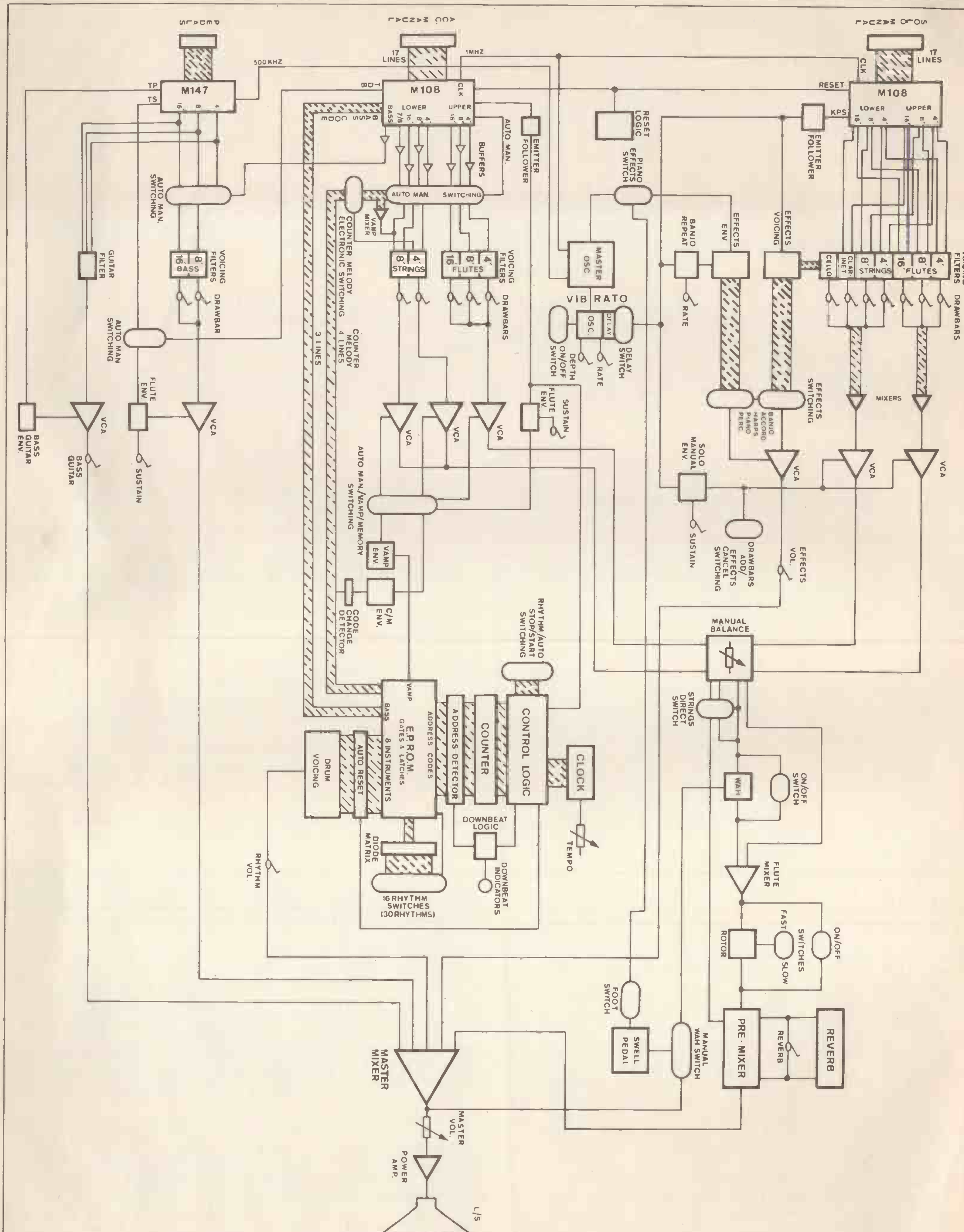


Figure 1: Block Schematic of the Matinee Organ.

the top octave with the result that one oscillator could go out of tune, making one note sound flat or sharp in every octave on the keyboard and you had to take the whole organ to pieces to cure the fault. The top octave synthesiser IC's eliminated this problem since all the frequencies could be adjusted from one control to pull the whole organ into tune in seconds.

Every note on the organ can then be created by dividing each top octave note by two, several times. For example, the C below top C is exactly half the frequency of top C and so on down to bottom C (see table 2).

The second advance came in the integration of rhythm generator IC's. For some years now, all popular electronic organs have had rhythm generators, mostly coupled with some form of simplified left-hand playing facility such as single finger chording. The early rhythm generators were boards of digital IC's and early chord generators were built from banks of diodes. In the mid-70's, both the rhythm and chord generators were condensed onto one IC or in some cases a two IC set.

The new M108 IC combines the top octave generator, the dividers, the rhythm generator timing, the chord generator and all the gating. It is the inclusion of this latter item that eliminates most of the tedious wiring and makes this a really easy organ to build. Instead of each keyboard needing 200 wires, the Matinee keyboards need just 17! This represents a saving of well over 80% in wiring the whole organ.

The gating is one of the most important features of an organ. What we mean by gating is switching the raw frequency to the main bus bars. For example, if middle C is pressed, we need 261.6Hz to be switched to the 8 foot voices, 523.3Hz to be switched to the 4 foot voices and 130.8Hz to be switched to the 16 foot voices. Then, if for example the 8 foot Flute stop is pressed, any frequency switched through to the 8 foot voices will pass through the Flute filters and the characteristic Flute tone will be heard at the correct frequency.

Various forms of gating are available. The simplest is the mechanical switch fitted under the key, or in our case with three footages we would need three separate contacts under each key. This is mechanically difficult and expensive and a great deal of wiring is required; 3 wires for each key if there are 3 footages. In addition, if envelope shaping is required, a further contact would be needed as a key-down detector, generating even more wiring.

The other most commonly found form of gating is the diode or transistor switch. This has the advantage of needing only one contact under each key regardless of how many footages there are. However, it still needs the same number of wires even though most are no longer connected to the key switches. One major advantage is that the attack and decay can be set individually for each key, though this is expensive to do and is not found on organs in the £700 to £1,000 price range. The disadvantages are that there are lots of components and the output is not symmetrical, so if a fast attack was required there would be an audible thump in the output (caused by the average DC level suddenly changing). Another disadvantage is that some of the signal leaks through a semiconductor switch even when it is fully off because of the inherent capacitance of a diode or transistor. It is a very tiny signal, but in an organ with lots of footages there will be hundreds of switches in parallel all adding their little bit. The result is a just audible broadband noise that is generally referred to as "singing".

The gating in the M108 is performed by MOS switches which unlike diodes and ordinary bipolar transistors do not allow any signal to pass when they are off and thus there is no singing in the Matinee organ. Also the output of the M108 is perfectly symmetrical, however many notes are played simultaneously. And finally the biggest advantage of all, of course, is that massive saving in wiring. Only 17 wires are required for each keyboard and only one simple contact is needed under each key, including the key-down detector.

The key-down detector is required so that we can provide envelope-shaping of some of the voices. In early electronic organs, the raw tones were simply filtered to produce the correct waveshapes to simulate the characteristic sound of an instrument. However, the voices did not sound very realistic, because one of the most fundamental characteristics of the sound of an instrument were missing. This characteristic was the way in which the volume of the sound changed with time, in particular at the beginning and end of a note.

If a key is struck on a piano, for instance, the volume of the sound reaches a maximum almost instantaneously, whereas if an accordion starts to play the sound it takes a whole second or more to reach full volume. We say that a piano has a fast attack; its envelope opens and reaches a maximum very quickly, whereas the accordion has a slow attack. If we have an amplifier whose gain we can control, we can simulate these attack rates by switching a particular preset volume change to the amplifier gain control when a given stop is pressed. All we need to know is when to start the volume change and hence the need for a key-down detector.

Similarly the amplifier could be set to close down the volume quickly or slowly when the note ends. Again different instruments stop sounding at differing speeds. For example an undamped string instrument will carry on sounding for a long time after the string is plucked; the volume gradually becoming less and less, whereas a wind instrument stops sounding almost the instant the musician stops blowing. We say that undamped stringed instruments have a slow decay whereas wind instruments have a fast decay. Again, the key-down detector is used to signal when the last key is released.

For example, on the Matinee the piano voice has a very fast attack and a fairly slow decay if the keys remain held down. However, if the keys are released then a fast decay is set in motion in order to correctly simulate the action of the dampers on a real piano. In addition, a control is provided that works like a "loud pedal" to sustain the notes for a long time or in other words to give a very slow decay. Although the basic tone of the piano voice on the Matinee sounds like a piano, the addition of this envelope shaping transforms the voice and makes it dramatically realistic. The other voices on the Matinee are treated similarly to add realism to the sounds.

The M108 makes all this possible very easily and it is this that has led to the low price and simplicity of construction. In fact

SPECIFICATION

Two 49-note manuals.
13-note pedalboard.
Solo voices all on drawbars: Flute 4ft, String 4ft, Flute 8ft, String 8ft, Clarinet 8ft, Flute 16ft, Cello 16ft, Sustain (3 seconds approx.).
Solo preset voices: Accordion, Banjo, Banjo Repeat, Harpsichord, Piano, Manual and Auto Wah, Percussion.
Accompaniment voices all on drawbars: Flute 4ft, String 4ft, Flute 8ft, String 8ft, Flute 16ft, Sustain (3 seconds approx.).
Pedal voices all on drawbars: Bass Guitar 8ft, Organ Bass 8ft, Organ Brass 16ft. Sustain (3 seconds approx.).
Other effects: Vibrato, Delayed Vibrato, Rotor Sound fast and slow, Strings Direct, Add Drawbars to Effects, Rhythm Tempo, Glide or Piano Sustain (control on swell pedal). Swell Pedal becomes Wah control when Manual Wah selected.
Controls: Vibrato Rate, Vibrato Depth, Reverberation, Rhythm Volume, Presets Volume.

Rhythm and Auto-Accompaniment

Controls:
- Rhythm stop/start
- Auto-rhythm stop/start
- Auto-chord
- Chord vamp
- Memory
- Variable tempo
- Countermelody
- 30 Rhythms each a full 2 bars long.

Other Features:
- Eight instruments: Bass drum, low bongo, high bongo, conga drum, claves, snare drum, short cymbal, long cymbal.
- Alternating Bass or Walking Bass dependent on rhythm chosen.
- Major, minor and seventh chords available.
- Minor and seventh chords controlled from pedalboard in automatic mode.
- Indicator flashes red on downbeat, green on the other beats in the bar.

Internal amplifier and 12 inch full range loudspeaker.
Headphone socket.

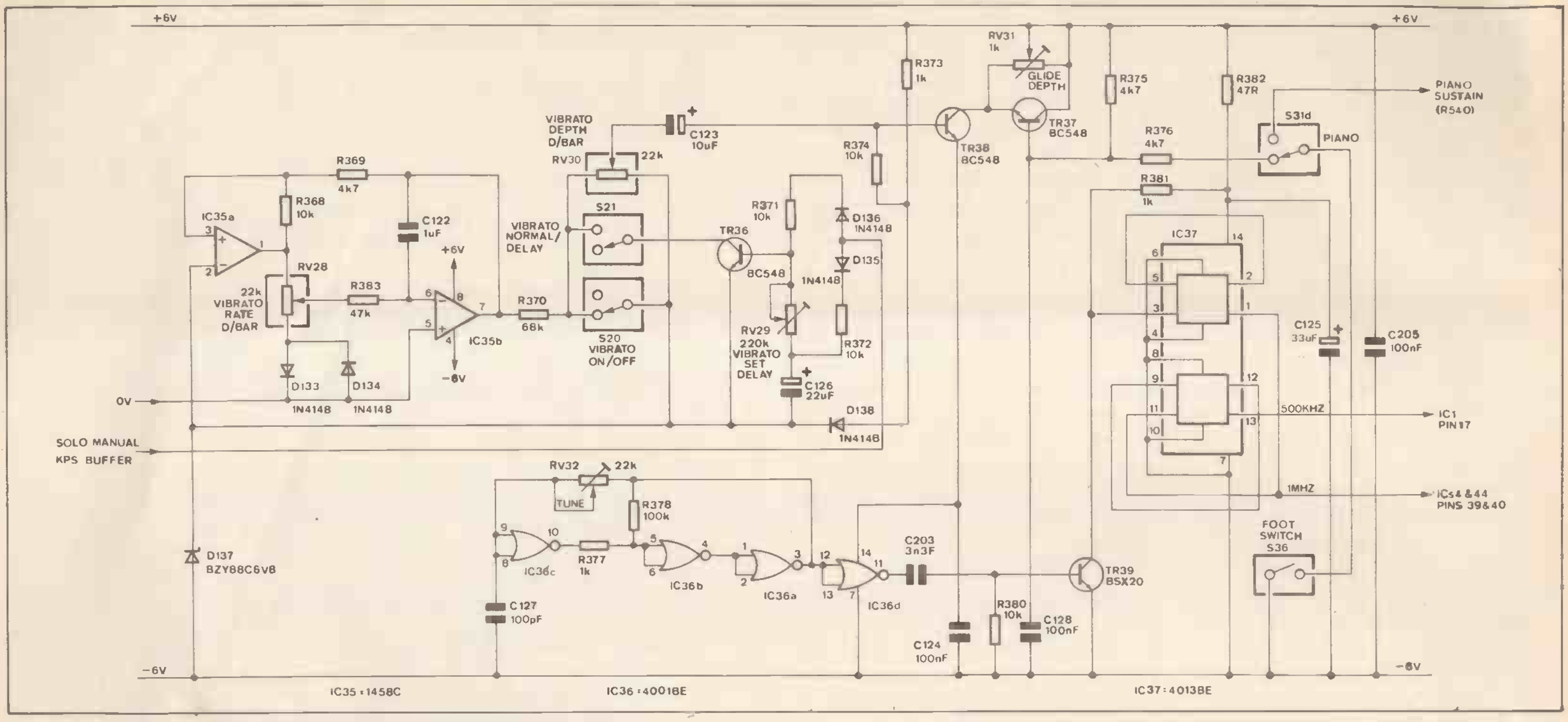


Figure 2. Master Oscillator/Vibrato/Glide circuit.

the only qualification you need to successfully build the Matinee is the ability to solder correctly. Virtually all the electronics are built on one large printed circuit board with only the main power supply located elsewhere. All the wiring is via simple PCB plugs and sockets so that everything just plugs together for absolute simplicity of construction. All the fixings, metalwork and woodwork are available for you to just bolt together if you wish, guaranteeing you a first class finish that will grace any living room.

Although we shall be going into the circuitry of the Matinee in depth, we wish to make it quite clear at this point that you do not need to read or understand any part of these technical descriptions to successfully build this organ. In fact many of the terms used may be a mystery to you, but anyone reading our beginners course that commences elsewhere in this first issue of E&MM will quickly gain an understanding of these descriptions.

Two M108 IC's are used in the Matinee, one for each keyboard. For the pedalboard a different IC is used: the M147 which will be described later. At this stage it is sufficient to know that the M108's require a master frequency of 1,000,120Hz to generate all the notes of the keyboard and carry out all their other timing functions, and the M147 requires a master frequency of 500,060Hz. In Fig. 2 we show the circuit of the master oscillator used in the Matinee from which all the tones and timing throughout the whole organ are derived.

The main oscillator is formed by IC36, a CMOS device containing four separate NOR gates. When power is applied, the voltage at the input to IC36c is low, at -6V, because C127 is uncharged. Since the input is low, the output of gate 'c' is high. Similarly the output of gate 'b' is low and gate 'a' high also. Gates 'a' and 'b' and R378 form a Schmitt trigger that greatly improves the sharpness of the edges of the waveform. The output of 'a' being high, now charges C127 at a rate set by RV32 which should be adjusted so that middle A on the keyboard produces 440Hz. When this is the case the frequency of the oscillation at this point will be exactly 2.00024 MHz.

When C127 is charged the input to gate 'c' will be high and hence the output now goes low. The outputs of gates 'b' and 'a' are now also forced to change state and the output of 'a' being low discharges C127 until the input at 'c' is low again. This process repeats itself continuously two million times every second. This oscillation is then presented to gate 'd' which simply acts as a buffer for the square wave output.

IC35 is a dual op-amp which produces an oscillation in much the same way as IC36 except that it is a triangular waveform and at a very low frequency. RV28 is the vibrato rate drawbar and sets the frequency between 2Hz and 20Hz. The amount by which the vibrato changes the frequency of oscillation of IC36 is set by the vibrato depth drawbar RV30.

With the vibrato switch SW20 off, the output of IC35 is short circuited to ground, but when switched on the output is coupled through the DC blocking capacitor C123 to the base of TR38. This transistor is supplying the main positive DC voltage that allows IC36 to operate. As the supply rail voltage changes under the control of the vibrato oscillator, so the points at which the switch-over thresholds in IC36 occur, change and the frequency of oscillation also changes slightly.

When the delay vibrato switch, SW21 is on and no key is pressed on the keyboard, C126 is charged and TR36 fully on, short circuiting the output of IC35. When a key is pressed, the positive voltage on D135, D136 is removed and C126 discharges slowly through RV29. This preset adjusts the length of the delay before C126 is sufficiently discharged to allow TR36 to turn off. As it does so the output of the vibrato oscillator is no longer inhibited. At the next instant when no keys are pressed on the keyboard, C126 charges again ready for the next key to be pressed.

A glide switch is fitted on the foot pedal to give Hawaiian Guitar effect. When the switch is operated the current through TR37 changes slightly over a short period set by the position of RV31. The effect of this is much the same as changing the voltage on the base of TR38: the frequency of the main oscillator is changed. The change is set by R375 and R376 to give a one semitone change on the keyboards. When the switch is released the current through TR37 returns to normal at the rate set by C128.

Because the main voltage rail to IC36 is used to produce the organ's vibrato and glide effects the output of gate 'd' can under certain circumstances reach voltage levels that are insufficient to correctly drive IC37. TR39 is therefore provided to apply sufficient amplification to the output of gate 'd' to ensure that IC37 is correctly driven in all conditions.

IC37 is a CMOS IC containing two D-type flip-flops that are connected here to function as frequency dividers. The main oscillator frequency of 2.00024 MHz is applied to pin 3, the input to the first flip-flop. The output at pin 1 is exactly half this frequency: 1.00012 MHz, the frequency required by the M108's. As well as being connected to the clock input of the M108's it is also connected to pin 11 on IC37, the input to the second flip-flop. The output at pin 13 is exactly half the frequency on pin 11:500,060Hz, the frequency required by the M147.

It may seem strange at first sight that we have set the main oscillator to run at 2MHz when the highest frequency used is 1MHz. There are, however, several advantages in starting with a higher frequency than that required. Firstly the higher frequency gives better accuracy and the Schmitt effect of IC36 gives excellent long term stability and secondly the 4013 generates an excellent square wave shape whose mark/space ratio is exactly 1:1. This circuit, then, provides an ideal waveform to drive the clock inputs on the M108's and M147.

Next month, we shall begin the construction details of the Matinee organ and continue the description of the circuits used. **E&MM**

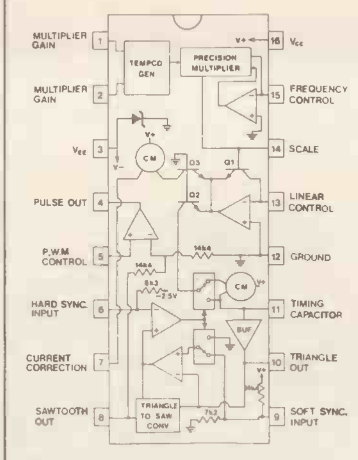
ICs FOR ELECTRO-MUSIC

Charles Blakey, Digisound Limited

Overheard at a recent meeting was a comment to the effect that if cars had made the same technological progress as electronics then a certain well known make would now cost 1.75p and do three million miles to the gallon. We will not go into the logic of this comparison but at least it puts the progress of our industry in perspective. Just one of the spin-offs is that it is now practical to produce specialised integrated circuits in relatively small quantities and end up with a product which is much cheaper than the equivalent circuit based on discrete components and having the same performance. In the last few years there has been a steady growth of IC's specifically designed for electronic music applications which in turn have made a large impact on the development of voltage controlled synthesisers. The designer can now readily apply his skills to producing compact units essential for both lead synthesisers and for polyphonic systems; to offering equal performance at a lower cost; or greater performance capabilities at an acceptable cost.

The object of this series of articles is to look inside these 'black boxes' so as to provide a greater understanding of their function and application. Do not be put off by an occasional mathematical expression dotted around the pages since this is always followed up by a practical solution. We also hope that the series will stimulate readers to experiment with these new products and share their ideas and designs with others interested in the field of electro-music.

The Spectrum Synthesiser project commencing in this issue utilises integrated circuits produced by Curtis Electromusic Specialities and I shall be dealing with some of this company's product line, including the CEM 3310 Voltage Controlled Envelope Generator, CEM 3320 Voltage Controlled Filter, CEM 3330 Dual Voltage Controlled Amplifier, and CEM 3340 Voltage Controlled Oscillator. One of the features which makes these IC's ideal for electronic music is that their voltage control response is exponential, that is, for a unit increase in voltage there is a doubling of the output. Refer to Figure 1 for the shape of this response. In the case of the oscillator this results in a doubling of frequency and this exponential relationship is a perfect match for the equally tempered musical scale. The use of an exponential VCO greatly simplifies keyboard electronics since one merely has to generate equal voltage intervals between notes; it allows the complete audio frequency range to be covered without switching; and it also means that two or more oscillators may be transposed in pitch while maintaining the preset frequency relationship. Exponential control is also necessary for the filter since



CEM 3340 V.C.O.

in many instances the keyboard control voltage will be used to adjust the cut-off frequency of the filter and the latter must therefore track the oscillator to maintain the same harmonic content irrespective of pitch. For the voltage controlled amplifier the exponential response is used to compensate for the design of the human ear which reacts to sound intensity in a logarithmic manner. Finally for the envelope generator the production of exponential contours is not unusual since use is frequently made of the characteristic charging/discharging response of a capacitor. By using, however, an exponential voltage control for the attack, decay and release time constants one is able to achieve a 50,000:1 range, say 2 milliseconds to 100 seconds, with a single control and with the most useful range utilising a high proportion of the potentiometer scale.

Other common features of the CEM devices include housing in standard plastic 16 or 18 pin DIL packages and their ability to operate from a wide range of power supplies. The latter includes the widely adopted ±15V supplies as well as the increasingly popular +15V, -5V supplies used in synthesisers incorporating CMOS logic controllers.

CEM 3340 Voltage Controlled Oscillator (VCO)

We will plunge straight in at the heart of the synthesiser, the VCO, since by dealing with the most critical part first we can avoid spending time on some simpler aspects later. We have extolled the virtues of exponential control but how is it achieved and how does one get the scale accurate over a wide range coupled with good temperature stability? Such generators make use of the fact that the

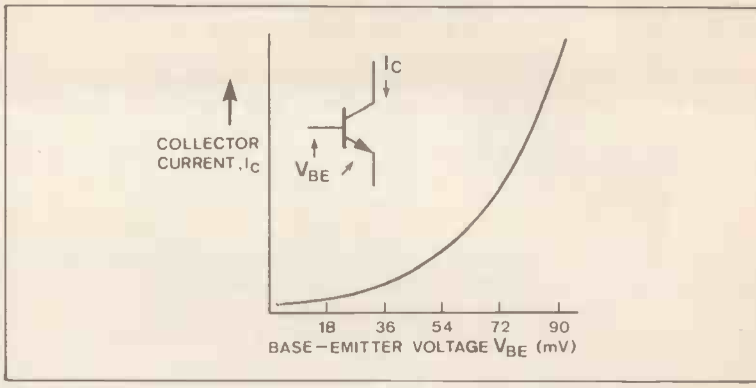


Figure 1. The exponential characteristic of a transistor junction.

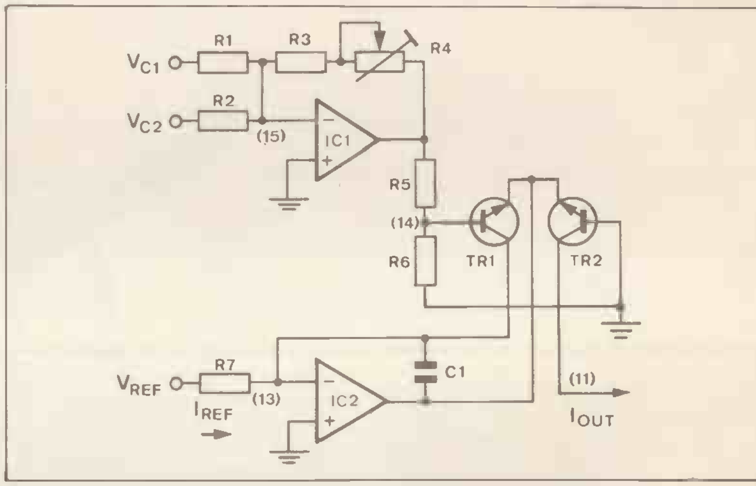


Figure 2. A typical exponential generator using discrete components.

current, I_c, flowing into the collector of a transistor is an exponential function of the base-emitter voltage, V_{BE}, namely the difference between the voltage at the base and at the emitter of the transistor. Hence $I_c = Fe^{(V_{BE}/V_T)}$ and a curve of V_{BE} versus I_c is shown in Figure 1. Unfortunately one of the components of F, namely the emitter saturation current, doubles for every 10°C rise in temperature and the first step is to cancel out this term by using a dual transistor, preferably contained on a single chip to ensure temperature equalisation. The front end of a typical VCO then becomes like Figure 2. IC1 is a standard inverter and its inverting input provides a summing node for the input voltages via resistors R1 and R2 (any number of resistors may be added). The gain of the op amp is set by R3 plus R4. Most synthesisers adopt a scale of 1 volt/octave, that is, one volt applied to R1, assuming that this is the resistor connected to the keyboard voltage, will double the frequency of the VCO. To achieve this with the arrangement of Figure 2 the component values are chosen to obtain an 18mV change at the base of Tr1 for each increment of one volt applied to R1. So that we are operating in the most accurate range of TR1 we need to apply a reference current to its collector and this is obtained from R7 connected to a positive reference voltage. The function of IC2 is to sink excess current from the emitters of TR1 and TR2. The output current, I_c, taken from the collector of TR2 then usually goes to some switching device, such as a FET, to charge and discharge a capacitor and generate a waveform.

The circuit will now give $I_c = I_{ref}\, e^{-(V_b/V_T)}$, where V_T is equal to about 26mV at 20°C with the emphasis being on the temperature. If the temperature of the transistor changes from 20°C, as it surely will, then the 1/T component will alter by 0.33% for every one degree Centigrade change and this would certainly not be acceptable for a synthesiser oscillator. To counteract this we have to alter V_b by an equivalent amount and the usual technique is to employ a special temperature compensating resistor either in the feedback loop of IC 1 or in place of R6.

Now turn to the functional block diagram of the CEM 3340 shown above and also refer back to Figure 2 where the numbers in brackets relate to the pin numbers on the CEM 3340. The similarity is apparent. The first step is to set the scale of the VCO and a 1k8 resistor to ground from pin 14 provides greatest multiplier accuracy. To obtain the widely used 1V/octave scale a 100k resistor is connected to the frequency control pin 15.

As already mentioned this latter pin is a summing node and so any number of resistors may be connected to this point. For example, suppose we wish to add a fine frequency control of ±0.5 octaves whose voltage is obtained from a potentiometer connected between ±15V then a resistor of 3M0 (3M3 would be near enough) connected to pin 15 would achieve this. Likewise a resistor or a variable resistor, or both, may be connected between the positive supply and pin 15 to set the oscillator at the desired initial frequency, i.e., the frequency with no keyboard or other external voltages applied. The reference current is taken to pin 13 and for the CEM 3340 the current should be in the range of 3uA to 15uA, so let us use 10uA which requires a 1M5 resistor connected to a +15V supply. Next connect the timing capacitor to pin 11 and this should be chosen to keep the current within the range of 50nA to 100uA and the frequency is given by $f = 3I_{EG}(V_{cc}.C_F)$ where I_{EG} is the output current from the exponential generator, V_{cc} is, as usual, the positive supply voltage and C_F the value of the capacitor at pin 11. Thus if the most accurate range for the VCO is to be 10Hz to 10kHz then the capacitor should be 1nF.

Where the CEM 3340 differs substantially from Figure 2 is in its unique method for compensating for the temperature dependence of the V_T term discussed earlier. Within the IC is a Tempco Generator which produces a temperature compensating offset and is generated by the same mechanism which causes the temperature dependence within the exponential generator. The cancellation of the latter is therefore nearly perfect. It means however that precise adjustment of the volts/octave scale is different to that expected from Figure 2 and so the arrangement of Figure 4 should be used, in which the 10k preset potentiometer provides for accurate adjustment of the scale.

One further problem with these exponential generators is the bulk resistance of the base-emitter junction which becomes significant at higher currents and so causes the oscillator to go flat at higher frequencies. In the CEM 3340 pin 7 outputs a current which is a quarter of the exponential generator current. This current is converted to a voltage by connecting it to a grounded trimmer (10k) and taking part of the voltage from the wiper back to the input summing node, pin 15, via a resistor (say, 1M0) and then using the trimmer to cancel out the bulk resistance effect by an additional calibration at high frequency, i.e., about 10kHz.

While the number of external components around the exponential generator have been kept to a minimum consistent with freedom for the designer the following rules should be observed in order to retain the accuracy of the device.

1. The positive supply is used as a reference voltage to generate the reference current and also possibly to set the initial frequency. This requires that the positive supply for the VCO is extremely stable in respect of both time and temperature.

2. All of the resistors should be metal film, or similar, with a temperature coefficient of 100ppm/°C, or better, and the trimmers should be cermet types. Resistor accuracy of 1% is adequate so long as only one of the frequency control input resistors is required for precise frequency control, namely from the keyboard. Do not have any inputs to pin 15 where vibration or a small change in temperature are likely to affect the frequency unless some means of isolating them when not in use is also installed.

3. Pins 13 and 15 require compensation components of a 470R resistor in series with a 10nF capacitor connected to ground.

4. The timing capacitor should be a low loss, low leakage type such as silver mica, polystyrene or, for larger values, polycarbonate. It is also worth noting that at low frequencies the currents are only a few nanoamps and leakage through residual solder flux or general dirt can create problems. It is good practice to clean the foil side of the PCB after soldering with a proprietary solvent and then apply a PCB varnish.

Next we turn to the subject of FM (frequency modulation) of the VCO. Pin 13 is referred to as linear control and sometimes as linear FM input. It is a summing node and so an additional resistor may be connected to this point to obtain linear FM using an AC waveform. Take note of what is happening in these circumstances, namely, one is effectively increasing and decreasing the reference current. The first effect is that if the current developed at this input were to exceed the reference current then the oscillator will be gated off (you may wish to use this fact in some application). Suppose, however, that we keep the 1M5 resistor connected to +15V for the reference current and add a 1M0 resistor for a linear FM input. This will give us about a 10% change in frequency for a one volt change in input, i.e., a ±50% frequency change for a ±5V waveform. There are two main uses for such an input. First to provide some dynamic timbre modulation using an envelope shaper (ADSR plus VCA) to shape the modulating waveform. Secondly, if a modulating waveform is applied to the linear FM input of two or more oscillators set to different intervals then a type of chorusing effect will be obtained since the tracking of the oscillators has been affected. The more usual FM effect is vibrato and one usually requires a deeper modulation as well as maintaining a constant depth over the frequency range and tracking between oscillators. Vibrato is therefore obtained with a modulating waveform applied to the exponential control input, pin 15, via an appropriate potentiometer and resistor network.

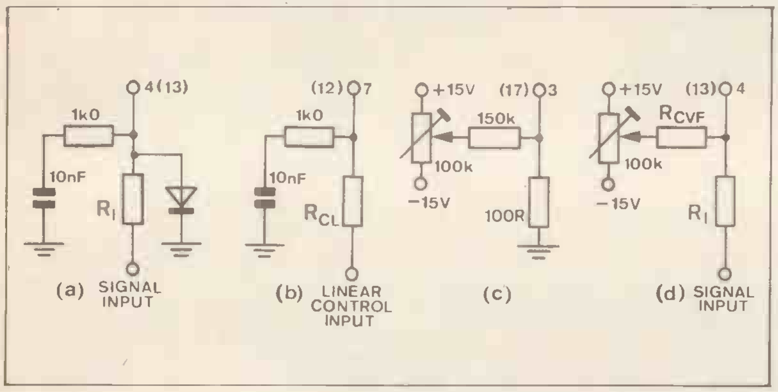


Figure 3.

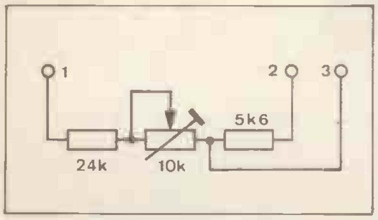


Figure 4. Scale trim for CEM 3340.

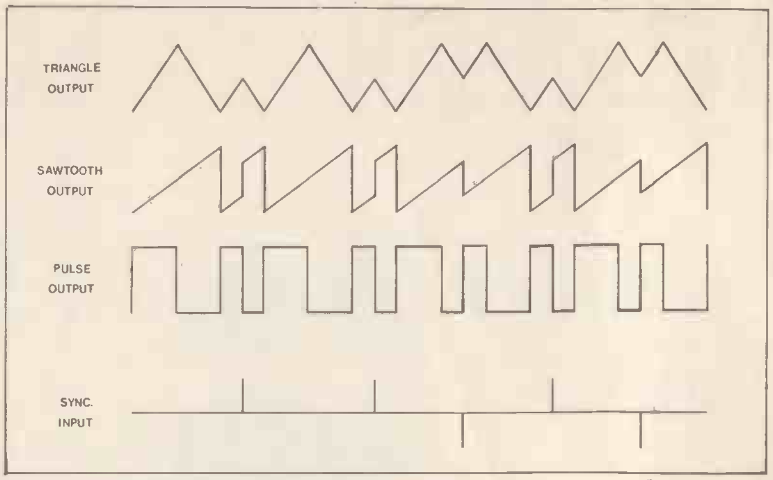


Figure 5. Hard synchronisation capabilities.

The CEM 3340 provides three simultaneous waveforms: sawtooth, triangle and pulse. They are nominally referenced to 0V and their amplitude is determined by the positive supply voltage, being: two thirds of the supply for the sawtooth; one third for the triangle; and 1V5 below the supply for the pulse. A particular point to note is loading of the triangle output will lower the VCO frequency since the output is also connected to an internal comparator. Even into a 100k load the frequency may drop by 0.15% and in any event the output should not directly drive a load of less than 10k and/or more than 1nF to ground. On the other hand the pulse output is an open NPN emitter and requires a pull down resistor to ground or a negative voltage. This output may be readily clamped to a lower voltage using a zener diode. The amplitude of the signals and whether they are ground referenced or AC is the free choice of the designer. For example, if a rotary switch is used to output one waveform at a time and the desired amplitude is, say ±5V, then this is easily accomplished by switching into an op amp inverter and selecting the appropriate input resistors to obtain the required gain for the different waveforms and then place a capacitor in the output line.

Pulse width may be varied from 0 to 100% duty cycle by 0 to +5V (V_{cc} = 15V) applied to pin 5. The +5V may be derived from the positive supply using a resistive divider and a trimmer in this network may be desirable if it is essential that the pulse does not completely disappear at the extreme ends.

The remaining facilities on the CEM 3340 VCO are for synchronisation. The hard synchronisation input, pin 6, may be configured in several ways but in its simplest form a 1nF capacitor connected to pin 6 will respond to inputs of both positive and negative pulses. The effect is illustrated in Figure 5 which shows that a positive pulse causes waveform reversal only during its rising portion whereas a negative pulse causes reversal during the falling portion of the waveform. Clearly this technique is only applicable to two or more oscillators. The oscillator of lowest frequency is referred to as the 'master' oscillator and the other(s) as 'slave' oscillator(s) and the pulse output from the master is used for synchronising the other oscillator(s). The complex waveforms which result are capable of yielding some pleasing timbral effects especially when only the slave oscillators are frequency modulated. Soft synchronisation requires negative pulses of about −5V amplitude and coupled via a 1nF capacitor to pin 9. The oscillators in this instance will usually be connected to a soft sync. bus and when one oscillator discharges its sync. pulse will cause premature discharge of other oscillators in such a manner that their oscillation period is an integral multiple of the reset pulse period.

The final but important point relating to the CEM 3340 concerns the negative supply voltage. If this is greater than −7V5 then a current limiting resistor must be placed between the negative supply line and pin 3. The value of the resistor is determined by (V_{EE} −7.2)/0.008 which for −15V gives a nominal 975 ohms and a practical choice of 910 ohms.

Next month I shall continue this look at the Curtis range of IC's, starting with the CEM 3320 Voltage Controlled Filter. **E&MM**

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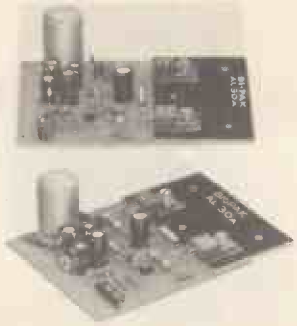

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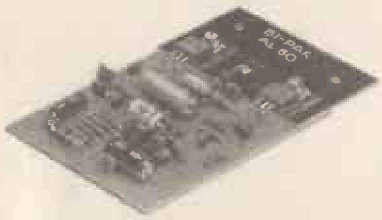

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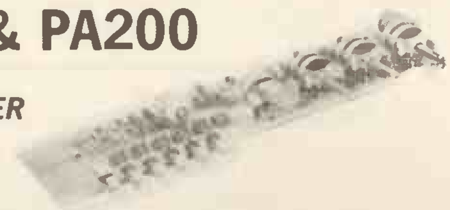

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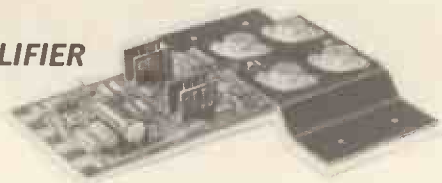

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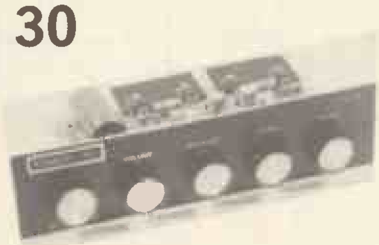

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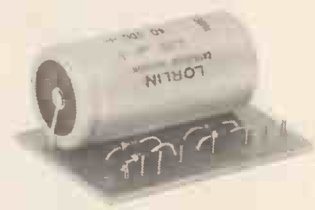

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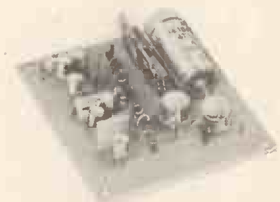

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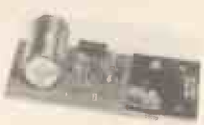

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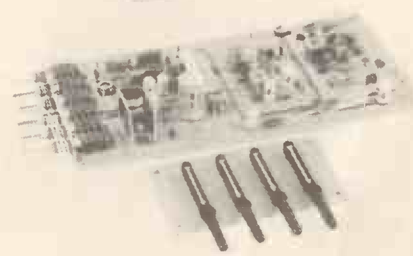

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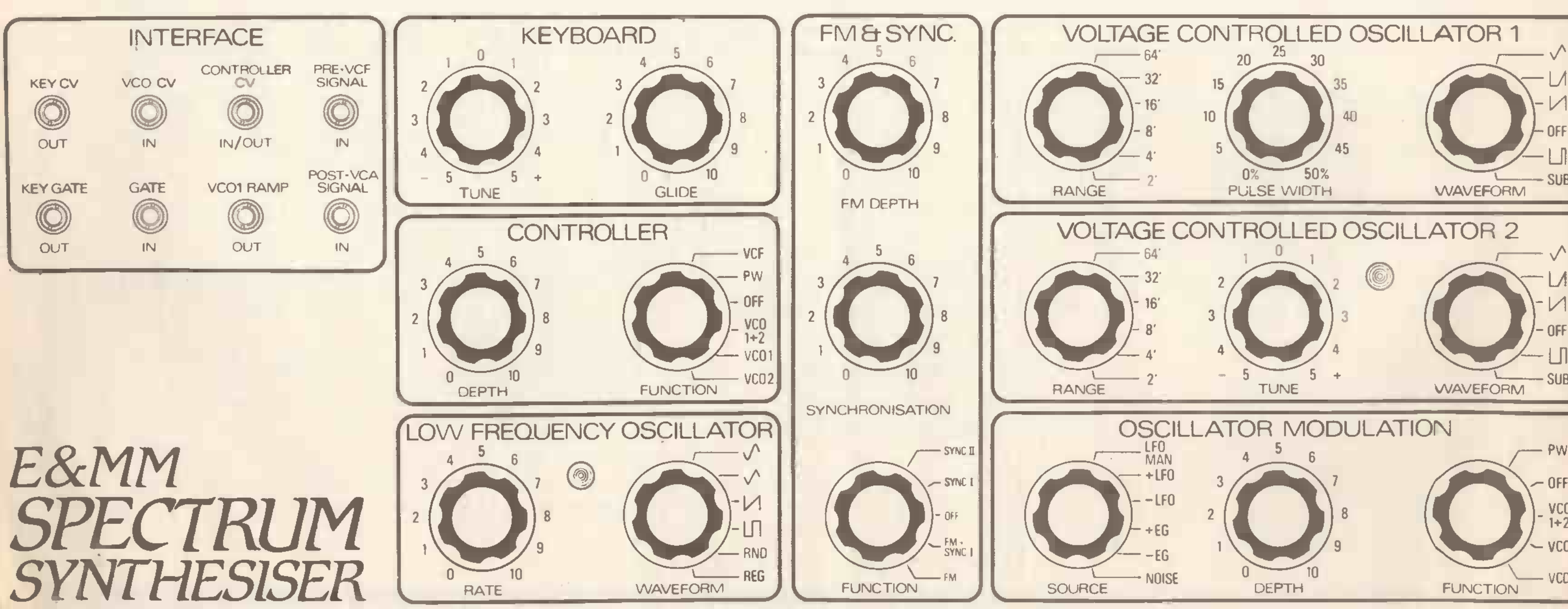
by Chris Jordan

The Spectrum is a monophonic two oscillator switch-linked synthesiser featuring advanced specification, constructional simplicity and low cost. Modulation, timbre control, and interface facilities not found on any comparable synthesiser make it extremely powerful and versatile for keyboard playing, sound effects and many other home, stage, or studio applications. Construction is simplified by the use of integrated circuits that each perform major synthesiser functions with few external components. Error-prone control wiring is eliminated by the use of a single PCB mounted behind the panel and holding the pots (PCB mounting) and switches. No glueing of contact blocks or bending of gold wires is needed to assemble the keyboard contacts — a new contact system only requires soldering of the contacts and drilling of the chassis to mount the contact PCB. This also contributes to the low cost — the Spectrum can be built for around £200 including metalwork and PCB's, but not including the case.

Description

Figure 1 shows a block diagram of the synthesiser and the front panel legending is reproduced below. Modulation routing is accomplished by source and function switches and depth controls, rather than the usual method of providing each source with its own depth for each controlled function found on some small synthesisers. Switching is most suitable for a large number of sources as here, and allows fast selection of source and selection of modulation effects with preset depths, in favour of simultaneous modulation of one parameter by more than two signals. Six modulation signals are available: keyboard, controller, low frequency oscillator (LFO), noise generator and external. The keyboard is of the highest note priority type and has a glide which always completes even after the key is released — this makes the keyboard much more useful as a controller for effects sounds. The joystick controller routes a voltage dependent on the side-to-side position of the stick to various voltage controlled circuits, allowing it to be used to control the pitch (pitch bend), timbre, or both (see later). The external voltage fed into the controller jack can override or add to the joystick voltage for control by additional synthesiser equipment, or a pedal can be plugged in and used for control by attenuating a fixed joystick voltage.

The low frequency oscillator generates random and regular sample and hold effects in addition to the four common waveforms. The regulator S/H option allows rising and falling scales, rising and falling repeating groups of two, three or more notes, and other sequencer-like effects, with the pattern controlled by the LFO rate. An LED displays the LFO cycle and the joystick's vertical position determines the amplitude at the LFO manual output. The envelope generator is of the exponential ADSR type and like the LFO has + and - outputs that can be separately selected for each controlled parameter. The envelope generator shares its gate signal with the envelope shaper, which determines the loudness contour of each note. 'Single' on the gate selector switch causes gating each time a first key is depressed; 'Multiple' retriggers when any new note is played, allowing fast runs without 'missed' notes. 'Hold' keeps the gate high for continuous effects, and 'LFO' causes gating on each LFO cycle. In the 'Repeat' position the envelope generator retriggers at the end of the decay period, acting as an additional LFO with variable symmetry. This allows complex rhythmic



E&MM SPECTRUM SYNTHESISER

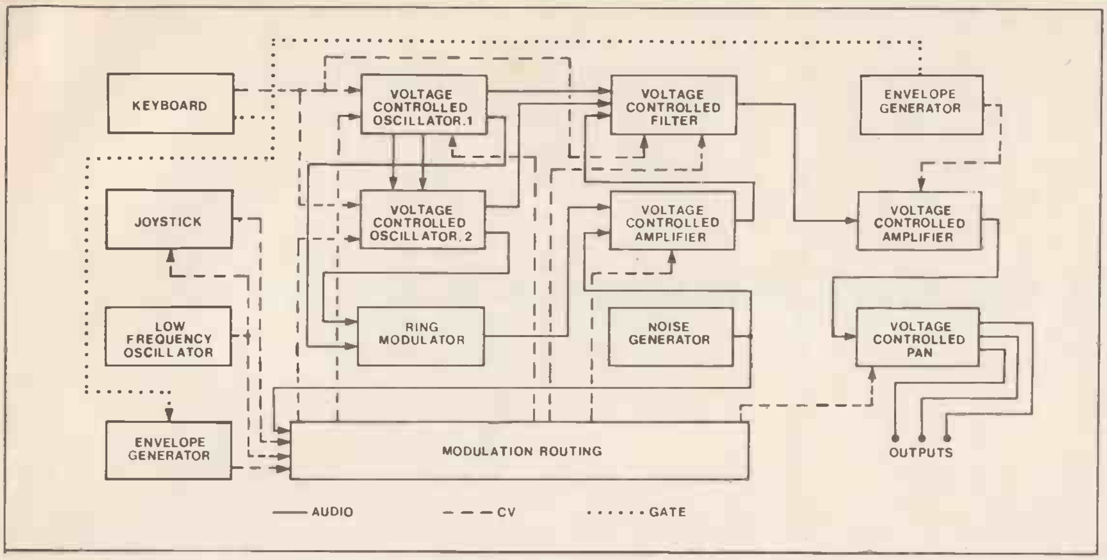


Figure 1. Block Diagram of the Spectrum Synthesiser.

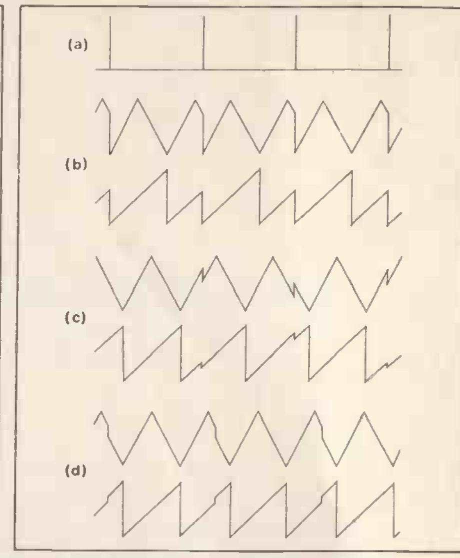


Figure 2. Sync. Waveforms. (a) Sync. Pulses. (b) Sync. I. (c) Sync. II. (d) Sync. II with decreased VCO1 frequency.

effects when used with the LFO, and gives great scope for 'backdrop' sounds based around complex S/H patterns with periodic timbre sweeping effects derived from the EG. 'Key Repeat' brings in the repeat only when a key is held, allowing key-synchronised repeating notes and delayed modulation (the delay determined by the attack time). An LED indicates the EG's attack segment.

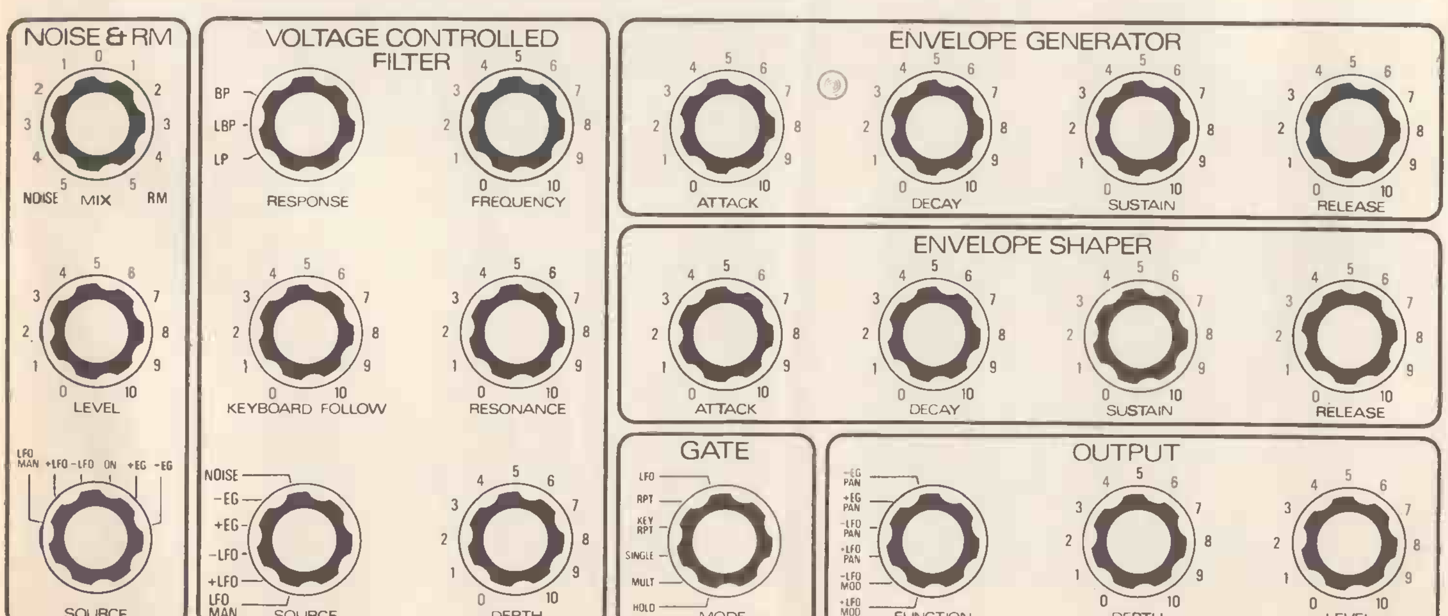
The voltage controlled oscillators (VCO's) each have five switched octave ranges and five waveforms. The sub-octave output is a pulse wave with a square wave added an octave below, making the sound fuller and richer. The tuning LED detects the beats between the oscillators, and indicates when the pitches are in simple musical intervals, useful for tuning without sounding a note (e.g. on stage). The pulse width of VCO 1 is variable, and VCO 2 has a tune control with a ± one fifth range.

The VCO's can be used together to provide a vast range of sounds not possible with basic synthesisers having only waveform, shape, VCF cutoff and VCF resonance as the controls affecting basic timbre. This is done by frequency modulation and synchronisation — special features of this design. FM uses the triangle output of VCO 1 to modulate the frequency of VCO 2 up to ±100% giving a whole range of non-harmonic tones for bell, gong, chime sounds etc. Synchronisation gives various waveforms from VCO 2 (see Figure 2) which have particular bands of harmonics emphasised for strong, voice-box-like sounds. This is achieved by resetting the output of VCO 2 upon each cycle of VCO 1, so the tones generated are always harmonic. Two modes of sync. are provided: Sync. I is that normally found on rampwave oscillators, the VCO 2 waveform beginning in the same way after each reset; Sync. II is something totally new — the triangle output is set to mid way each time but then carries on in the same direction in the new cycle. VCO 2 locks on to VCO 1 harmonics with the change from one harmonic to the next emphasised by a sharp change in tone. This enables automatic arpeggiation and incredible tone sweeps to be obtained since VCO 2 now is effectively a voltage controlled waveform generator/frequency multiplier. The sync. control attenuates the pulses fed to VCO 2 so that it only resets if the wave form is above a certain threshold, resulting in the oscillators being locked together in musical intervals (3rds, 5ths etc.). Simultaneous sync. I and FM produces harmonic tones with the shape of FM-ed waveforms within each cycle.

The ring modulator uses triangle and square VCO waveforms to provide further complex tones. Its output is mixed with the noise signal and fed into a special voltage controlled amplifier (VCA). This can be controlled by the LFO or EG, and gives the signals their own loudness contours. Hence noise 'chiffs' can be added to notes, or ring modulation set to swell in as a note decays.

The VCA output is fed to the voltage controlled filter (VCF) mixed with the VCO outputs. The VCF offers the two most useful responses, low pass and band pass, plus an intermediate response for bright sounds that remain strong in lower harmonics. Cutoff frequency and resonance controls perform their normal functions and a keyboard follow control determines how the cutoff frequency varies over the keyboard range.

After envelope shaping, the signal is fed to the voltage controlled pan circuit which can modulate the location of the sound in the stereo field by the LFO or EG signals. The stereo outputs can also be used for



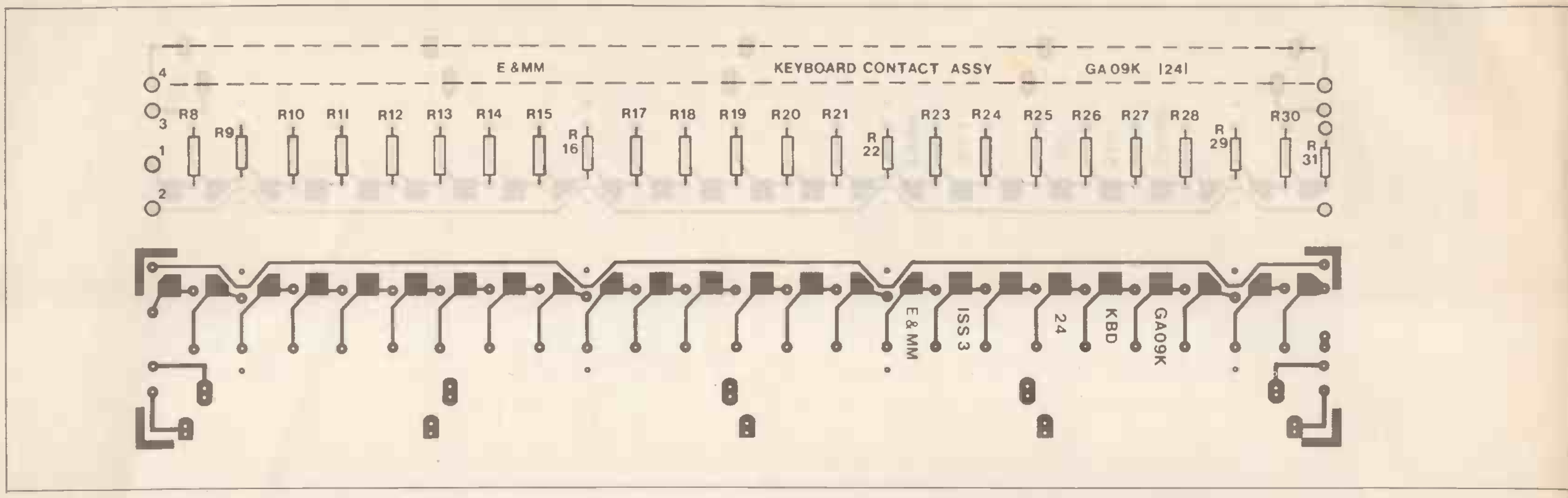


Figure 5. Keyboard printed circuit board.

voltage control of the depth of external effects such as reverb, phase, and echo, by routing one signal via the effects unit and one direct to the amplifier. A mono output is also provided, and the pan VCA can also be used for additional amplitude modulation with the LFO as source (for tremolo and other effects).

The interface jacks allow connection to external devices such as sequencers, additional VCO banks, waveform processors etc, and designs for these will be published in the future. The Spectrum Synthesiser and future equipment will use the 1V/octave CV standard, and can be interfaced to any other exponential CV synthesiser.

Keyboard

The Spectrum uses a unique key contact system which is cheaper, more reliable, and easier to construct than alternatives using gold-plated wire and contact blocks. A single moving contact is used for each key with all contacts and their associated divider chain resistors held on a PCB (in two parts) fixed to the keyboard chassis.

The moving contacts are silver plated springs, each fixed at one end and moved at the other by the plunger of the respective key such that the spring makes contact with two palladium bars when the key is depressed (Figure 1). The first bar is connected to the sample and hold circuit which stores the voltage representing the last key depressed, and the second to a circuit which generates a gate signal for the S/H and the envelope generators. The moving contacts connect to the divider chain (see Figure 2). These functions are usually carried out by separate contact pairs, where unless the contacts are precisely set up, note-jumping will occur when the envelope is gated before the S/H receives the new key voltage. The system used here is immune from this since the construction ensures the correct sequence of operation, and no initial setting up is required. The keyboard recommended in the parts list has removable key plungers so that cleaning the contacts is much easier too. Unclipping a plunger allows access to the sides of the bars and springs that meet.

Keyboard construction

Use the printed circuit board as a template to mark the fixing holes on the underside of the keyboard chassis. Mark them such that the edge of the board holding the bars will be about 5mm from the plungers and then drill for 6BA clearance. Fit the 48 divider resistors on the component side of the board along with the 12 veropins and solder in place. Cut the palladium bars to length and fit them to the track side using small loops of wire passed over the bar, through the

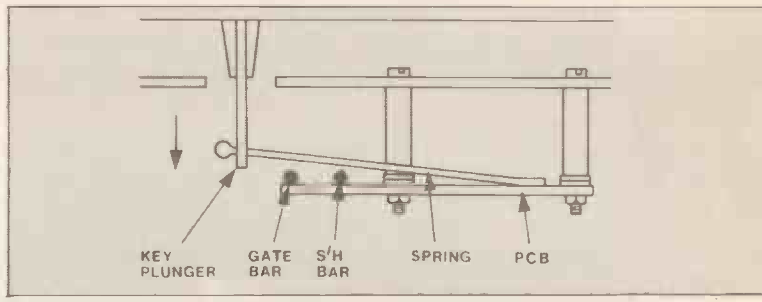


Figure 3. Key contact construction.

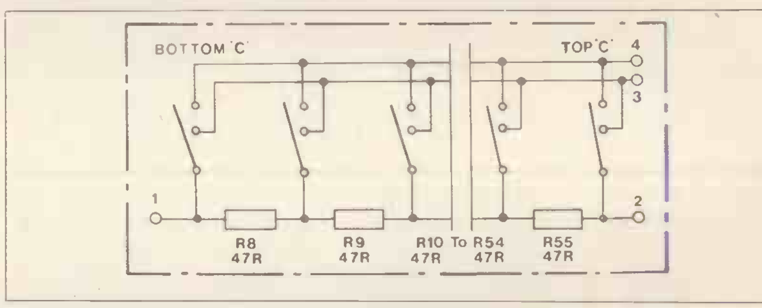
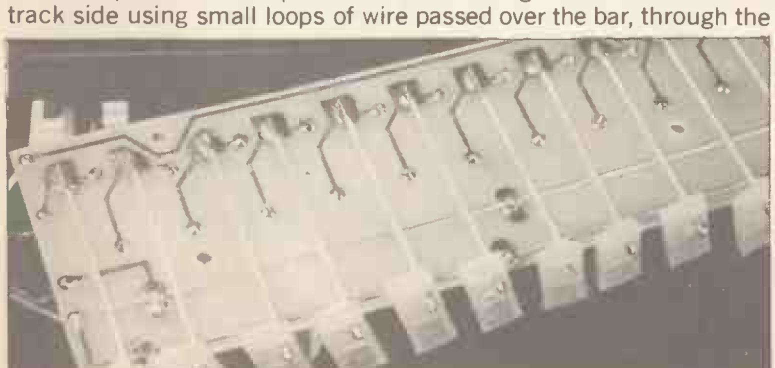


Figure 4. Circuit of key contact assembly.

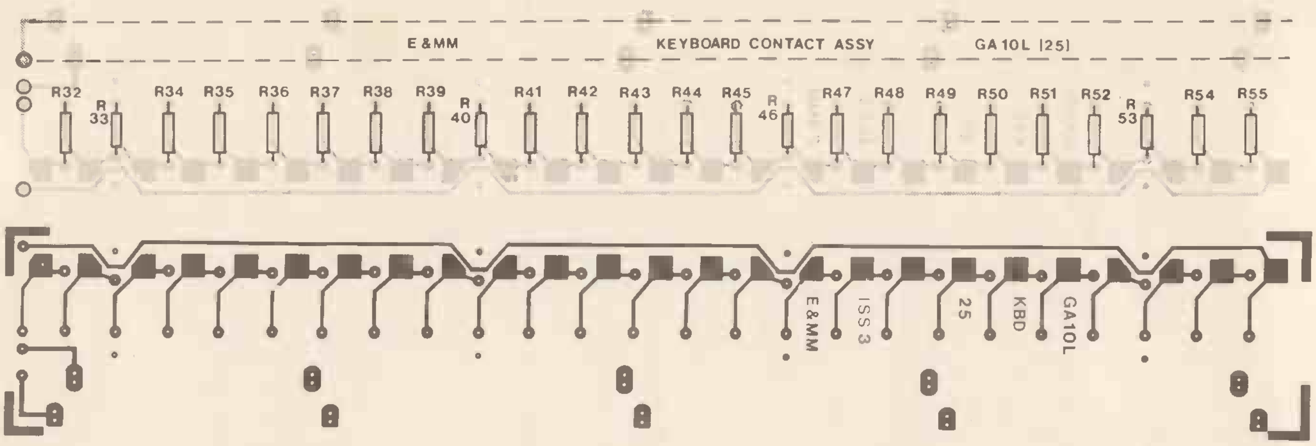
mounting holes and twisted on the component side. Make sure each bar is well seated before soldering at each loop position on both sides. Cut each plunger to length, leaving the nearest slot to the key end for the contact. Tin 5mm of both ends of the contact springs and fit each one by passing the thin end through the detached plunger and soldering it to the pad on the PCB. If you've marked the PCB mounting holes correctly then for proper operation the end of the spring should be about 2mm from the far edge of the pad. The positioning of the PCB and the springs on the PCB is not critical as long as when the PCB is mounted and the plungers clipped on, the springs are under slight tension to ensure positive contact. Mount the PCB to the chassis using 6BA bolts, ½" spacers and nuts, and washers to separate them further. The keys opposite the mounting positions will have to be temporarily removed to fit the bolts, and this should be done before drilling if a hand-held drill is used, to avoid the possibility of damage to the keys. Again, the spacing is not critical so long as all the contacts normally clear both bars and make contact with both when their keys are depressed.



A view of the key contacts before mounting of the board.

KEYBOARD PARTS LIST

Resistors			
R8-55	47R 2%	48 off	(X47R)
Miscellaneous			
	49-note C-C keyboard		(XB17T)
	Contact springs	49 off	(QY07H)
	Palladium bars, 1.2mm × 330mm	Set of 4	
	24-contact PCB		(GA09K)
	25-contact PCB		(GA10L)
	6BA 1" bolts		(BF67H)
	6BA ½" spacers		(FW35Q)
	6BA washers		(BF22Y)
	6BA nuts		(BF18U)
	Veropins		(FL24B)

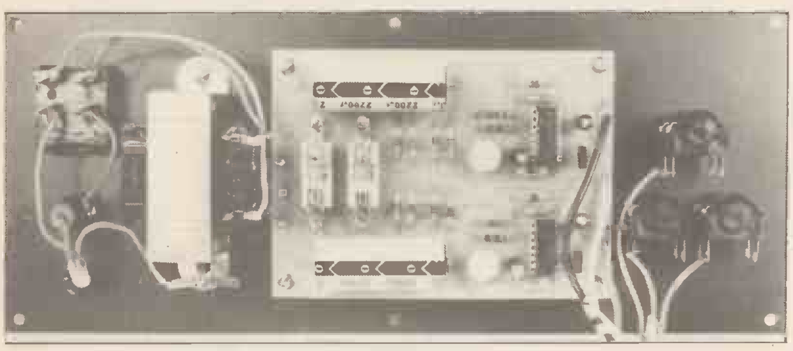


A ½" spacer and one nut were found to be about right, though washers could be used if a high or low action to the keys is preferred. Connect the two halves of the board together using short wire links across the veropin pairs. This completes the keyboard construction.

The assembly can be tested on its own by connecting a multimeter set on the low resistance range across pins 1 and 3. Depressing the bottom key should give zero resistance, and the top key about 2.4K. Check that all the other keys give intermediate readings and repeat for the other bar with the meter across pins 1 and 4.

Power Supply Unit

The proper operation of synthesiser circuits requires a stable, noise-free supply, so it is important that the Power Supply Unit (PSU) is well-regulated and has current in reserve. The Spectrum PSU uses monolithic regulators and low temperature coefficient components in a dual design to provide ± 15V at 270 mA maximum.



The completed PSU fitted to the back plate.

PSU Circuit

The Power Supply Unit consists of two identical circuits providing the positive and negative supplies, driven by a dual secondary transformer. Each secondary produces about 21V when the AC signal is rectified and smoothed, and is fused for protection in the event of a power supply fault. Regulation is carried out by the well-known uA723 regulator IC which is used with an external power transistor in series pass mode to provide the required current. This current limits at 270 mA when the voltage across series resistor R1 (R2 in the -ve side) reaches 0.6V. RV1 (RV2) allows the rail voltage to be adjusted to exactly 15V, and D1 (D2) protects against reverse polarity, again in the event of a fault. The +15V regulated output of the side based around IC2 is connected to 0V of the IC1 side, giving the -15, 0, +15V supply rails.

PSU Construction

The prototype PSU was mounted on an aluminium panel along with the mains cable, switch, and fuse. This was then fixed by screws to the wooden back of the synthesiser allowing the PSU to be separately assembled and easily removed if necessary (see photograph).

All components except the transformer fit on the PCB. Assemble the components onto the printed circuit board, starting with the resistors, diodes, polystyrene capacitors and IC sockets. These can all be inserted and soldered in together, before the large components are fitted. Note the orientation of the diodes, particularly in the bridge rectifiers (D1-8).

Use 4BA bolts and nuts to fix the chassis fuse holders, and connect them using veropins through the tag holes. Insert and solder in the cermet presets and electrolytic capacitors, followed by the two power transistors. The leads leave the transistors quite close together and should be bent apart about ⅛" from the package before putting them in place. Check that you have put them in the right way round, with the metal sides facing the nearest board edge. Solder in the eight remaining veropins and check the orientation of the electrolytic capacitors diodes, and transistors. Fix the PSU board to the back panel, or whatever else you are using, using 6BA bolts with spacers. Fit the mains switch, fuseholder, and transformer to the panel, using 4BA bolts for the latter and including two solder tags on one side for the

POWER SUPPLY UNIT PARTS LIST

Resistors — all 5% ⅓W carbon unless specified.			
R1,2	2R2 ½W	2 off	(S2R2)
R3,4	3k3 1%	2 off	(T3K3)
R5,6	3k0 1%	2 off	(T3K0)
R7	330R		(M330R)
RV1,2	1k cermet preset	2 off	(WR40T)
Capacitors			
C1,2	2200uF 25V axial elect.	2 off	(FB90X)
C3,4,7,8	2u2 63V PC elect.	4 off	(FF02C)
C5,6	100pF polystyrene		(BX28F)
Semiconductors			
IC1,2	uA723 14-pin DIL	2 off	(QL21X)
TR1,2	BD135	2 off	(QF06G)
D1-D10	1N4001	10 off	(QL73Q)
Miscellaneous			
T1	240V prim. 0-15, 0-15 sec. 10VA		(LY03D)
S1	DPST rocker switch with neon		(YR70M)
FS1	20mm 500mA quick blow fuse		(WR02C)
	20mm panel fuseholder		(RX96E)
FS2,3	20mm 1A quick blow fuse	2 off	(WR03D)
	20mm chassis fuseholder	2 off	(RX49D)
	14-pin DIL socket	2 off	(BL18U)
	Printed circuit board		(GA03D)
	3A 3-core mains cable 2m		(XR01B)
	13A mains plug		(HL58N)
	6BA 1" bolts		(BF07H)
	6BA ½" spacers		(FW35Q)
	6BA nuts		(BF18U)
	4BA ½" bolts		(BF03D)
	4BA nuts		(BF17T)
	4BA solder tags		(BF28F)
	Cable grommet		(LR48C)
	Veropins		(FL24B)

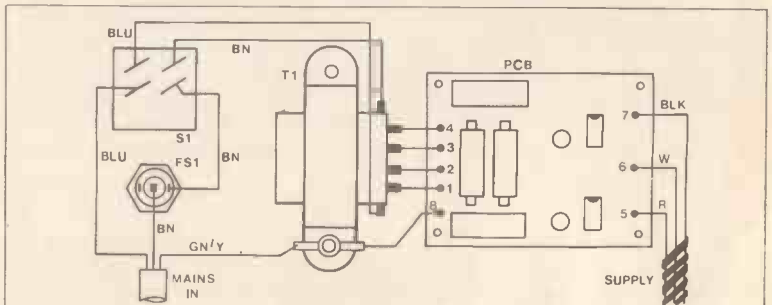


Figure 8. PSU and mains wiring.

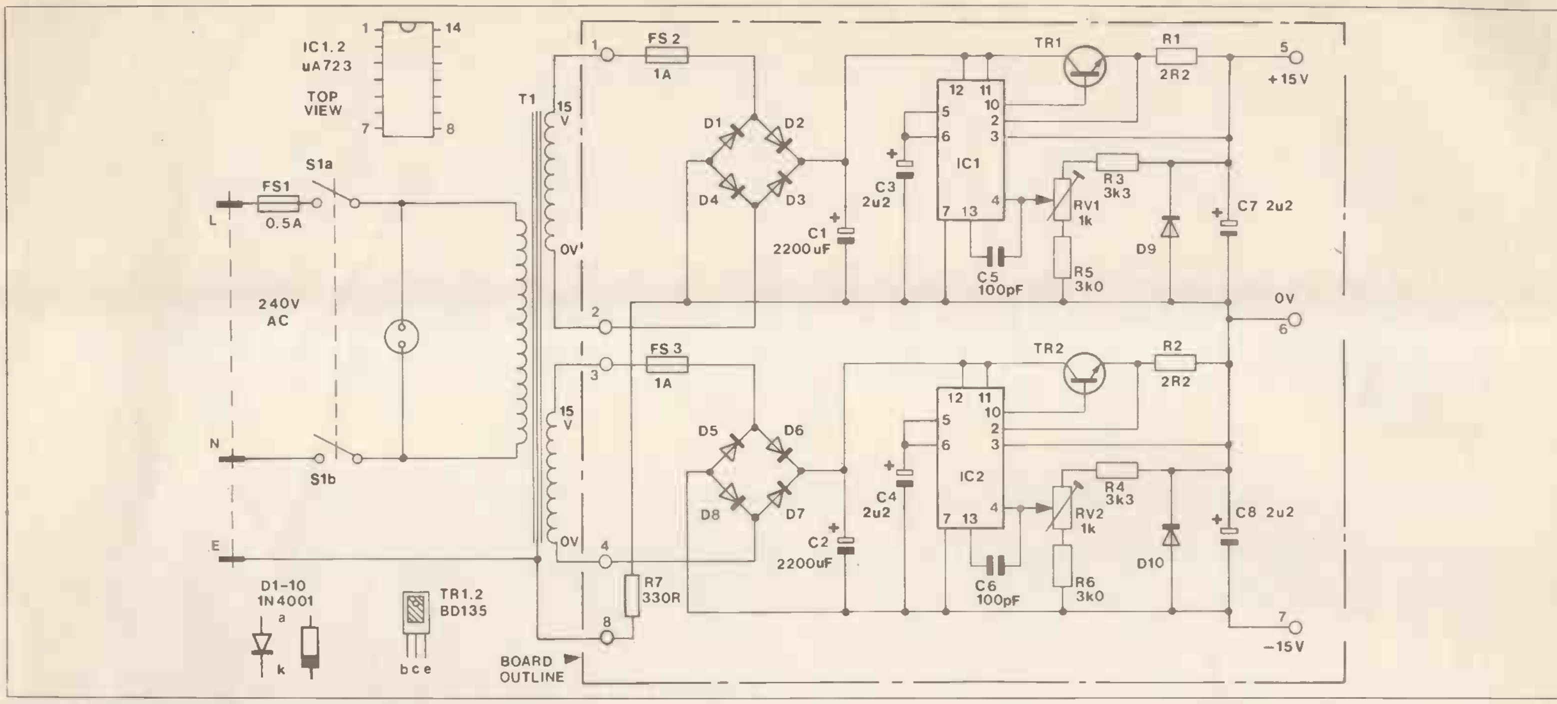


Figure 6. Circuit of the Power Supply Unit.

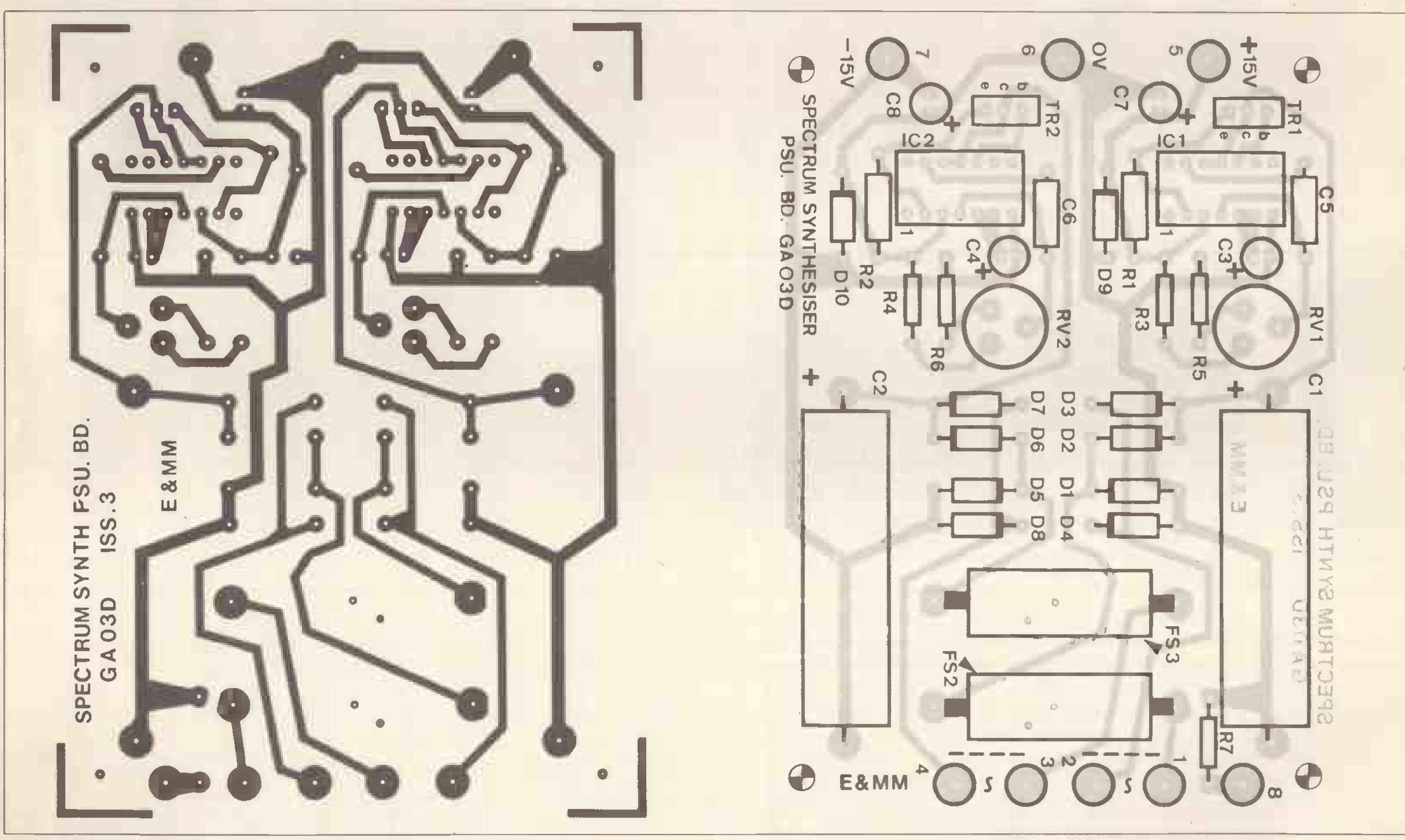


Figure 7. PSU printed circuit board.

earth connections. Strip back a length of the mains cable and cut off some of each core for connecting the switch, fuse, transformer and PCB. Connect these as shown in Figure 7, and then connect the mains cable and secure it with the grommet. The fuse is wired on the supply side of the switch, so that the switch neon will go out if the fuse blows. Fit a mains plug with a 3amp fuse and then check the wiring before going on to the next stage.

PSU Setting Up

Before inserting FS2, 3 or IC1, 2 first insert FS1, plug in, switch on, and measure the voltage across each secondary. This should be around 15V RMS. Now fit FS2 and 3 with the power off, switch on, and measure the voltage across C1 and 2, each of which should be about 21V. Switch off again, insert IC1 and 2, switch on, and measure the output voltages (across points 6,5 and 7,6). If you are confident in your constructional abilities, you can leave these checks and try the PSU with all the fuses and IC's in first time. Either way, the rail voltages should be measured and RV1 (+ve) and RV2 (-ve) adjusted so that they are exactly 15V. An oscilloscope will probably be more accurate for this than a cheap multimeter, though use a digital multimeter or a good mechanical meter if one is available.

Digisound Ltd. will be offering a full set of the CEM IC's used in this project at the special reduced price of £29.00 inc. VAT and postage. Ready-made metalwork and PCB's will be obtainable from Maplin Electronic Supplies. A cassette demonstrating the Spectrum's facilities will be made available from E&MM.

E&MM

DRILL CONTROLLER

Electronically changes speed from approximately 10 revs to maximum. Full power at all speeds by finger-tip control. Kit includes all parts, case, everything and full instructions. £3·45
Made up model £2·00 extra

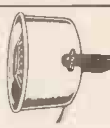
SIX DIGIT COUNTERS

One pulse moves one digit—Type 1 for 230v AC or 100v DC not resettable. Price 80p—Type 2 for 48v DC or 115v AC and re-settable £1·85.

COMPONENTS BARGAIN

Ref. W0998. Modern fibre glass board, contains a multitude of very useful parts, some of which are:— SCR ref. 2N 5060/2, 35 assorted rectifiers including four 3 amp 400v types (made up in a bridge) 8 transistors type BC 107 and 2 type BFY 51 electrolytic condensers. 250uf 100v DC and 100uf 25v DC and over 100 parts including variable, fixed and wire wound resistors, electrolytics etc. Don't miss this snip at £1·15.

SIREN OR BLEEPER



American Delta mechanical type, works on 6 to 12v to DC or 12 to 24v AC. Price 75p or £60 per 100. Electronic Bleeper TH3S emits high pitched wailing note of varying pitch. In red plastic case with fixing bracket. £5·00.

CASSETTE PLAYER/RECORDERS

With record and playback heads, all electronics, switches and speaker. Price £9·95 (surely this must be the bargain of the year). Music centre replacement stereo with heads but not electronics. £14·95.

DESOLDERING PUMP

Ideal for removing components from computer boards as well as for service work generally. Price £6·35.

INTERCOM OUTFIT

Brand new intercoms with 50' inter-connecting lead. Master and sub, in neat plastic cases suitable for office or home or as a baby alarm etc. These are new stock but please expect a little fault. Offered at less than the price of the 2 speakers, switches and cases. Only £3·74 the pair.

HEADPHONE AMPLIFIER (STEREO)

With volume, tone and balance control 9v operation. All made up ready to go. Price £4·50.

MAINS SOLENOIDS

All have powerful pull.
TT2 size 1½" × 2¼" × 2". Price £2·95
TT6 size 2½" × 1⅞" × 2". Price £3·50
TT10 size 3" × 2½" × 2". Price £4·86

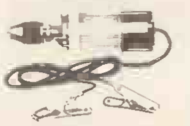
ELECTRONIC JIGSAW PUZZLE

One of the many things you can make with this miniature uni-selector. We give the circuit free when you order. Price £3·45.

MAINS OPERATED VALVES

Made by Asco. Two models available both suitable for water and non-corrosive liquids, both for normal mains operation. Ref. VI for ½" pipes and low pressure operation. V2 is for ½" pipe and high pressure operation.

VERSADRILL



A 12 volt battery operated power drill, not just suitable for printed circuit boards but will do all the jobs and is powerful enough to perform all the functions and operations normally expected of Black & Decker and other mains drills. Its chuck accepts up to ⅛" drills. Size approx. 150mm × 50mm. Price £16·75.

DOOR SWITCH

Neat tubular pattern for letting into door frame. This is a changeover switch so can be used in opening or closing circuits. Price 57p. D.I.Y. burglar alarm parts available, request diagram and price list of our mains operated system.

V3 MICROSWITCHES

Over 50,000 in stock, all 250 AC working, all with 3 silver contacts for c/o circuits. 10 amp 25p each or £20 per 100, 15 amp 35p each or £30 per 100.

TANGENTIAL BLOWER

Metal bladed Smiths made super silent with dozens of applications, cooker hoods, fume extractor—blower heater fresh air impeller etc. Air outlet is rectangular size approx. 10½" × 2¼" £4·95. Post £1·50.

MULLARD UNILEX

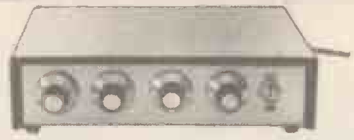
A mains operated 4+4 stereo system. Rated one of the finest performers in the stereo field this would make a wonderful gift for almost anyone. In easy-to-assemble modular form this should sell at about £30—but due to a special bulk buy and as an incentive for you to buy this month we offer the system complete at only £16 including VAT and postage.
FREE GIFT—Buy this month and you will receive a pair of Goodman's elliptical 8"×5" speakers to match this amplifier.

8 BATTERY MOTORS
For model makers, smallest is about as big as a thimble and the biggest is powerful enough for a drill. £2 the 8.

12V MOTOR BY CROUZET
A powerful motor virtually impossible to stop by hand, size approx. 2½" long and 2¼" dia. permanent magnet so reversible simply by changing polarity and has a relatively constant speed with or without load. Fitted with a splined shaft which could directly engage a toothed wheel or to which a pulley could be attached. Ideal for large models, or small machines etc. Priced £4·25.

MAINS OPERATED LOW SPEED MOTORS
Programmer type as used in time switches etc. The following final speeds in stock:—
1r 24 hrs — 1r 8 hrs — 1r 4h — 1rh — 2 rh — erh — 4rh — 12 rh — 20 rh — 30 rh — 1r min — 2rm — 4 rm — 8 rm — 15 rm — 25 rm — 30 rm — 200 rm — all at £3·50 each.

SPIT MOTORS
These are powerful mains operated induction motors with gear box attached with easy to fix to, squared shaft, final speed is approx. 5 revs. per min., price £5·25—similar motor but with final speed 110 rpm, 80 rpm £5·15.

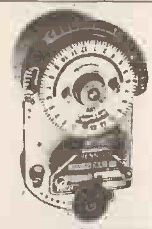


3-CHANNEL SOUND TO LIGHT KIT

Complete kit of parts for a three-channel sound to light unit controlling over 2,000 watts of lighting. Use this at home if you wish but it is plenty rugged enough for Disco work.
The unit is housed in an attractive two-tone metal case and has controls for each channel, and a master on/off. The audio input and output are by ¼" sockets and three panel mounting fuse holders provide thyristor protection. A four-pin plug and socket facilitate ease of connecting lamps. Special snip price is £14.95 in kit form or £19.95 assembled and tested.

DELAY SWITCH

Mains operated — delay can be accurately set with pointers knob for periods of up to 2½ hrs. 2 contacts suitable to switch 10 amps — second contact opens a few minutes after 1st contact.



VENNER TIME SWITCH mains operated with 20 amp switch, one on and one off per 24 hrs. repeats daily automatically correcting for the lengthening or shortening day. An expensive time switch but you can have it for only £2.95. These are new but without case, but we can supply plastic cases (base and cover) £1.75 or metal case with window £2.95. Also available is adaptor kit to convert this into a normal 24 hr. time switch but with the added advantage of up to 12 on/offs per 24 hrs. This makes an ideal controller for the immersion heater. Price of adaptor kit is £2.30.

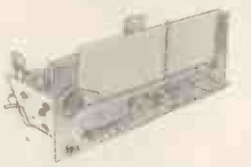
FLUORESCENT TUBE INVERTER

For camping — car repairing — emergency lighting from a 12v battery you can't beat fluorescent lighting, it will offer plenty of well distributed light and is economical. We offer Phillips inverter for 12" 8 watt miniature tube for only £2.75 with tube and tube holders as well.

SUPER HI-FI SPEAKER CABINETS

Made for an expensive Hi-Fi outfit — will suit any decor. Resonance free cut-outs for 8" woofer and 4" tweeter. The front material is carved Dacron, which is thick and does not need to be stuck in and the completed unit is most pleasing. Colour black. Supplied in pairs, price £6.90 per pair (this is probably less than the original cost of one cabinet) carriage £3 the pair.

CHASSIS BARGAIN



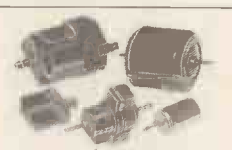
3 wave band radio with stereo amplifier. Made for incorporation in a high-class radiogram, this has a quality of output which can only be described as superb. It is truly hi-fi. The chassis size is approximately 14". Push buttons select long, medium, short and gram. Control are balance, volume, treble and bass. Mains power supply. The output is 6+6 watts. Brand new and in perfect working order, offered at less than value of stereo amp alone, namely £6.90. Post £2.00.

THIS MONTH'S SNIP

THERMOSTAT ASSORTMENT 10 different thermostats. 7 bi-metal types and 3 liquid types. There are the current stats which will open the switch to protect devices against overload, short circuits, etc, or when fitted say in front of the element of a blower heater, the heat would trip the stat if the blower fuses; appliance stats, one for high temperatures, others adjustable over a range of temperatures which could include 0-100°C. There is also a thermostatic pod which can be immersed, an oven stat, a calibrated boiler stat, finally an ice stat which, fitted to our waterproof heater element, up in the loft could protect your pipes from freezing. Separately, these thermostats would cost round about £15.00 — however, you can have the parcel for £2.50.

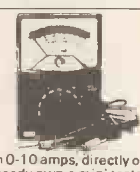
INDUCTION MOTORS Mains working as used in record players, fans, etc. Speed usually 1,400. All have ample spindle length for coupling fan blade, pulley etc. Power depends on stack size. ⅝" stack £2.00; ¾" stack £2.50; ⅞" stack £3.00; 1" stack £3.50; 1½" stack £4.50. Add 25p to total motor cost to cover postage and then add 15% VAT.

8 POWERFUL BATTERY MOTORS



For models, Meccanos, drills, remote control planes, boats, etc. £2.

MINI-MULTI TESTER



Deluxe pocket size precision moving coil instrument, jewelled bearings — 2000 o.p.v. mirrored scale. 11 instant ranges measure: DC volts 10, 50, 250, 1000. AC volts 10, 50, 250, 1000. DC amps 0-100 mA. Continuity and resistance 0-1 meg ohms in two ranges. Complete with Test Prods and instruction book showing how to measure capacity and inductance as well. Unbelievable value only £6.75 + 50p post and insurance.
FREE Amps ranges kit to enable you to read DC current from 0-10 amps, directly on the 0-10 scale. It's free if you purchase quickly but if you already own a mini tester and would like one, send £2.50.

Terms: Cash with order – but orders under £10 must add 50p to offset packing, etc.
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IT'S FREE

Our monthly Advance Advertising Bargains List gives details of bargains arriving or just arrived—often bargains which sell out before our advertisement can appear—it's an interesting list and it's free—just send S.A.E. Below are a few of the Bargains still available from previous lines.

DUE TO THE HIGH & RISING PRICES OF FUEL many companies and probably many householders are looking around for ways of saving some of this cost. One Company bought a number of fans from us and fitted these on the ceiling of their workshops where the hot air tends to collect and they blow this hot air downwards. Another Company has bought fans from us to suck the exhaust from their oil fired central heaters through a zig zag of asbestos pipes, the asbestos pipes being in a separate chamber which becomes a hot air chamber, the hot air from this is blown through ducting to where ever it is needed. Basically, they have cut out the normal chimney and replaced this with one of our high power extractor fans. If you have any other good ideas on heat cost saving, let us know and we will pass it on to other readers.

EXTRACTOR FANS

Ex-Computer made by Woods of Colchester, ideal also as blower; central heating systems, fume extraction etc. Easy fixing through panel, very powerful 2,500 r.p.m. but quiet running. Choice of 2 sizes, 5" £5·50, 6" £6·50; post £1 per fan.

PING PONG BALL BLOWER-UPPERS Have you got to organise a Party or Charity Fund-Raising Event? Then one always popular way is to have ping pong balls going up and down and being caught. We have some powerful blowers and these should be ideal for this, and of course for more serious purposes. They are 4 stage blowers, coupled to synchronised AC mains motors of approximately ¼ h.p. They have a terrific suction as well as a high velocity blow. Ex computers, price £26·00.

TRANSMITTER SURVEILLANCE
Tiny, easily hidden but which will enable conversation to be picked up with FM radio. Can be made in a matchbox—all electronic parts and circuit. £2·30.

RADIO MIKE
Ideal for discos and garden parties, allows complete freedom of movement. Play through FM radio or tuner amp. £6·90.

SAFE BLOCK
Mains quick connector will save you valuable time. Features include quick spring connectors, heavy plastic case and auto on and off switch. Complete kit £1.95.

LIGHT CHASER
Gives a brilliant display—a psychedelic light show for discos, parties and pop groups. These have three modes of flashing, two chase-patterns and a strobe effect. Total output power 750 watts per channel. Complete kit. Price £16. Ready made up £4 extra.

FISH BITE INDICATOR enables anglers to set up several lines then sit down and read a book. As soon as one has a bite the loudspeakers emits a shrill note. Kit. Price £4·90.

6 WAVEBAND SHORTWAVE RADIO KIT
Bandspread covering 13·5 to 32 metres. Based on circuit which appeared in a recent issue of Radio Constructor. Complete kit. Includes case materials, six transistors, and diodes, condensers, resistors, inductors, switches, etc. Nothing else to buy, if you have an amplifier to connect it to on a pair of high resistance headphones. Price £11·95.

SHORT WAVE CRYSTAL RADIO
All the parts to make up the beginner's model. Price £2·30. Crystal earpiece 65p. High resistance headphones (give best results) £3·75. Kit includes chassis and front but not case.

RADIO STETHOSCOPE
Easy to fault find—start at the aerial and work towards the speaker — when signal stops you have found the fault. Complete kit £4·95.

INTERRUPTED BEAM KIT
This kit enables you to make a switch that will trigger when a steady beam of infra-red or ordinary light is broken. Main components—relay, photo transistor, resistors and caps etc. Circuit diagram but no case. Price £2·30.

OUR CAR STARTER AND CHARGER KIT has no doubt saved many motorists from embarrassment in an emergency you can start car off mains or bring your battery up to full charge in a couple of hours. The kit comprises: 250w mains transformer, two 10 amp bridge rectifiers, start/charge switch and full instructions. You can assemble this in the evening, box it up or leave it on the shelf in the garage, whichever suits you best. Price £11·50 + £2·50 post.

G.P.O. HIGH GAIN AMP/SIGNAL TRACER. In case measuring only 5½in × 3½in × 1½in is an extremely high gain (70DB) solid state amplifier designed for use as a signal tracer on GPO cables etc. With a radio it functions very well as a signal tracer. By connecting a simple coil to the input socket a useful mains cable tracer can be made. Runs on standard 4½v battery and has input, output sockets and on-off volume control, mounted flush on the top. Many other uses include general purpose amp. cueing amp, etc. An absolute bargain at only £1·85. Suitable 80 ohm earpiece 69p.

VU METER
Edgewise mounting, through hole size 1⅞" × ½" approx. These are 100 micro amp f.s.d. and fitted with internal 6 volt bulb for scale illumination, also have zero reset. The scale is not calibrated but has very modern appearance. Price £2·88p.

BALANCE METER
Edgewise mounting 100 UA centre zero. Price £2·30p.

1½" SQUARE PANEL METER
Eagle full vision plastic front, 50 UA. Price £4·60p 1 mA Price £4·03p.

WATERPROOF HEATING WIRE
60 ohms per yard. This is a heating element wound on a fibre glass coil and then covered with p.v.c. Dozens of uses—around water pipes, under grow boxes in gloves and socks. 23p metre.

DIAL INDICATOR
As used in tool making and other precision measuring operations, the famous John Bull accurately shows differences of 0·1mm. A beautifully made precision instrument, price in most tool shops would be £12-£15. We have a fair quantity. Price £9·20p.

COMPONENT BOARD Ref. W0998.
This is a modern fibre glass board which contains a multitude of very useful parts, most important of which are: 35 assorted diodes and rectifiers including four 3 amp 400v types (made up in a bridge) 8 transistors type BC 107 and 2 type BFY 51 electrolytic condensers, SCR ref. 2N 5062 25 Ouf 100v DC and 100uf 25v DC and over 100 other parts including variable, fixed and wire wound resistors, electrolytic and other condensers. A real snip at £1·15.

FRUIT MACHINE HEART. 4 wheels with all fruits, motorised and with solenoids for stopping the wheels with a little ingenuity you can defy your friends getting the "jackpot." £9·95 + £4 carriage.

DESOLDERING PUMP
Ideal for removing components from computer boards as well as for service work generally. Price £6·35.

4-CORE FLEX CABLE
White pvc for telephone extensions, disco lights, etc. 10 metres £2, 100 metres £15. Other multicore cable in stock.

MUGGER DETERRENT
A high-note bleeper, push latching switch, plastic case and battery connector. Will scare away any villain and bring help. £2·50 complete kit.

HUMIDITY SWITCH
American made by Honeywell. The action of this device depends upon the dampness causing a membrane to stretch and trigger a sensitive microswitch. Very sensitive breathing on it for instance will switch it on. Micro 3 amp at 250V a.c. Only £1·15.

Starting Point

by Robert Penfold

As it is hoped this series will show, it is within the capabilities of practically anyone to gain a good basic understanding of electronics. For those whose main interest is electronics construction, design, or servicing, it is probably best to concentrate mainly on the characteristics of the various components and the way in which they are employed in practical designs, rather than on the detailed theory of their operation. This approach will be used in this series, and it should enable even absolute beginners to quickly and easily grasp an understanding of electronic circuits. Each subsequent part of the series will be accompanied by a simple constructional project which will demonstrate the practical application of the theory that has been covered, as well as being a useful and worthwhile piece of equipment in its own right.

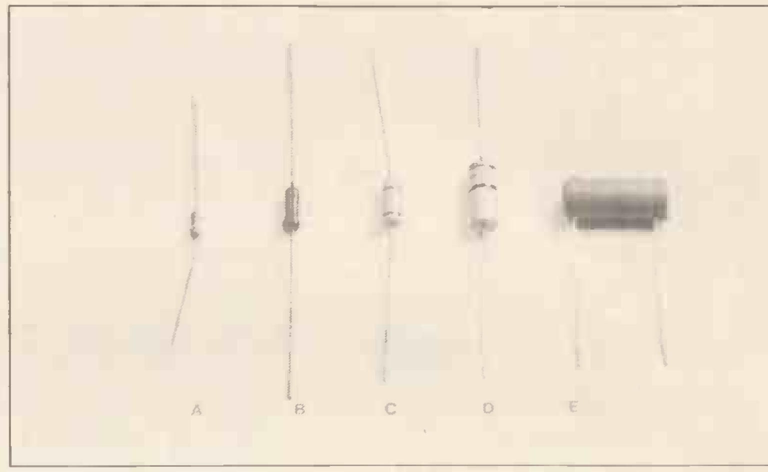
Current Flow

A basic understanding of current flow is an essential piece of background knowledge for anyone trying to get to grips with electronic components and circuits. An electronic current consists of a flow of minute particles called electrons. All matter is made up of miniscule building blocks called atoms, and electrons are one of the constituents of atoms. The electrons are very much smaller than the rest of the atom (the 'nucleus'), and they are in orbit around the nucleus. In the case of most substances all the electrons are held firmly in orbit and are not easily dislodged, but in others there is a 'free electron' in the outer orbit which is only loosely bound to the atom. In fact the free electrons tend to move randomly from one atom to another.

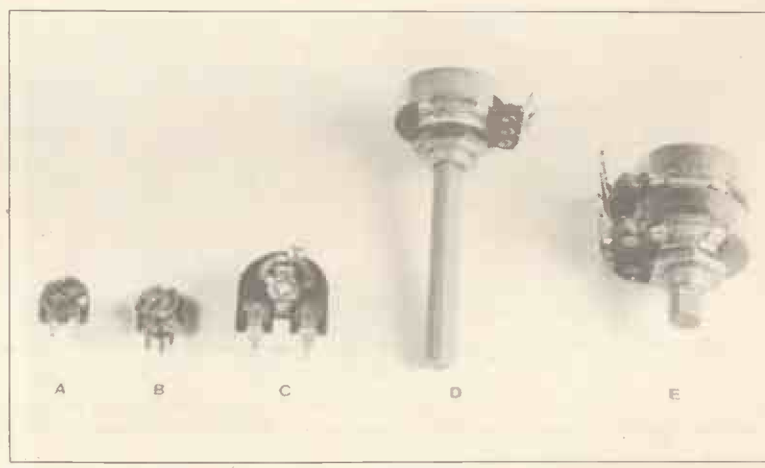
By applying an electro-motive force (E.M.F.) to materials having free electrons, these electrons can be made to proceed in the same general direction (although still in a rather haphazard fashion). This flow of electrons constitutes a current flow.

A common source of E.M.F. is a battery, and metals are the main materials which are plentiful in free electrons. Thus if a piece of wire is connected across the terminals of a battery a heavy current flows through this 'circuit'. Substances which readily permit a heavy current flow are called 'conductors'. Most materials, such as plastics, are practically devoid of free electrons and strongly resist any current flow. These are known as 'insulators'. Thus virtually no current flows if, for example, a piece of PVC sleeving is connected across a battery.

The two terminals of a battery are identified by '+' (positive) and '-' (negative) signs. The electron flow is from the negative terminal to the positive one. Unfortunately, the pioneers of electricity assumed a positive to negative current flow and based many laws of physics on this assumption. This has led to a situation today where we sometimes talk in terms of electron flow (negative to positive) and at other times in terms of 'conventional current flow' (positive to negative). The behaviour of components and circuits can be explained satisfactorily using either, and it is really a matter of choosing whichever is the more convenient. However, to avoid confusion it is necessary to make it clear which convention is being used.



The power rating of resistors tends to be reflected in their physical size, the greater surface area of larger types permitting more rapid dissipation of heat into the air. (a) ⅓W carbon film, (b) ½W metal oxide (close tolerance), (c) ½W carbon film, (d) 1W carbon film, and (e) 5W wirewound.



Examples of potentiometers: (a) 0.1W horizontal preset, (b) 0.1W vertical preset, (c) 0.25W horizontal preset, (d) carbon potentiometer, and (e) dual gang carbon potentiometer.

Ohm's Law

The amount of current flowing in a circuit is measured in units called 'amperes', but the abbreviated terms 'amps' and 'A' are more commonly used. The current flow in a circuit is governed by two factors:-

1. The strength of the E.M.F. applied to it
2. How readily it conducts or resists a current flow

The strength of an E.M.F. is measured in volts (V), and obviously the higher the voltage, the larger the current it will force through a given circuit. In fact the current flow is proportional to the applied voltage and a doubling in the voltage applied to a circuit, for instance, doubles the current flow.

Rather than specify how readily a circuit conducts it is more usual to specify its 'resistance' to a current flow, and resistance is measured in ohms. The higher the resistance in ohms, the more difficult it is to force a given current through the circuit. The current flow is inversely proportional to the resistance of a circuit, and so halving the resistance of a circuit, for example, would double the current flow.

Resistance, current, and voltage are mathematically related to one another by 'Ohm's Law', and if any two quantities are known, the third can be calculated. Ohm's Law is as follows:-

Current = Voltage divided by Resistance, or
Resistance = Voltage divided by current, or
Voltage = Current multiplied by Resistance

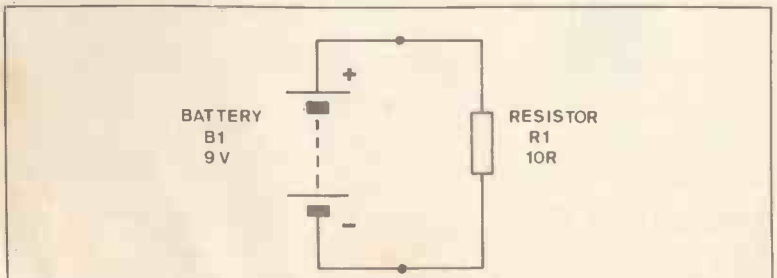


Figure 1. Current flow through a resistor.

If we consider a simple example, the circuit diagram of Figure 1 shows a 9 volt battery connected across a 10 ohm resistor. It should perhaps be pointed out that in circuit diagrams the components are represented by a set of symbols; two of which are shown here (others will be introduced when we come to consider the component concerned). The lines joining them represent the connecting wires, and dots on the lines indicate connections. Where lines cross one another without a dot at the intersection there is *no* connection; this is just a point on the diagram where it is necessary for lines to cross over one another.

In our simple example of Figure 1 the current flow is 9 volts divided by 10 ohms, or 0.9 amperes. If we knew the battery voltage and current flow but not the resistance of R1, then this resistance could be calculated (9V ÷ 0.9A = 10R). The word 'ohms' is often abbreviated to the Greek letter omega (Ω) or shown as a capital R, as it appears here. If the battery voltage was the unknown quantity this could be calculated as 10R × 0.9A = 9V.

As Ohm's Law is not merely of academic importance and is much used when tackling practical problems in electronics it is well worth spending some time and effort to ensure a proper understanding of it, working out a few contrived examples if this will help.

Units

In practical electronics it is often necessary to use very large or very small quantities. It is quite common for circuits to employ resistors having values of many thousands or even millions of ohms. On the other hand, circuits often handle signals having amplitudes of only a few thousandths or millionths of a volt. To avoid constantly using very large or very small numbers, quantities are often given a prefix ahead of the letter denoting the units in use. The prefix indicates that the value is given in some multiple or subdivision of the basic unit. The prefixes commonly encountered are listed below:-

× 1,000 = k (kilo)
× 1,000,000 = M (mega)
× 1,000,000,000 = G (giga)
× 1,000,000,000,000 = T (tera)
1/1,000 = m (milli)
1/1,000,000 = μ (micro)
1/1,000,000,000 = n (nano)
1/1,000,000,000,000 = p (pico)

A potential of 0.005V could therefore be given as 5mV or 5 millivolts, or a resistor value could be given as 3.9M or 3.9 megohms instead of 3,900,000 ohms.

Series and Parallel

It is possible to combine resistors (and other components) in series or in parallel, or in a combination of the two. Series and parallel connection are illustrated in Figure 2a and Figure 2b respectively. In each case three devices are shown, but obviously any number of components could be used with either method of connection.

As one would expect, when several resistors are added in series the total resistance through the combination is higher than the resistance of any one component in the circuit. This is merely because the current has to negotiate not just one resistor, but all those in the chain. In fact the total resistance is simply equal to the sum of all the resistances in the circuit. Thus with the example values shown in Figure 2a there is a total resistance of 7.9k (1k + 2.2k + 4.7k = 7.9k).

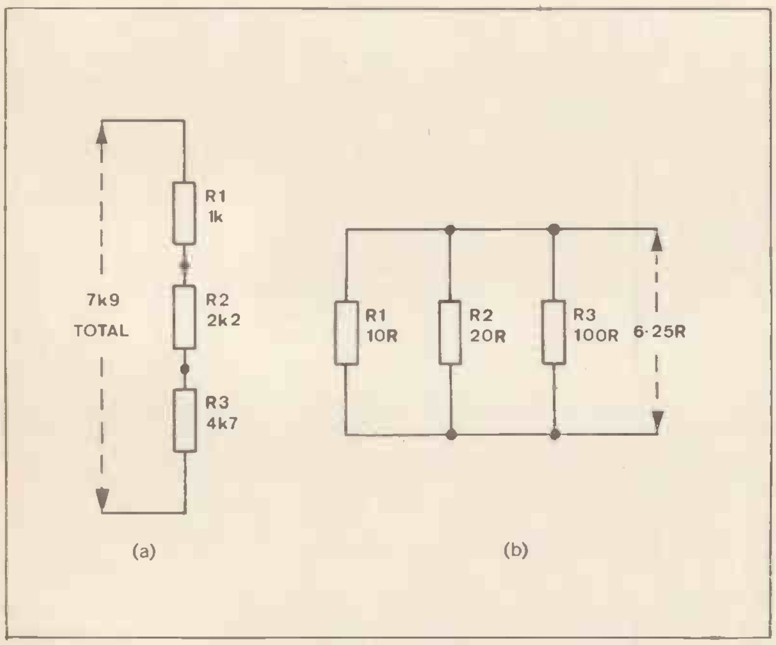


Figure 2. a. Resistors in series. b. Resistors in parallel.

When resistors are connected in parallel the total resistance of the circuit is less than the value of any one resistor in the circuit. This is due to the additional current paths provided by the other resistors in the circuit, with the applied voltage causing the appropriate current to flow through each resistor. Therefore, for a given level of current flow a lower supply voltage will be needed for several resistors in parallel than for just one of the resistors, and the parallel combination obviously gives a lower resistance.

The equation for parallel resistance in a circuit containing two resistors is:-

$$R\,total = \frac{R1 \times R2}{R1 + R2}$$

For example, a 10 ohm and a 30 ohm resistor in parallel exhibit a combined resistance of:-

$$R\,total = \frac{10 \times 30}{10 + 30} = \frac{300}{40} = 7.5\text{ ohms}$$

For three or more resistors in parallel the equation is:-

$$R\,total = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}} \quad \text{etc.}$$

Thus (say) 10, 20, and 100 ohm resistors in parallel would have a combined resistance of:-

$$R\,total = \frac{1}{\frac{1}{10} + \frac{1}{20} + \frac{1}{100}} = \frac{1}{0.1 + 0.05 + 0.01} = \frac{1}{0.16}$$

1 divided by 0.16 equals 6.25 ohms.

Parallel resistance calculations are not as easy as series resistance calculations, but are not really difficult when done with the aid of an electronic calculator.

It must be stressed that these equations cannot be applied to components of any type (e.g. capacitors). Different components behave in different ways when combined in series or parallel. Batteries for example, produce the same voltage when connected in parallel (see Figure 3a), no matter how many are used. This method of connection is not advisable in practice incidentally, since the actual (rather than nominal) voltage supplied by a battery varies according to the amount of 'charge' it contains. An ordinary 9 volt dry battery for instance, might have an actual voltage of 9.5 volts when new, and only about 7.5 volts when it is

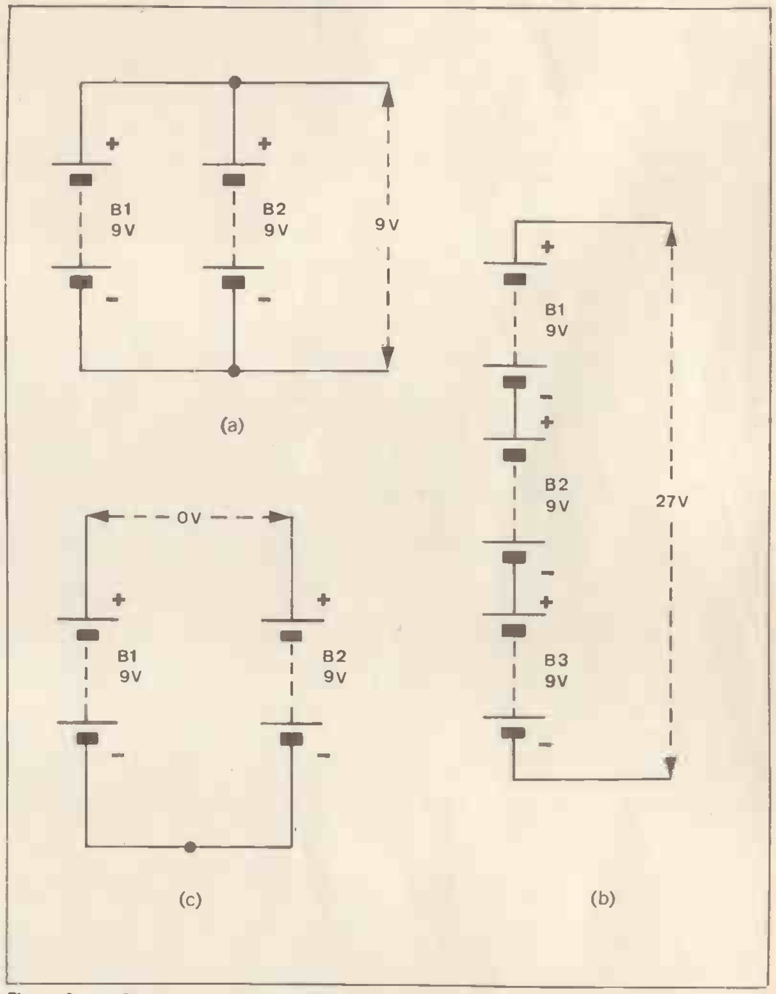


Figure 3. a. Batteries in parallel. b. Batteries in series. c. Batteries in reverse series.

nearly exhausted but still usable. Therefore, two practical batteries might well have slightly different voltages, causing the one having the higher voltage to drive a current through the other! The amount of current that would flow depends upon the difference in the battery voltages and the internal resistances of the batteries. The internal resistance is that contained within the internal structure of the battery. Although an innate property of a battery, the effect is much the same as if an actual resistor was connected in series with the battery, and in this case it limits the current that would flow.

Internal resistance also results in the battery voltage falling as the current drain is increased, the lost voltage effectively being dropped across the internal resistance. For example, a battery having an internal resistance of 10 ohms would suffer a drop in output voltage of 2 volts if a current of 200mA (0.2A) was drawn from it (V = C × R = 0.2 × 10 = 2 volts). All practical power and signal sources possess internal resistance, and there is thus a limit to the amount of current they can provide.

When batteries are connected in series in the manner shown in Figure 3b, their total output voltage is equal to the sum of the individual battery voltages, giving an output of 27 volts in this case. The method of connection shown in Figure 3c is of no practical value since one battery tends to cancel out the other, giving zero output voltage if they have the same voltage!

Voltage Dividers

When a voltage is fed to a series resistor circuit (as in Figure 4) part of the input voltage will be present across each resistor. It would be possible to calculate each voltage by first finding the total series resistance, then

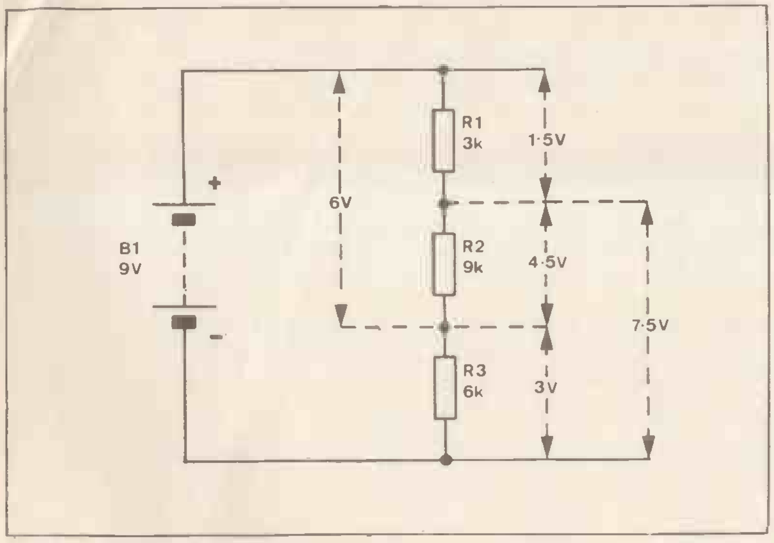


Figure 4. Kirchoff's Voltage Law.

calculating the current flowing in the circuit using Ohm's Law, and finally using Ohm's Law again to work out the three voltages.

A quicker method is to calculate the total resistance in the circuit, and then work out what fraction of this each resistor's value corresponds to. The voltage across each resistor is then equal to the input voltage multiplied by the appropriate fraction. In our example of Figure 4 there is a total resistance of 18k, and R1 has a resistance equal to 3/18ths of this, or 1/6th in other words. Therefore one sixth of the input voltage appears across R1 and with a 9 volt supply this obviously equals 1.5V ($1/6 \times 9/1 = 9/6 = 1.5$V). If you calculate the voltages for R2 and R3 you should find these are 4.5V and 3V respectively.

The voltage across two or more resistors is equal to the sum of their individual voltages. In our example this gives 4.5V (1.5V + 3V) from the bottom of R3 to the top of R2, and 6V (4.5V + 1.5V) from the bottom end of R2 to the top connection of R1. From the lower connection of R3 to the top of R1 there is obviously the input potential of 9 volts, and the sum of the voltages across the resistors must equal this value (1.5V + 4.5V + 6V = 9V). This is known as Kirchoff's Voltage Law.

Voltage dividers are much used in practical circuits because they enable any required voltage (less than the supply voltage) to be easily obtained. Sometimes a variable voltage is required, and then a component called a potentiometer is used. A potentiometer has a track which is usually made from carbon, but is sometimes wound using a special wire (resistance wire) which, unlike ordinary wire, has a fairly high resistance even over quite a short length. A connection is made to each end of the track and there is a fixed resistance between these two points. A third connection is made to a wiper which by means of a control shaft can be moved from one end of the track to the other.

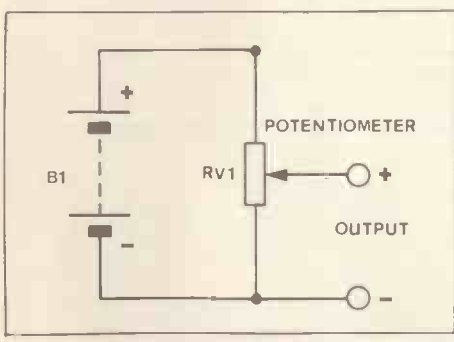


Figure 5. Use of a potentiometer to give a variable voltage.

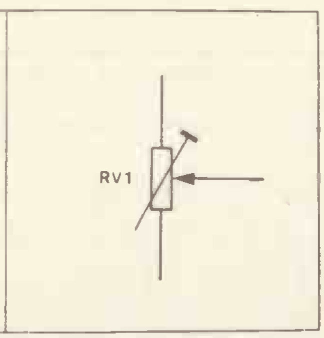


Figure 6. The circuit symbol for a preset potentiometer.

Figure 5 shows the circuit symbol for a potentiometer, and also shows how it can be used to give a variable voltage. If the wiper is right at the top of the track the output potential must be equal to the full input voltage, since the wiper connects direct to the upper track terminal. Similarly, taking the wiper down to the bottom end of the track connects it direct to the lower terminal and gives zero output voltage. With the wiper at an intermediate setting there is an intermediate output voltage, with the sections of track above and below the wiper acting as voltage divider resistances. For example, half the input voltage would be present at the wiper if the latter is set at the centre of the track. Thus the wiper voltage can be varied from zero to the full input potential.

Potentiometers are commonly used as volume and tone controls, and similar applications where a panel mounted control is required. There is also a preset type which is normally of very simple construction, and intended for mounting inside equipment on a component board. These are adjusted using a screwdriver when initially setting up the equipment and may never need any further adjustment. Figure 6 shows the circuit symbol for a preset potentiometer.

By ignoring one of the track connections of a potentiometer, or connecting it to the wiper, it can be used to provide a resistance that is variable from zero to the full track resistance by using the other end terminal and the wiper. It is quite common for potentiometers to be used in this way.

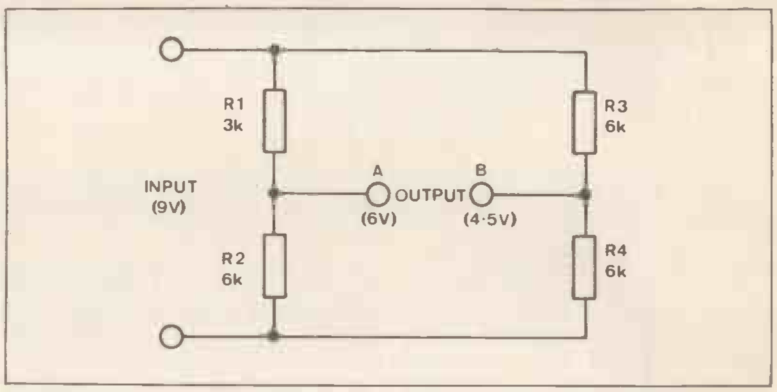


Figure 7. Four resistors in a bridge circuit.

Bridge Circuit

Figure 7 shows a simple example of a form of circuit known as a 'bridge'. In this case the four elements of the bridge each consist of just one resistor, but other components are sometimes used in this configuration. The resistors are arranged as two voltage dividers, and with the values shown there is 6 volts at output A and 4.5 volts at output B. As the voltage across the two outputs is equal to the difference between the two potentials there is obviously 1.5 volts (6V - 4.5V = 1.5V) in this example. The voltage at output A is closer to the positive input rail potential than the voltage at output B, and output A is therefore positive of output B.

A useful property of this circuit, and one that is often exploited in practice, is that with identical voltages at the outputs there is zero output from the circuit.

Power

The amount of power or energy applied to a component depends upon both the voltage applied to it and the amount of current it passes, and the power level is proportional to both. Power is expressed in units called watts, and power is simply equal to voltage multiplied by current. To take a simple example, if 10 volts is applied to a resistor and a current of 300mA (0.3A) flows, the power in the resistor is 3 watts ($10 \times 0.3 = 3$ watts).

Most of this energy will be converted into heat, and a resistor will overheat and be destroyed if it is unable to lose the heat that is generated into the surrounding air with adequate rapidity. Resistors are therefore given a power rating which should not be exceeded, and in the interest of good reliability they should really be run well within this rating. In most modern circuits only very low powers are involved, and miniature resistors having a rating of around ¼ watt are more than adequate in the vast majority of cases.

Tolerance

Apart from a resistance value and power rating, resistors also have a tolerance rating. This merely indicates that the actual value of the component is within a certain percentage of its marked value. Thus a 100 ohm resistor could have an actual resistance of anything from 90 to 110 ohms (ie 100 ohms ± 10%). Ordinary 5 or 10% components are suitable for most circuits, but in some applications close tolerance (1 or 2%) components are required.

Obviously it is not possible for resistors to be manufactured and sold in every possible value, and so they are available in a series of standard values, or 'preferred values' as they are known. Most circuits specify values from what has become known as the E12 series of values, which is as follows:- 1, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, and 8.2 ohms. Components having values higher than these by a factor of 10, 100, 1,000, etc. are also available, up to a typical maximum of 10 megohms. Some ranges of resistors include values which are lower than these by a factor of 10, but such low values are only required very infrequently.

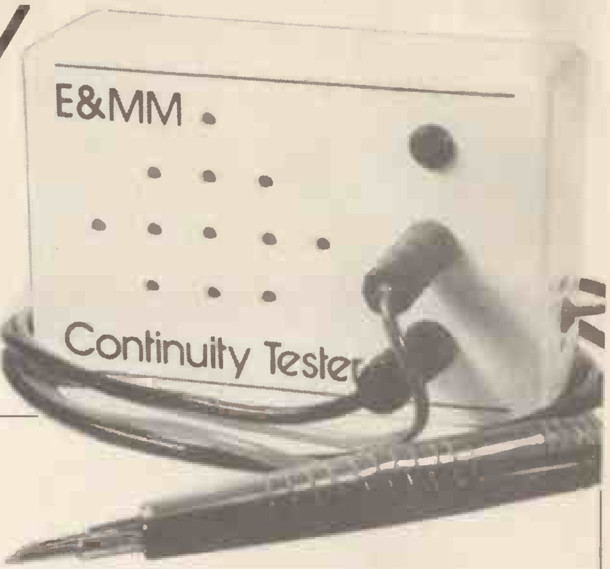
There is another series of values known as the E24 series and this includes all the E12 values plus the following:- 1.1, 1.3, 1.6, 2, 2.4, 3, 3.6, 4.3, 5.1, 6.2, 7.5, and 9.1 ohms. These additional values are only available with a tolerance of 5% or less, and are used much less often than the E12 series.

These sequences of values probably look rather illogical at first, but this is not the case. The E12 series gives a range of values that steadily increase by roughly 20% per step, and the E24 series rises in increments of approximately 10%.

E&MM

CONTINUITY TESTER

by Robert Penfold



A continuity tester is a very useful gadget around the home, workshop and on stage - it is invaluable for testing fuses, jack leads, speakers, semiconductor junctions, printed circuit boards, power transistor/heatsink insulation and a multitude of other potential sites of trouble. Like most testers, this design gives an audio indication of continuity, and has the advantage of two modes of operation, giving increased versatility particularly for printed circuit board checking.

A problem that is often encountered when testing for short circuits on component boards is that a semiconductor junction (which can be a diode or part of a transistor or integrated circuit) connected across tracks to be tested could give a false alarm. When forward biased there is a voltage drop of about 0.6 volts across the junction, but this drop is not normally sufficient to prevent the tester from operating and indicating continuity. Though false alarms of this type can often be checked by reversing the test probes (ineffective in circuits where there are two junctions connected 'back to back') this tester can operate such that continuity will only be indicated if the voltage drop across the test probes is less than about 0.5 volts, avoiding misleading results due to forward biased semiconductor junctions.

The Circuit

The circuit diagram of the continuity tester appears in Fig. 1; it is basically just an audio oscillator feeding a loudspeaker.

IC1 is an audio power amplifier device, and it is made to oscillate at a frequency of several hundred Hertz by applying positive feedback through R3, C1 and R1. R2 reduces the amount of feedback somewhat, and prevents the oscillations from becoming unstable. C2 couples the output signal to a high impedance loudspeaker.

With S1 in the 'off' (open) position the unit can be used as a simple continuity tester for leads, fuses, semiconductors etc. and shorting the two test probes together will connect the supply to the circuit producing an audio tone. L.E.D. indicator D1 will also turn on giving a visual indication of continuity. When using the unit for checking semiconductors, connecting the junction one way round will result in it blocking the supply and preventing oscillation, while connecting it the other way round produces conduction and an audio output tone from the unit. The device is open circuit if oscillation cannot be obtained, or closed circuit if both methods of connection produce oscillation.

If S1 is switched to the 'on' position, power will be applied to the oscillator circuit via the base -

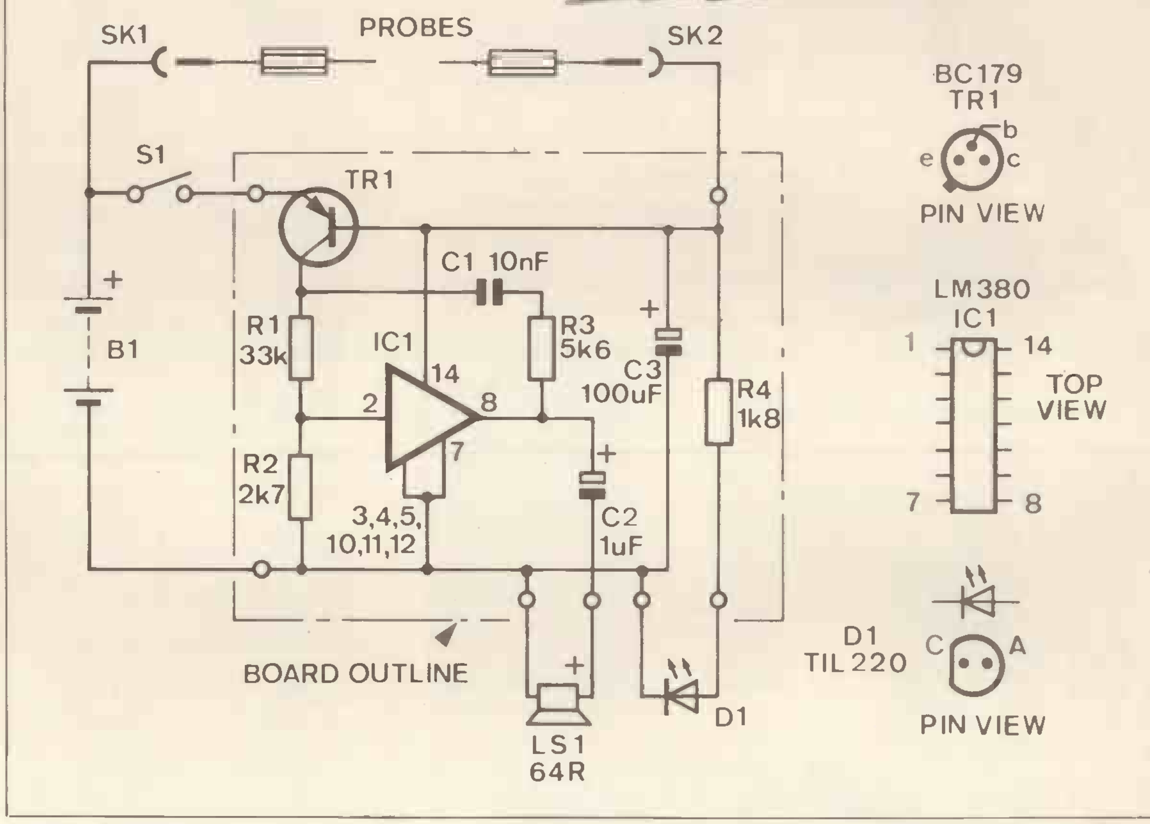


Figure 1. Circuit Diagram of the Continuity Tester

Internal view of Continuity Tester.

emitter junction of Tr1. However, the circuit will not oscillate as the current flowing in the base - emitter circuit of Tr1 switches this device hard on. It therefore obstructs the feedback, and also feeds a small D.C. potential to the input of IC1 so that it is not biased correctly. D1 now operates as an on/off indicator and helps to prevent the unit being inadvertently left switched on.

If the test probes are short circuited, Tr1 becomes switched off by the short circuit across its base-emitter terminals, and the oscillator is able to function normally. A certain amount of resistance across the test probes is also sufficient to switch off Tr1 and produce oscillation. A forward biased silicon junction will give a voltage of between about 0.5 volts and 0.7 volts (depending upon the exact type) across the base-emitter terminals of Tr1. As Tr1 is a high gain device, even the lower figure is sufficient to maintain the device in a state of conduction and block the oscillator. Thus the unit will not respond to forward biased silicon junctions.

Germanium semiconductor junctions have a lower forward voltage drop than silicon types, so a forward biased germanium junction connected across the test probes will switch off Tr1 and give an audio tone from the unit. This is not too important as most germanium devices are now obsolete and little used, but Tr1 can be replaced by a germanium p.n.p. device (OC72, OC81, OC81D, AC128, etc.) if it is likely that the unit will be used to test equipment employing germanium devices.

The current consumption of the circuit is only about 10 to 15mA, and this is provided by a small (PP3 size 9 volt battery.

Construction

A plastic box measuring about 114 x 76 x 38mm (type PB1) makes an ideal housing for the unit. A speaker grille must be made in the left hand side of the front panel, and this can merely consist of a pattern of holes about 4mm. in diameter. D1, SK1, and SK2 are mounted in a vertical line down the right hand side of the panel, and S1 is fitted on the right hand side of the case. The speaker can then be fitted in place, using epoxy-type glue as there is no provision for screw fixing on miniature speakers. Fit the loudspeaker in a position leaving sufficient space for the PP3 battery to fit next to it.

The other components are fitted onto a small printed circuit board which is detailed in Fig. 2, and construction of this is quite straight forward. The completed board is wired to the rest of the unit before being mounted in the case, and Fig. 2 also shows this wiring. 6BA or M3 fixings are used to mount the board on the rear panel of the case so that it fits in the space to the right of the speaker and battery. The printed circuit board can be used as a template when marking the positions of the two 3.3mm diameter mounting holes in the rear panel.

After giving all the wiring a couple of thorough final checks, the unit is then ready for testing and use.

E&MM

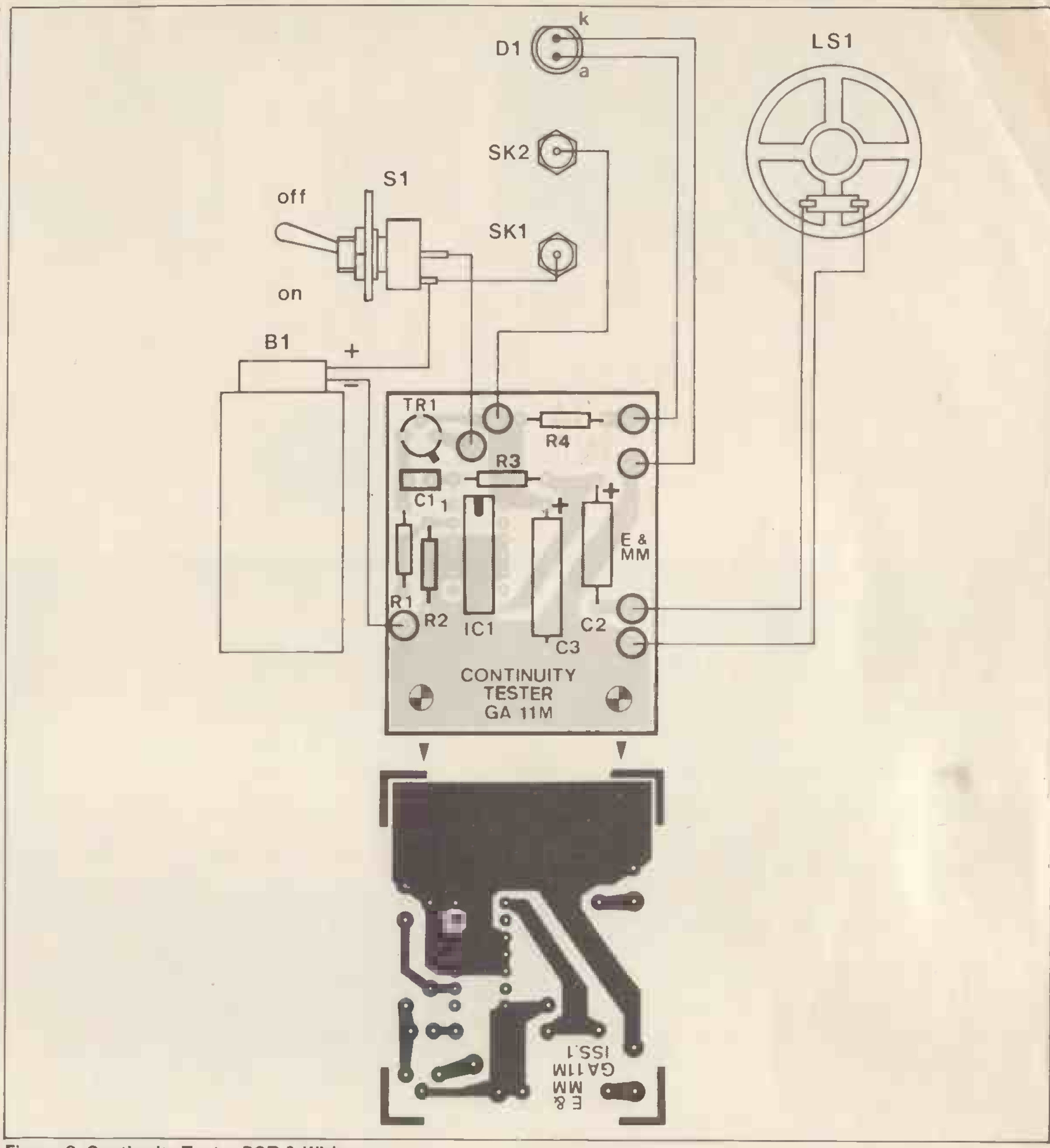


Figure 2. Continuity Tester PCB & Wiring

PARTS LIST

Resistors - all 5% ⅓ W carbon		
R1	33k	(M33K)
R2	2k7	(M2K7)
R3	5k6	(M5K6)
R4	1k8	(M1K8)
Capacitors		
C1	10nF mylar	(WW18U)
C2	1uF 63V electrolytic	(FB12N)
C3	100uF 10V electrolytic	(FB48C)
Semiconductors		
IC1	LM380	(QH40T)
TR1	BC179	(QB54J)
D1	TIL220 (0.2 in. red LED)	(WL27E)
Miscellaneous		
S1	Ultra-miniature SPST toggle switch	(FH97F)
LS1	Loudspeaker 66mm diameter 64R impedance	(WF57M)
SK1	Red 4mm socket	(HF73Q)
SK2	Black 4mm socket	(HF69A)
	Test probe pair	(HF33L)
B1	PP3 battery	
	PP3 connector	(HF28F)
	Printed circuit board	(GA11M)
	LED Cover	(YH54J)
	Case PB1 (or similar)	(LF01B)
	Insulated hookup wire	(BL00A)
	6 BA ½" bolts	(BF06G)
	6 BA nuts	(BF18U)

TRANSCENDENT 2000 SINGLE BOARD SYNTHESISER

Designed by consultant Tim Orr (formerly synthesiser designer for EMS Ltd.) and featured as a constructional article in ETI, this live performance synthesiser is a 3 octave instrument transposable 2 octaves up or down giving sweep control, a noise generator and an ADSR envelope shaper. There is also a slow oscillator, a new pitch detector, ADSR repeat, sample and hold, and special circuitry with precision components to ensure tuning stability amongst its many features.
The kit includes fully finished metalwork, fully assembled solid teak cabinet, filter sweep pedal, professional quality components (all resistors either 2% metal oxide or ½% metal film), and it really is complete — right down to the last nut and bolt and last piece of wire! There is even a 13A plug in the kit — you need buy absolutely no more parts before plugging in and making great music! Virtually all the components are on the one professional quality fibreglass PCB printed with component locations. All the controls mount directly on the main board, all connections to the board are made with connector plugs and construction is so simple it can be built in a few evenings by almost anyone capable of neat soldering! When finished you will possess a synthesiser comparable in performance and quality with ready-built units selling for many times the price.
Comprehensive handbook supplied with all complete kits! This fully describes construction and tells you how to set up your synthesiser with nothing more elaborate than a multi-meter and a pair of ears!

COMPLETE KIT ONLY £168.50 + VAT!

Cabinet size 24.6" x 15.7" x 4.8" (rear) 3.4" (front)

1024 NOTE SEQUENCER/COMPOSER — see our advert on Page 56

ETI VOCODER

COMPLETE KIT ONLY £195 + VAT!

Panel size 19.0" x 5.25". Depth 12.2"

Featured as a construction article in Electronics Today International this design enables a vocoder of great versatility and high intelligibility to be built for an amazingly low price. 14 channels are used to achieve its high intelligibility, each channel having its own level control. There are two input amplifiers, one for speech either from microphone or a high level source e.g. mixer or cassette deck and one for external excitation (the substitution signal) from either high or low level sources. Each amplifier has its own level control and a rather special type of tone control giving varying degrees of bass boost with treble cut or treble boost with bass cut. The level of the speech and excitation signals are monitored by LED PPM meters with 10 lights — 7 green and 3 red which indicate the level at 3dB steps. There are three internal sources of excitation — a noise generator and two pulse generators of variable frequency and pulse width. Any of the internal sources and the external source can be mixed together. There is a voiced/unvoiced detector which substitutes noise for the excitation signal at the points in speech where the vocal chord derived sounds of the speaker are substituted for by the unvoiced sounds of sibilants, etc. There is a slew rate control which smooths out the changes in spectral balance and amplitude enabling a change of the speech into singing or chanting and other special effects. A foot switch is provided to permit a complete freeze in spectral balance and amplitude whenever required. An LED on this indicates when the freeze is in operation.
An output mixer allows mixing of the speech, external excitation and vocoder output. The majority of the components fit into the large analysis/synthesis board with the rest on 8 much smaller boards with the controls and sockets mounted on them for ease of construction. Connectors are used for the small amount of wiring between the boards.
The kit includes fully finished metalwork, professional quality components (all resistors 2% metal oxide), nuts, bolts, etc. — even a 13A plug!

TRANSCENDENT DPX MULTI VOICE SYNTHESISER

Another superb design by synthesiser expert Tim Orr published in Electronics Today International

COMPLETE KIT ONLY £299 + VAT!

Cabinet size 36.3" x 15.0" x 5.0" (rear) 3.3" (front)

The Transcendent DPX is a really versatile 5 octave keyboard instrument. These are two audio outputs which can be used simultaneously. On the first there is a beautiful harpsichord or reed sound — fully polyphonic, i.e. you can play chords with as many notes as you like. On the second output there is a wide range of different voices, still fully polyphonic. It can be a straightforward piano as a honky tonk piano or even a mixture of the two! Alternatively you can play strings over the whole range of the keyboard or brass over the whole range of the keyboard or should you prefer — strings on the top of the keyboard and brass as the lower end (the keyboard is electronically split after the first two octaves) or vice-versa or even a combination of strings and brass sounds simultaneously. And on all voices you can switch in circuitry to make the keyboard touch sensitive! The harder you press down a key the louder it sounds — just like an acoustic piano. The digitally controlled multiplexed system makes practical touch sensitivity with the complex dynamics law necessary for a high degree of realism. There is a master volume and tone control, a separate control for the brass sounds and also a vibrato circuit with variable depth control together with a variable delay control so that the vibrator comes in only after waiting a short time after the note is struck for even more realistic string sounds.
To add interest to the sounds and make them more natural there is a chorus/ensemble unit which is a complex phasing system using CCD (charge coupled device) analogue delay lines. The overall effect of this is similar to that of several acoustic instruments playing the same piece of music. The ensemble circuitry can be switched in with either strong or mid effects. As the system is based on digital circuitry digital data can be easily taken to and from a computer (for storing and playing back accompaniments with or without pitch or key change, computer composing, etc., etc.).
Although the DPX is an advanced design using a very large amount of circuitry, much of it very sophisticated, the kit is mechanically extremely simple with excellent access to all the circuit boards which interconnect with multiway connectors, just four of which are removed to separate the keyboard circuitry and the panel circuitry from the main circuitry in the cabinet.
The kit includes fully finished metalwork, solid teak cabinet, professional quality components (all resistors 2% metal oxide), nuts, bolts, etc., even a 13A plug!

POWERTRAN

MANY MORE KITS ON PAGE 56 — MORE KITS AND ORDERING INFORMATION ON PAGE 4

All projects on this page can be purchased as separate packs, e.g. PCBs, components sets, hardware sets, etc. See our free catalogue for full details and prices.

HI-FI SUB BASS WOOFER

by Jeff Macaulay

Add full deep Hi-Fi bass down to 27 Hertz to your stereo system

This woofer system is designed to be used in conjunction with existing speakers to extend the bass response, but at the same time is capable of being integrated into a full scale active speaker system.

For maximum flexibility the woofer is fed from the output terminals of the power amplifier used in the existing system. A variable cut-off 2nd order Butterworth filter is employed so that the woofer can be rolled on to complement the bass roll-off of the existing speaker system.

Before discussing the woofer in more detail it is instructive to consider the deficiencies of most speaker systems when it comes to reproducing deep bass, where an important constraint is the maximum permissable size of the enclosure. It is well known that the infinite baffle enclosure rolls off at 12dB/octave below the bass unit's resonant frequency. This situation can be improved to some extent by making the enclosure more inefficient, but then a high power amplifier is required to reproduce good bass. Another problem facing designers is that the bass unit is usually intended to reproduce the midrange as well. It is clearly advantageous to roll off the bass at some reasonable point to avoid intermodulation distortion which would occur due to the large cone excursions that are required. Interestingly the required output at 30Hz is some 8dB less than is required in the midrange. The peak power in music and speech signals occur at around 150 Hz.

Of all the possible forms that a woofer can take the most simple and effective method is to employ a bass reflex system. By suitable choice of drive unit a fairly compact, and hence domestically acceptable enclosure can be built that will respond down to 30Hz without problems. I write from experience of two such systems, one of which has been working in my own lounge for over a year, where the bass is often felt as well as heard. Even at high volume levels there is no apparent distortion and efficiency is also very high.

30Hz seems to be the optimum value at which to fix the lower -3dB point. Any lower and the cabinet begins to assume massive proportions. Moreover the dimensions of the average domestic listening room limits the lowest frequency that can be reproduced to around 30Hz. Going this far down will usually add another octave to the response in any case. The output power at this low frequency depends on the available cone excursion. At 30Hz the port is radiating sound as well as the speaker and this effectively doubles the area of the cone. When the relevant calculations have been made the output sound pressure level (SPL) is found to be 90dB at 1 metre. Put another way, if the main system is producing 96dB the bass unit will still have plenty of headroom. In fact these output figures are average - the bass speaker is capable of handling larger peaks.

The electronics required consist of an amplifier and a variable active filter system, designed to roll off between 50-100Hz adjustable by means of a potentiometer. The filter and power amp are installed inside the speaker cabinet, with the controls externally accessable.

The size of the cabinet is closely related to the characteristics of the drive unit employed. After some research the most suitable unit was found to be the Kef B200, requiring an amplifier power of only 20 watts RMS in this application. This unit has a free air resonance at 25Hz and when mounted in a sealed undamped enclosure of 2.4 cu.ft. this rises to 45Hz. From this information the acoustic volume (ie. the cabinet volume which enables the response to extend to 25Hz at -3dB when reflexed) can be calculated.

$$V_{as} = V\left[\left(\frac{f_c}{f_o}\right)^2 - 1\right]$$

Where f_o = free air resonant frequency, f_c = resonant frequency in cabinet, V = volume of cabinet. This gives a value for V_{as} of 5.38 cu.ft. By rearranging the formula for V the cabinet volume can be determined for any chosen value of f_c. In order to maintain a smooth response to 30Hz the resonant frequency must be 42Hz ($\sqrt{2} \times 30$Hz). For the B200 the volume is 3.4 cu.ft. This is a little large to be accommodated in the average lounge and so experiments were undertaken to lower the resonant frequency. The easiest way is to add a small amount of extra mass to the cone itself. This was conveniently done by adding two ¾" sq. pieces of bitumised felt panels to the cone, spaced equally on opposite sides of the centre. Suitable material is readily available as self adhesive car damping panels. This lowered f_o from 25Hz to 21Hz and, more importantly, allows a 2.4 cu.ft. cabinet to be used for a f_c of 40Hz. By the time damping has been added to the enclosure it can be reflexed down to 27Hz.

Having actually determined the required enclosure size attention can now be turned to its mechanical details. Because the highest frequency to be handled is 100Hz the cabinet will be acoustically small. What this means is that air resonances inside the cabinet cannot occur because the dimensions are small compared with wavelength of the sound being emanated. The wavelength of a given frequency can be found simply by dividing the speed of sound, $344ms^{-1}$, by the

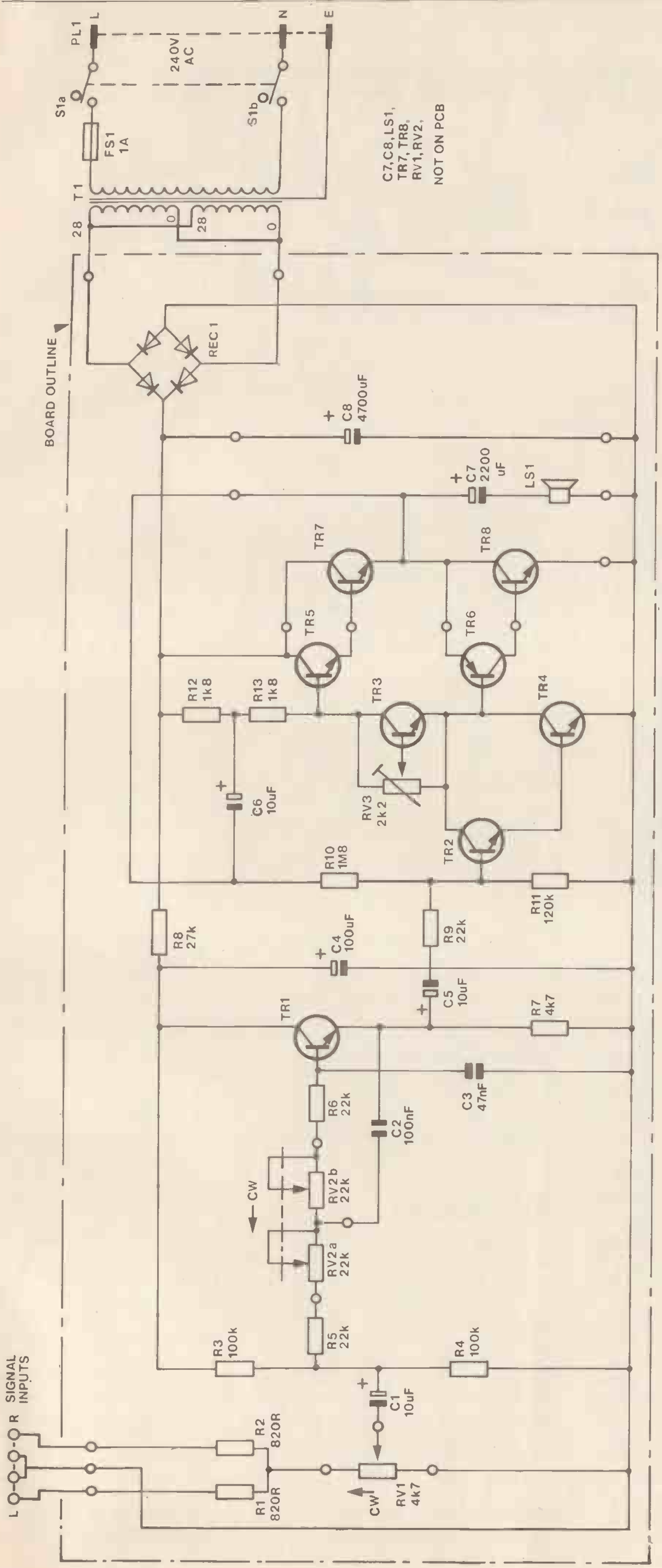
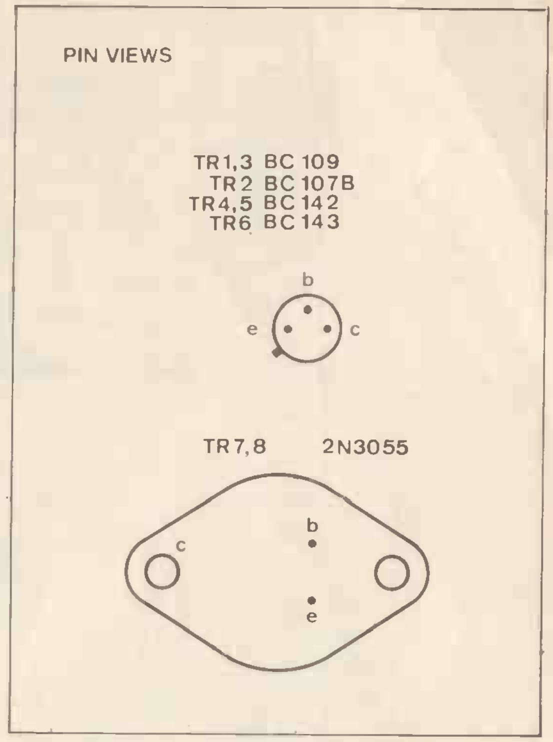


Figure 1. Circuit diagram of the Hi-Fi Sub-Bass Woofer.



PARTS LIST

Resistors - all 5% ⅓W carbon unless specified

R1,2	820R	2 off	(M820R)
R3,4	100k	2 off	(M100K)
R5,6,9	22k	3 off	(M22K)
R7	4k7		(M4k7)
R8	27k		(M27K)
R10	1M8		(M1M8)
R11	120k		(M120k)
R12,13	1k8	2 off	(M1k8)
RV1	4k7 log. pot.		(FW21X)
RV2	22k lin. dual gang pot.		(FW86T)
RV3	2k2 carbon preset		(WR82D)
Capacitors			
C1,5,6	10uF 25V electrolytic	3 off	(FB22Y)
C2	100nF polyester		(BX76H)
C3	47nF polyester		(BX74R)
C4	100uF 25V electrolytic		(FB49D)
C7	2,200uF 63V electrolytic		(FF22Y)
C8	4,700uF 63V electrolytic		(FF28F)
Semiconductors			
TR1,3	BC109	2 off	(QB33L)
TR2	BC107B		(QB31J)
TR4,5	BC142	2 off	(QB39N)
TR6	BC143		(QB40T)
TR7,8	2N3055	2 off	(BL45Y)
REC1	S005		(QL09K)
Miscellaneous			
T1	Transformer 240V prim. 0-28, 0-28 sec. 84VA		(WB17T)
LS1	Kef B200 SP1014		
FS1	Fuse, 20mm 1A Quick Blow		(WR03D)
	Chassis fuseholder, 20mm		(RX49D)
S1	Toggle switch, DPDT		(FH39N)
PL1	P429 3-pin chassis plug		(HL20W)
	P646 3-pin line socket		(IL44X)
	4-way push-type connector		(BW71N)
	TO3 Mounting kits	2 off	(WR24B)
	Heatsink, 2.1°C/W		(FL54J)
	Control knobs	2 off	(RX08J)
	Acoustic wadding	1 m	(RY06G)
	Mains cable, 3A	3 m	(XR00A)
	Connecting wire	3 m	(XR37S)
	Capacitor clip to suit C7		(FL33L)
	Capacitor clip to suit C8		(FF35Q)
	Printed Circuit Board		(GA08J)

The KEF B200 SP1014 drive unit is available from:

Wilmslow Audio Ltd,
35/39, Church Street,
Wilmslow,
Cheshire.

Price £13.50 inc. VAT + £1.00 p. & p.

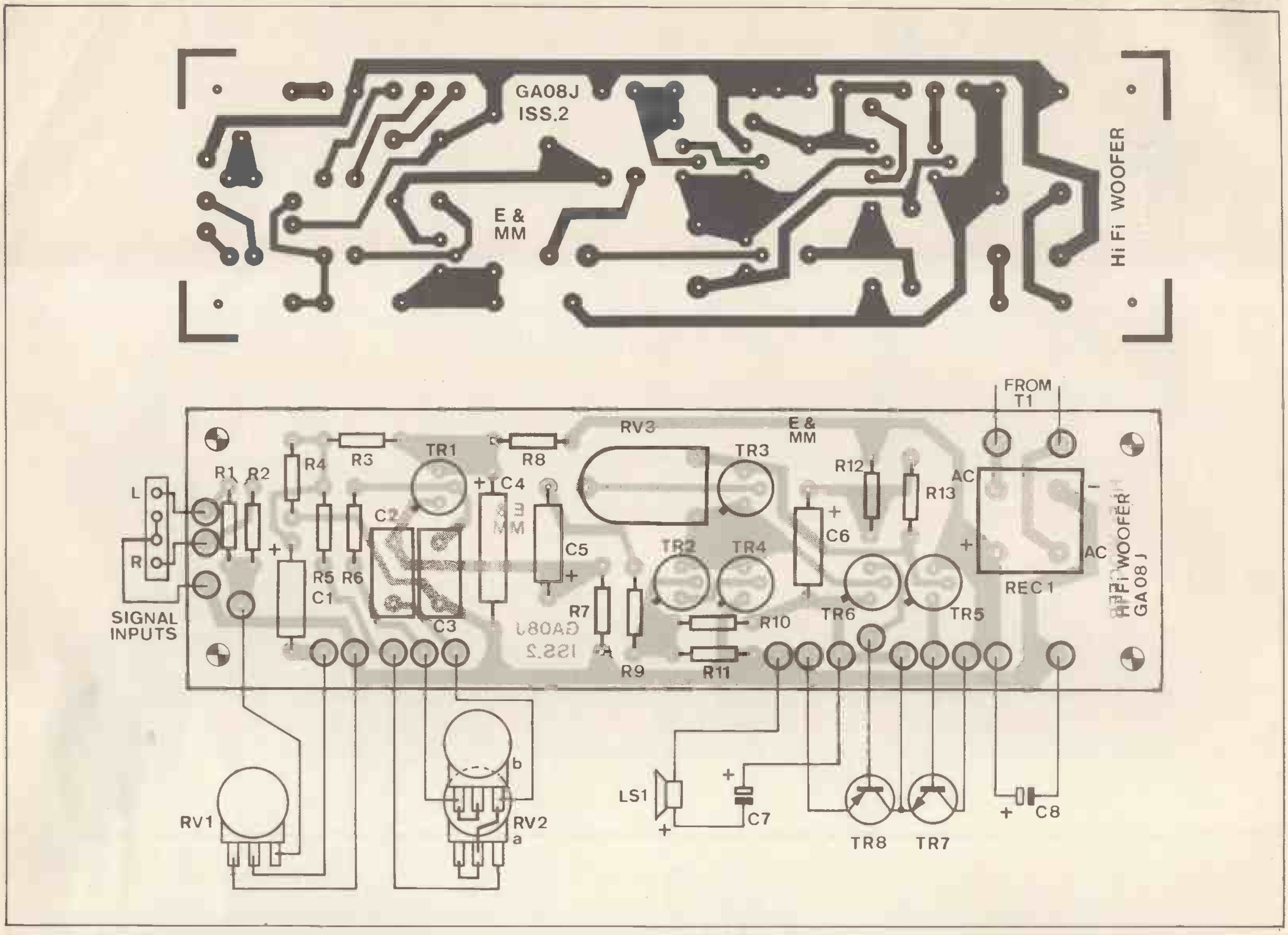


Figure 2. The Woofer PCB.

frequency. Thus the wavelength of a 100Hz tone is some 3.44m and a 30Hz tone has a wavelength of 344/30 = 11.45 metres. The resonances that plague normal speaker systems occur when one of the internal dimensions is equal to or a multiple of the wavelength of a reproduced signal. Since the largest internal dimension of our cabinet is 0.53m these resonances will be avoided. Another consequence of the smallness of the cabinet is that the polar diagram is totally symmetrical across the working range. In other words the speaker is omnidirectional. However, the wavelength of the sounds emanating from the enclosure have practical consequences for the positioning of the unit in the listening room.

The lowest note that can be sustained in a room is a function of its maximum dimension. The lowest note, in fact, that can be reproduced is found from the relationship, F = 344/2L where L is the longest room dimension in metres. Different dimensions will cause peaks and dips in the response, but of course this will happen whatever form the woofer may take and occurs naturally even in large halls. It does have a bearing on the siting of the enclosure which must be chosen for best results by empirical methods.

Circuit

Figure 1 shows the complete circuit of the sub-bass woofer electronics. For descriptive purposes it can be divided into three sections; mixer, filter and power amplifier.

R1, R2 and RV1 form a passive mixer and gain control. The signals from the speaker sockets of the amplifier are fed into the 'top' of R1 and R2. The signal from the wiper of VR1 is fed via the DC blocking capacitor C1 into the filter built around TR1. The values of the components are such that a 2nd order Butterworth response is obtained with maximum slope and minimum ripple in the pass band. RV2 allows the cut-off frequency of the filter to be varied from 50-100Hz to suit the bass roll-off of the existing pair of speakers.

The active element of the filter, TR1, is configured in the emitter follower mode. This produces a low impedance drive for the power amplifier, which is a little unusual in that the circuit is of the shunt feedback type. The reason for its adoption here is that it is easy to build and unconditionally stable. The 2N3055's on the output are more than capable of delivering the 4mV/us slew rate required for a bandwidth of 100Hz! The output power of the amplifier is 20W RMS and unlike the majority of current designs the output is capacitatively coupled to the speaker. This has the advantage that if a breakdown were to occur in the amp then the speaker will be protected from DC current. The value of C7 is such that the response is 3dB down at 10Hz.

Construction

The printed circuit board should be assembled following the component overlay, in usual order of resistors first, then capacitors, followed by the semiconductors. The pins for the off-board wiring can be soldered in at this stage, but the wiring should be left until after the cabinet is completed. Check the orientation of the electrolytic capacitors and semiconductors, and make sure there are no tracks shorted by solder bridges. Drill holes in the cabinet back for the push-connector, volume and cut-off frequency pots, on-off switch, and mains chassis plug. Fit these components. Mount the transformer and fuseholder using woodscrews and then the two capacitors C7 and C8 using clips and screws. Drill the heatsink to take the TO3 power transistors, and mount them using mica washers etc. Mark fixing positions for the PCB and heatsink, and then wire up all the off-board components. This is best done by soldering wires of the right length to the veropins on the PCB before mounting it, then connecting the mains and output components. Finally mount the heatsink and PCB, and solder the wires from the latter in place.

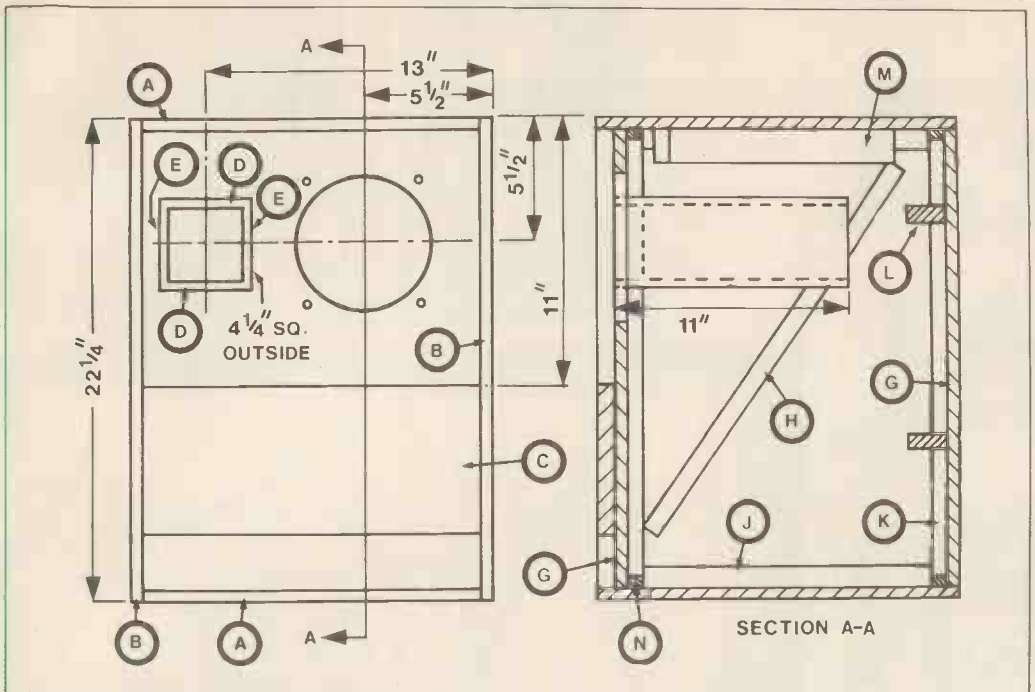


Figure 3. Woofer cabinet construction.

CUTTING LIST

Quantity	Dimensions (inches)	Material	Part
2	15 × 15 × ⅝	Veneered Chip	A
2	22¼ × 15 × ⅝	Veneered Chip	B
1	15 × 7 × ⅝	Veneered Chip	C
2	11 × 3 × ⅝	Veneered Chip	D
2	11 × 4¼ × ⅝	Veneered Chip	E
2	21 × 15 × ⅝	Veneered Chip	G
2	20 × 2 × 1	Soft Pine	H
4	10⅛ × ⅞ × ⅜	Hardwood	J
4	21 × ⅞ × ⅜	Hardwood	K
2	13 × 2 × 1	Soft Pine	L
1	13 × 2 × 1	Soft Pine	M
4	15 × ⅞ × ⅜	Hardwood	N

Cabinet Construction

There are several possible materials that could be employed for the cabinet. Domestic considerations, and the desire for a ready made finish dictated the use of veneered chipboard. Melamine teak board has an added advantage of being denser material than either the white or wood veneered board. These facts led to its adoption for this project. The internal volume of 2.4 cu.ft. and the desire to keep the woodworking simple determined the dimensions at 22½" × 15" × 15" external. This means that the cabinet, excluding battens, can be fabricated entirely from 15" boards. If the wood is cut to size at the timber yard the only tools required will be an electric drill and jigsaw attachment.

Assembly is straightforward and should proceed as follows:

1) Label each panel with its respective part letter on the worst face. This saves any possible confusion as work proceeds.
2) Cut the battens H, J, K, M and N to size and mark as in 1).
3) Mark out the positions of the battens on the panels with a felt tip pen. This is about the only thing that will mark the surface of the boards without smudging.
4) Glue the battens into their respective positions. The best glue to use with this material is 'Thixofix'. This adhesive is often employed for fixing table tops. It is a contact adhesive having the advantage that the glued surfaces can be moved relative to one another before they are permanently joined. A permanent joint is made by simply pressing the parts together.
5) Having fixed the battens with adhesive secure more permanently with ¾" panel pins. Use four for each batten.
6) Using the B200 template mark out the position of the four fixing screws on the front panel. Remove the central area of the template and mark the inner circle. Remove the template and drill out the mounting holes.
7) Mark out the 4¾" square cut-out for the port. At this point it is advisable to drill four ⅜" holes near the corners of the port cut-out to facilitate the use of the jigsaw.
8) Take part C and glue it into position on the baffle.
9) Cut out the front baffle apertures. The baffle can be painted matt black at this stage. Blackboard paint is suitable.
10) Take parts D and E and glue and pin together to form a square tube as shown in detail two.
11) Insert the port just constructed into the aperture on the front front baffle. If there are any gaps between the port and front panel it should be filled from the rear of the baffle. The port must be mounted so that the end is flush with the front of the baffle.
12) Take the side, bottom and top panels (A and B) and the front baffle, apply adhesive to all surfaces that will butt together, and leave for 15 minutes.
13) Assemble the cabinet except the back panel, using screws in addition to the glue to fix the front panel to its supporting battens. Check that the back panel will fit tightly in position.
14) Glue and screw the battens (L) onto the back panel (G).
15) Add the felt panels to the KEF B200's cone as previously described, then attach the drive unit to the front baffle using the bolts and T nuts provided.
16) Install the electronics. Stretch a 12" square piece of acoustic wadding across the back of the drive unit and fix it with a dab of glue in each corner.
17) After the setting-up stage, roll up 2 metres of wadding and place it in the cabinet (the position is not critical) then screw the back on.

Setting Up and Use

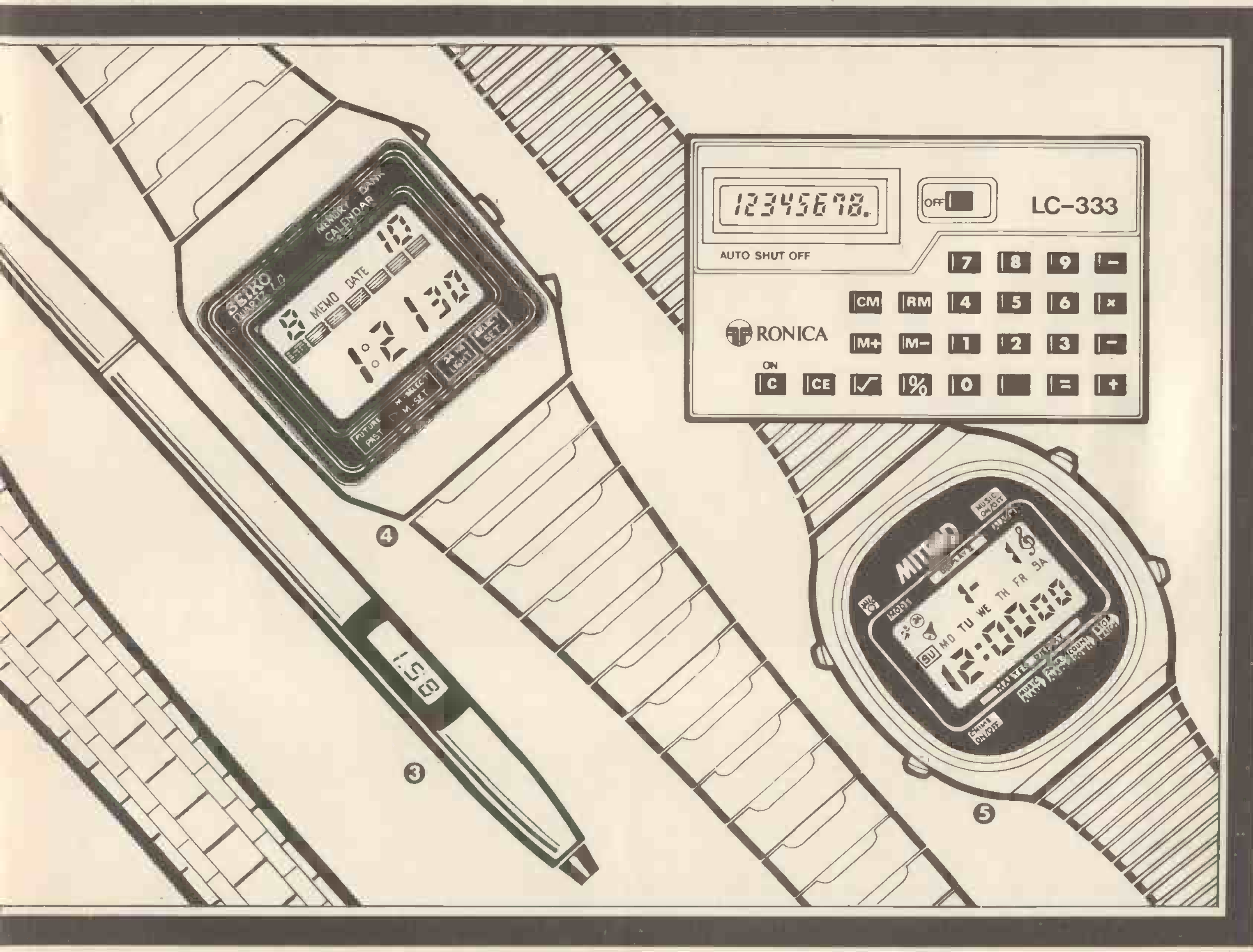
The quiescent current of the output pair must be set to eliminate crossover distortion. Before applying power turn RV3 to its most clockwise end and cover the mains terminals of the transformer switch, and fuse with insulating tape. Apply power and if all seems well measure the voltage at the positive terminal of the output capacitor C7. This should be 20V ± 2V. Switch off and disconnect the wire to the collector of TR7. Insert a multimeter to read current and switch on again. The current should be 10mA. Adjust RV3 until it reaches 30mA. Reconnect TR7. Remove the tape from the mains terminals and screw on the back of the cabinet.

Play some programme material with a good bass content. Experimentally adjust the volume control on the bass unit for what you judge to be the correct level. At this point it is as well to go and sit in the stereo seat and listen carefully. Often further adjustment will be required since the level of bass heard depends on one's listening position. The filter is best set with a voice signal. Radio 4 is a good source of assorted voice signals. Start adjusting from the 100Hz (clockwise) end downward. Speech will probably sound a trite boomy but as you adjust a point will be found where the voice sounds natural and well balanced. Play some music, preferably a piece that you know well with a reasonable bass content. In all probability it will take some time to find the optimum position for the controls. However, even before that you should find that your enjoyment of all signals will be enhanced. It should go without saying that these adjustments should be made with the tone controls in the flat position, or better switched out.

It is most important that the woofer be sited with care. Although no stereo information is broadcast below 100Hz it is important not to disturb the stereo image. If you sit too near the woofer the sound is likely to suffer because of the Haas effect (if two independent speakers are reproducing the same signal it will appear to come from the nearer source).

E&MM

E TIME



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CIRCUIT MAKER

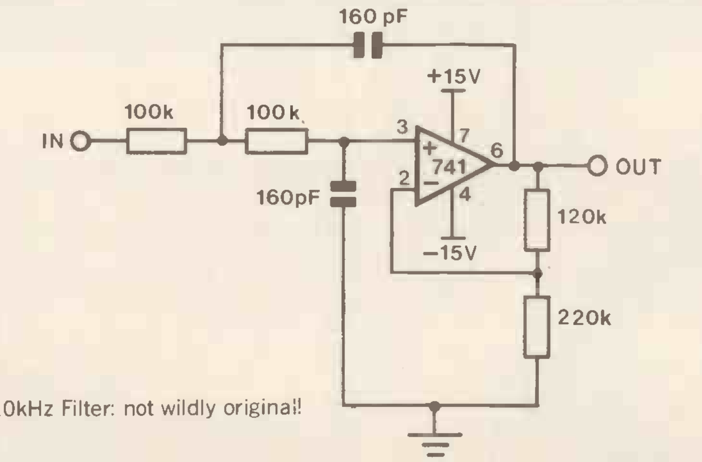
One of the nice features about a magazine such as this is the way readers can contribute, thus presenting their ideas to a large number of people. Each contribution may be a full feature or constructional article describing some piece of electronic, electro-musical equipment, or more probably, a short piece containing the circuit diagram and a short piece of explanatory text. It is thus our intention to set aside pages in each issue for 'Circuit Maker', a feature dedicated to short ideas, mostly sent in by readers.

Circuit maker will be an informal area of the magazine where the best submissions each month will be published. No set theme is intended, and all ideas will be treated equally. Naturally, if the idea is good enough it may form the basis of a full article written by yourself or one of our main contributors. The ideas submitted need not be circuits - general tips to save money or make life easier will also be considered.

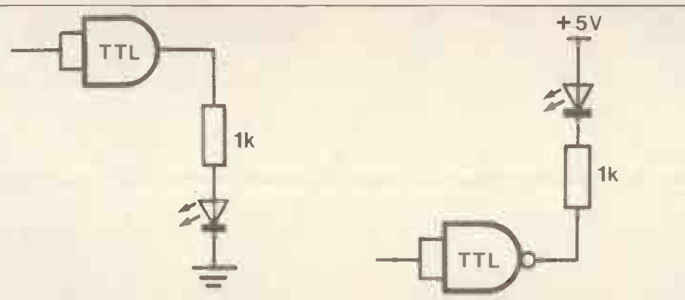
It may often be hard for you to decide if your idea is worthy of possible publication. The simple answer is to read the notes that follow and try it. It is important to have a go since many good ideas are missed, purely because the designer thinks that the idea is of no interest. For those people who have ideas and would like to contribute here are some notes to assist you in making up your submission.

The main problem with a 'new' idea is that it might not be new. If the circuit has been published before it is not original, and generally cannot be published again, even by a different magazine. It is very hard to define the meaning of 'original' in this case, and much of the meaning depends on the circumstances. In general, a circuit technique is original if it has not been published before, otherwise an acknowledgement should be made even if it is only '... the standard 741 circuit ...' A good example of where this occurs is in the active filter. It uses the Sallen and Key configuration of resistors and capacitors to give a Butterworth type of roll off. The quote 'I designed this active filter for a 12 dB roll off after 10kHz' is a bit much, but 'I designed a Sallen and Key 2nd order Butterworth filter using a 741' is quite all right.

Improvements to previously published circuits are useful, and very relevant, but the source of the original idea must be clearly stated.



10kHz Filter: not wildly original!



(a) Naughty! Gate will fail. (b) Correct method

So, the idea seems to be original. Obviously the prototype works, but is a second version using a different batch of components certain to work as well? To be suitable for publication every correctly built version of the circuit should work. Designs to be wary of contain transistors biased without feedback, bipolar op-amps with very high value resistors around them and devices used near their rated maximum. Different manufacturers use different specs, and so any design must be based around the lowest specifications available. Circuit bodges which work 'but we don't know why' must be avoided at all costs, as well as designs that work, but overload the device. For example, a TTL gate driving an LED. In (a) the gate stands a real chance of failing since most gates will only source uAmps rather than the mAmps required for the LED. It does work for a time but the gate will not like it. The technique in (b) is fine because the gate will sink typically 10 mAmps without any trouble.

Having established that the design is original and practical it is worth sending in. How should it be presented? Firstly, and most importantly, the presentation should be neat and legible so that we can read it. Envelopes and cigarette packets are out! Text (typed and double spaced) and diagrams should be on separate sheets, preferably A4 size and clipped together rather than stapled. Naturally all the text and drawings should be numbered, the drawing numbers corresponding to the text. The length of the text depends on the complexity of the idea, but 50-300 words should suffice.

The drawings must be clear, preferably done with black ink on white paper; a black ball pen is suitable and cheap. It is worth buying an electronics stencil for drawing from a good office supply shop, and with the aid of this and a ruler clear drawings are easy to do. As a rule inputs should be on the left, outputs on the right, with the drawing going from top to bottom. Number all IC pins, including the power pins and check that all component types and values are indicated where relevant.

Prepare a declaration sheet stating the parts that are original and indicating those that are not. Also state that the circuit has not been submitted to any other magazine, and will not be so unless rejected by us. Sign this declaration. Finally, photocopy all the sheets (it is not unknown for things to get lost in the post) and send it off to our editorial address, with the envelope clearly marked 'Circuit Maker'. You will hear fairly quickly after the submission reaches us.

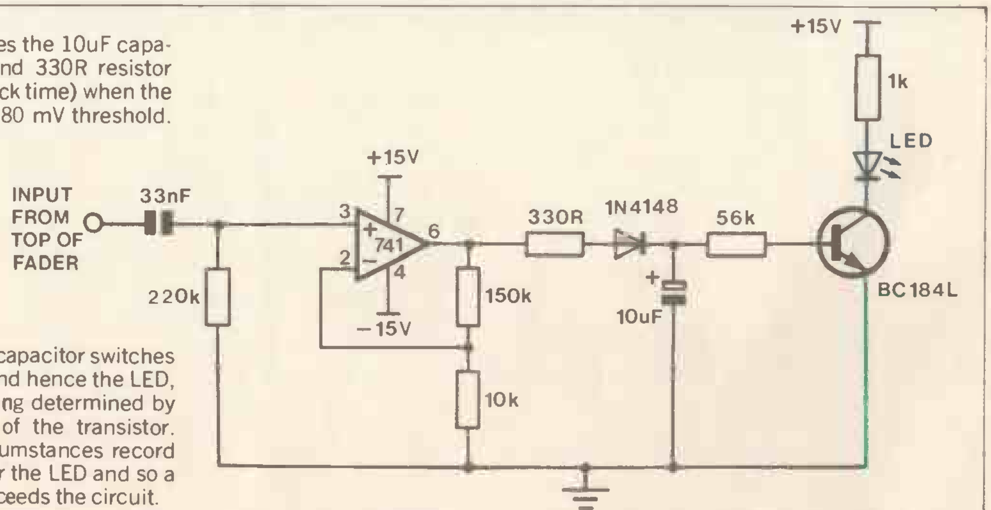
Chris Lare

Disco Cue Light

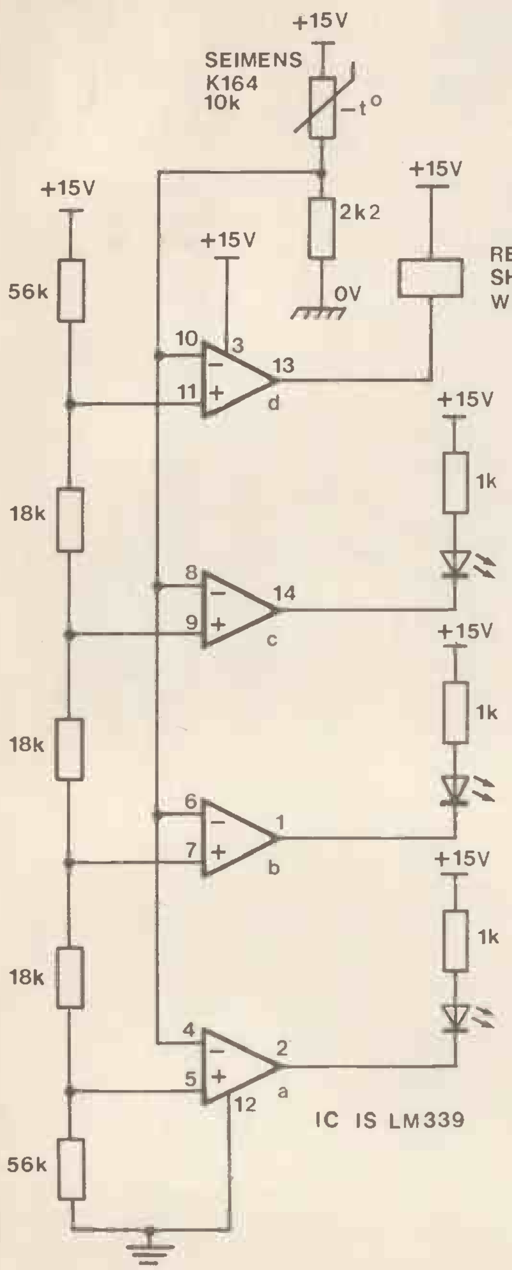
Terry Barnaby, S. Glamorgan

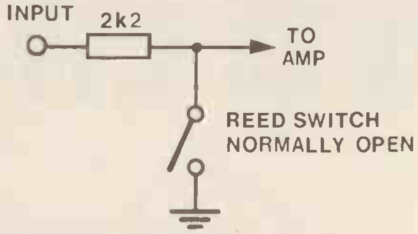
Nearly all disco DJ's use headphones to cue up the next record, but, for the majority of records, a simple LED will suffice. The LED driver circuit is connected to the top of each deck fader, or to the original cue output, thus obtaining a signal irrespective of the fader position. Provided that the LED driver has the right attack time (sufficient to miss clicks and scratches) and a long delay time (to make the indication clear) cueing becomes very easy. Naturally this system will not work if the record starts very quietly when headphones must be used.

The circuit is very simple. A high gain op-amp charges the 10uF capacitor via a diode and 330R resistor (which sets the attack time) when the signal exceeds the 80 mV threshold.



The voltage on the capacitor switches on the transistor, and hence the LED, the decay time being determined by the base current of the transistor. Under certain circumstances record rumble may trigger the LED and so a high pass filter preceeds the circuit.





Over Temperature Indicator and Cutout

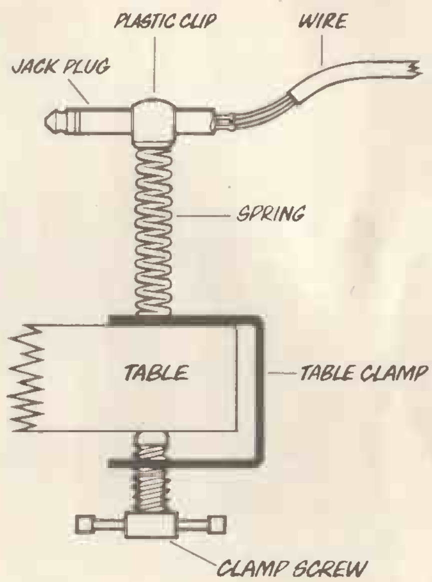
Some items of equipment, particularly amplifiers, are prone to overheat if the heatsinks are covered or the air flow is somehow obstructed. The temperature rise continues until the equipment fails, usually expensively. A method of automatic shutdown is desirable, but at the same time warning of over temperature is needed since a sudden uncontrolled shutdown in a disco is awkward to say the least.

This simple circuit uses a thermistor to sense the temperature, and a quad comparator to drive three LEDs and a reed relay. The thermistor and resistor develop a temperature dependent voltage which is fed to each stage of the comparator, where it is compared with reference voltages generated by the resistor chain. The comparator outputs are normally high, thus the LEDs are off until the relevant threshold voltage is reached. The fourth comparator feeds a small reed relay which is used to short out the signal input to the amplifier when finally triggered. The sensitivity of the circuit may be altered by adjustment of the resistor chain (here set to 50°C range), and the lower point set by altering the 2k2 in series with the thermistor. A fourth LED could be added to indicate operation at low temperatures, by connection with a 1k0 series resistor between the power rails.

Cheap Third Hand

Philip Watkins, Gwent

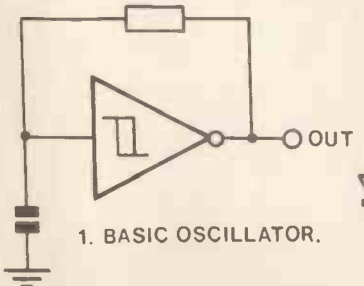
Soldering wires to plugs and sockets can be a real nuisance. At the rate of one hand for soldering iron, one hand for solder, one hand... Obviously it helps if the wire is fastened to the plug first by passing it through the terminal holes and bending it back, but the plug and wire still move all over the place as soon as the soldering iron is applied. A cheap answer to this problem is a cable spring for a domestic iron, sold to lift the iron cable up and stop it rubbing against the ironing board. These can be purchased at any good hardware shop. These springs come complete with a table clamp and a plastic clip - which just happens to fit jack plugs etc. The plug is put in the plastic clip, which holds the plug and wire very firmly.



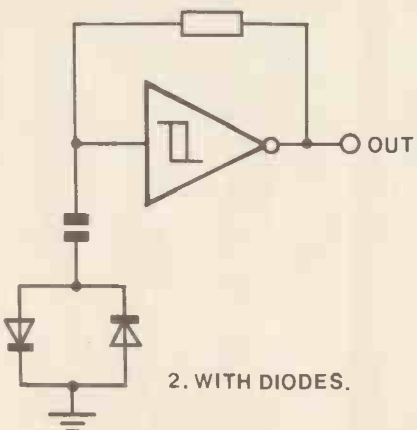
Multiple Speed Oscillator

There are many non critical applications where a logic-controlled multiple speed clock oscillator is required. The usual way of doing this is to provide a free running oscillator for each desired clock speed and then gate them, or physically stop the oscillators not required. The alternative here uses only one oscillator block; the speed is changed by switching in extra capacitors.

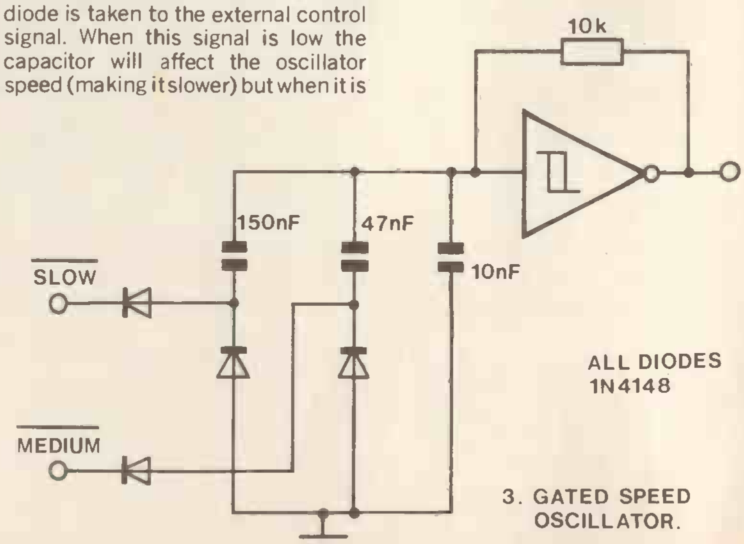
The circuit is based around the standard Schmitt trigger oscillator (1). The capacitor alternately charges and discharges through the resistor, thus producing a square wave output. The addition of two diodes does not normally affect the operation, but if either one of these diodes is disconnected the oscillator stops, and this is the way the multiple speed version works (2). The capacitor corresponding to the fastest speed is permanently connected, but the other two are only connected via one diode. The other diode is taken to the external control signal. When this signal is low the capacitor will affect the oscillator speed (making it slower) but when it is high (or floating) the capacitor is effectively disconnected. Using the values shown speeds of 11kHz, 4kHz and 1kHz approx. were obtained (3).



1. BASIC OSCILLATOR.



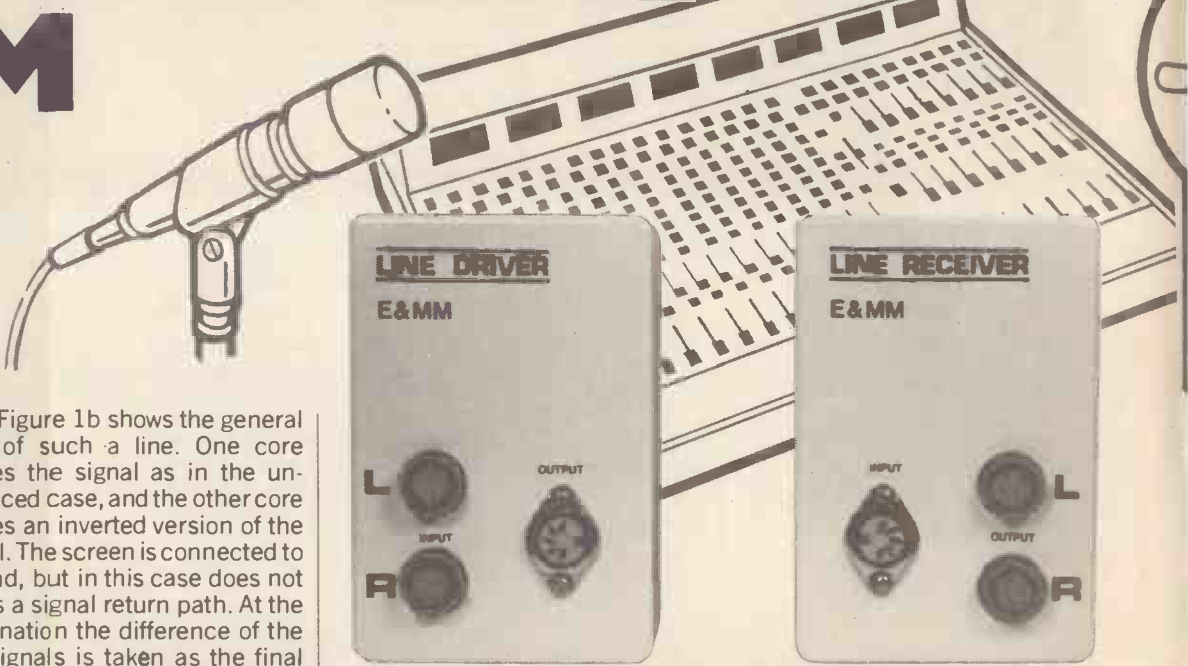
2. WITH DIODES.



3. GATED SPEED OSCILLATOR.

BALANCED LINE SYSTEM

by Chris Lare



This interface system was originally designed to connect two high impedance microphones to a tape recorder with a high impedance input, with a long cable run between them. The system has been tried with up to 25 metres of cable and little degradation of the signal was noted, even in a very hostile environment next to a major thyristor lighting installation. The system consists of two parts; a stereo line driver and a stereo receiver. They are connected by a standard 5-pin DIN plug lead, which is very convenient. A slight penalty is paid for this convenience since the interchannel crosstalk is degraded, but not noticeably so. In the ideal situation separate line drivers and receivers should be used for each channel, and with independent connecting leads.

The Unbalanced Line

The unbalanced line is the usual method of connecting audio equipment (Figure 1a). The audio signal is carried by the centre core, contained within a screen formed by the return path which will always be the 'earthy' side of the transmission. The screen helps reduce inductive couplings of external noise (hum, RFI etc.) to the core, but it's effect is only limited, and over a long cable run the noise picked up will be of a high level. The amount of pick-up can be reduced by running the core from a low impedance source into a fairly low impedance termination. A typical termination impedance would be 600 ohms, although 200 ohms will sometimes be found. Low impedance driving has a further advantage in that treble loss due to cable capacitance is much reduced, as is shock noise which occurs as the cable is moved.

The Balanced Line

The balanced line overcomes all of the problems mentioned above, but the main disadvantage is that two signal cores are required as well as the screen. This naturally makes the cable and connectors much more expensive. Figure 1b shows the general idea of such a line. One core carries the signal as in the unbalanced case, and the other core carries an inverted version of the signal. The screen is connected to ground, but in this case does not act as a signal return path. At the termination the difference of the two signals is taken as the final output, thus the output is identical to the inputs, although a gain of two will be noted. However, any noise induced into the system will be of the same phase on both lines, and will cancel out at the differential point. The rejection ratio is very high indeed, limited only by the common mode rejection of the differential point. The only problem that may occur is the noise (particularly spikes) causing intermodulation distortion at the differential point. This can be avoided with suitable high frequency filtering ON BOTH INPUTS to the differential point. This problem is very small when compared with the overall improvement obtained.

Early balanced lines used transformers, and lines of the highest quality still do. Figure 2 illustrates the operation of a balanced line with transformers. The input signal is split into two phases by the first transformer, and travels to the second transformer which acts as a differential point. Note that the screen serves only to earth the source (if necessary) and screen the cores; it does not carry any part of the signal. Transformers of this quality are very expensive, and are themselves prone to pick up hum, so until the introduction of op-amps balanced lines were limited to studio applications.

The op-amp is an ideal building block for balanced lines, as shown in Figure 3, since both phase inverters and differential amplifiers may be easily implemented.

Balanced lines are never run at high impedance, and 600 ohms is the norm. In some equip-

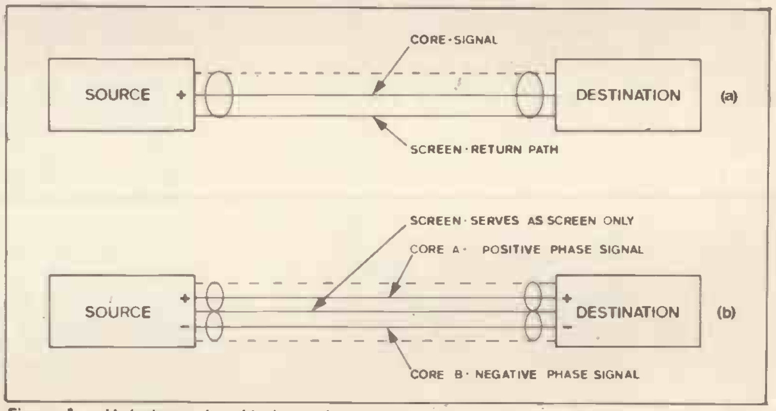


Figure 1. Unbalanced and balanced systems

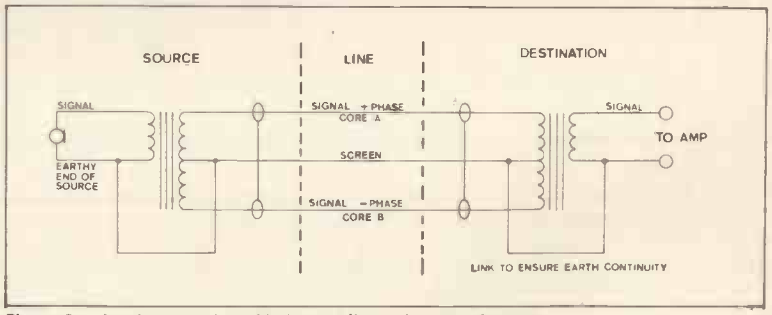


Figure 2. Implementation of balanced line using transformers

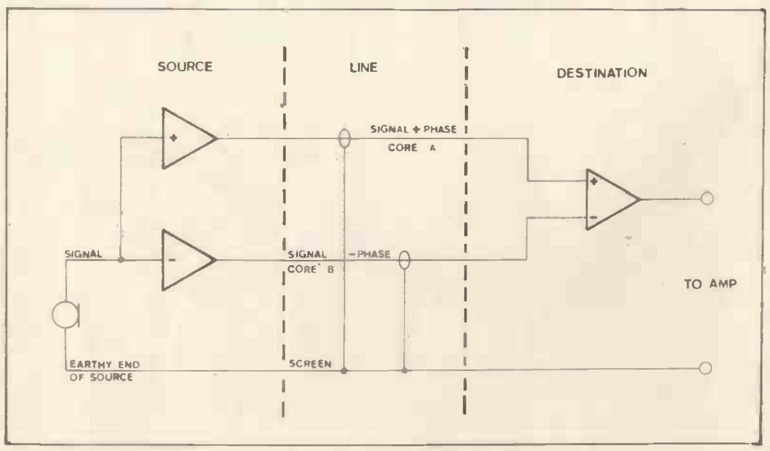
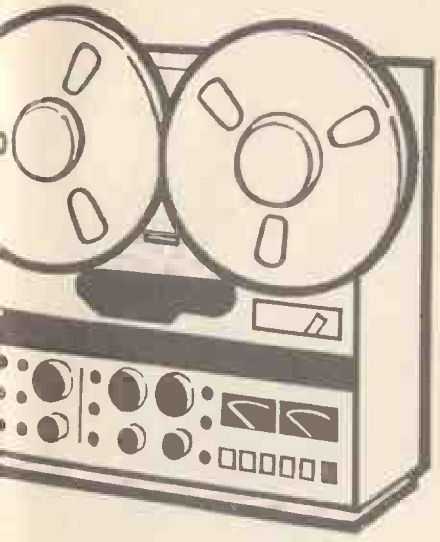


Figure 3. Implementation of balanced line using operational amplifiers



ment (particularly continental microphones) a 200 ohms system may be found, but as a rule this can be plugged into a 600 ohms system with little or no consequence.

Line Driver Circuit

A stereo pair of drivers was built around a quad JFET op-amp (Figure 4) chosen mainly for its very low power consumption. Each pair of amplifiers forms a phase and antiphase generator. The first op-amp inverts the signal and the second op-amp re-inverts the output from the first such that the two outputs are of the same level but exactly out of phase and can be used directly. A 100R resistor is included in each output as a protection against short circuits, and a capacitor is obviously required to block the D.C. level. The op-amps are biased to half rail by R15 and R16 which hold the non-inverting inputs at 4.5 Volts.

A single 9 volt battery is used to power the circuit. This is switched by the right input jack socket, which is stereo and has its screen and centre spring contacts connected together when a mono jack is inserted.

Line Receiver Circuit

The line receiver circuit (Figure 5) takes the out of phase signals generated by the driver and produces a single output from them. In this way the receiver performs an identical function to most mixer input stages.

The in phase and out of phase signals are applied to the non-inverting and inverting inputs of the op-amps respectively. These op-amps are connected as standard differential amplifiers, with a gain of 0.5. This gain loss counters the natural effect of a balanced

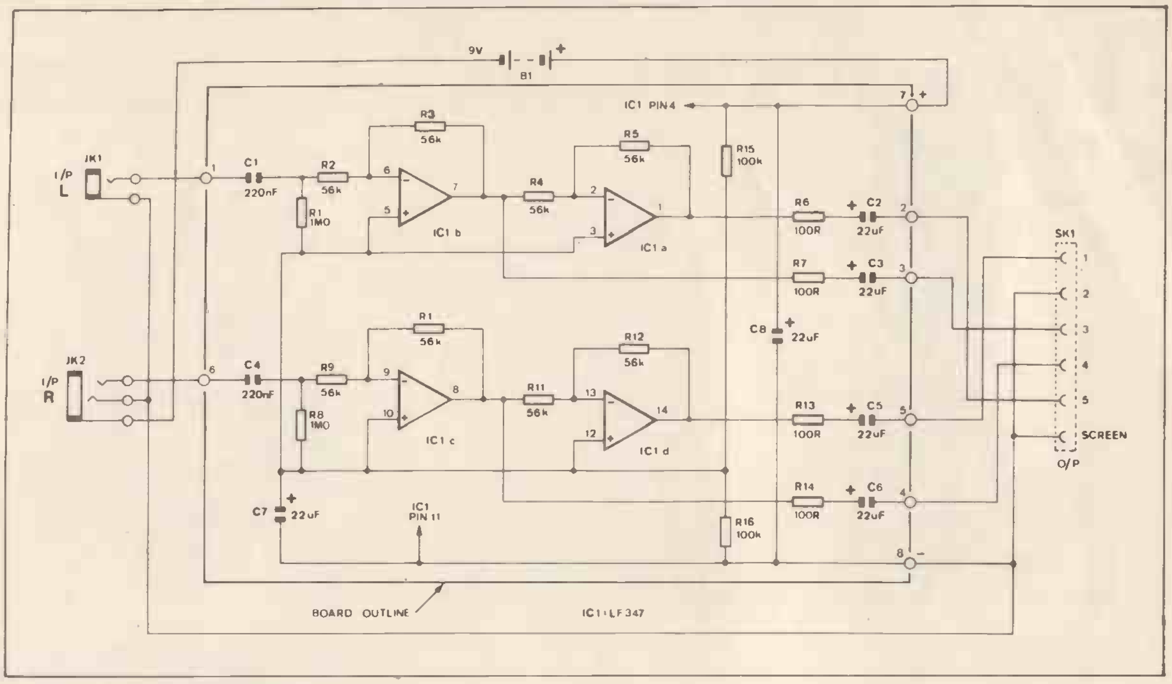


Figure 4. Line driver circuit diagram

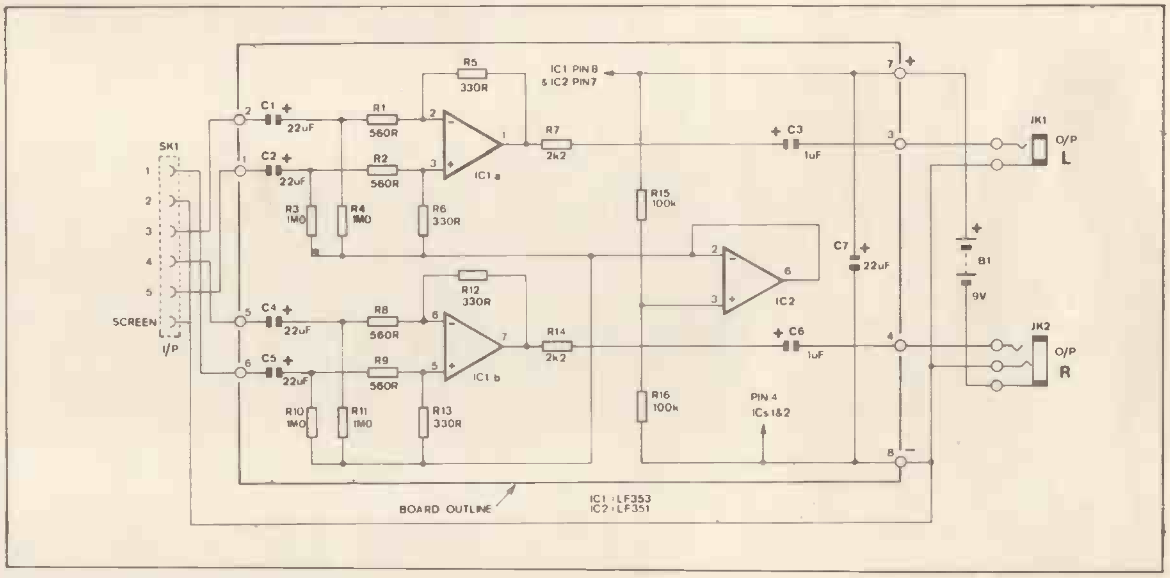
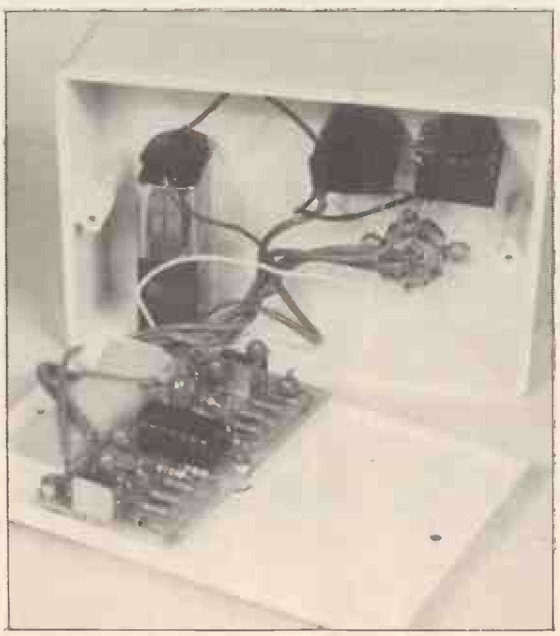


Figure 5. Line receiver circuit diagram



Line Driver

Line Receiver

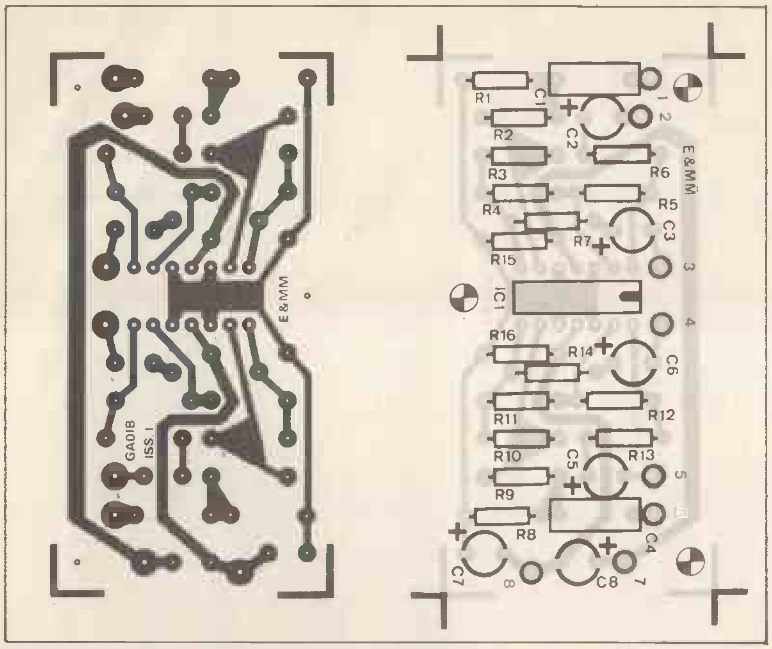


Figure 6. Line driver track layout and component overlay

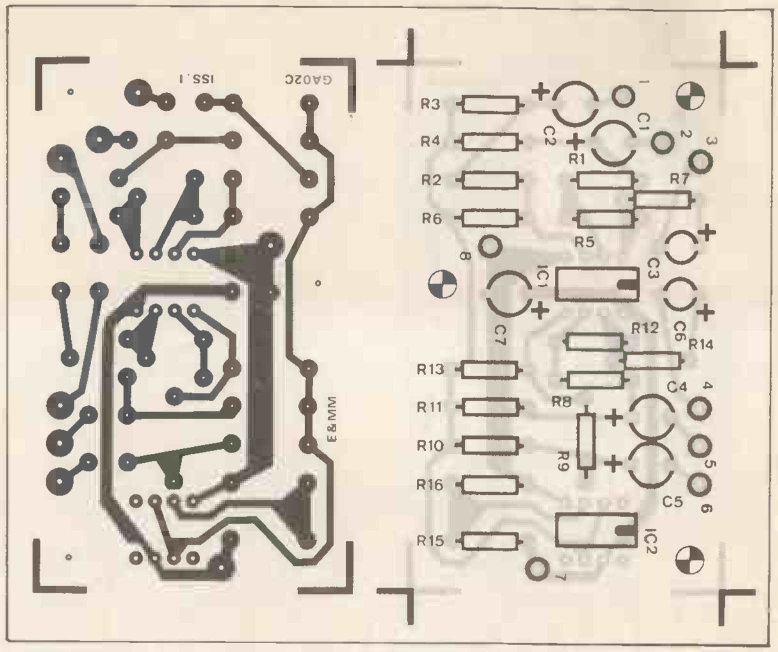


Figure 7. Line receiver track layout and component overlay

line of this sort and ensures that the output is exactly the same as the input (Note: the 100R output impedance of the driver and the 560R input impedance give 660R total, hence the 330R feedback is exactly correct). Due to the nature of this circuit a low impedance rail splitter is required, and so IC2 is connected as a voltage follower to achieve this.

The input capacitors are not required if the receiver will always be connected to the driver since that has output capacitors, so they may be replaced by links. Do not be tempted to miss out the output capacitors from the driver as well since the d.c. offsets required are half the battery voltage, and there is no guarantee that the battery voltage will be the same in both units, besides which it is bad policy to leave equipment with a D.C. offset on its output.

LINE DRIVER PARTS LIST

Resistors - all 5% ⅓ W carbon			
R1, 8	1M0	2 off	(M1M0)
R2-5, 9-12	56k	8 off	(M56K)
R6, 7, 13, 14	100R	4 off	(M100R)
R15, 16	100k	2 off	(M100K)
Capacitors			
C1, 4	220n polycarbonate	2 off	(WW45Y)
C2, 3, 5-8	22uF tantalum 16V	6 off	(WW72P)
Semiconductors			
IC1	LF347		(WQ29G)
Miscellaneous			
JK1	Mono jack socket		(HF90X)
JK2	Stereo jack socket		(HF92A)
SK1	5-pin DIN socket		(BW989)
	Case PB1 (or alternative)		(LF01B)
	Printed circuit board		(GA01B)
	PP3 connector		(HF28F)
B1	PP3 battery		
	Miniature screened cable		(XR15R)
	6 BA ½" bolts		(BF06G)
	6 BA nuts		(BF18U)
	1mm Veropins		(FL24B)

LINE RECEIVER PARTS LIST

Resistors - all 5% ⅓ W carbon			
R1, 2, 8, 9	560R	4 off	(M560R)
R3, 4, 10, 11	1M0	4 off	(M1M0)
R5, 6, 12, 13	330R	4 off	(M330R)
R7, 14	2k2	2 off	(M2K2)
R15, 16	100k	2 off	(M100K)
Capacitors			
C1, 2, 4, 5	22uF tantalum 16V (see text)	4 off	(WW72P)
C3, 6	1uF tantalum 35V	2 off	(WW60Q)
C7	22uF tantalum 16V		(WW72P)
Semiconductors			
IC1	LF353		(WQ31J)
IC2	LF351		(WQ30H)
Miscellaneous			
SK1	5-pin DIN socket		(BW98G)
JK1	Mono jack socket		(HF90X)
JK2	Stereo jack socket		(HF92A)
	Case PB1 (or alternative)		(LF01B)
	Printed circuit board		(GA02C)
	PP3 connector		(HF28F)
B1	PP3 battery		
	Miniature screened cable		(XR15R)
	6 BA ½" bolts		(BF06G)
	6 BA nuts		(BF18U)
	1mm Veropins		(FL24B)

Construction

The Line Driver and Receiver are each constructed in a small plastic box with the sockets fitted on the front and the printed circuit board fixed to the removeable back with 6BA bolts. When the components have been soldered to the board (IC's last), wire up the sockets using screened cable making sure that the screens are connected at the socket ends only, in order to avoid the possibility of internal earth loops. Connect the earths of the sockets together and wire up the battery connector, paying careful attention to the stereo jack socket connections. Note that Dinlatch sockets are specified in the parts list. Used with latching plugs these are well suited to this application, but non-latching connectors could be used. As specified the units can still be connected by a non-latching 5-pin DIN lead. Construction is completed by screwing on the back of the case, with the battery held in place by a piece of foam or pneumatic packing material. Each prototype was finished off with rub-on lettering followed by a coat of varnish and four stick-on rubber feet.

In Use

Figure 8 indicates how the units are used to connect a tape recorder and microphones. Since the system will easily manage 770mV (0 dBm) it can be used to connect pre-amps and power amps for group or disco.

Conclusion

This balanced line system offers considerable advantages over the more standard unbalanced system. In most cases the extra cost of using balanced lines will be more than justified.

E&MM

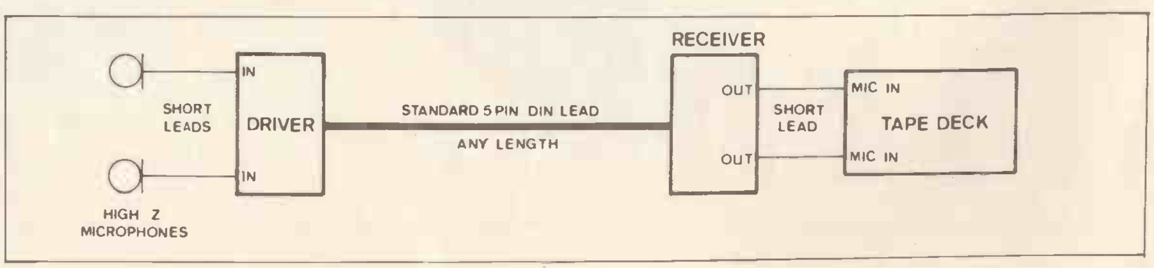


Figure 8. Using the balanced line system for tape recording

CIRCUITS & STANDARDS

The concept of a 'standard' and the modern electronics industry do not seem to mix. Each day a different manufacturer introduces a device which may or may not conform with previous similar devices, the term 'compatible' being used for those which are similar and might work instead. The list of examples of failure to comply with standards is endless, for example it might be thought that the 741 offers a standard pin out for all op-amps and comparators since it was among the first op-amps to be universally manufactured. Instead we have devices such as the 311 comparator, where not only are the power requirements different, but the inverting and non-inverting inputs are reversed!

The most notable non-compatability that has occurred was when CMOS logic was first introduced. The designers, for reasons best known to themselves, ensured that none of the standard CMOS chips followed well established TTL patterns, either in pinout or numbering. Although it must be accepted that CMOS cannot usually be plugged into a TTL circuit directly the adoption of a standard numbering system would have saved many design problems. Naturally CMOS has improved over the years, to such an extent where a CMOS gate will drive TTL, and pin compatability became important. Thus a completely new CMOS family called the 74C series was launched, offering numerical and pin compatability with TTL.

The T092 transistor package deserves a brief mention. This package has three leads, and at some time manufacturers have assembled this package with most possible combinations of base, collector and emitter. Not content with these six alternatives other enterprising people designed the T092z, which features the centre lead offset from the other two.

Nowhere, however, is this lack of standardisation less excusable than in the area of circuit diagrams. Up to a few years ago it was well-known that circuit diagrams might differ in the symbols used, although in time a traditional set had slowly evolved. In order to try and improve the situation the British Standards Institution prepared a specification of circuit symbols in the hope that everybody would follow it. These new symbols tended towards the European style, obviously desirable with increasing communication between countries. The only problem with the new symbols was that very few people liked them at the time and they were largely ignored, resulting in yet more hybrid diagrams. Understandably, in some ways, the most reluctance to adopt the symbols has come from established companies and publications who have developed their own 'standards' previously, or even in some cases, since. However, we at Electronics & Music Maker feel that as a new publication with a particular responsibility to all who are interested in electronics at every level from the classroom to the professional lab., and one which will soon be considered an authority in its field, we should set out from the very first issue to use a professionally recognised system for the representation of electronic circuits and functions. To this end, all circuit diagrams will be drawn in accordance with British Standard 3939; Graphical Symbols for Electrical Power, Telecommunications and Electronics Diagrams.

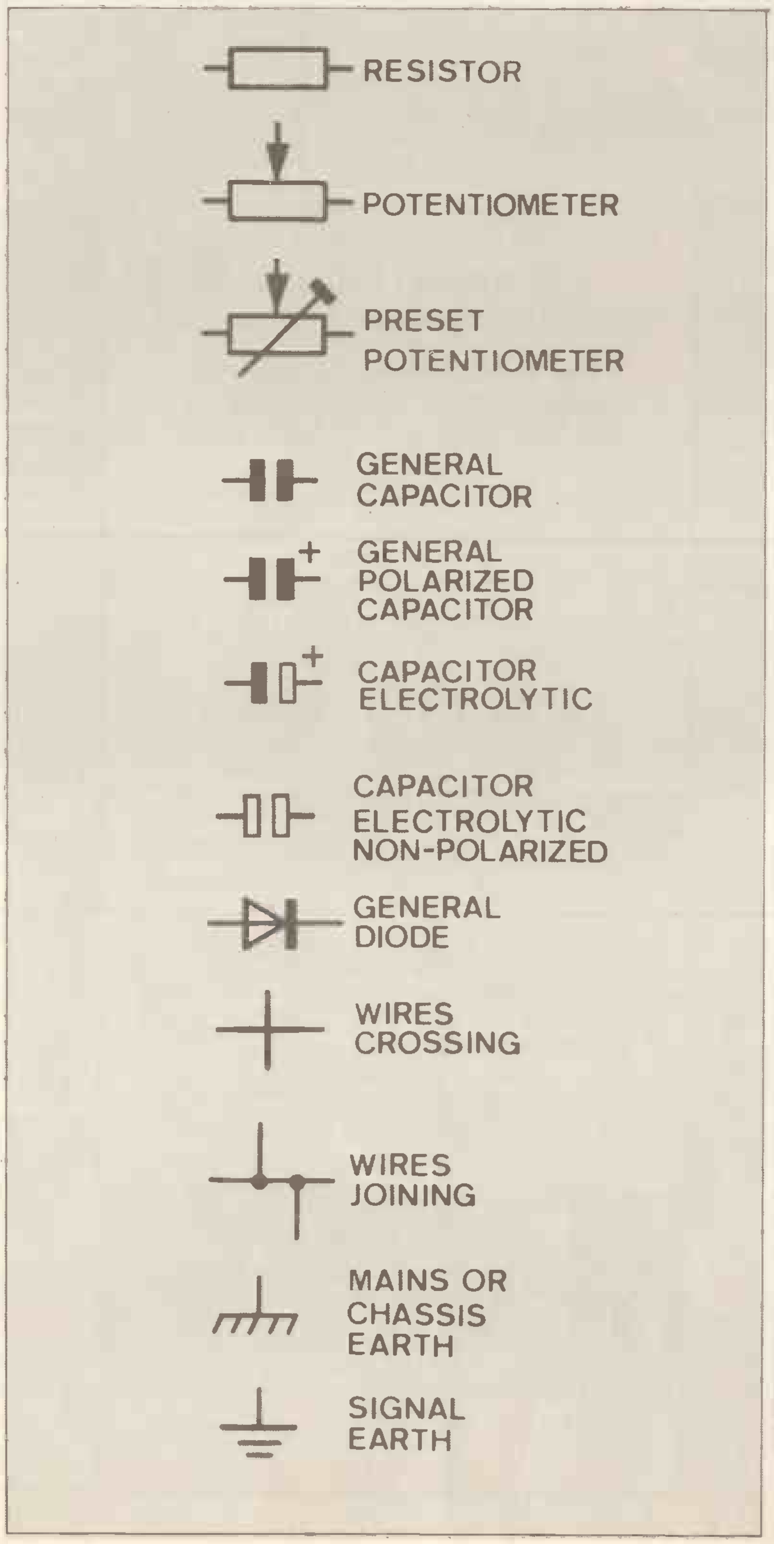


Figure 1. Component Symbols

Since this implies that circuits in E&MM will be presented in a slightly different way to many of the established magazines it seems well worth a page or so examining the way they will be drawn and documented.

Component Symbols

The most obvious difference is the rectangular symbol for the resistor which replaces the zig-zag. Potentiometers will be drawn as the box, to which an '↑' is appended. When the potentiometer is functioning as a variable resistance rather than a divider the relevant circuit connection will actually be drawn, rather than rely on an oblique arrow. The symbol for a preset resistor is somewhat obscure, in that it is the standard potentiometer symbol, through which an oblique 'T' is drawn.

Fixed capacitors follow old established principles, and four main types are specified, although only three are in common use. All non-electrolytic capacitors are drawn as two solid rectangles perpendicular to the wire connection. A tantalum capacitor, although non-electrolytic, is polarised, and as such a '+' sign will be appended to the positive end. Electrolytic capacitors will still have the '+' on the positive end, the associated rectangle of which will be merely outlined to indicate the electrolytic type. The fourth class, and the rare one, is the non-polarised electrolytic, which naturally will be shown as two outlined rectangles. Manually variable capacitors will appear as the standard non-polarised rectangles, through which is placed an oblique arrow.

The use of a ring, or envelope around a semiconductor is optional, except where connection is made to it. This will be turned to good effect in our circuits because a single discrete transistor will be surrounded by its own envelope, where as those within an array or integrated circuit will not. This will save much time on the part of the reader who is looking for 5 transistors, only to find them all enclosed in a single chip. Diodes, on the other hand will not be ringed.

Another item in circuit diagrams that frequently causes confusion is not a true symbol, but simply the method of illustrating connections. If two wires cross on a diagram, usually at 90° then no connection between the two is intended. The traditional 'hoop' over the second wire will not be used. A junction would be shown as a dot over the intersection, but this can obviously lead to mistakes if the dot is not clear, so to avoid this a junction will only be shown at a 'T' between two wires.

Finally, a brief mention of the ground symbols to be used. It is very important to distinguish between mains earth, chassis earth and circuit earth. Under normal circumstances mains earth and chassis earth will be the same, simply for safety reasons. Chassis earth is shown as a horizontal line, with several oblique lines beneath it. Signal earth on the other hand is very rarely mains earth, particularly in audio work where earth loops must be avoided. Such a signal earth appears as three horizontal lines, diminishing in size. Note that this earth will be frequently connected to mains earth by a resistor, and should not as a general rule be left completely floating.

Figure 1 shows the component symbols I have specifically mentioned, and many of the rest are quite familiar or self explanatory. In the near future we shall be preparing a free wallchart/leaflet showing a complete set of standard symbols in use in E&MM, along with component reference details, value representations, etc., to help you draw your own circuit diagrams clearly and accurately.

Value Conventions

One very good system that has emerged in recent years is the method of expressing a component value using the scaling factor to replace the decimal point. This avoids many mistakes of the sort that occur if the point is not clear. In this notation 2.2kΩ is written as 2k2, 100kΩ as 100k, 2.2Ω as 2R2 and 1kΩ as the specific 1k0. Capacitors follow the same pattern, so that 2.2μF becomes 2u2, and 12pF remains the same. As a rule 'μ' (10^{-6}) will be written as the letter 'u', which will simplify typing and typesetting considerably. The very nice point about this format is that it is not necessary to specify 'Ohms' and 'Farads' because resistance or capacitance is implied by virtue of the component symbol and the magnitude involved. The one exception to this is the way of writing a 0.001 Farad capacitor, which is not, as one may expect, 1m0 (corresponding to milli - 10^{-3}), but simply 1000uF. All mean the same, but the latter is much more common. To aid those people not sure about the scaling factors, those commonly used in electronics are shown in Table 1.

Factor	Value	Commonly Scaled Units
p	10^{-12}	F
n	10^{-9}	F
μ(u)	10^{-6}	F,A,V,S
m	10^{-3}	A,V,S
k	10^{3}	Ω(R)
M	10^{6}	Ω(R)

Table 1. Scaling Factors

Components and Parts

Each electronic component in the circuit will be identified by one or more letters and a number, for example R1, C3, TR6. Components for stereo use will generally have a fixed numerical offset added to the number for one channel. In this way, component R101, a resistor in the right channel, will be matched in the left channel by R201, where an offset of 100 has been added. The low numbers (1-100) are generally used for components common to neither channel, most obviously those associated with the power supply. All potentiometers, fuses, sockets and transformers will be included in the numbering system with appropriate identification letters, although obviously some items such as the box will not be numbered.

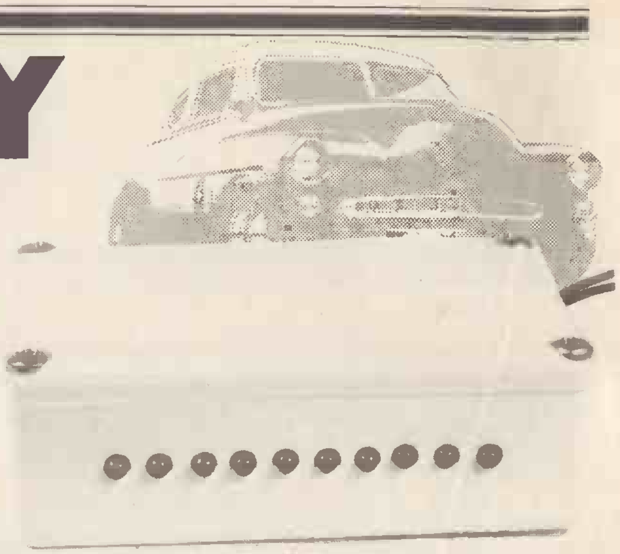
These component numbers, and the parts not numbered, will be collated into a single component list at some stage in the article. This collation will be in the form of a four column listing. These columns will contain respectively the component identifications, component type, value and/or description, the number of each component required where it is greater than one, and finally the Maplin Electronic Supplies stock number for the part, allowing the constructor to obtain a full set of components with the minimum of bother.

Further information about the British Standards can be found in the British Standards Institution Year book, available in most public libraries, and a full set of the standards, including BS3939, can be found in many large reference libraries. Copies of the B.S.I. Yearbook and standards are available from:
British Standards Institution,
Newton House,
101, Pentonville Road,
London N1 9ND

E&MM

CAR BATTERY MONITOR

by David Hough



Any number of things from a faulty alternator to left-on headlights can result in a flat car battery - and the first you are likely to know about it is when you turn the key one morning and the car won't start! This useful little unit is designed to warn you in advance by displaying the battery's state of charge with a row of ten LED's. The Monitor costs less than a fiver to build, and since it consumes a miserly 20mA, can be left connected directly to the battery.

The Car Battery Monitor will even reveal faults like a slipping fan-belt, which prevent the battery charging but leave the dashboard battery warning light off, and show how the battery is handling the strenuous work of starting the car (it takes 20 minutes of running to put back what a five-second start takes out).

Circuit

The National LM3914 bargraph IC is used to drive a row of red, orange, and green LED's, indicating the battery charge voltage in ten steps of approx. ½V each from 9V to 14V. The IC contains an input buffer, a potential divider chain, comparators, and an accurate 1.2V reference source. Logic is also included which gives the choice of bar or dot-mode operation - the latter is used in this application. The comparators cause the LED's to light at 0.12V intervals of the input voltage.

TR1 acts as an amplified diode and raises the lower end of the divider chain and the negative terminal of the reference source (pins 4 & 8) to 1.9V. The upper end of the chain (pin 6) is connected to the reference source output (pin 7) and therefore is at about 3.1V. The potential divider formed by R1 and RV1 attenuates the supply voltage and uses it as the signal input to the comparators such that a supply range of 9-14V covers the span of the divider chain and is indicated over the whole of the ten-LED display. The LED brightness is held constant by an internal constant current source.

Construction

Bend the leads of each LED through 90° about 5mm from the body, then solder them in position on the PCB with all the other components. Drill a line of ⅛" holes in the front of the base for the LED's, two in the bottom for mounting the PCB, and one in the back for the supply leads. Mount the PCB using 6BA bolts with ¼" spacers, connect the supply, and after setting up screw the lid on.

Setting Up

Adjust RV2 until the voltage at its wiper is 1.9V, and then adjust RV1 until the end green LED lights with a fully charged battery (alternatively use a variable voltage bench PSU).

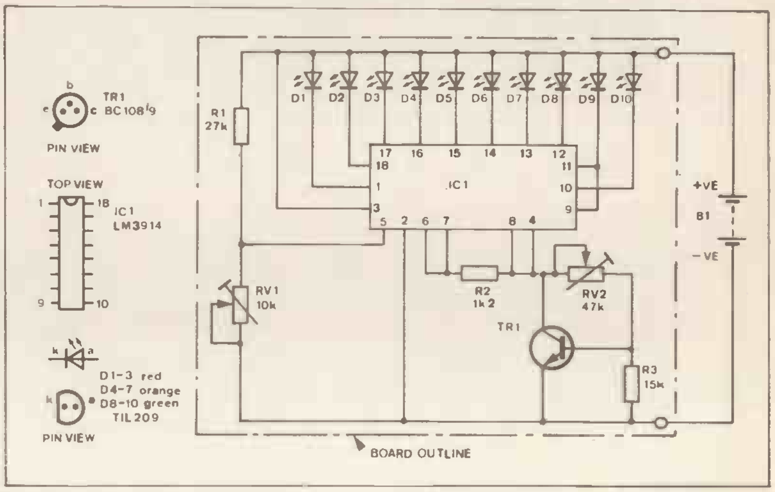


Figure 1. Circuit diagram of the Car Battery Monitor.

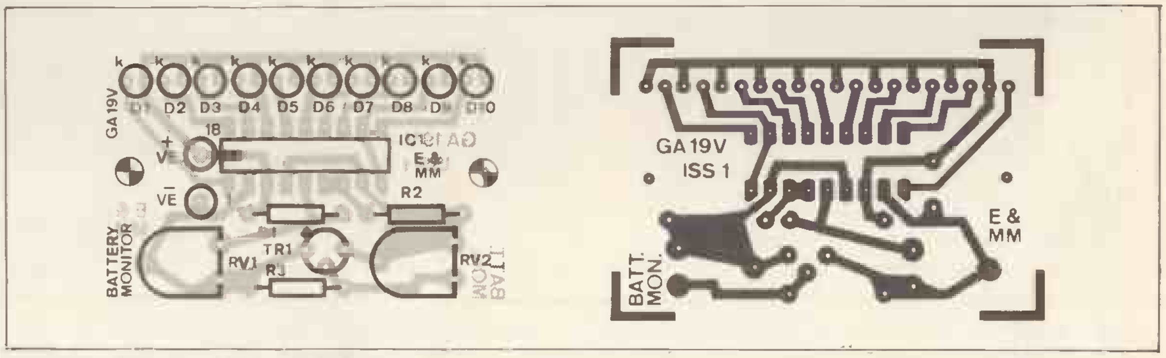
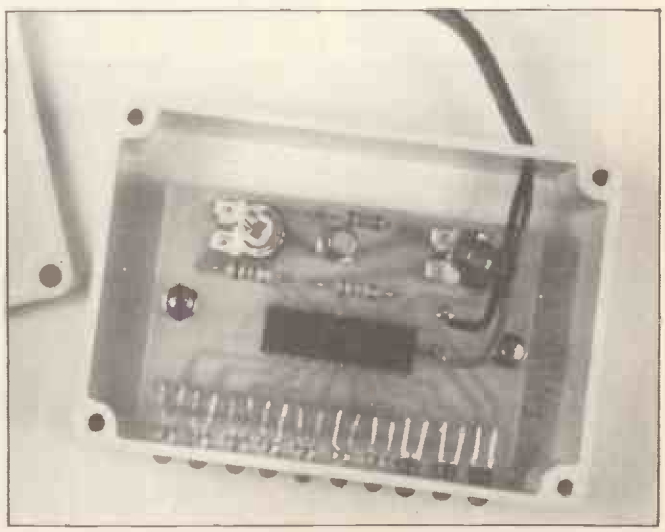


Figure 2. Car Battery Monitor PCB.

PARTS LIST

Resistors - all 5% ¼W carbon unless specified.

R1	27k		(M27K)
R2	1k2		(M1K2)
R3	15k		(M15K)
RV1	10k Hor. 5-min preset		(WR58N)
RV2	47k Hor. 5-min preset		(WR60Q)
Semiconductors			
D1-3	TIL209 red	3 off	(WL32K)
D4-7	TIL209 orange	4 off	(WL34M)
D8-10	TIL209 green	3 off	(WL33L)
TR1	BC108		(QB32K)
IC1	LM391		(WQ41U)
Miscellaneous			
	Printed circuit board		(GA19V)
	Verobox 301		(LL12N)



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USING MICROPROCESSORS

Peter Kershaw BSc.

The aim of this series of articles is to teach by example the basic principles of microprocessor hardware and software to the level at which the reader will be able to understand, modify and even design microprocessor-based projects. The basic ideas will be presented as clearly and as simply as possible, and by working through complete design exercises the details will be dealt with as they arise. Whilst specific processors will be used for the examples, the reader should have enough knowledge at the end of the series to interpret data sheets and thus design working systems around any of the popular microprocessors.

Minis & Micros

First of all, let us discuss a few important terms. A microprocessor is a multi-functional device which can perform simple, logical, arithmetic and control operations during the execution of external programs (software). Note that the microprocessor itself is useless without software (stored in memories) to control it, and some connections to the outside world (keyboards, sensors, displays, etc.). Clearly, there is little point in a microprocessor carrying out a calculation if the result cannot be observed in any way. Connections to and from the microprocessor system are referred to as 'input' and 'output' (I/O) and compatability between the processor and the sensor or indicator is ensured by use of an interface. The sensors may detect switch closures or physical quantities such as temperature or pressure; different types of interface will be required accordingly.

So, a working microprocessor-based system must include memory devices and I/O devices. A special case is the micro-computer, a typical example of which is shown in Figure 1. The special features of a computer are that it is automatic and reprogrammable. This system is automatic in that once execution of a program has started the processor will continue to carry out instructions in a sequence determined by the results of simple, logical decisions. No operator intervention is required to make processing progress from one instruction to the next. The system is reprogrammable because the software in the program memory may be modified; the number of possible programs is effectively unlimited. The only additional requirement for a microcomputer is that the central processor unit (CPU) must be a microprocessor.

By contrast, the CPU in a mini-computer is composed of discrete logic gates, the job of the microprocessor being done by a large number of devices. The minicomputers of 15 years ago were very similar to many of today's microprocessors. Many of these older machines are still used because very large amounts of software have been written for them and it is often more expensive to change to micro-based systems than to maintain the minicomputers. However, contemporary minicomputers are used where higher speed and greater precision are required.

Somewhere between the microprocessor and the microcomputer is the dedicated micro system. Here, the microprocessor software and hardware are configured to perform just one function. For example, an electronic chess game may use a dedicated micro. This approach is becoming more and more common as micro-electronic devices become cheaper. Some of the projects in this magazine will feature dedicated micros.

A word of warning - there are many different microprocessors on the market, all with their advantages and disadvantages, as reflected in their usage and their price. Some are better for numerical work, some for process control and yet others for text manipulation. The one chosen for a project will depend upon the application and upon the user's experience (better the devil you know?). Usually, neither the software nor the hardware are compatible between one machine and another. But don't despair; with the knowledge gained from this series and a manufacturer's data sheet you should be able to handle virtually any of the more common microprocessor types.

Limits of Use

There is nothing that can be done by microprocessors which could not have been done before. However, it would nearly always have required circuits of far greater size and cost and would very often not have been worthwhile in terms of time and cost. Furthermore, the reprogrammable aspect of microprocessors means that greater versatility can be built in.

However, there are some jobs for which microprocessors are simply not suitable. For example, for direct processing of video signals a microprocessor is many times too slow. Such limitations are often overcome by using several processors or by using the processor to control other, faster circuitry. On other occasions, however, the objective is best met by the use of discrete analogue or digital techniques or by special devices such as programmable logic arrays (PLA's). It pays the designer to be aware of the alternatives to microprocessors so that he can choose the best solution to a problem.

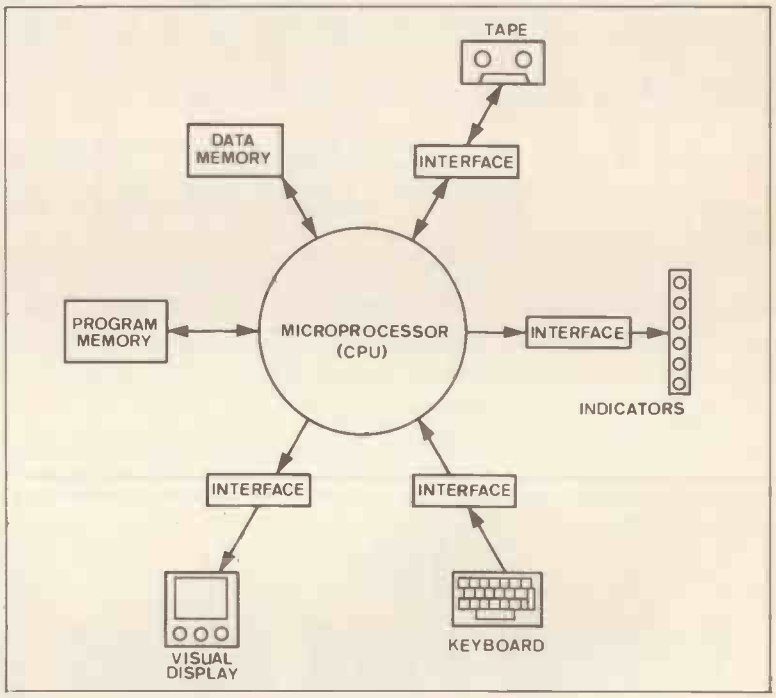

Figure 1. The elements of a basic microcomputer system

Memories

It is clear from the preceding discussion that memories form an essential part of any microprocessor-based system; they are required to store programs and data.

The following terms will help us to distinguish between the many different types of memory device:

Volatile - A volatile memory is one from which the data is lost if the power supplies are disconnected. This is the case with many semiconductor memories (memory 'chips'). Magnetic discs and tapes, however, are non-volatile.

Read/Write - As the name implies, read/write memories may be written to and read from by the processor during the execution of a program. On the other hand, read-only memories (ROM's) may only be read by the processor. They are programmed with permanent or semi-permanent data before connection to the microprocessor system. For historical reasons, semiconductor read/write memories are generally referred to as RAM's (random access memories) even though ROM's may also have random access.

Random/Sequential Access - Data may be read from or written to any location within a random access memory, irrespective of the previous location accesses. Semiconductor memories are normally random access. Data may only be read from sequential devices in the order in which it is stored. Thus, magnetic tape is a sequential access medium. For program execution, random access is preferable. Therefore most microprocessor systems contain some random access memory in the form of semiconductor ROM's and RAM's.

Static/Dynamic - These terms are usually applied to semiconductor RAM's. A static RAM retains its data for as long as power supplies are maintained. Dynamic RAM's, however, need to be 'refreshed' some 500 times per second by the application of a special sequence of signals. Some microprocessors provide these signals automatically; with others, special circuitry is required. However, dynamic memories are usually cheaper for comparable storage capacities, and more data may be stored on one 'chip'.

Specific memory devices will be introduced in the examples in later articles so that readers can become familiar with their use.

Note that in the system illustrated in Figure 1 data memory and program memory are shown separately. The microprocessor, however, cannot tell data from programs and the two are usually mixed together within memory. In some cases, some or all of this memory may be on the same 'chip' as the CPU. This is the so-called 'single-chip microcomputer'. The memory is then usually mask programmed by the manufacturer and this is economical only for very large quantities.

Note also that all inputs and outputs must go via the microprocessor. This is usually, though not always, the case in small systems.

Signals

Electrical signals may be divided into two types; analogue and digital. Analogue signals may take on any voltage. For example, audio signals are analogue. Digital signals may only take on a limited number of voltages. More specifically, binary signals have only two possible values, on and off. For most of the devices which we will be dealing with the two voltage levels are approximately zero and plus five volts. As the voltages do not have to settle to accurately defined levels, switching can occur at very high speed.

The signals are also quantized in time. This means that changes in voltage level only occur at particular times. The timing is controlled by a high-speed reference signal (clock) so that all the various signals within the system are synchronised.

Binary data

As the signals with which we are dealing may have only one of two levels, data is expressed using the binary number system.

In the denary number system (the one which we normally use) there are ten digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9. The binary number system has only two digits: 0 and 1. Consider a three-digit denary number, 295. The right-most column shows five units (5×10^0), the centre column nine tens (9×10^1) and the left-most column two hundreds (2×10^2); columns to the left of these would show increasing powers of ten.

Similarly, the columns in binary numbers show increasing powers of two. For example, consider the binary digit 100110_2 (the subscript indicates base 2 or binary). The weights of the columns are shown below.

	2^5	2^4	2^3	2^2	2^1	2^0
Column value:	=32	=16	=8	=4	=2	=1
Binary number:	1	0	0	1	1	0

Thus, 100110_2 =(1x32) + (0x16) + (0x8) + (1x4) + (1x2) + (0x1)
=32+4+2
=38

The standard word length for the most common microprocessors is 8 bits (binary digits). An 8-bit binary word is called a 'byte', and this may be used to represent numbers between 0 and 255. To familiarise yourself with the use of binary numbers, try converting between decimal and 8-bit binary.

Binary Addition

First, we will look at decimal addition. Take the following example:

```
   16
 + 27
   43
carry 1
```

Only the digits 0-9 are allowed, so when 9 is exceeded a carry must be added to the next column. Similarly, in binary arithmetic only 0 and 1 are allowed and when 1 is exceeded a carry must be added to the next column:

```
      0101 (5)            0111 (7)
      0110 (6)            0011 (3)
      1011 (11)           1010 (10)
carry 1             carry 111
```

Signed Binary Integers

So far, we have only looked at positive numbers represented in binary form. For reference, these are shown in Table 1. However, we very frequently need to represent negative numbers for mathematical purposes. One way in which this might be done is by simply using one bit of the number as the sign and the remaining bits as the magnitude.

In Table 1(b) the most significant bit (MSB) is the sign; 0 for positive, 1 for negative. However, this representation is almost never used. Note that there are two representations for zero (+0 and -0) and also that there is an discontinuity between 0111 and 1000. The simplest (and most common) form of binary counter increments 0111, to give 1000 as in the unsigned case. But with the system shown in Table 1(b) this results in a change from +7 to -0. The system is computationally unwieldly and a far better one is available.

Binary	Decimal	Binary	Decimal	Binary	Decimal
0000	0	0000	+0	1000	-8
0001	1	0001	+1	1001	-7
0010	2	0010	+2	1010	-6
0011	3	0011	+3	1011	-5
0100	4	0100	+4	1100	-4
0101	5	0101	+5	1101	-3
0110	6	0110	+6	1110	-2
0111	7	0111	+7	1111	-1
1000	8	1000	-0	0000	+0
1001	9	1001	-1	0001	+1
1010	10	1010	-2	0010	+2
1011	11	1011	-3	0011	+3
1100	12	1100	-4	0100	+4
1101	13	1101	-5	0101	+5
1110	14	1110	-6	0110	+6
1111	15	1111	-7	0111	+7
(a) Unsigned binary		(b) Signed binary		(c) 2's complement	

Table 1. Various binary number representations

The 'two's-complement' number system is illustrated in Table 1(c) and it is almost universally used for the representation of signed binary numbers. Notice that as the binary number is incremented the decimal number it represents is also incremented for all values within the range -8 to +7. (If more digits were available the range would be increased). This implies that the addition of any two of the numbers will result in the correct sign and magnitude. For example:

```
    0100    +4
    1110    + -6
(1) 0010    = -2
```

Notice that there is a carry from the most significant bit. However, as the two numbers added were of different signs, the result must be within the range, and the carry may be ignored. Let us consider another example:

```
 0100     4
+0110    +6
 1010    = -6
```

The answer is clearly wrong, as the two numbers added were positive but the answer is negative. The correct answer lies outside the range of a 4-bit 2's-complement number.

In order to determine the magnitude of a 2's-complement negative number it would be useful to be able to negate it (i.e. convert it to a positive number with the same magnitude - its '2's-complement'). This is done by negating the individual bits of the number and adding 1. For example, take -5:

```
1011    -5
0100    Invert
   1    Add 1
0101    +5
```

and conversely,

```
0101    +5
1010    Invert
   1    Add 1
1011    -5
```

As subtraction may be accomplished by complementing and adding, an inverter and adder may be used for 2's-complement subtraction. For example, let us subtract 2 from 5:

```
    0010    +2
    1101    Invert
    0001    Add 1
    1110    = -2
    0101    +5
(1) 0011    Total = 3
```

Again, the overflow may be disregarded as we are subtracting numbers of similar sign within the range.

With 8-bit microprocessors, we are normally concerned with 8-bit or 16-bit 2's-complement numbers, and although the range is greatly increased the principles involved are essentially the same. In general, the number range for an n-bit 2's-complement word is $+(2^{n-1}-1)$ to $-(2^{n-1})$. Thus an 8-bit word may represent numbers from -128 to +127 (2's-complement) or 0-255 (unsigned binary).

Next month we will take a look at the structure and operation of a real microprocessor, and see how it communicates with memory and interfaces.

E&MM

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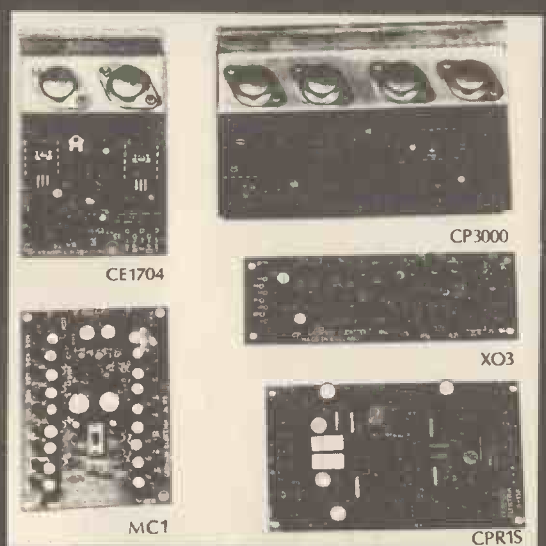

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SPECIFICATIONS

Type	O/P8ohms*	O/P4ohms*	PSU	H/Sinks	Slew	S/N	Sensitivity	THD (typ)	FR	Size
CE 608	38		CPS1	50mm	30V/µS	110dB	775mV	0.0035%	1.5Hz 50Khz (3dB)	80 · 120 · 25
CE1004	44	70	CPS3	100mm	30V/µS	110dB	775mV	0.0035%	1.5Hz 50Khz (3dB)	80 · 120 · 25
CE1008	65		CPS3	100mm	30V/µS	110dB	775mV	0.0035%	1.5Hz 50Khz (3dB)	80 · 120 · 25
CE1704	85	121	CPS6	150mm/FM1	30V/µS	110dB	775mV	0.0035%	1.5Hz 50Khz (3dB)	80 · 120 · 25
CE1708	125		CPS6	150mm/FM1	30V/µS	110dB	775mV	0.0035%	1.5Hz 50Khz (3dB)	80 · 120 · 25
CP3000		250	CPS6	FM2	30V/µS	110dB	775mV	0.0035%	1.5Hz 50Khz (3dB)	161 · 102 · 35
CPR1(S)	Output	77mV	REG1		3V/µS	70dB	2.8mV/RMS	0.008%	20Hz 20Khz	138 · 80 · 35
MC1(S)	Output	2mV	REG1			65dB	70uV/150	0.008%	20Hz 20Khz	80 · 120 · 35
XO2 XO3	Output	775 2500mV	REG1		9V/µS	90dB	775mV	0.01%	C over points pre set	150 · 50 · 20

*Power output is quoted WRMS and is given for two modules run off the same power supply. Higher powers are obtainable if using one module per P.S.U. or if using a stabilised P.S.U.

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Power Amplifier Modules		Power Supply Modules		Heatsinks	
CE 608	£21.00	CPS1 (80VA)	£19.50	50mm	£1.70
CE1004	£24.50	CPS2 (150VA)	£23.50	100mm	£2.70
CE1008	£27.50	CPS6 (250VA)	£30.00	150mm	£3.50
CE1704	£35.00	REG1	£9.30	FM1	£36.00
CE1708	£35.00	TR6	£2.50	FM2	£42.00
Pre Amplifier Modules		**Active Crossovers**		**Hardware**	
CPR1	£34.00	XO2	£19.00	Pre Amp	£39.80
CPR1S	£44.50	XO3	£28.35	Power Amp	£38.00
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SHARP MZ-80K - the melody micro!

Graham Knight

Many of the latest generation of microcomputers can be adapted to play electronic music with the addition of a few components. Some micros have built-in speakers and one, the Sharp MZ-80K, has particularly appealed to musicians interested in playing and composing melodies on a computer. Musical notes can be programmed on the Sharp using both Machine Code and Basic language, and the graphics can be used to display a keyboard on the screen.

Let us examine the musical commands available from the Sharp Basic in detail. Seven tempos can be assigned from very slow to fast using Tempos 1-7. Notes are assigned according to their pitch (octave and scale) and the duration can be selected from a semibreve note to a demisemi quaver. Similar durations can also be assigned to rests when no sound is heard.

Playing a musical scale on the Sharp MZ-80K is simplicity itself - enter MUSIC "CDEFGAB¯C" to hear the scale of C Major. The length of note is assigned by adding a number to the pitch designation with the numbers 0 to 9 giving a full range of durations including dotted notes.

When a series of notes are to be played which have the same duration the number only needs to be assigned after the first note. For example MUSIC "C5DEFGAB¯C" plays the C Major scale in crotchets. The same scale can be played at different speeds by selecting Tempos 1 to 7.

Any notes can be sharpened by prefixing with a # sign, thereby allowing music to be programmed in any key. Thus the scale of D Major would be programmed as MUSIC "D3E#FGAB¯#C¯D" and when played will be in quavers. With a little practice it is soon possible for anyone with a little musical knowledge to adapt music to a Sharp program. The example listing the program to play 'The Entertainer' shows just how easy it is to write music in Sharp Basic.

Many tunes have repeating or recurring passages which would be tedious to program. In the second example the program plays an Etude which changes in tempo and goes from a major to a minor key. Although the program is quite short the tune plays for a considerable time - program space is saved by assigning the repeating passages to string variables. The music contained in lines 5, 6, and 7, defined as strings J1$, J2$ and J3$, is the major section of the melody. Line 8 defines the Tempo and also selects the number of times the first three lines of music are to be played. Similarly lines 9, 10 and 11 are musical strings which are called by line 12.

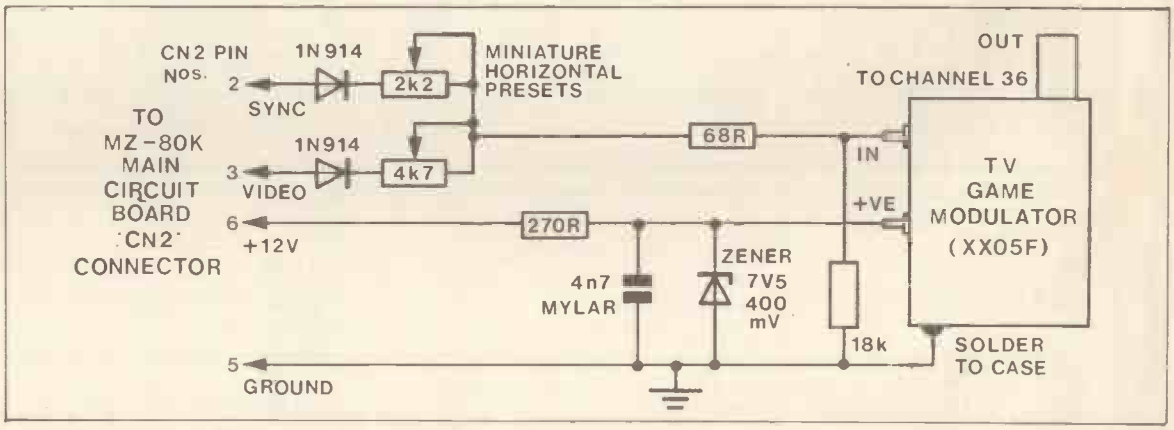
It is also possible to use the Sharp Basic 'Poke' commands to write machine code programs which can vary the pitch at high speed and over a very wide range. Examples are given of programs to reproduce various sound effects which can be used to greatly enhance games like Space Invaders and Startrek. The variety of sounds produced are limited only by the ingenuity of the programmer but the examples of police sirens, trimphones, wolf whistles etc show what can be achieved using POKE, STEP and USR instructions.

Many schools are already using the Sharp MZ-80K in their physics and mathematics departments for a whole variety of microcomputer applications. Some of these schools are now beginning to realise the potential of the Sharp in assisting with the teaching of music. For music teaching the Sharp can display a keyboard, with notes played from the computer keys. It is also easy to program a stave with musical notation on the screen with appropriate notes lighting up as a tune is played.

Although the built-in VDU makes the Sharp compact, it is often useful to be able to display the information on your own television. The circuitry shown enables a standard TV to be used via its aerial input and is easy to construct and set up.

The UHF modulator add-on unit contains very few components and it can easily be constructed on a small piece of Vero board. The modulator itself is of the type commonly used in TV games and these are relatively inexpensive but reliable devices. the output is around Ch36 and can be tuned in on an ordinary UHF TV set. Although the Sharp MZ-80K is a 525 line unit with 60Hz vertical syncs this does not present any problem on a standard British 625 line TV set. The vertical hold will need to be reset and the height (frame amplitude) control adjusted - no further adjustments will be needed to the set. The levels of sync and video signals can be adjusted with the two potentiometers to give a good picture on the external TV set.

The four leads going to the MZ-80K main circuit board are simply connected to pins 2 (sync), 3 (video), 5 (ground) and 6 (+12v) on connector CN2. There are six pins to this connector and pin 1 is marked clearly nearest the centre of the board. **E&MM**



Circuit diagram for connecting external TV to MZ-80K

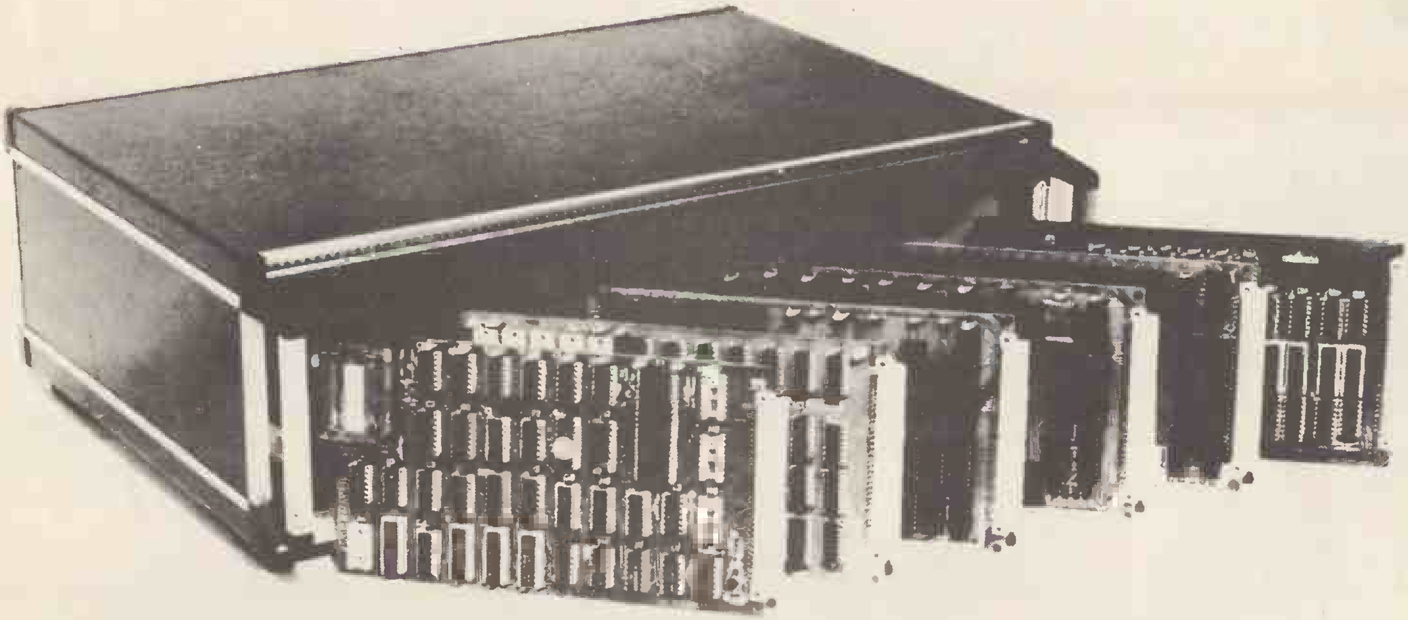
```
 5 PRINT"                 '' THE ENTERTAINER ''
 6 CLR:TEMPO5
 7 MUSIC"D3#D3E3¯C5E3¯C5E3¯C3¯C7¯C3R0¯C3¯D¯#D3¯E¯C¯D"
 8 MUSIC"¯E5B3¯D5¯C7R5D3#D3E3¯C5E3¯C5E3¯C¯C8A3G#F3A¯C"
 9 MUSIC"¯E5¯D3¯CAB5¯C¯DD3#D3E3¯C5E3¯C5E3¯C3¯C7¯C3R0¯C3"
10 MUSIC"¯D3¯#D3¯E¯C¯D¯E¯EB¯D5¯C8R0¯C3¯D¯E¯C¯D¯E¯E¯C¯D¯C¯E"
11 MUSIC"¯C3¯D¯E¯E3¯C¯D¯C¯E¯C¯D¯E¯EB¯D5¯C7R9"


 5 J1$="C1¯C¯E¯C¯G¯E¯C¯ECA¯DA¯F¯DA¯D"    ' ETUDE '
 6 J2$="G16¯B¯A¯G¯#F¯F¯D6¯C¯E¯CBGFD"
 7 J3$="C1_BC_GECGE¯C5R"
 8 TEMPO5:MUSICJ1$;J2$;J1$;J2$;J3$
 9 N1$="D1_F_ADFA_G_#ADGA#A_A#CEG#AAGF¯F¯DAF"
10 N2$="D1FA¯D¯F¯AEG#A¯E¯G¯#A¯A¯F¯D¯E¯#CA¯D#GAEF#C"
11 N3$="D1_D_F_ADEF#CDFA¯#C¯D5R5"
12 TEMPO4:MUSICN1$;N2$;N1$;N2$;N3$


The Sharp MZ-80K Computer has a built-in
music generator and the following notes
can be programmed from Basic
```


```
There are 3 octaves (36 notes)
          9 note durations
          9 rest durations
          7 tempos
```

```
307 PRINT"The tone is continuously variable over
308 PRINT"a wide range.
309 FORJ=1TO1000:NEXT:CLR
310 FORJ=1TO240
311 FORK=1TO255STEPJ*2
312 POKE4514,J:POKE4513,K:USR(68)
313 NEXTK:NEXTJ:USR(71)
314 PRINT"A variety of effects can be produced for
315 PRINT"use with games etc..
316 FORJ=1TO2000:NEXTJ
317 PRINT"AMERICAN POLICE SIREN
318 FORJ=1TO12:POKE4514,3:FORK=1TO255STEP7
319 POKE4513,K:USR(68):NEXTK:NEXTJ:MUSIC"R7"
320 PRINT"PHOTON TORPEDOES":FORJ=1TO4:FORK=1TO150
321 POKE4514,K:USR(68):NEXTK:MUSIC"R1":NEXTJ:MUSIC"R7"
322 PRINT"TRIMPHONE      ";:TEMPO4
323 FORJ=1TO3:FORK=1TO2:POKE4514,1:FORL=1TO15
324 POKE4513,150:USR(68):FORM=1TO6:NEXTM
325 POKE4513,255:USR(68):FORM=1TO6:NEXTM
326 NEXTL:MUSIC"R3":NEXTK:MUSIC"R8":NEXTJ
327 PRINT"ENGAGED !!"
328 MUSIC"G4RGRGRGRGRGRGR6"
336 MUSIC"R6"
337 PRINT"SEXY WHISTLE
338 FORJ=1TO2:FORA=-255TO0STEP12
339 B=ABS(A):POKE4514,1:POKE4513,B
340 USR(68):NEXTA:MUSIC"R1"
341 FORA=-255TO255STEP8
342 B=ABS(A):POKE4514,1:POKE4513,B
343 USR(68):NEXTA:MUSIC"R7":NEXTJ:MUSIC"R7"
363 PRINT"AND NOW ....
364 FORJ=1TO1000:NEXT
```



BASICALLY BASIC

This regular series will attempt to teach BASIC to those who would like to use it for any home, business, scientific or musical application, but have no previous programming experience.

Graham Hall

BASIC is a programming language currently widely available and used on most personal computer systems. It was devised at Dartmouth College in the U.S.A. as a high-level language that would be easy to teach and learn. There are many versions of BASIC but they are all based on a standard. Once you have learnt the fundamental concepts and how to think about writing a computer program, you will find that it is relatively easy to write and modify your own programs to run on any computer (provided it has an interpreter which translates the BASIC statements into a form which can be executed by the computer). This series will describe the BASIC language by giving specific examples of the fundamental statements and examples of how they can be combined to achieve more intricate programs.

What is a Programming Language?

A programming language is a very well defined way of communicating with a computer. Imagine that you are giving instructions to a friend to teach him how to mend a puncture. The sequence of instructions that you tell him are the equivalent of a program. His brain can be thought of as a computer which recognises words and translates them into actions enabling him to carry out your instructions. Programming a computer is just as straightforward. You tell the computer what you want it to do using statements from a strictly defined language (such as BASIC). The computer recognises and converts your instructions into actions - there is already a program in the computer's memory which changes the BASIC statements that you type in, into the strings of binary numbers which the computer can manipulate to perform the actions.

This analogy can be extended - if you tell your friend what to do using nonsense words he would not be able to interpret what you are trying to tell him and would probably ask you to repeat your instructions using words he could understand. Similarly, if you try to type into the computer words or statements which are not defined in the BASIC language, the interpreter program in the computer memory will not understand and will tell you by displaying an error message on the screen. Although the interpreter program may except your BASIC program the statements taken together may not do quite what you had intended because of a small programming error. Then you will have to 'debug' the program by analysing what it does and why. Once the mistake has been located one or more of the statements will have to be

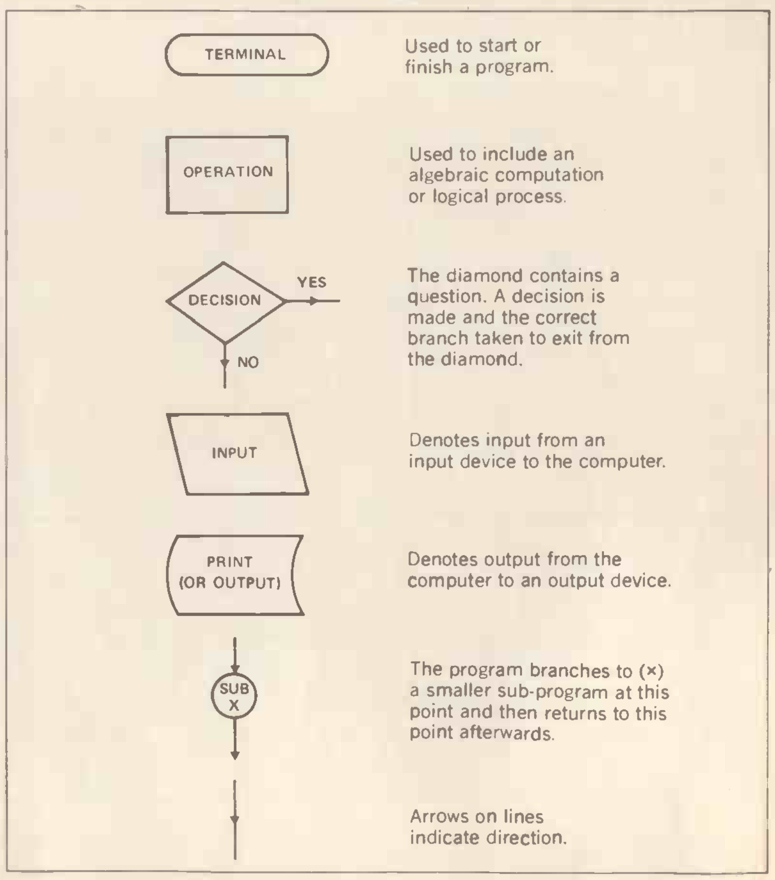


Figure 1. Common flow chart symbols.

changed. As you gain more programming experience you will find it becomes much easier to write programs that do exactly what you had intended first time. Remember you are always in control of the computer - it only does what it is programmed to do. You may have heard the computer jargon word 'GIGO' which stands for Garbage In Garbage Out - if you type a nonsensical program into the computer you will not get meaningful results.

Algorithms and Flow Diagrams

The key to writing an efficient computer program which can be understood by other people is to spend quite a lot of time thinking about the problem to be solved before writing any code. Although this may be time consuming, it will in the long term save you considerable time and effort. In computing terms the solution to a problem is called an 'algorithm'. An algorithm is a finite number of steps which have to be carried out one by one in order to solve the problem. Each of the steps can be translated into the relevant statements of a programming language to enable a computer to perform the operations necessary to provide you with a solution to the problem.

A clear concise way of expressing an algorithm is in the form of a 'flow diagram'.

A flow diagram enables you to quickly see the sequence of operation or flow of an algorithm. By studying a flow diagram it is often easy to see omissions or errors in the algorithm. It is then straightforward to change the flow diagram before any code is written. The program may still contain errors but they should be easy to correct without large scale alterations to the program.

There are certain conventions used by programmers when drawing flow charts. The symbols used most frequently are shown in figure 1.

Now lets see how a flow diagram helps to give a clear representation of a problem.

An airline operates a service to Edinburgh. The standard single fare is £40. However, at certain off-peak times the single fare is reduced to £25. The return fare is £10 cheaper than the combined cost of two singles but this reduction does not apply to the off-peak reduced fare.

At first glance the information content makes things a little confusing. We can simplify the way the information is presented using a flow diagram (see Figure 2). Note that an algorithm is not needed to solve this particular problem.

Suppose you want to know how much the off-peak return fare to Edinburgh will be. The information is quickly obtained by glancing at the flow chart, answering the questions in the decision boxes and reading the fare from the statement box.

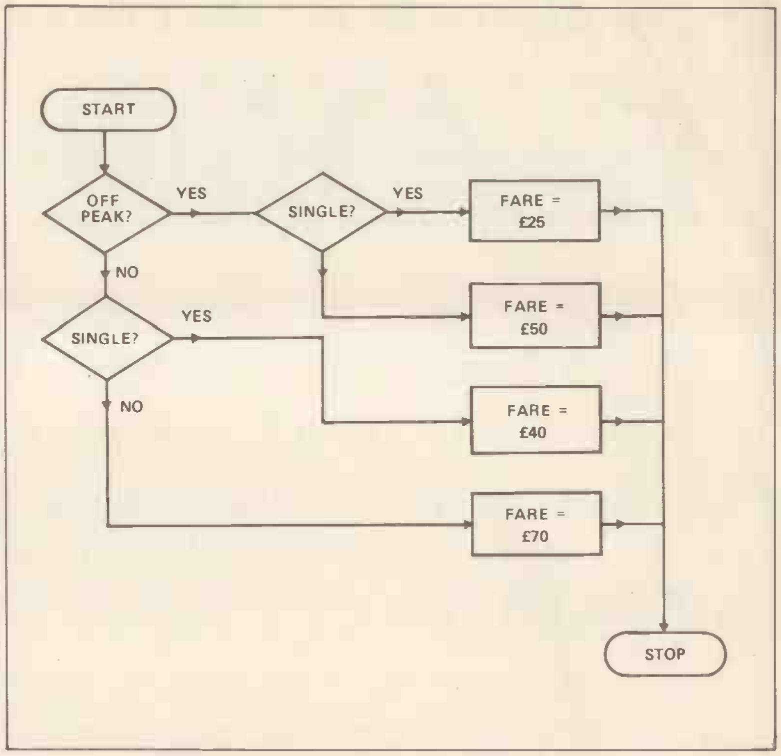


Figure 2. Flow diagram to represent airline fare information.

Next month we will look at a more complicated problem and an algorithm to solve it. Some of the BASIC language statements will be introduced so that you can start to write your own programs.

E&MM

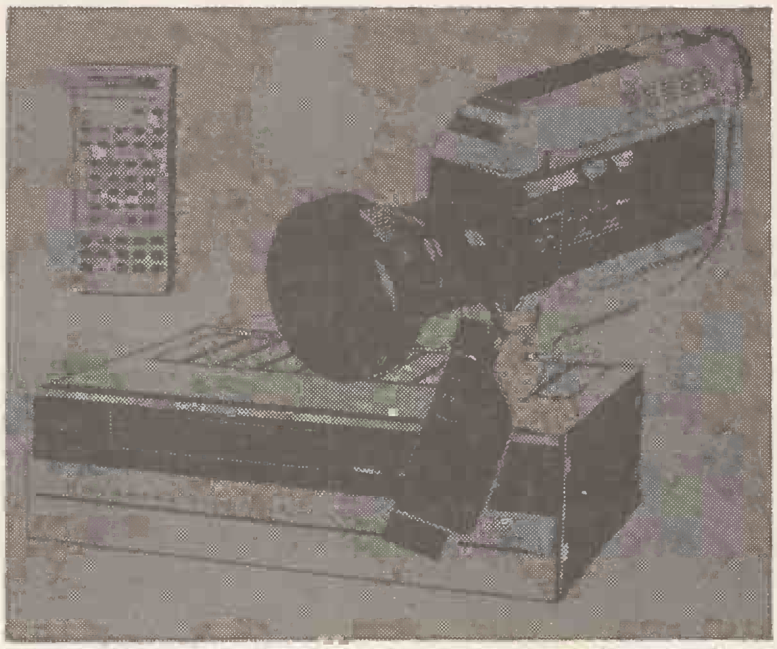
WORKING WITH VIDEO

New readers start here! That includes you so welcome to "Working with Video". We've called it that because if you have taken the trouble to buy this magazine you must have a fairly creative interest in building, making and modifying things, not just connecting together black box systems bought straight off the shelf in the High Street. So if your interest in video extends beyond taping "The Professionals" so that you can watch "Shoestring" as well, or taping a whole week's "Coronation Street" while you take your winter sports holiday this column should appeal to you.

The idea is to take an active view of video and describe some of the things you can get up to without having to apply for a second credit card. In other words we will be taking a fairly sane and value for money approach to what you can do with video. From time to time we will review new machines and report on accessories: we will tell you if they are worth buying and whether they really do represent the first major advance since the Philips 1500. Value for money will be discussed and no doubt names will be named.

We will not adopt a pseudo-intellectual approach but neither will we insult your intelligence by leaving out every technical fact. Three of the newest video magazines have averred that they will not confuse their readers with technical jargon, but half the reason why people buy technical products is to feel that they are participating in "Tomorrow's World"! So we won't shy away from volts and megahertz when necessary. And by the way, we assume you are reading this column to find out about video, so we won't waste your time with write-ups about home computers, citizens band or programmable calculators which are all very nice but nothing to do with video.

Right, having got that over with, what have we left to write about? Let's start with something contentious, like cheap tapes. Are they worth buying, will they damage your machine's health? If you have a VHS machine (and according to the ads, seventy per cent of you do) you will probably have taken more than a cursory glance at a recent statement issued by JVC Ltd. It warned buyers that there were 'pirate' VHS cassettes being imported from countries like Hong Kong, Korea and Taiwan which were not licenced by JVC (the originators of the VHS system) and that these unlicenced blank tapes *might* damage your machine. What it failed to say was they were considerably cheaper than 'legit' VHS tapes, even at discount prices, and *might* damage the profits on blank tapes made by the 'proper' manufacturers. Fundamentally the statement is true. These 'non licenced' tapes *may* be diabolical, but I wouldn't say they all are. For instance, there is a brand on sale in some areas which has a name ending in ". . . rex" (no, not Memorex, but that's the brand of tape in them!). These blank tapes retail at £6 for an E-180 which is not bad when some provincial monopolists are still charging £14 for the same article (someone will write in and say he knows a shop charging £15). Are the 'pirate' tapes any good? Well, the distributor claims the tape in them is Memorex (a job lot,



of course) and the plastic shells, marked made in Japan, are the same as you see on many other tapes. Results are just slightly poorer than best branded tapes, i.e. a few more dropouts (tiny spots of missing picture) and a slightly noisier (grainier) picture. If you don't buy many tapes I'd leave them well alone; on the other hand, if you use a lot of tape and want to save £3 or £4 a tape you can probably put up with a slightly poorer picture.

Not to be confused with 'pirate' cassettes are the USA imports which have been around for several months. When the first VHS video recorders arrived in this country there were some local shortages of blank tape and some enterprising people imported tapes from the United States. Whether the tape now on sale is still the remnants of these imports I don't know – I doubt it – but several shops have them, including a large national discount store whose name would appeal to astronomers. Most of the tapes carry the RCA trademark and they are of top quality. The only thing which may confuse you is the numbering, VK250 and the like. I don't know what these numbers mean unless they relate to the physical length of tape inside, but the VK250 actually lasts for about 3 hours and ten minutes. One shop in London's Tottenham Court Road sells them for £7.90 which is a very reasonable price, so look out for these.

While on the subject of tapes, it's pleasant to see the price of prerecorded material coming down. It's still got a long way to go to reach a sufficiently realistic level where you and I will go out and buy a film a month, but the latest IPC Video catalogue shows a welcome step in that direction. They sell all sorts of tapes, not only their own company's offerings, and they have knocked off several pounds from the price of most. The only snag is that by the time you have added on a hefty post and packing charge you're almost back to recommended selling price! Not quite though, and it probably indicates there is a fair old margin in the price ready to be cut if sales start to take off or someone starts a price war. It is tempting (but somewhat misleading) to look across the pond and make comparisons with the United States where virtually all hit feature films are available on tape more or less immediately, and at sensible prices. Very few big-name films cost more than the equivalent of £30, many are less, and many shops will get you the film of your choice within a couple of days, that is if it is not already in stock. There are several mail order tape clubs (like book and record clubs over here) but the difference is that you are not committed to buying merchandise you don't want and the introductory offers really *are* a bargain. Such is life!

By the way, don't ask your friend in the States to send you across one of these tapes unless you happen to have a multistandard TV set and video recorder. It won't work, so save the disappointment. I know people who have been sent really 'exotic' material which they couldn't play back. While they seethed because they couldn't watch their films somebody else was probably grinning, because a significant proportion of tapes are now inspected by our customs, and, yes, they *do* have viewing equipment for foreign TV standards. You can tell when your tapes have been inspected: the parcels are resealed and to cap it all, they don't bother to rewind the tape afterwards! Bit of a nerve isn't it? A friend rang them up about this and also complained he had been 'stung' quite heavily on some blank tapes he had been sent as a gift. To have to pay VAT and customs duty on four blank tapes sent as a gift didn't seem fair to him. Well, it did to the customs, who were just carrying out instructions, but they did suggest that if you were having tapes sent regularly, they would be less likely to attract duty if they were sent in ones or twos. I daresay not many of you are, but in fact a multistandard machine need cost no more than £100 over the price of a normal videorecorder if you go to the right place. Of course you will need a dual standard TV set as well, but careful study of the small advertisements in 'Exchange & Mart' might find you a bargain. I myself got a beautiful six month old Sony 18" dual standard set for £230 in this way, which is far cheaper than the list price. In a future column we will discuss the pleasures and pitfalls of secondhand purchases in greater detail.

Well, that's it for the first issue. Look forward to seeing you again in the next issue, and if you have any comments, queries, or nasty video problems drop us a line at the magazine. We cannot answer technical problems individually (unless they are written on the back of a five pound note) or we'd never find time to write the magazine, but if we feel the problem will be of interest to many readers we'll answer it on this page. Meanwhile, if you have had any funny dealings with mail order traders or good secondhand buys why not share the news?

Andy Emmerson.

Guide to Electronic Music Techniques

Vince S. Hill

The word techniques encompasses a large variety of meanings, not only is it the way or means to do something but also the skill, operation and approach to get that something done. All techniques are of a very personal nature, and can be adapted to one's own style of playing, once you have achieved a certain basic level, these techniques will grow with you in terms of operation and creativeness.

The most fundamental technique is to understand the instrument you will be using, not only in its capabilities but in the way it is eventually heard by the listener. We will be examining the synthesiser and its associated equipment, not only in their workings but the basic techniques involved in using electronic instruments especially in various forms of music.

Understanding your synthesiser

When you sit down with your synthesiser, whether it be keyboard operated or modular based the understanding of what actually happens when you rotate a knob or depress a switch is of the utmost importance.

A synthesiser completely and simply reverses the processes by which our brain discerns sound. Sound is broken down by the human ear into three basic elements and their possible changes. These elements are: Pitch, Timbre and Volume. Let us take a closer look at how these can be thought of in synthesiser terms.

Pitch

The frequency of 'cycles' per second determines the pitch of a soundwave. Frequency is measured in Hertz (Hz) units, one Hz equals one cycle per second. In musical references we use common relationships, i.e. A = 440 Hz or the tonic solfa, do-re-mi scale.

Changes in pitch

When referring to changes in pitch we are relating to vibrato, tremolo and pitch bending. When you come to make use of a change in pitch there are certain questions to ask yourself:

(a) How many times do I want the pitch to go up and down each time I play a note?
(b) How many times per second do I want the pitch to rise and fall (fluctuation speed)?

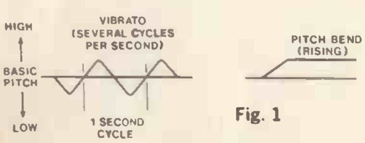


Fig. 1

Figure 1 shows that in vibrato the pitch fluctuates regularly above and below the basic frequency of a note, but in pitch bend the pitch rises or falls just once.

You must be clear about this difference because on the synthesiser you will be using two completely different modules to synthesise these effects.

Timbre

Timbre or tone colour depends on the shape of the sound wave in operation. Any regular waveform can be broken down into its fundamental frequency and a finite number of harmonic components which are odd

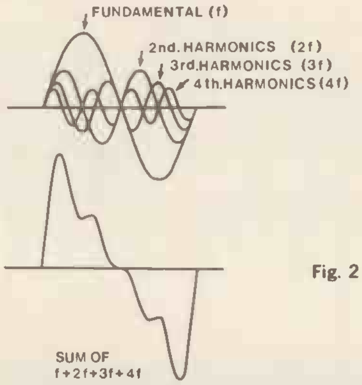


Fig. 2

and even multiples of the fundamental, these are otherwise known as overtones.

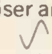
It is the ratio of each of these harmonics in relation to others which determines the waveform, therefore any increase or decrease in the amount of harmonics will change the timbre. When we talk of a sound being bright, clear, heavy or dull we are responding to its timbre.

Taking a sawtooth wave as an example, Figure 2 offers visual confirmation that any complex periodic wave consists of a number of sine waves (the fundamental, which is of greatest intensity and lowest pitch, and harmonics or overtones which are simple multiples of the fundamental and of lesser intensity).

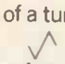
The waveforms and their uses

Waveforms can be broken down into two basic groups, periodic and aperiodic. Periodic waveforms are those that have pitch and are of a repeating nature, i.e. in a chain of complete cycles the cycle being produced looks like the preceding cycle. Aperiodic waveforms do not have any repeating patterns, sounds with aperiodic waveforms have no pitch, e.g. those made by wind, surf, snare drum, etc.

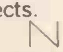
The most common waveforms found on a synthesiser are as follows:

Sine Wave: 

The sine wave has no harmonics, it is a very pure tone, it is a very rounded sound akin to that of a tuning fork.

Triangle Wave: 

A very basic waveform having very few harmonics, a triangular wave may be changed into a sine wave by the use of the Low Pass Filter. The timbre is soft and rounded, excellent for flute and vibe type effects.

Sawtooth Wave: 

The sawtooth wave, sometimes known as a 'ramp' waveshape is rich in all harmonics, and one of the most useful to the synthesist. Used for string, brass, voice and other harmonically rich sounds. Due to the plentiful supply of overtones the VCF is highly effective.

Rectangle Wave: 

The rectangle or square wave is variable depending on the width at the top, called the pulse width, when the top and botton widths are of equal distances it is a square wave, and possesses the hollow qualities of the reed family. Like a clarinet there are no even harmonics.

Pulse Wave: 

As the pulse width proportionately decreases, a strong shift in tone colour occurs, the sound becomes 'nasal' in quality, i.e. oboe or harpsichord.

Noise: 

Noise signals are unique in that they are irregular, have no clear pitch and contain a mixture of all frequencies together. Noise can be used as a sound signal source for special effects, and as a control signal for irregular modulations. There are two common forms that noise usually takes, these are pink noise and white noise.

Pink noise has a greater proportion of low frequencies than high, being perfect for thunder, waves and deep percussive effects.

White noise is noise which is musically balanced; high and low frequencies sound equally loud, white noise is very useful to synthesise wind, surf, gun shots and rim-shot percussive type sounds, it is also very effective when used as a modulation signal to obtain the sound of the musicians breath when playing a wind instrument - again the VCF is well applied here.

Changes in Timbre

We do not pay much attention to changes in timbre in the everyday sounds we hear around us, eg. traffic, talking, telephone etc. Only when something dramatic happens, ie. car crash, shouting, increase in telephone volume does one pay any clear attention.

If you hear a trumpet being played softly, you hear a rounded and mellow tone, if played loudly the sound becomes bright and sharp, a clear indication of how timbre changes in proportion to volume. Applying vibrato to a brass instrument will also cause small variations in timbre which in this case, are proportional to the regular fluctuations in pitch. You will see the same type of cyclic pattern as in Figure 1.

Try to visualise changes and timbre in graph formation, this is an important skill in playing and understanding the synthesiser.

Volume

When we relate to a sound being too soft or loud, we in fact mean its average volume albeit that the amplitude is constantly changing. With a synthesiser it is much more important to think about how the volume changes over time. For example how do you really differentiate between a flute and piano if they played the same note? The most obvious difference is the way the volume rises and falls. In this way volume does not have 'static' characteristics like pitch and timbre, the other two elements that determine 'sound quality'.

Changes in Volume

In Figure 3 you can see from the graphs the characteristic patterns produced as volume rises and falls during one note. The changes in volume on a synthesiser are effected by the envelope. Again, develop an understanding of what happens when you hear a sound, how does the volume rise?

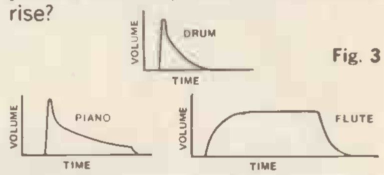


Fig. 3

Does it remain constant? What is the decay of the sound? All these factors relate to every sound made.

Let us now relate this to the synthesiser, the pitch is effected from the Voltage Controlled Oscillator (VCO), the timbre is created from the waveshaping circuitry on the VCO and finally altered by the Voltage Controlled Filter (VCF) or resonance controls and the volume is processed through the Envelope Generator (EG) and Voltage Controlled Amp. (VCA).

Whether you switch link, patch link or pin patch, to synthesise any sound you should use the technique of producing the sound in the following steps.

Analysis

Analyse the sound you have in mind, break it down into its three elements and look at them individually.

(a) What is its pitch?
(b) What kind of timbre does it have?
(c) How does its volume change over time?

Selection

Select the modules you will need accordingly to the results of your analysis. Decide which modules will be able to produce pitch, timbre, and volume and their respective changes. You must have a clear concept of exactly what each module is capable of.

Programming

Programme your selected modules by patching them together and adjusting their control voltages. Programming is the end result from selection and analysis, hooking up in the correct order to obtain the effect required.

If you look at the synthesiser in this way, a far more logical direction to sound and its characteristics is obtained and can be directed to any form of sound make up and synthesis.

In the next article we will be looking at the modules and following the sound to its end. **E&MM**

INSTRUMENT REVIEW

Each month we review the latest Electro-Music Equipment — from synthesisers to sound reproduction and effects!
E&MM's special in-depth reviews look at what's new in the world of commercial music — a vital updating for both electronics designers and musicians.

Yamaha Symphonic Ensemble SK20

With polyphonic synthesisers appearing in the shops more frequently now, it must be natural for a manufacturer's design team to want to make their instrument have more 'orchestra' groups and effects than their competitors. Yamaha, however, in their SK20 have produced a synthesiser that takes the three most important polyphonic sounds and utilises their unique custom chips to give an advanced technology machine for its price. The SK20 functions as a polyphonic synthesiser and a string synthesiser (with the POLYSYNTH section), as well as a harmonic drawbar ORGAN. The keyboard plays up to seven notes over its 5 octave range or fourteen notes in either of the split keyboard modes. In addition, string chorus effects, Leslie-type tremolo, delayed vibrato and detuning are featured.

The Construction

Yamaha's instruments always have a high class finish in terms of physical materials, and the SK20 is certainly no exception. Styled like the CS40/20M and 15D it has rosewood grain end panels, semi-matt black metal panels and wooden base. The weight of the whole package is only 33lb which must make it one of the lightest polyphonic instruments for its size (10(W) × 15.8(H) × 40.6(D) cms). No case is provided and the footswitch (FC-4) and footcontroller (FC-3) are optional extras at £13 and £19 respectively. Servicing couldn't be easier with all of the main panel opening up as in Figure 4 and a removable keyboard (see Figure 3).

The Circuitry

The SK20 essentially comprises three separate sound sources — organ, string and polysynth driven by a common keyboard. The machine is built around 4 Yamaha custom large scale chips. The 61 note keyboard speaks to the digital tone generators via a 40-pin chip called the 'Key Assigner YM62100'. There are 13 note lines, 5 upper and 5 lower octave lines on the input, interfacing with the key switches through a diode matrix. Octave and note identities are sent by the Key Assigner and output as 12-bit codes indicating octave, note, keyboard and keying state. These 12-bit codes or parties are output on 4-bit data lines $\overline{KC1}$ to $\overline{KC4}$. They are organised as 4-bits wide by 3-bits long. Each bit is 1 microsecond duration. The Key Assigner is the same device used in Yamaha's more up-market organ range and for this reason has the output capability of instructing up to 18 sound channels: 7 upper, 7 lower, 1 pedal and 3 auto arpeggio sounds. In this particular application, only the 7 upper and 7 lower instructions are used.

Tone Generation

Two tone generator LSIs are used for production of the basic waveforms and their associated sound amplitude envelopes. The 2 ICs share the same 4-bit input data lines $\overline{KC1}$ to $\overline{KC4}$ from the Key Assigner.

The organ wave generator IC YM70200 receives 13 master input frequency instructions C_I-C from an LSI daughter chip, YM62200, which combines with the keyboard data on its $\overline{KC1}$ to $\overline{KC4}$ terminals. This produces a set of sine wave outputs 16' through to 1' by Yamaha's Pulse Analogue Synthesis System(Pass). These sine signals are low pass filtered and sent through to the volume slider controls of the panel. 4' and 2' pitches are also connected through two VCA envelope control gates for the percussive attack voices. Three preset flute combinations are derived from mixing resistors and their associated FET resistor gates. Normal flute voices are collectively passed through a 'brilliance' filter circuit and on to a 'level' control and

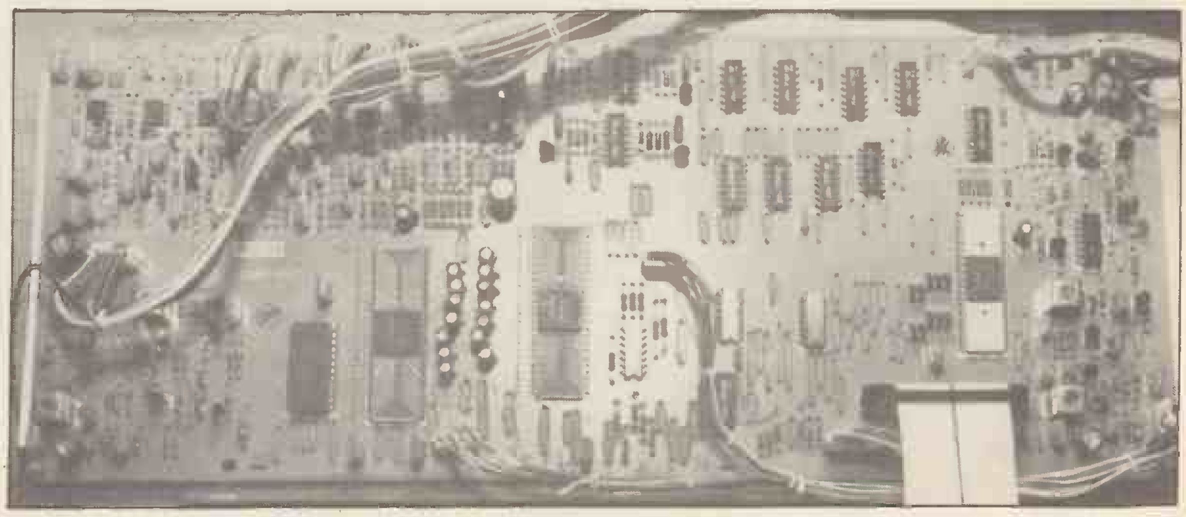


Fig. 2. This board contains Yamaha's own LSI chips employing their PASS technology.

'tremolo/ensemble' selector gating.

The polysynth and string basic sound sources are produced from another (Pass) wave generator LSI chip, YM70400 — this device produces 8' and 16' square waves and 4' sawtooth waves which pass through mixing amplifiers into selector gating which directs these sources to the appropriate treatment (sawtooth 16' and 8' are derived from the square wave mixing with the 4' sawtooth).

Polysynth and sources are routed through a voltage controlled filter, TG00156, giving gate selectable high pass or low pass outputs. The filter provides voltage control for attack time, decay time, sustain level and release time.

Three diode resistors matrices provide preset control for the various parameter voltages (e.g. initial level, attack) required to set the particular presets on the panel.

Two string voice sound sources, 16' and 8' sawtooth, are passed through their selector gates and a common LDR to the string level control (which can be the optional Foot Controller FC-3).

Polysynth and string level outputs are mixed and passed through a common 'brilliance' filter and out to the tremolo/ensemble selector gates.

Effects

Tremolo/Ensemble effects are obtained from a common board employing 3 delay paths (BBDs). Another Yamaha custom LSI, YM63300 clock generator, provides 3 outputs of 0.64Hz with 120° phase difference between them and 3 outputs of 6.4Hz, also with 120° phase difference. These 0.64Hz and 6.4Hz output groups are mixed and provide 3 composite control lines for the VCO drives to the BBDs which then have a 120° phase difference. This produces either a complex ensemble effect or by modulating the VCA at its output achieves a rotating speaker/tremolo effect.

A slightly unexpected method of interfacing some of the parameter controls is employed, e.g. organ sustain lengths. Here the sustain slider selects diodes via internal switch connections and outputs a 3-bit code to a parallel to series converter (multiplexer) through to a serial data input on the wave generator instructing it to produce the appropriate sustain lengths.

The two tone generator ICs (organ and poly) are driven from the two keyboard code groups — upper and lower. The polysynth IC is driven by upper key codes and the organ generator IC is driven by lower key codes. By dividing the connections of the upper and lower octave input lines with the common note lines, the tone generator groups are similarly divided, giving the keyboard split.

The two tone generator ICs have separate master clocks which can be frequency modulated by the vibrato drive circuit. Modulation may be applied to either one or both in separate degrees. Pitch control is applied in a similar fashion to the two clock circuit inputs giving individual pitch control on both tone generator groups.

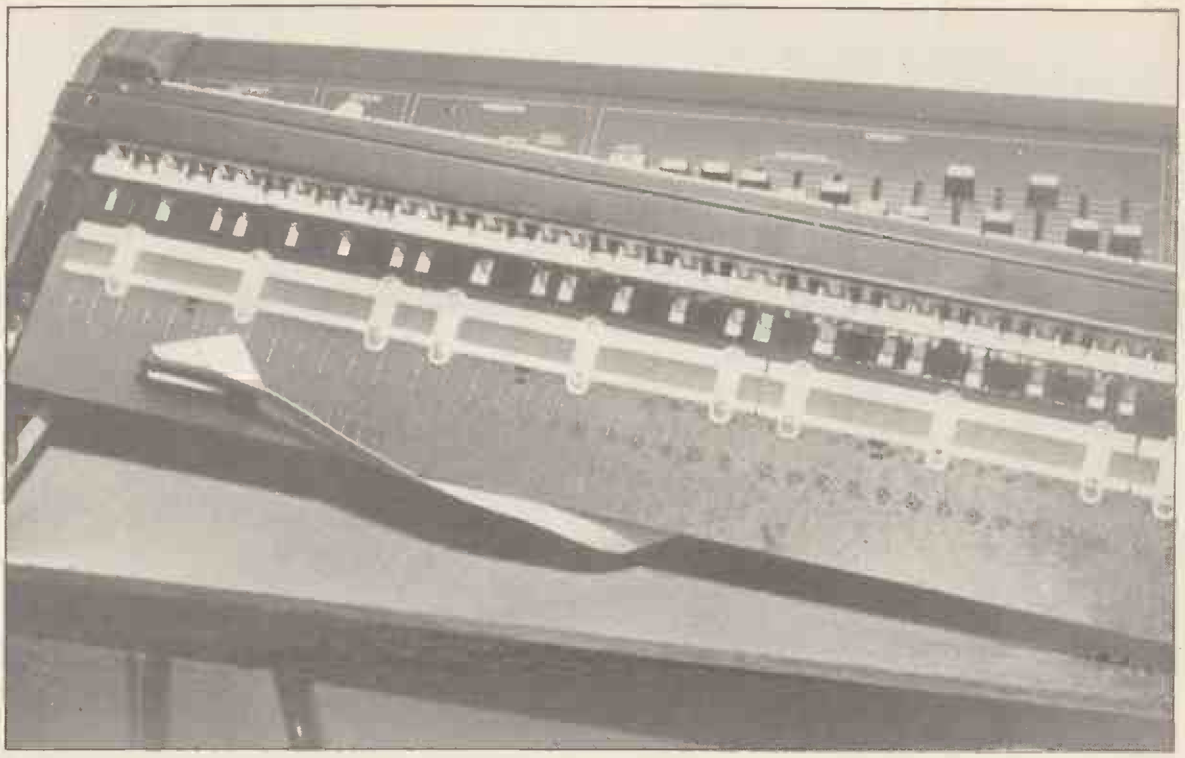


Fig. 3. Keyboard is removable and links via a ribbon cable.

The Controls and their Musical Effects

The controls are well placed on the angled main control panel with micro-touch switches (that have LED indicators) in a row conveniently above the keyboard. There are 5 control blocks above the switches from left to right: Output, Pitch, Vibrato, Organ and Polysynth. Sliders make setting up much easier although it takes a while to get used to the organ section — maximum volume on each drawbar is in its lowest position — as if you were pulling a Hammond drawbar towards you.

A connection panel on the rear links a 'sustain' footswitch (for organ and polysynth sections — either or both can be selected from the panel) and a foot controller for 'string' or 'mixed' output volume. There are three standard jack outputs available — polysynth/string, organ and mixed polysynth / string / organ. A low impedance stereo phone socket gives the mixed output and a standard 11 pin connector is provided for use with a Leslie Speaker System (2 channel input type). An adjacent switch allows the speed of the rotating speaker to be switched from the panel to fast/slow and on/off.

The 'Output' block has independent sliders for setting the volume of organ, string and polysynth with a rotary master volume control that can have its output signal (the mixed output) switched on or off. Since the background noise of the instrument is very quiet it's not really needed as a standby switch or noise reducer for a multi-keyboard set-up, but can prove useful when the other two outputs go to effects boxes or different spatial positions. If you get our demonstration tape for this issue you'll hear a

Fig. 4. The SK20 opened up.

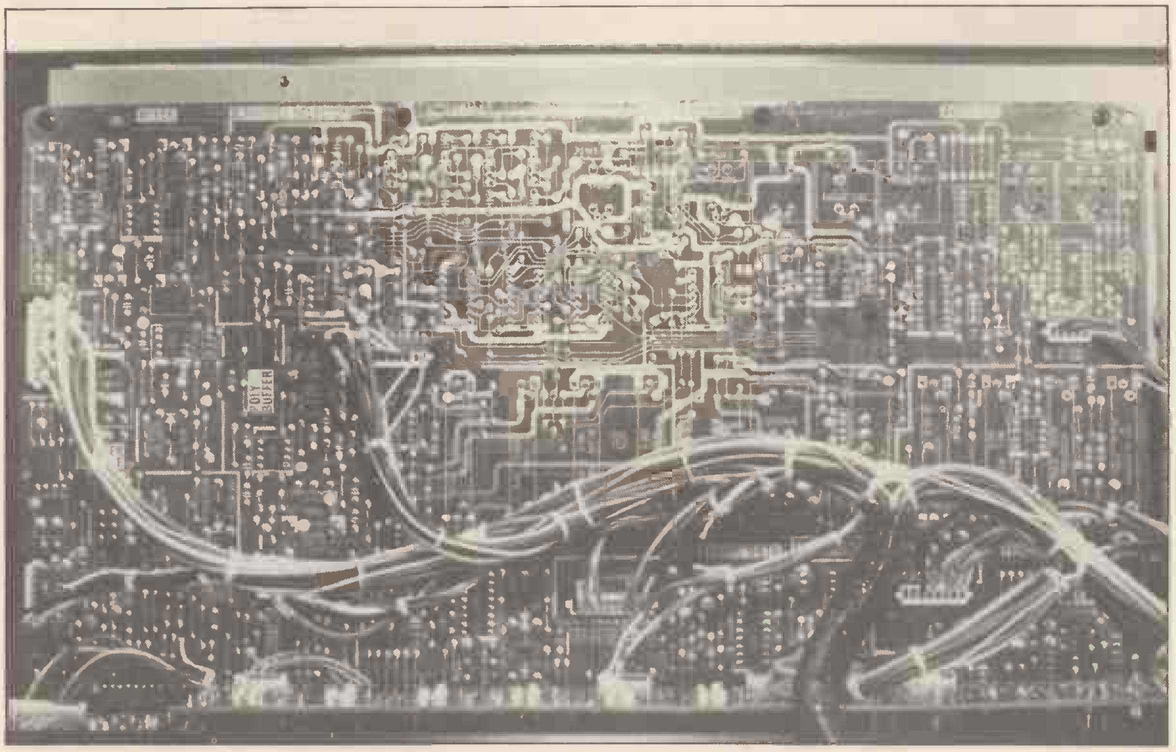


Fig. 5. Front panel (left) circuitry with sections clearly labelled.

very broad stereo image from the SK20 which is due to the mixed output feeding to the centre with slight echo added. The separate organ and poly-synth/string outputs are then panned left and right respectively with a phase box and flanger linked in the polysynth signal line for further effects. Incidentally, the Roland CR-78 gives the drum sounds (adapted for stereo with split instrument outputs), and the CS-30, operating from a Yamaha pedal board and drum trigger pulse, gives a bass line to the opening piece (see page 96 for details of demo tape).

There are two rotary controls in the 'Pitch' block for tuning adjustment to the organ and polysynth sections. Since the string sound is derived from the polyphonic synthesiser section, the polysynth tuning also affects the pitch of the strings. Interesting de-tuning effects can be obtained by first tuning the organ to your playing 'standard pitch' (e.g. 440Hz=A) and then very slightly moving the poly-synth pitch sharper so that slow beating occurs. A small amount of de-tuning will enrich the overall sound and a large amount will give, for example, organ and strings (without tremolo/ensemble) a fairground organ effect. Pitch is variable from A=435-450Hz.

Vibrato can be applied to organ and polysynth in separate amounts using 'depth' and 'speed' sliders and has an initial delay of up to 3 secs. It's useful on organ for improving the fast tremolo effect and with delay will allow playing with or without vibrato depending on your use of slow or quick notes.

Organ

The organ block contains the main features of a good harmonic drawbar organ with separate sliders for selecting 16', 8', 5⅓', 4', 2⅔', 2' and 1' pitches in varying degrees. Despite the lack of the two top mixtures, it has a full-bodied tone that is particularly clean in the bass. There's a 'brilliance' control to boost the top as well. Two switches select 'sustain' (which gives a decay after release of the keys) or 'decay' (which replaces the normal organ on/off key action), both adjusting from one slider. To complete the section there are 2 percussion sliders that give 4' and 2⅔' punch to the sound using 'decay' on minimum. Increasing the decay time gives glockenspiel or vibraphone (with vibrato) tones. There is a certain amount of key click present, especially with increased brilliance, for jazz/pop organ sound. A slight drawback is that with 'sustain' on this bright click effect is removed. Four panel switches give 3 presets: 16'8'5⅓'; 16'8'4'2' and full, plus 'manual' selection.

Trigger action is worth noting — the polysynth only triggers when all notes are released and a new note or chord is played. The strings always play and the organ plays according to decay/sustain settings. The note limitation is only evident with long 'sustain' set, playing runs up the keyboard when it only sounds 7 notes at any time.

Tremolo/Ensemble

Tremolo is a very realistic rotating speaker effect that is produced electronically. It can be applied to both main synth sections and has two-speed switch selection that speeds up or slows down during changeover for jazz chorus and church organ sounds. Ensemble is best suited to applying phase to the strings although it can be used with organ and polysynth. Unless you are buying an external tone cabinet then you have a compromise here — when ensemble is selected for polysynth/strings, then tremolo is cancelled on organ and also reverts to ensemble! Nevertheless, these two treatments make a big contribution to the final sound.

Polysynth

Within this section are two controls that also affect strings. They are switches for adding 'slow attack' and 'sustain'. Once again the latter is really the release control for the VCA. Two string pitches can be selected, either 16' or 8'.

The Polysynth section can have its oscillator and wave source to be either 16', 8' or 4' sawtooth, 16' or 8' square-wave, or 8' sawtooth in bandpass mode — the others go through a low pass filter. All the useful synthesiser filter controls are provided — cut-off frequency, resonance, EG depth and ADSR — and if you've played any of the CS50, 60, 80 range you'll know the kind of sounds you can get from these. It's a powerful synth sound by any standard with very smooth filter control using resonance that really picks out the harmonics. Three presets for Polysynth give brass sounds — so now perhaps you're realising this instruments potential!

Finally, the keyboard can be split with the organ on the left and the polysynth on the right and vice versa. You can get a walking percussive bass from the organ in your left hand with the right making rich strings swell in from the foot controller whilst polysynth sounds shoot through the harmonics using added 'brilliance'! All very exciting and there's an SK50 two manual on the way shortly so obviously Yamaha have a lot of hopes for this type of instrument which has benefited from their research and development in the lucrative home organist market — this machine would have been quite impractical for manufacturers who use conventional off-the-shelf devices. If you can't afford its price of £870 including VAT, then take a look at the smaller SK10.

Mike Beecher and Martin Christie

Fig. 6. Rear connection panel.

Advanced Music Synthesis

Chris Jordan

If you are already thinking in terms beyond unison ramp waves through a decaying cutoff LP filter with a backdrop of sweeping filtered noise, then you've probably realized that a fully variable system with comprehensive patching facilities, or at least a versatile switch-linked instrument with FM, Sync, PWM etc., is essential for original and creative synthesis, even if used in conjunction with simpler pre-patched and/or polyphonic instruments. If so, these articles will tell you about advanced techniques of synthesis to help you make your own music, however humble it is, rather than infinitely less satisfying collections of well-worn synthesiser clichés. If not, don't be put off - perhaps we can simply stimulate your imagination. And remember, if you are using equipment you've made yourself, then you have an advantage over the person who has bought something equivalent - not only do you have an insight into the way it works which can only help you in using it to the full, but you're in a position to make your own modifications and expansions when you reach its limits of capability. After all, no-one is more suited to designing the specification of a piece of equipment than its eventual user.

Voltage Control

What makes a synthesiser different from any other electronic musical instrument, and also what makes a synthesiser player different from, in particular a keyboard player, is the extensive use of voltage control. It allows the parameters of signal generators and processors to be determined by the outputs of other generators and processors, in a way that is fundamentally independent of the method of producing the control signal or the nature of the parameter controlled. So, for example, a keyboard can control the cutoff frequency of a filter in the same way as an oscillator can control the pitch of another oscillator.

The most important difference that can exist between one piece of synthesiser equipment and another is the way the voltage controlled parameters respond to their control voltages. This is the much talked about subject of 'linear' and 'exponential' (sometimes called 'logarithmic') control voltage laws. The problems arise from the fact that it is most useful for the pitch of an oscillator to rise by one octave for each unit rise in control voltage wherever this may be in the overall range, but conventional analogue oscillators are based around integrators which give a doubling of rate of change of voltage, and therefore a doubling of frequency, for a doubling of input current. Since pitch is related to frequency in an exponential fashion, an exponential converter is required to process the control voltage (CV) in order to produce the correct response. Additional circuitry, and sometimes trimming, is needed to reduce the effects of temperature variation on the law and the tuning of each oscillator, so some systems do without precision converters, directly generating a keyboard voltage with increasing CV intervals for the same musical interval as it moves up the range. These latter are the so-called 'linear' systems, which are potentially more stable and cheaper to make. It was the insufficiently compensated exponential synthesisers of the early seventies that gave the synthesiser a reputation for perpetual bad tuning, and later on prompted one linear system manufacturer to advertise with the line "Avoid the embarrassment of an out-of-tune performance"!

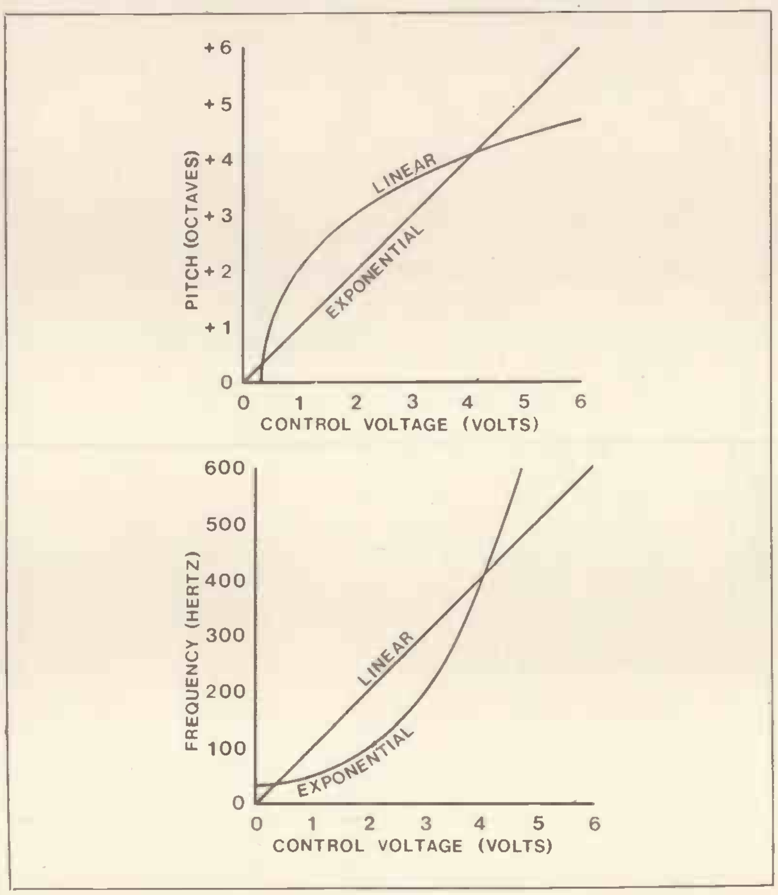


Figure 1. Linear and Exponential control voltage laws.

Generation of a 'pre-converted' keyboard control voltage gets over one of the problems of a linear system, but since a control voltage change must be greater at higher frequencies for the same effect on the pitch, a simple effect such as vibrato requires the secondary CV to be multiplied by the keyboard voltage before it is used, and where the precision of this must be as good as that of the keyboard itself (for example when using an analogue sequencer), the multiplying operation must be very accurate. This is usually only available with the keyboard as the primary source - when two low frequency oscillator waveforms or sample and hold outputs are used to control pitch they will appear to interact to condense the higher pitches, and the provision of a cheap uncompensated linear - to - exponential converter is hardly a satisfactory answer. Glide ('portamento') is usually produced by processing the keyboard CV, and where this is so it will suffer from the same effect. Glide that has been generated by a resistor/capacitor (RC) network will have the extent of the curve increased on the way up and decreased on the way down, whereas the linear type will be equally condensed towards the higher pitch in either direction. Because linear glide features a constant slew rate for each setting of the control, it will also take proportionately longer to cover the same musical interval the higher up it is played.

A more fundamental feature of linear control is the fact that to transpose the pitch of a keyboard-controlled oscillator up or down requires the keyboard CV to be multiplied or divided - adding or subtracting a DC voltage as one would to transpose in an exponential system causes disruption of the scale intervals. Hence tuning of linear oscillators is often achieved by a 'Range' switch which changes the integrator time constant giving three or more footages, in conjunction with a 'Tune' pot which varies the gain of an input CV amplifier from around 0.6 to 1.6. Using an oscillator without a keyboard-type controller then becomes a bit awkward, since in the absence of an input CV it will not run. So an extra pot is required to provide this CV; this is called 'Sweep' or 'Free Run' and allows the whole range to be covered with a single control, though it suffers from the same old problem when a secondary CV is patched in for additional control and this time multiplication is not practical. Of course, the Free Run control must be returned completely to zero for equal temperament from the keyboard, sequencer, quantiser or whatever. Unfortunately, not doing so does not provide equal macro or micro-tones - alternative tunings of this type cannot be practically produced in a linear system, though with an exponential keyboard this is just a matter of amplifying the CV by the required scaling factor. In fact this is what happens when one exponential system is interfaced with another that employs a different pitch-to-voltage ratio.

Most exponential synthesisers use 1V/Octave as standard, but may require trimming to match the scales of physically separate units. Connecting linear synthesisers together also requires attention to the CV range, though since all oscillators must just stop with no input, and gain errors appear as transpositions, the Tune control can correct for any minor mismatches.

For those of you who like sums, all this can be represented quite simply by:

$$f=2^{k}$$

where k represents the note required and corresponds to a depressed key, and f is the frequency that will sound. In an exponential system we can vary the scale and transposition easily:

$$f=2^{(ak+b)}$$

where a is the scaling factor and b is the interval. In a linear system, 2^k is generated directly so transposition requires multiplication:

$$f=2^{(k+b)}$$
$$=2^k \times 2^b$$

and for scaling:

$$f=2^{ak} \times 2^b$$
$$=(2^k)^a \times 2^b$$

Now we see why variable scale control from a quantized CV generator such as a keyboard is impractical. It requires the value of CV to be raised to a variable power!

Figure 1 shows the relationships between linear and exponential control voltages and the pitch and frequency of a VCO.

The fact that one cannot necessarily cause an important parameter to vary in accordance with the sum of two control voltages by adding the CV's and patching the result to the parameter control input is a severe limitation of the linear control system, and makes it only really useful for small, pre-patched synthesisers, where the VCO's are always under keyboard control and simultaneous modulation of a single parameter by many signals is not required. The use of constant temperature ovens and more advanced compensation circuitry, plus the availability of internally compensated monolithic exponential VCO's means that exponential synthesiser designs have the temperature dependance of exponentiating semiconductor junctions well under control, with stability approaching that of linear instruments, and certainly good enough even for live performance.

Since voltage controlled filters are often required to track keyboard-controlled oscillators maintaining constant harmonic content for different pitches, they must exhibit the same law as the VCO's. Accuracy and temperature stability are not as important, though these will necessarily limit the usefulness of resonating filters as sine wave oscillators. It is interesting to note that the CV law of VCF's seems to impose particular design restrictions which affect the filter's audio characteristics, causing linear VCF's to sound weedy and lacking in character when compared with exponential VCF's: this is more than a matter of 2-pole verses 4-pole though discrete exponential VCF's often show steeper cutoffs than linear ones. We'll talk more about filter characteristics in future articles.

Since signal amplitude is rarely required to track another controlled parameter, voltage controlled amplifiers do not necessarily exhibit the same law as other modules in the same system. The choice is often dictated by the envelope/transient generators since the most useful envelope shapes have exponential attack and decay portions, like acoustic instruments where decays proceed with a constant percentage loss of energy from a vibrating body in each unit of time. This shape of envelope is achieved with an exponential envelope generator and linear VCA, or vice versa, and since exponential envelopes are more useful for controlling other modules, and like VCO's an exponential VCA is often just a linear VCA plus a (non-precision) exponential converter, the former alternative is the most common. This is almost always the case in small pre-patched synthesisers, and often so in patchable envelope shapers, each being a combination envelope generator and VCA. The choice of linear or exponential control on a VCA is useful, especially where it is controlled by a non-keyboard initiated envelope or a periodic or complex low frequency waveform, possibly controlling the amplitude of another control signal. Where an envelope generator is of the AD or ADSR type it is usually exponential, linear slopes being reserved for multiple-stage or patch-programmable generators.

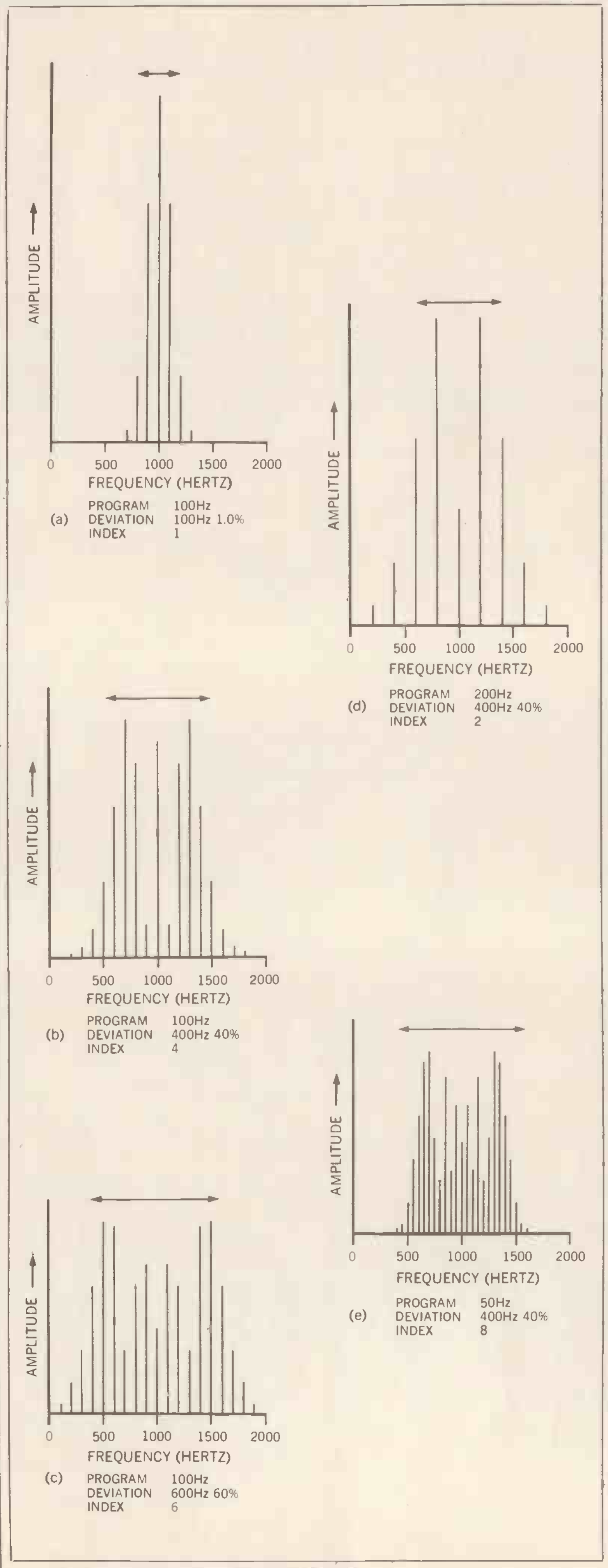


Figure 2. Spectra of frequency modulated sine waves.

Linear control of most exponential VCO's is possible, though the input may not be provided. Where it is, a number of techniques can be used to extend the capabilities of the VCO, such as stopping the oscillator with a low input voltage (only useful where the linear control input is DC coupled), waveform shape modulation, and by far the most powerful application: audio frequency FM.

Frequency Modulation (FM)

Frequency modulation is the dynamic control of the frequency of a periodic waveform, and as such includes most techniques of voltage control of oscillator frequency such as keyboard control and vibrato. However the term is usually reserved for the technique of producing new timbres by modulation of the frequency of one audio frequency tone by another, especially where it appears abbreviated to FM. This technique has the ability to produce such complex spectra using simple sine waves as the modulating ('program') and modulated ('carrier') signals that bright waveforms such as pulse and ramp are not often used, except for dense, noise-like sounds.

The effect of FM is to produce a group of frequency components above and below each harmonic of the carrier signal, each new partial being referred to as a sideband. With a sine wave as carrier, two groups of sidebands are produced, and if the program is a sine wave as well, the distribution of the sidebands is simply determined by the program frequency and the depth of modulation. This is illustrated in Figure 2, which shows spectra of a 1000Hz sine tone modulated with another sine tone at various frequencies and depths. The spacing between the resultant components is equal to the modulating frequency.

The depth of modulation is expressed as a deviation from the carrier frequency in Hz or as a percentage, and determines the spread of the sidebands with 90% of the energy contained with the range of deviation (indicated by the double-headed arrows on Figure 2).

The Modulation Index is the deviation in Hz divided by the modulating frequency, and determines the relative amplitude of each sideband, so that for each value of the index there is a characteristic distribution, except where the deviation exceeds about 50% and the symmetry becomes corrupted by lower sidebands which 'reflect' through 0 Hz, adding to or interleaving with components within the deviation range. Since the number of sidebands within each half of the range of deviation is equal to the modulation index, the index tells how many significant sidebands there are in an FM spectrum. For example, in Figure 2c the modulation index is six and there are six significant components each side of the carrier.

The modulation index is an idea borrowed from the field of FM radio where the modulating frequency and the frequency deviation are small in comparison with the carrier frequency, and the relationship between the sideband spacing and the carrier frequency is unimportant. More useful to the synthesist are the deviation and the ratio of the two frequencies - if one frequency is an integral multiple of the other then the sidebands will form a harmonic series with the fundamental at the frequency of the lower, though it may be of zero amplitude. If not, a non-harmonic overtone series of the sort that is so characteristic of frequency or amplitude modulation is produced. It is interesting to note that the results of FM with simple fractional ratios such as ⅔, ¾ are ambiguous sounds with perceived pitches dependant on acoustic or musical context.

Going back to Figure 2, it can be seen that the total spread of (b), (d) and (e), non-reflecting spectra with the same deviation, is largely independent of the carrier and modulating frequencies. Note that within the deviation the sideband pairs are of superficially irregular amplitude, and outside they decay rapidly to zero. In all illustrated spectra except (a) the carrier frequency has a lower amplitude than the strongest new component - at some values of the modulation index, the lowest of which is around 2.7, the carrier disappears altogether and the amplitudes of individual sideband pairs can also become zero at certain index values.

To make practical use of FM, we ideally need independent control of the pitch of the oscillators, the interval between the modulating and modulated oscillators, and the percentage deviation. The first two are simple enough - they are basic requirements of a system limited to simpler synthesis techniques - but the deviation is dependant on the amplitude of the modulating waveform which will normally give a constant frequency deviation in Hz, requiring multiplication to retain a constant percentage deviation with changing pitch. The resulting decrease in the number of partials and their spread as the pitch rises is a disadvantage but is usually tolerable, and sometimes quite useful, when FM is being used for simulation of natural instruments for example. The percentage deviation can be held constant over a limited range by passing the program through an exponential VCA controlled by the sum of the carrier oscillator input CV's. If you're thinking that this was the point of the exponential converter

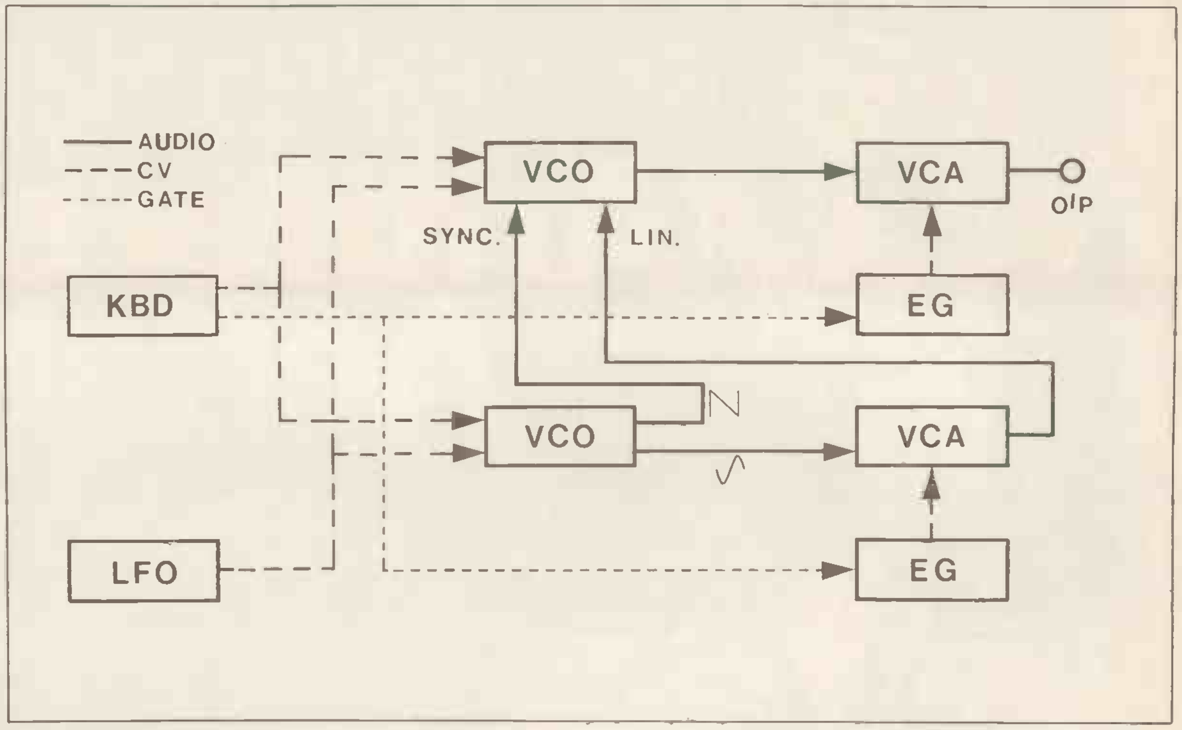


Figure 3. FM evaluation patch.

in the first place you are right, but the linear control input should be used for two reasons:
1. The exponentiation would distort a modulating sine wave, introducing extra sidebands into the result.
2. More importantly, the distortion would shift the mean level of the modulating waveform, causing the carrier frequency to rise with increasing modulation depth.

This latter effect occurs even if the program is AC coupled where it leaves the oscillator, as it must be for proper linear FM, due to the different effect exponentiation has on the upper and lower portions of the waveform. The pitch shift effect can be demonstrated quite simply on a Minimoog: with only oscillator 1 switched into the mixer, oscillator 3 is set to independent control and the oscillator modulation is turned on with the modulation mix control completely on osc. 3. Holding a note and then pushing up the modulation wheel introduces frequency modulation and the pitch rises accordingly. If this doesn't sound like too much of a disadvantage remember that a small change of oscillator frequency has a great effect on the relationship of the overtones in resultant sound. This means that retuning is needed every time the modulation depth is changed, but FM remains quite useful in a exponential system where the VCO's don't have linear CV inputs.

Linear CV systems are better suited to FM than exponential ones since the provision of a keyboard CV multiplier makes constant percentage deviation FM trivial, though not if the patchable keyboard CV modulation input is equipped with a simple linear-to-exponential converter as is often the case, when it will have to be bypassed to obtain the full benefits. These include the ability to dynamically change the deviation, which is also available with linear-input equipped exponential VCO's.

The sound of a FM tone with the modulation depth decaying after the beginning of each note is rapidly becoming something of a cliché of computer music and in particular music using modern digital synthesisers, though it would probably be described as a decaying index sound by the composers who use it, since the modulation index is still considered a useful measure of FM depth by computer synthesists. Frequency modulation is very widely used in digital synthesis systems since in addition to providing a large selection of harmonic waveforms, it saves enormous amounts of computation time over comparable methods of producing sounds with non-integrally related overtones. In fact one might almost say that FM is to digital synthesisers what resonant low-pass filtration is to simple keyboard-based analogue synthesisers.

One disadvantage with FM, which is particularly important in imitative synthesis and computer synthesis where the result of an alteration is only heard after a delay, is that to all but the most experienced synthesist finding a particular sound is a matter of trial and error, unlike subtractive synthesis where one soon learns how a filter cutoff frequency or Q must be altered to get the right timbre. This can be alleviated to some extent by using degenerate forms of technique which limit the number or values of the variables and hence the range of possible sounds, making FM easier to use.

Groups of degenerate FM spectra where the carrier and program are fixed in simple musical intervals result from the use of oscillator synchronisation and this also allows the elimination of beating effects from sounds produced by straight FM. Using Linear FM with the type of sync that unconditionally resets the second oscillator at the same point in each cycle of the first yields a whole range of waveforms which retain a harmonic overtone series whatever the settings of the VCO's. This is particularly effective where one oscillator is the source of the waveforms for both functions and the other is set at a higher footage, whereupon the second one becomes a waveform generator locked to the pitch of the first, with the timbre controlled by the FM depth and slave VCO 'pitch'. Since the latter is potentially voltage controlled, startling timbre sweep effects can be obtained, and because only true harmonic series are generated, this provides a versatile source of 'safe' sounds for melodic keyboard playing.

Figure 3 shows a patch for comprehensive evaluation of frequency modulation using sine waves with or without synchronisation. Modulation depth is under control of an envelope generator and either or both of the carrier and program can be modulated by the LFO in addition to the keyboard.

A simple single VCO synthesiser can be used for basic experimentation with FM if the filter is able to self-oscillate. The oscillator output must be re-routed to the filter CV input so the VCO generates the program and the filter becomes the modulated sine wave oscillator. An unused position on the waveform selector switch can be connected to bring in the FM if a spare pole is also available to connect the triangle output to the filter CV input, using a series capacitor to remove DC from the waveform. If the oscillator has its own output level control, taking the program from its wiper will give control of modulation depth without the need to reassign an existing filter modulation control or to add another pot. The level control should be AC coupled to the waveform switch or VCO output so that the level will not re-adjust itself each time the depth is altered, though if the filter is exponential a pitch shift will occur anyway.

E & MM

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Hot Wiring your GUITAR

Adrian Legg

The electric guitar is a simple beast, indeed in terms of today's micro-chip technology, downright primitive. I don't propose to change that, I like it, but what I will do in this series of articles is show you how you can exploit an existing wiring system more fully in order to make your guitar capable of coping with a variety of tonal demands. A couple of humbuckers can give a wide range of sounds, and can be persuaded to do so without going active, although ultimately, dropping output impedance will help the treble you achieve on the guitar to make it to the amplifier.

Firstly, it'll all make a bit more sense if we understand a few pick-up basics.

A single coil pick-up consists of a coil wound around a bobbin, and in the centre of the bobbin are either six magnets, one bar magnet, or six poles that conduct the magnetic field from magnets underneath the unit. The wires from each end of the coil are connected to two stronger wires, or a single conductor and shield.

The vibration of the string (which contains nickel) over the pick-up excites the magnetic field, and generates a minute alternating current, the frequency of alternation of which is exactly the same as the frequency of alternation of the strings. That is, simply if you twang A 110, the string is vibrating 110 times per second, so the current from the pick-up will alternate positive to negative 110 times per second. This current, when suitably magnified by the amplifier, will push the speaker cone back and forth 110 times per second, and a beautiful, loud A will sound as the air between the speaker and your ear is vibrated 110 times per second. Do not believe the occasional expert who tells you a pick-up gives D.C. - guitar mythology has to stop here.

The variation in the number of windings, choice of wire, type of magnet and so on give the pick-up its power and tone characteristics, and single coil pick-ups are available that give you the option of earthing out part of the coil to vary said characteristics accordingly.

Many single coil pick-ups can cause problems with intonation, and Fender Strat- or Telecaster owners know them well. Where a pick-up has magnetic pole pieces, the magnetic field is closer to the string and interferes with its free vibration, causing a double note effect particularly on 6th and 5th strings in higher fret positions. The only cure for this is to lower the pick-up and sacrifice a little power. A pick-up which has magnets underneath and conducting poles will not give this effect to all practical purposes, but for the purist this type may not be tonally desirable. This problem crops up less on humbuckers as few manufacturers use magnetic poles in this situation. You may notice a slight pull on some power pick-ups, for example the Dimarzio X2N, which uses a very strong magnetic field. On this pick-up, the extra magnets under the pick-up are cut away under sixth and fifth strings, so installing the unit the right way round is important. In fact, there is such a healthy output from pick-ups like this that dropping them a little further from the strings gives a negligible power loss - I run three X2Ns in one guitar with no problems.

A humbucker consists of two coils wired in series and over a magnetic field that varies from maker to maker. Here, I'm merely concerned with the alteration of the wiring up to get different sounds, so suffice it to say that various arrangements of pole pieces conduct the field to the area of the vibrating string.

The out of phase bit can be confusing, because as experienced players, we tend to associate 'out of phase' with the honky type of sound given by two pick-ups operating together in a mix, but with the output of one taken from the opposite end of the coil(s) to the other - that is, the phase of one is completely reversed in relation to the other. An apparently similar tone quality can be had from a single humbucker (with a corresponding drop in volume) by running the two coils in series, and in phase. This sound most of us would instinctively call 'out of phase', and the smooth fat sound of a normally wired humbucker, coils actually out of phase, we would regard as sounding 'in phase'. Where we get to wiring up for this in this series, I shall therefore refer to normal and reverse coil phase, and hope that that avoids confusion. If you should find that you have a coil phase problem, remember you solve it simply by swapping around the two wires from one of the coils.

The actual hum-cancelling effect is achieved because the coils are in opposite phases, and when one 'hears' electrical interference, the other 'hears' exactly the opposite and cancels it out. The system does not cancel out string vibration, mainly because the strings are doing a much more thorough job of agitating the magnetic field. In fact, a similar hum-cancelling effect can be had on a Fender Stratocaster. I found that on my test-bed Strat, which has phase reverse switches fitted to all three pick-ups for test purposes, reversing the phase of a back and centre pick-up mix cancelled out hum. Unfortunately, it also sounded vile. This brings up another old chestnut, the straight mix between these two pick-ups has been referred to for a long time as an 'out of phase Strat sound'. To get that sound, the pick-ups have to be wired in phase. Wire them actually out of phase, and your Mark Knopfler licks will sound not the slightest bit like Mark Knopfler.

If you are going to rewire an existing humbucker from single conductor and shield cable to three or four conductor, the phase of the coils will need checking carefully. In some humbuckers, the phase reversal of the coils is done by winding the coils in opposite directions, and in others, simply by running the output from one into the equivalent wire end on a same-way-wound second coil. Diagrams throughout this series will assume the latter, as in Figure 1.

For humbucker wirings, I shall stick to these colour codings as they also apply to most four conductor pick-ups already on the market.

Figure 2 shows the standard arrangement of volume and tone controls for a single pickup (in this case a humbucker) guitar. The volume pot acts as a potential divider with the pickup connected between the most clockwise end of the track and earth, the anti-clockwise end earthed, and the output taken from the wiper. In the full on position the wiper is connected directly to the pickup and the full signal is fed to the jack socket. As the control is rotated anti-clockwise the wiper moves towards the earthed end, tapping off a progressively smaller proportion of the pickup signal, until the live of the jack socket becomes directly connected to earth in the off position.

The tone control is connected as a variable resistance in a simple low-pass filter circuit, giving a variable amount of treble cut. The capacitor bypasses high frequencies from the pickup to ground, so that when the tone pot wiper is at the pickup end of the track, the amount of treble is reduced. At the other end, the full track resistance is in series with the capacitor, and so most of the treble is allowed to reach the volume control. The capacitor is usually of disc ceramic type, with a value of 50 or 22 nanofarads (0.05 or 0.022 microfarads). The treble cut effect will extend to lower frequencies with larger capacitor values, and this will also depend on the pot resistance, so that at maximum treble the highest frequencies will be cut slightly leaving the lower treble unaffected, and with the tone control at minimum the highest frequencies will be cut a lot, with the lower ones cut slightly.

Two alternative wirings of the tone pot, which give exactly the same result, are shown in Figure 3. Sometimes the unused end of the tone pot track is connected to the wiper: this reduces the effect of dirt on the track and causes the pot to act as if it was in its clockwise position (max. treble) should the wiper become totally disconnected.

Next month we'll start with a description of how to rewire two pickup guitars for independent operation of the volume controls. **E&MM**

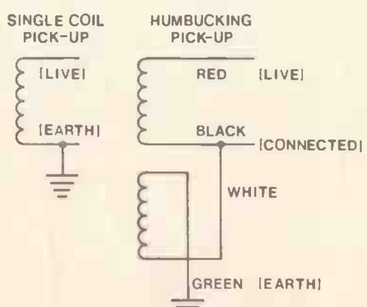


Figure 1. Pickup connections

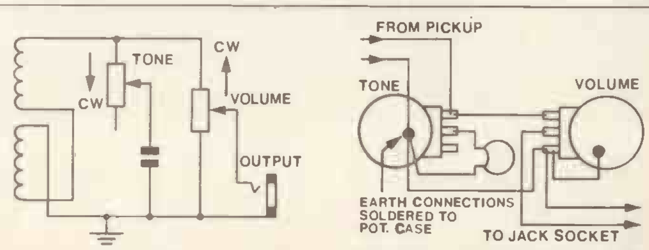


Figure 2. Standard volume and tone circuit

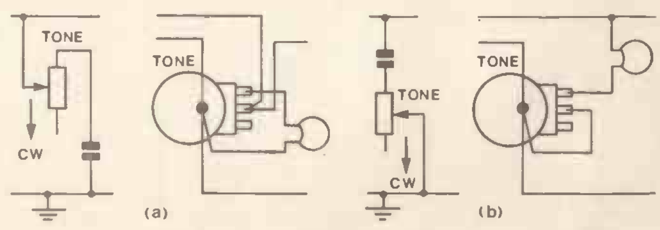


Figure 3. Alternative tone control wirings

DISCO TEK

Ben Duncan

In which Ben Duncan takes a break from mixing discs and instead, mixes electronics, philosophy and pragmatic advice to show that discotheque systems can be much more than a pile of indifferent gear plus mandatory Rosko-esque geezer at the mic.

At the Controls

The control desk is the nerve centre of the DJ's operations, and regardless of technical merits, the overriding requirement is to be on intimate and understanding terms with your console. Like a 48 channel concert desk, a Gibson or a Bonneville, it's an extension of your body and operating it must become instinctive. Another point that is rarely appreciated is that the desk is just another link (kink??) in the chain; later on we'll look at the discotheque as a whole, seek out the weak links in the system and look at ergonomics, but first a survey of the constituent parts.

Gramophonology

The ideal discotheque turntables are American broadcast models from Rusco, Gates and QRK, or the UK broadcast standard - the Japanese Technics SP10. Regrettably, a pair of these with matching arms will cost over £1,000 and most of us will have to make do with something a little less expensive. A good discotheque turntable is, of course, a single player, with two speeds (though 78 rpm can have its abuses!) and a cueing arm. Less obvious is the need for mechanical simplicity (which usually implies robustness and reliability), readily available spares and an arm that will comfortably track at 3-5 grams. Only a handful of turntables meet these criteria, and perhaps the best known and best loved is that exceptional budget Hi-Fi model - the Garrard SP25 in its Mk. III and Mk. IV guises. Although obsolete, second hand ones will be around for some years after stocks of spares have been exhausted. The only essential modification is to remove the superfluous bits that make up the autochanger mechanism. Rather than attempt to describe this operation, it's much easier for you to simply examine the deck and remove all the cogs and levers that appear inessential. Other useful modifications apply equally to other turntables:

(1) A piece of foam glued below the stylus will prevent damage should you drop the arm as it swings from the rubber mat to the arm rest.

(2) Wiring the mains and audio feeds via reliable connectors will make life much easier if you have to remove the deck in a hurry for repairs.

The SP25 III/IV has only a few faults. Sometimes the 45 rpm setting provides a very embarrassing 36½ rpm! The problem could be a badly worn pinch wheel (these should be checked monthly), grease or oil on the pinch wheel, the motor drive shaft or the turntable rim, or less often, a motor drive shaft that has slipped down slightly, causing the pinch wheel to straddle the 33 and 45 rpm steps simultaneously. Another heartache is the ease with which the headshell snaps off, usually five minutes before the show! For this eventuality, a supply of cocktail sticks and PVC tape will bandage the damage until you have five minutes to replace the arm. Superglue could be used, but with the mind boggling possibility of being literally glued to your turntable for the remainder of the gig! Finally, the contacts under the headshell can make bad contact with the cartridge carrier, resulting in the sudden loss of one channel. Cleaning and re-springing the contacts may help, but often the best course is to replace the cartridge carrier.

Other low cost turntables for your evaluation include the old BSR models, the ubiquitous Technics models and the now obsolete Connoisseur BD2, although the latter turntable is unsuited to switch starting.

Many DJ's like to use slip mats, and whilst the SP25 can be used for slip-cueing, a far better turntable with a high torque motor is another obsolete Garrard model - the 401 (the fact that all of Britain's best disco turntables are obsolete reinforces the feeling that British industry is intent on self destruction). For many years, the 401, and its predecessor, the 301, were the basis of the standard BBC turntable, and their tank-like construction makes them perfect for discotheque applications. And because the 401 is out of fashion, it's readily available second hand at low cost - witness the classified advertisements in hi-fi journals. Since the 401 is just a turntable, you will have to find a suitably robust 12" arm. Most ex-Hi-Fi 401's will have SME arms; ideally, these should be exchanged for a broadcast arm (e.g. QRK).

Mobile DJ's will often meet floors which are slightly uneven, and tilting the turntables only a few degrees can have amazingly nasty effects on sound quality. A spirit level allows you to check the tilt of the floor and beer-mats/cigarette packets can be used to cancel out any unevenness. Mobile work also involves the turntables in a lot of shaking around, and it's always a good idea to check the tracking weight is set correctly immediately after setting up, and if the stage is wooden, a goose stepping colleague can seek out any potential record bounce problems at the same time.

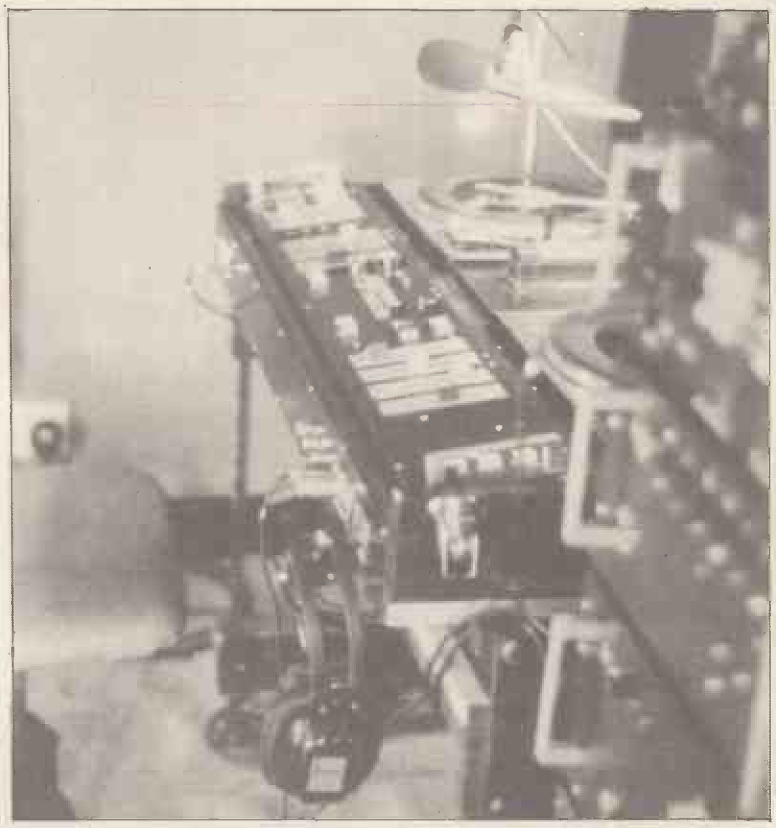
Cartridges are much simpler. Ceramic cartridges are robust, cheap to buy and cheap to keep in stylii, and whilst the best ceramics are capable of reasonable reproduction, the equalisation required can be horrendously difficult to design. Contrary to popular belief, getting the best out of a ceramic cartridge requires much more than a high input impedance stage; rather, that is an excellent way of killing all the treble at the expense of thudding bass. In any case, a medium cost magnetic cartridge will always give better top end and the only drawback is the cost of replacing worn stylii. Domestic magnetic cartridges, especially the more esoteric types are exceedingly fragile, and will obediently self destruct (so decreasing profit margins) when subjected to back-cueing and excessive tracking weight, let alone being dropped on a record! Broadcast models are a must - these heavy duty cartridges are built to be thrown around, to withstand the rigours of back-cueing and the 3-5 grams of tracking weight necessary for bounce free discotheque work. In addition, the stylii are designed for good visibility (invaluable when you have 5 seconds to cue up track 7 - or is it track 8?? - on a K-Tel album!). The almost legendary broadcast/disco cartridge is the Stanton 500AL, but the Stanton 680EL, the Shure SC35 and SC39ED are also used. All of these cartridges come as near to audio perfection as is necessary in a discotheque, but they each have a characteristic 'sound' or colouration, and apart from cost, the choice is basically which sounds best to you.

Die Vinyl Solution

Considering the cost of replacing stylii, and that of replacing 2,000 ruined records, knowing when to replace the stylus is a natural headache. A good test is to compare the sound quality of a suspect stylus with a spare (virgin) stylus by crossfading quickly between two identical recordings - preferably good 12" pressings which are kept purely for test purposes. However, the virgin stylus should initially 'run in' on a well worn disc for a few minutes to polish the tip. Alternatively, a small self adhesive label, bearing the date of the last replacement on the side of the cartridge can be invaluable if you don't have time to check your stylii regularly and can only be bothered to change stylii at, say, quarterly intervals. Lastly, broadcast cartridges are invariably supplied in exotic boxes with hinges lids, reminiscent of jewel cases. These can be glued onto the space between the turntables and used to store record centres, stylus cleaning brushes and stylii covers.

Disc amplification

Two conflicting requirements arise here - good headroom and low noise. They conflict because to keep the noise low, it's necessary to bring the disc signal up to line level as soon as possible. Once at line level (775 mV) we can start to process the signal without undue worry about adding hum and extra noise to it. However, low noise also demands boosted high frequencies when records are cut (and simultaneously bass frequencies are attenuated to achieve a sensible playing time). The resulting constant amplitude recording characteristic results in a very inconstant input to the disc amplifier, the treble being up to 20 dB higher in level than the midrange and the lowest bass being 20 dB down. Clearly, if we raise the midrange to line level in one jump to achieve low noise, an additional 20 dB of headroom or input overload margin is necessary to handle the high treble. In addition, 8 dB's of extra headroom are



Part of the author's 3kW rig.

required to handle heavily modulated, well pressed 12" singles with toppy synthesiser riffs, and another 10 dB's or so are required as leeway, because many amplifier stages show significant distortion just before the onset of overloading. Thus we need at least 38 dB of headroom and if for the sake of low noise, we decide to amplify to line level in one jump, the output of the disc input amplifier will require a 110 volt peak output capability! A more practical alternative is to send the disc signal through a unity gain amplifier with treble cut - once the high amplitude treble is tamed, the headroom requirement falls to a more reasonable 20 dB and the next stage can happily amplify to line level. Unfortunately, this can be a noisy solution and a good compromise is to provide the input stage with a mild (15-20 dB) gain and treble cut, followed by a preset attenuator to allow for variations in the output levels of different species of cartridge, and finally another stage to bring the disc signal up to line level; this stage can also handle tape inputs.

Bass boost also has to be applied to one of the stages, and the choice is essentially a question of which stage will handle the burden of an additional feedback network without incurring excessive distortion. With this arrangement, an overload margin of 40dB can be readily achieved and the signal to noise ratio is only marginally (2 or 3 dB) lower than the theoretical maximum for bipolar disc input stages (around -70 dB, depending on the reference level). Fortunately, this degree of residual hiss is just adequate in the disco, for whilst ambient sound levels of 110-120 dB make the residual noise rather louder than it might be at home, hiss ridden moments between vocals and music will invariably be masked by your audience.

The need for good headroom is much more important and the commonly encountered 20-25 dB of headroom is inadequate unless you roll off all the treble above about 8 kHz; otherwise the sound will be 'gritty', distorted and very obnoxious at high levels. Finer aspects of disc input stages are discussed at length in the serious hi-fi and electronic journals, and remembering that your discotheque system is but a chain with links, expensive improvements, to (for example) the speakers might well go hand in hand with an improved disc input stage, because these are two particularly fussy links in any record playing system.

Tape Sources

Apart from discs, some DJ's use taped material in their shows, and to allow almost any tape machine, from Revoxes to nondescript cassettes of dubious oriental origin to be patched in successfully, regardless of output level or impedance, a high-sensitivity (typically 50 mV), high impedance (50-100 K) stage is required, together with a fader to match the level to that of the disc output. A headroom of 20 dB will normally be quite adequate, provided the fader/attenuator lies before any amplification stages; often the tape input stage is designed for unity gain and is merely a buffer.

Patching in external mains powered tape machines can bring hum as well as Sister Sledge, and whilst ripping out mains earth leads may solve the problem at home, it's simply too risky in a public place rife with inquisitive fingers and spilt Guinness; Disco-electrocution may be spectacular, but the court damages can be somewhat sobering. Later, we'll look at safe ways of avoiding niggling buzzes.

In the next issue - console structure, crossfading and voice-overs.

E&MM

RADIOPHONIC WORKSHOP

A Glimpse of Current Activities

Four a.m. and sounds of a robot tripping over emerge from a room at Maida Vale. But it's not really a robot, just a young man who is beginning to feel rather mad as he walks around with one foot in a bucket whilst rattling a waste paper bin! His determination to get the right sound has taken him many hours into the night and despite the array of electronic sound making equipment he finally resorts to anything else at hand. It doesn't really matter what time you call in on the Workshop — there's always someone hard at work.

Such is the life style of the composers at the BBC Radiophonic Workshop studios, who spend a great deal of time preparing incidental music, theme tunes and sound effects for over three hundred radio and television programmes each year. With schedules fully booked three months in advance, the team of six musicians under the enthusiastic directorship of Desmond Briscoe make a very important contribution to the programmes we watch and listen to.

I met Brian Hodgson at the studios one afternoon before Christmas. Brian is responsible for the general working of the studios, besides contributing a great deal himself to the success and future development of the workshop. After a quick cup of Beeb tea we took a look in Studio H.

Elizabeth Parker in Studio H.

'Lord of the Rings'

Seated next to a large mixing desk was Elizabeth Parker, now working on 'Lord of the Rings' and also responsible for the last set of sounds for 'Blakes 7' and many radio programmes. She will also be doing next year's 'Blakes 7' and probably 'The Day of the Triffids' as well. We concentrated on the 'Lord of the Rings' for our discussion. This was commissioned last June although Elizabeth had only just started working on it ready for first studio takes, with further recording sessions planned before the programme goes out in February in 26 episodes. It's a full time job for Elizabeth with lots of overtime thrown in as well, even though she is only concerned with the effects. Whereas the 'Hobbitt' was made previously with the help of Radiophonic sounds, this time the approach is to more 'natural' scunds. In fact, natural sounds are used as the basic material. For example, 'Shadowfax' the horse is represented by an actual horse neigh which is slowed down and treated by an Eventide Harmoniser which returns it to its original pitch giving a slightly out-of-this-world feel to it.

To get a thunder effect, Elizabeth started off with tin foil, tearing it apart slowly to make a cracking sound. She likes this much better than using sound effects records or even a synthesiser, because it retains such a sharp edge which can be spliced and edited together using the live recording for multi-tracking at different speeds. Add to that two white noise tracks and various degrees of echo and you've got the final effect.

Here in a nutshell is the art of the Radiophonic Workshop — combining Music Concrete with pure electronic synthesis to make sonorous landscapes and effects for radio and television programmes. Brian refers to Music Concrete as a 'big bouncy baby — its been the starting point for so many sound effects!' and points out that electronic synthesis very often emasculates the final result. The programme producer Jane Morgan also prefers these more naturalistic effects rather than electronics. Elizabeth's main task is to integrate the sounds with the accompanying string music for the series. It is also important that she establishes a good working relationship from the outset with the producer, who is obviously initially very busy with casting and rehearsals.

Each episode lasts half an hour and the effects, some specific, others only broadly outlined are indicated in the actor's scripts, e.g. a rippling and sucking tentacle noise of a nasty lake monster! Whilst the sound for the Ring required liaison with the producer, most of the time Elizabeth works independently. Very often the script simply indicates 'high vibrating' or 'low pulsing' when the author really has no definite idea what he wants. Gandolf's 'staff' was created by recording a striking match which was then slowed down on playback and sent through a phase box with other treatments added on top. Another sound was bubbling water, done by Elizabeth gurgling, wet towels slapping together and a river played back at low speed. Despite recent popularity of the vocoder, it was only used for one sequence (it's the Roland rack Vocoder that's used) for a sustained 'Aah' tone through it as a background to magic spells. You can't quite tell whether its human or electronic and like most of their effects it takes a lot of time and experiment to find the right combination of natural sound and electronic treatment.

Turning to the other equipment in the studio, Elizabeth prefers to use Roland's 100M modular synthesiser system, especially for 'Blakes 7', rather than start off on a keyboard. The Jupiter 4 was also sitting prominently in Studio H, although this and other instruments — synthesisers in particular — are in fact shared by all the team using the studios. If Elizabeth wants a particular sound from the Yamaha CS80, for example, then she books Studio B instead. Yamaha's CS40M is used to play to stored sounds in addition to the Jupiter 4.

Recording equipment in the studio includes a Revox A700, two Studer A80 machines and a Scully 8-track. The mixing desk is a Soundcraft 16 into 8 and Chartwell speakers are used for monitors. The other studios are very familiar with a Studer B62 in Studio G and a Glennsound 24 into 8 custom designed desk. Two other mixing desks are used, the Neve 8066 24 into 16 and a special desk from Technical Services which is 24 into 8.

Elizabeth emphasises that her aim in composing the sounds for 'Lord of the Rings' is to integrate them successfully with the acting and Stephen Oliver's music.

Dick Mills. Inset shows Time Code on Video picture.

Paddy Kingsland.

When all the sounds have been assembled on tape they are taken to another studio where they are inserted in the script so that the actors can react to them. Safety copies of the master recordings are kept and more obvious sound effects such as closing doors and footsteps are left to the Studio Managers. Picking up the technical know-how is something that Elizabeth is doing all the time — in the end it's the ideas that count.

'Dr. Who'

We then moved on, passing a training room and an interesting old mixer that had pan-pots actually fitted onto its faders, until we reached Studio G,

The Wavemaker Polyphonic System.

where Dick Mills was putting together another 'Doctor Who' set of sound effects. He's responsible for all the programme's weird and wonderful sounds that emerge every week from our TVs, especially voice treatments that can't be done in studio. Peter Howell and Paddy Kingsland share the incidental music, alternating three programmes each usually, with Roger Limb popping in to fill in the occasional episode. Incidentally, later this year Peter Davidson (from 'All Creatures Great and Small') takes over Dr. Who's part. The 'Dr. Who' incidental music is now almost all electronic although sometimes it may not seem so. For example, 'Warriors Gate' used a time flip to a medieval banquet and the authentic early instruments were programmed on the Yamaha CS80. Roger Limb is currently doing the series 'Keeper of Traken'.

Collaboration between the music composer and Dick's sound effects is essential to avoid clashes of sound and music at any one time. Dick chooses his frequencies for sound effects carefully so that they don't appear as wrong notes in the music! Before video recorders and electronic synthesisers were standard equipment for 'Dr Who', the composer could often lose track of the story line by the time he had got together musicians using conventional instruments to play the music. Now, the video recorder picture has a 'timing code' inserted during recording to enable each sequence of music or sound effect to be synchronised within a hundredth of a second.

Dick prefers to use natural sounds as his starting point whenever possible — after all, he was one of the first composers at the Radiophonic Workshop — and then uses a Stereo Flanger, Phase Shifter, Double Reverb and Pitch to Voltage converter for treatment. For example, in 'Warriors Gate' a mirror was the gateway to time travel. In the script the aural sensation required was described to Dick as the audio equivalent of what you feel when you touch the front of a TV screen — static charge. To get the tingling effect he decided to use a large sheet of oven foil. Even grunting of pigs was recorded and treated for one programme! Dick finds that he gets better ambience using natural sounds. In the early days he recalls using BBC's large Studio 1 to get a long reverb time. He likes the Stereo Flanger for robot voices and talking weighing machines! The Phase Shifter gives him a constantly changing background ambience that makes sounds like spaceship hum much more interesting. He uses an Envelope Follower to deaden speech by cutting off a VCA sharply at the end of words. An old BBC PA stabilising device provides an unusual way to get phasing and since it could be voltage controlled, a high frequency input can ring-modulate a voice for bell sounds. He's even tried a long tape loop round a ribbon microphone that gives a very long fade because each time it passes the mic a little more gets wiped! Dick remembers when effects like Flanging didn't come in small black boxes, but were made by pressing your thumb on the flange of a tape reel, thus altering the tape speed slightly.

All the 'Dr. Who' effects are recorded in full track mono and similarly the music produced is also mixed down to mono.

'Hitch-Hiker's Guide'

If you've been watching the new, TV version of 'The Hitch-Hiker's Guide to the Galaxy' then you should be interested in the work of Paddy Kingsland who I found in Studio E. Paddy has been composing the incidental music for this series (on BBC 2) since last June, when a pilot version of episode 1 was first approved and six episodes planned. Besides providing the incidental music, Paddy has to 'orchestrate' all the computer animation which appears as letters or graphics on the screen — they all have to have sounds that fit with the music. Other effects that are required are explosions, spaceships taking off, monster noises and, of course, alien voices that usually need special treatment. For the latter, an actor speaks the alien's lines and Paddy uses various treatments on the taped voice. The story had an interesting start for him, with a spaceship arriving and the earth being destroyed. Unlike the radio programme, where the timing of an event is not absolutely critical for perhaps an explosion, the TV version requires precise sounds for the pictures so that a 'spaceship close-up' which immediately cuts away to 'people panicking in the middle of London' proved to need a complex series of sounds, although the distinct sounds required were defined by the picture action. Paddy's sound tapes are made in short sections, e.g. a spaceship has its sound fitting the exact number of frames. On the dub which is done at BBC TV centre with the sound engineers, they play in the effects tape at the right time onto a multi-track machine that eventually records the whole sound score (including actors' parts and possibly a sync track to ensure the mix stays with the picture).

The Narrator in the story has two functions — as a story teller and as the voice of a futuristic book that plays like a cassette tape recorder. You punch in a code and it comes out with some information and that's what the 'Hitch-Hiker's Guide to the Galaxy' is! Behind this narrator is music which must not swamp out the words — it must create the right mood for the scene. Nearly all of the music is electronic, although one exception is the commercials — there's a 'Pan Galactic Gargle Blaster' drink advert. This is treated like a real commercial using live music on keyboards, guitars and drums. Paddy's work load is so heavy that he often has to switch every few days to a different programme to keep up with scheduled series. In addition, each adventure of four episodes has a different director, so that several groups of episodes can be overlapped to save time. Some directors simply do the first and last episodes of an adventure.

Instruments in the studio included the Oberheim OB-X8 polyphonic synthesiser, often used for sustained sounds. The Roland Jupiter 4 was used a lot — the spaceship soaring away was done with white noise and four-note chords near peak resonance just before oscillation of the filter. For the animation, computer blips and bleeps came from this also and occasionally during a 'wipe down', where a graphic style face is printed out, a single chord was played on the J4 with its special arpeggio effect added during a long decay. The Roland CR78 rhythm machine is used by Paddy all the time for guide tracks and occasionally for his own special rhythms. He also employs a Stereo Flanger, Voltage Controlled Stereo Panner and likes to use the old Yamaha SY-2 preset mono synthesiser.

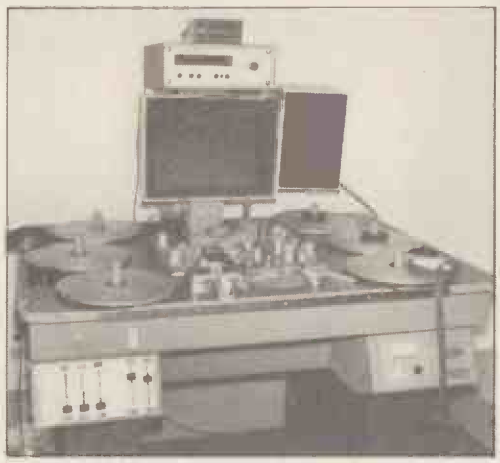
The main areas of Paddy's work are sound effects, music background and voice treatments and for the latter he uses a clean voice recording treated by Harmoniser, Vocoder, Flanger, as well as echo plates (looped round the flanger so that echo is phased as well as the voice). When the vocoder is used on a voice, a 'dirty' noise input is used as the carrier e.g. for the alien voice, and a slow frequency modulated echo is added to make the 'depressed alien' voice.

Other Areas

We paid a brief visit to another vital room within the complex that contains all the film and video facilities. In this room producers can check film against sound tracks, measuring time in frames at TV speed (25 per sec.) or cinema (24 per sec.). The film track is simply inserted with the sound track (see photo) and run through so that frames can be located and checked for synchronisation. Sync 'pips' are sometimes inserted on one track of a 16-track recorder as reference points for intended music cues. There is a useful device designed by their own technical lab that stores the total number of frames edited and searches for this amount at the start of a new editing session. Also kept in this room are copies of all the BBC's sound effects records and these are often used for specific items in a script e.g. a steam train, bird sounds, animal noises and natural sounds.

In rounding up my enjoyable visit we spent a few minutes with Peter

Peter Howell.



Film editing equipment.

Desmond Briscoe, Mike Beecher and Brian Hodgson.

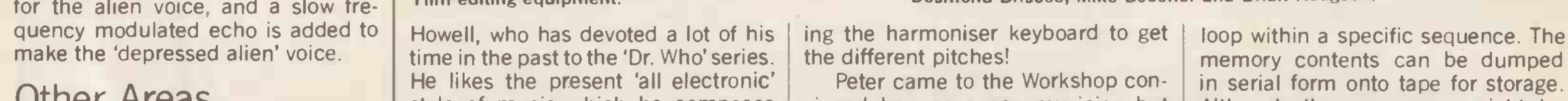
Howell, who has devoted a lot of his time in the past to the 'Dr. Who' series. He likes the present 'all electronic' style of music which he composes mostly on the CS80. Listen for an autoharp in the programme too — it was recorded via piezo pick-ups under each string. (We plan to review Roland's electronic autoharp costing around £160.) One day's work on 'Dr. Who' for Peter produces only a few minutes of music, taking about 8 days per episode, although that is often cut to four or five days to meet deadlines. We talked about his frequent use of augmented 5ths to create a sense of anticipation - suspended minor 9ths are a favourite too. He uses plenty of chromatic harmony, often starting from the key of C then modulating to some remote key such as F# minor! The timing for his music writing has to be accurate to 6 frames a second and final juggling can be done at the dubbing stage. He revealed that kettle-drums in the 'Dr. Who' music are really made by using a single tuned tom-tom with bottom skin removed through a harmoniser. Whilst someone hit the drum, Peter was playing the harmoniser keyboard to get the different pitches!

Peter came to the Workshop convinced he was a pop musician but over the last five years has realised his music is much more classical in style. 'You don't have to dislike electronic sounds here but it helps! — it makes you try and round them into something more interesting!

Looking to the future, Radiophonic Workshop have had the 'Wavemaker' Polyphonic System designed for them by Ken Gale (he was responsible for a lot of the EMS Synthi 100 final development from David Cockerell's designs). It has a 10-note digital keyboard which is touch sensitive. With the keyboard is a digital control voltage recorder that stores your performance on one track of a ¼" tape. You can also lay one track at a time, then play it back whilst accompanying it on the keyboard and it will re-record automatically. Thus previous tracks can be edited or added to without any noise degradation. Next to the recorder is the 16,384 events, 10 layer sequencer with micro-memory and the ability to actually loop within a specific sequence. The memory contents can be dumped in serial form onto tape for storage. Although the sequencer might be considered primarily for storing voltages to drive VCO's, the 10 output control voltages can also be used for filter control, sound envelopes or spatial control. The sequencer itself can receive up to 256 'instructions' which in turn can be loaded on tape for use again at any time. A new modular synthesiser system is also under development and should prove ideal for the workshop as it will always be expandable.

To the aspiring musician, the Workshop composers task is an enviable one, but motivation is not easy — getting down to composing, deciding on the right sound when working alone, and then finishing the programme on time. Despite the long hours and dedication to the sole task of getting music produced, Desmond Briscoe has formed a team that brings us a vast amount of electronic music through the medium of broadcasting.

E&MM



HI-FI

Jeff Macaulay

For several years now Hi-Fi enthusiasts have been experimenting with their turntables in the hope of getting a better sound. Turntable mats, record clamps and special headshells have appeared on the market in profusion, each claiming substantial improvements.

I must admit to being highly sceptical of these claims although some recent experimentation with my own equipment has justified some of them.

Before going on to describe these experiments in detail it would be as well to describe my own deck. Back in the heady days of '74, when the Hi-Fi boom was at its peak, most turntables were made by Garrard.

The only viable alternative to the ubiquitious SP25 was the 401 turntable fitted with a SME arm and V15 III cartridge.

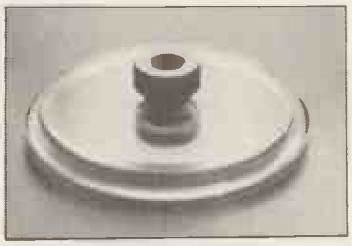
Around this time I swopped my SP25 for a BD1 turntable kit and an Acos Lustre arm fitted with a Shure M75ED. The arm is still available, albeit in a modified form, as the Rega arm for round £40. Since then only the cartridge has been changed for an Ortofon VMS20EII. This cartridge is one of the most neutral sounding moving magnet designs available at any price. The rest of the system consists of a home brew pre-amp and bi-amped speakers, the deep bass end being taken care of by an active woofer system. It is, by now, a well known fact that any record deck can be made to act as a microphone.

This can be easily demonstrated by placing the stylus on the stationary turntable and monitoring the output on a 'scope. Providing the 'scope is reasonably sensitive signals will be seen whenever sound is present in the room.

Turntable mats have a dual purpose. One of these is to support the disc. This may sound obvious but with the standard of flatness of modern records, this is no easy task. The other main purpose is to damp out platter resonances and acoustic pickup of the type described above. All turntable mats do both these jobs to a greater or lesser extent. The recent wave of accessory mats claim to do better and positively improve the sound.

The first of these mats of which I have personal experience is made by Griffin and retails for about £6. When tried it certainly improved the treble and to a lesser extent, the mid-range, but at the expense of the bass. The latter disappearing below 100Hz or so. Several other mats have since been tried with varying degrees of success. Although they all provide an improvement on certain aspects of the performance they all seem to do so at the expense of others.

Naturally the differences are in some ways extremely subtle. This applies especially to those which affect the stereo image. It is only possible to judge this properly on those recordings which have not been multi-miked. These albums tend to be something of a rarity these days! Record clamps as well seem to be somewhat problematical. Again several types are available. Most of them have a collet type fitting which is pushed over the spindle on top of the record. A disc of material in turn fits over this and is pressed onto the record and secured by a nut which tightens the collet.



Metrosound clamp.

Completed turntable mat.

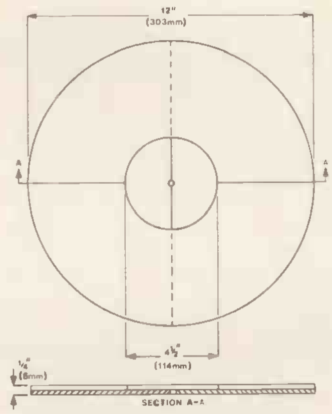


Fig. 1. The turntable mat fabricated from four 'Bostic' car sound-damping panels.

A typical example is the metrosound clamp which costs around £4.50. Like the mats this is claimed to improve the separation between instruments, improve the bass and generally reduce coloration. In fact I found this device did fulfil some of the claims made for it. It seemed to make the instruments better defined and made low level information more intellegible.

However I found that the device tended to lift the record away from the turntable mat rather than bind it more closely.

On the Rega turntable, however, with its more compliant mat the clamp operated as intended. Surprisingly though the difference was not so marked as with the BD1. An improvement none the less.

Most turntables, if struck with a screwdriver blade across the rim, will ring like a bell. My BD1 was a particularly bad offender in this respect. If a note of the same frequency were to be picked up by the turntable it will react like a mechanical tuned circuit causing a peak in the response. My first experiment was to remove this resonance.

The obvious way to damp out a resonance of this kind is to add mass to the turntable. The most convenient material to use are Bostic car damping panels. These are basically bitumised felt pads and are self adhesive. They can be cut to size and shaped with scissors and are thus convenient to use. Taking the turntable out I stuck a strip of this material around the internal rim of the platter. This treatment lowered the frequency of the note produced and the decay time was reduced. Some squares of material were then added to the underside of the platter and this again reduced the decay time to a few milliseconds. It sounded dead when struck. After refitting the platter and replacing the existing mat some listening tests were tried. The main subjective result was that the music sounded much cleaner at high levels. Tapping the deck with the stylus resting on the turntable showed that the whole assembly was less prone to pickup problems.

All this leads on to this month's do it yourself project. The 'Macaulay' turntable mat! This is fabricated from four 'Bostic' car sound damping panels. As already mentioned these are self adhesive. The sticky side being protected by a paper sheet. Figure 1 shows the completed mat in plan and cross section view.

This material's self damping properties absorbs vibrations in the disc whilst damping platter resonances.

Construction starts by laying a pair of sheets side by side, paper side down. Take an LP record, preferably an old one, and lay it on the panels with the central hole over the join. Mark round the LP with a Stanley knife. Remove the album and cut out the semi-circles with a pair of scissors. Repeat this exercise with another two panels.

At this stage you should have four semi-circular cutouts. Take two of these and butt them together to produce a circle. Now find a circular object of about 4½" diameter. Place this on the centre of the disks, mark round it and cut out the circle. The cutout is required so that the record can lay flat and clears the raised portion in the centre.

Peel the backing paper from the two panels with the 4½" cutouts and press these into place on the other two panels as shown in Figure 1. Don't at this stage remove the backing paper from the other two panels until you have tried the mat out. The prototype improves the bass response and stereo imagery of my BD1 and imparts a dry quality to the sound. Preferably the mat should be used in conjunction with a record clamp to provide intimate contact between the disc and turntable.

As with all things audio the only sensible way to judge the difference is to hear it. If you like it the bottom panels can have their backing paper removed and the mat stuck to the turntable, further improving the damping.

One thing to watch when experimenting with different mats is to readjust the arm height for parallelism in order to keep the vertical tracking angle correct.

Other less obvious factors can affect the performance of record decks. The most common of these is the build-up of oxide on the pickup plugs and the cartridge pins. Even if these are clean they can still give trouble if they are loose fitting. The cure for these ailments are self evident and it does no harm to check and clean all connections periodically.

The sound of a cartridge can be modified by adjusting the input impedance and, or, the capacitive loading. Most pre-amps offer an input impedance of 47k. A couple of metres of connecting lead between the cartridge and pre-amp will also produce a capacitive load in parallel with the resistance. Some cartridges, notably Shure and Ortofon models, require a load capacitance of 200-400pF. Often the capacitance of the cable is not sufficient to produce the optimum load. If your connections allow it 500pf trimmers can be soldered between the hot sides of the inputs and ground.

If a record is then played it is possible to adjust the sound to a certain extent to suit one's taste simply by adjusting the trimmers.

These comments only apply to moving magnet designs. Moving coils are low inductance and capacitive loading will have no effect.

The reason that capacitance actually alters the response may not be immediately obvious but it has to do with the internal inductance of moving magnet cartridges. The impedance of the inductance becomes larger with increasing frequency. In the extreme hf the response may go down by several dB. The capacitance forms a tuned circuit lifting the response. **E&MM**

LOOKING AT MICS

by Chris Lare

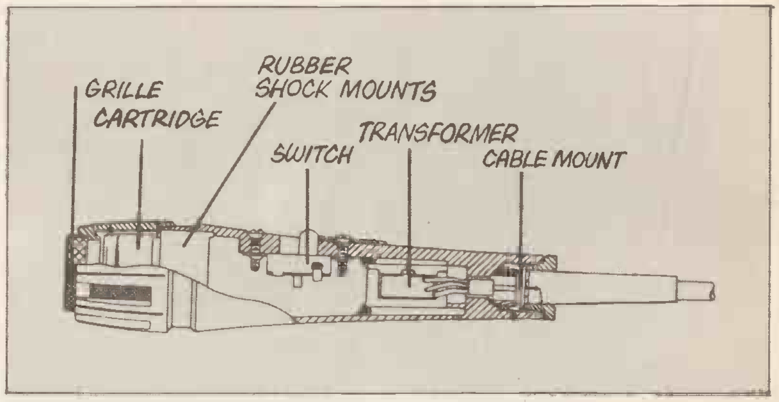


Figure 1. Cutaway view of a typical microphone (Shure Unidyne B)

A microphone converts sound energy into an electrical signal, and as such is the first device in the audio reproduction chain. Unlike the other parts of the reproduction chain (tape recorders, amplifiers, speakers) microphones are not often seen in the High Street shops, thus leaving a large number of people unaware of their importance. Indeed, a microphone will probably place more characteristics on the final sound than any other item in the chain. This implies that the choice of microphone is critical and that it is well worth while taking some trouble to establish which microphone(s) is best for the job in hand, particularly as one or two microphones will really stand out in any one application.

The array of microphones available is considerable, and while the products of three manufacturers (AKG, Beyer Dynamic and Shure) dominate the scene, several other manufacturers contribute on a smaller scale. As a rule the characteristic of the microphone is dependent on the 'cartridge' employed and so little is gained by putting a cartridge in another mounting; unlike the domestic loudspeaker market where small companies all over the place are designing their own boxes around standard products.

A microphone consists of several parts (Figure 1). The actual work is done by the cartridge which is generally mounted on shock absorbing rubber supports. The cartridge is protected by the grille and case, the cable usually leaving the rear end of the case. Additional parts may be included depending on the end product such as switches and transformers. The cartridge will be one of three types, ignoring carbon types which ceased to be seriously used many years ago.

These types are dynamic, ribbon and capacitor, each offering different characteristics, although some overlap does occur.

Dynamic Microphones

The dynamic microphone (sometimes called moving coil) is the converse of a normal loudspeaker. A diaphragm is fixed to a set of coils suspended between the poles of a magnet, and as the sound causes the diaphragm to move current is induced in the coils by the magnet (Figure 2). The coil and diaphragm must be very light to allow the microphone to respond quickly to sound (ensuring a wide frequency response) and yet be strong enough to withstand jolts during its life. This is why high quality dynamics are expensive, the cost purely related to the difficulty of manufacture of the diaphragm/coil assembly. A small transformer is often used to adjust the output voltage and impedance to make the microphone easier to interface to other equipment.

One problem with dynamic microphones is that they are prone to pick up hum in the coil, and in view of the very low signal levels present this can be quite serious. Many microphones overcome this problem by mounting another coil next to the moving coil, but wound in the opposite direction. The outputs of the two coils are added, either directly or by means of a transformer, and any hum induced into both coils cancels out since the induced hum will be of opposing phase. The fixed coil is often called a 'humbucker' (Figure 3).

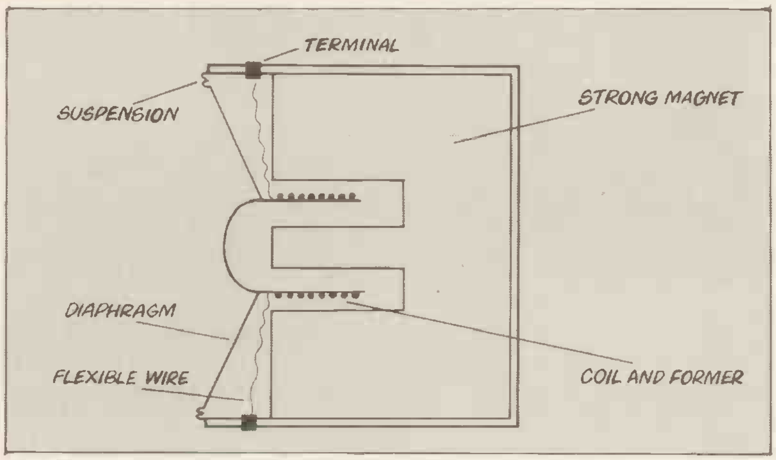


Figure 2. Dynamic Microphone Cartridge

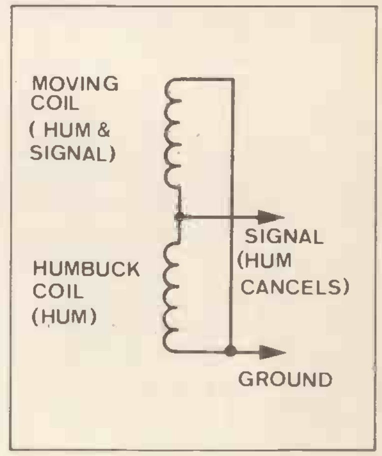


Figure 3. Humbucking coil connection

Ribbon Microphones

A ribbon microphone still employs a magnet to induce an electric field, but this time into a single fine metal strip. The strip is very light and carefully shaped, making ribbon microphones expensive and delicate. They do offer tremendous clarity of sound because of the lightness of the ribbon and are thus very popular professional microphones.

Capacitor Microphones

It is important to distinguish between true capacitor (previously called condenser) microphones and the cheap electret capacitor microphones (see Figure 4). The true capacitor microphones work on a totally different principle to the magnetic microphones, and depend on the charge stored on a capacitor. The amount of charge that can be stored on a two plate capacitor is related to the area of the plates, and the distance between them, implying that if the distance is altered the charge stored must change resulting in current flow.

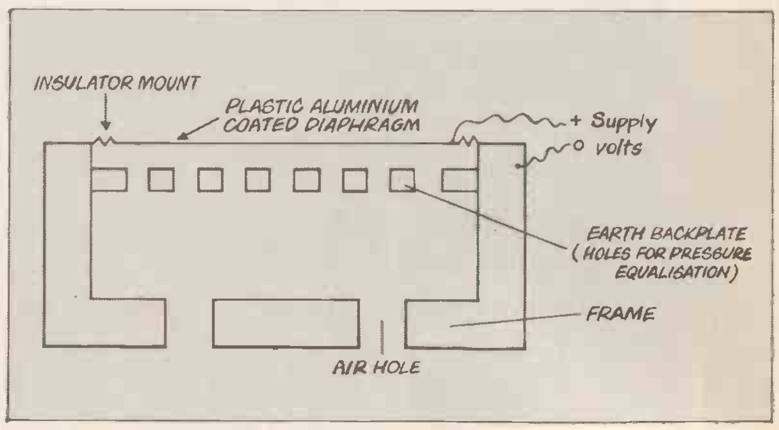


Figure 4. Capacitor microphone cartridge

In a capacitor microphone the base of the cartridge forms one plate, and the diaphragm forms the other. As sound impinges on the diaphragm it moves closer to the base, resulting in a capacitance change (Figure 4), causing a flow of current. However, the plates must be charged for this to occur, resulting in the major problems with capacitor microphones because an external power supply is required, capable giving up to 50 Volts or so. This supply can be arranged to use the microphone signal cables, a technique called phantom powering (Figure 5). A D.C. path is maintained to the microphone via the coil which prevent any A.C. interfering with the power supply. The A.C. signal is superimposed on the D.C. and then retrieved by means of the capacitor which removes the D.C. component at the receiver end. This sort of capacitor microphone is in great demand in spite of the power supply, because they are very versatile and tough.

The electret capacitor microphone was developed a few years ago in an attempt to gain the advantages of capacitor techniques without the need to provide an external power supply. In an electret, one of the plates is charged at the time of manufacture (a process involving heating and cooling — analogous to magnetisation) and so the polarizing voltage is not required. The output of these cartridges is very low, and a small field effect transistor is usually used to amplify it. This amplifier is usually mounted in the cartridge itself and is powered by a 1.5 Volt battery held in the handle of the microphone.

The major problem with these microphones is that the charged plate is necessarily the diaphragm and needs to be slightly thicker than a normal diaphragm to hold sufficient charge. As a result these electret microphones generally exhibit poor frequency response and dynamic range, and should be avoided at all costs, although there are a few notable exceptions, by Sennheiser in particular.

Technical Specifications

The most important specifications of any microphone are the polar response pattern and the frequency response. It is essential that these characteristics be decided upon before any microphones are actually considered for purchase. Other factors such as sensitivity and impedance can often be considered later because many microphones are offered in different configurations.

Polar Pattern

The polar pattern defines where the sound source has to be placed with respect to the microphone. Three main patterns exist (Figure 6), although a development of the cardioid gives steeper sides to the pattern, and is not surprisingly called 'hyper-cardioid'. In a meeting or open interview an omni-directional type is desirable because it does not matter where the person speaking is with respect to the microphone. The bidirectional ('figure of eight') type is generally used in a pair at 90° to each other to cover the entire area, but in stereo. By far the most common is the cardioid, since sound in front of it is picked up, but sound from behind (audience noise, etc.) is suppressed. This pattern is also much used by the PA industry because sound emerging from the PA, and then reflecting from walls causing feedback is largely rejected. It is interesting to note that the polar pattern is likely to change with frequency, and account of this should be taken.

One very important property of the true capacitor microphone is that its polar pattern may be varied by altering the supply voltage. This is because the plates tend to pull further together in the presence of high voltages, resulting in different stress points, hence a different polar pattern. Some capacitor manufacturers supply remote control boxes for this purpose. An additional trick which is very popular is to design the microphone as a standard body, upon which is screwed a capsule offering the desired response. This means that an entire range can be obtained more cheaply than buying several different microphones.

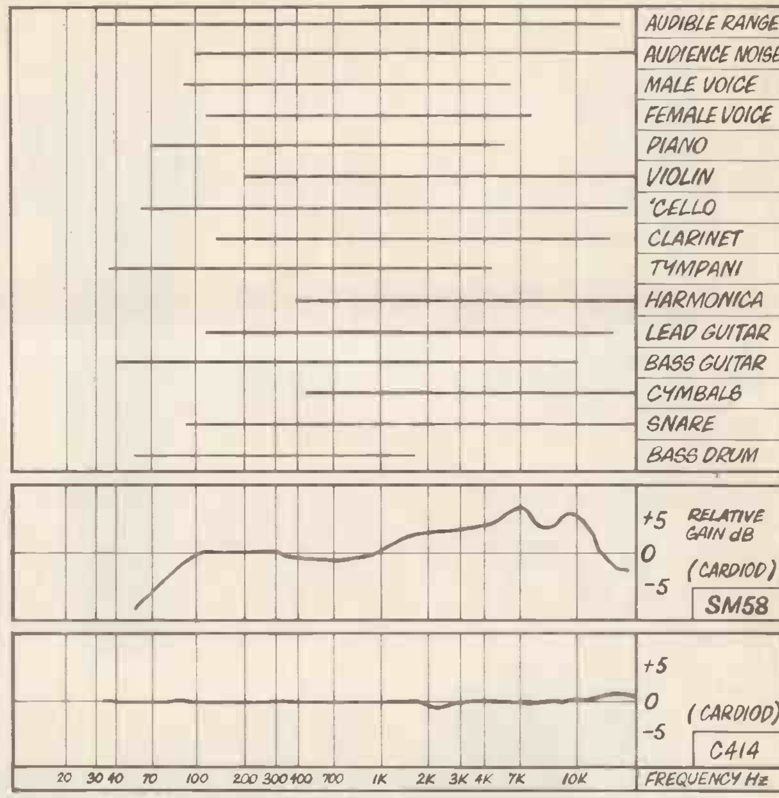


Figure 7. Frequency ranges of various instruments and responses of two microphones

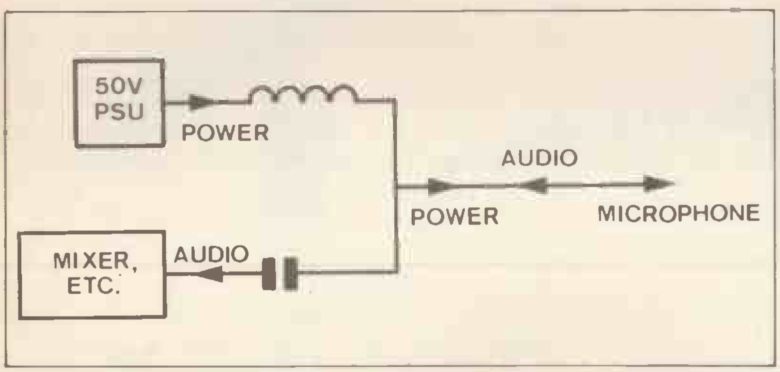


Figure 5. Phantom powering

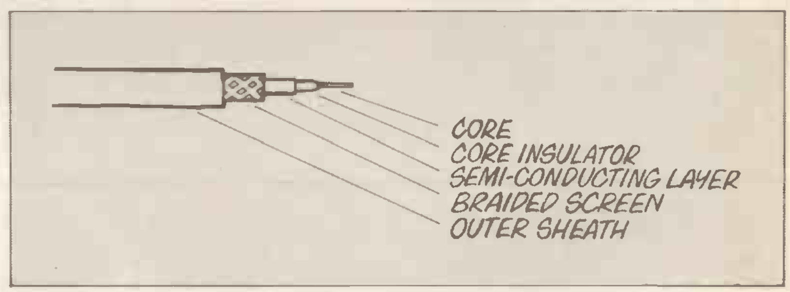


Figure 8. Construction of high quality cable

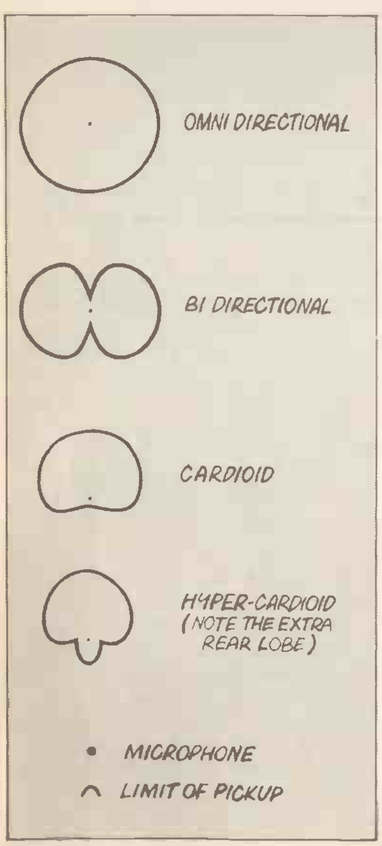


Figure 6. Polar patterns

Frequency Response

The table in Figure 7 shows the ranges of typical instruments and voices. Obviously the microphone should be capable of picking up all these frequencies if a natural sound is required. The response of a typical vocal microphone, the Shure SM58, is also shown. It can be seen that the respose is flat for the most part, rising above 2 kHz. The rise will give the voice 'presence' and generally make it more pleasant to listen to, although it would be disasterous for orchestral recording.

This peak leads on to feedback, which occurs when sound emerging through a PA travels back into the microphone and is preamplified causing the characteristic 'ringing' or 'howl-round' so often heard from poor PA systems. Many people believe that a wide frequency response will give rise to more feedback problems, but it is in fact the peaks in the response which cause the trouble. For example the SM58 peaks at 5kHz and 9kHz, and thus feedback at these frequencies is much more likely due to the increased 'gain' of the system. In spite of this the SM58 is one of the most popular vocal microphones ever made because it not only sounds good, but is easy to use and very robust. As a rule capacitor microphones exhibit very flat responses, and for comparison purposes the response of the AKG C414 is shown next to the SM58.

Sensitivity and Impedance

Microphones are also specified in terms of sensitivity, which simply describes how much output voltage a given sound level will produce. As a rule the sensitivity is not all that relevant, but regard should be paid to overload, either electrical or physical when dealing with loud sound. Electrical overload is more likely to occur at the tape recorder or mixer than in the microphone, and happens when a very loud sound is picked up, resulting in a very large electrical signal which is clipped at the following electrical stage. Some microphones, particularly capacitor ones with built-in amplifiers, overcome this by providing a built-in attenuator to reduce the output signal level. Physical overload occurs when the diaphragm cannot move far enough and hits the end stops. This can quite often damage the microphone, and must be avoided. A bass drum is a very severe test of a microphone's capabilities, and only one microphone is universally accepted as being tolerant enough for this, the AKG D12, which was designed in 1954, and generates only 0.5% t.h.d. for a sound level of 128 dBA (Comparison — about the threshold of pain).

Impedance ratings define the load (usually a resistance) that the micro-

1
A Beyer Dynamic Ribbon unit (M500).

2 & 7
Two extremes of dynamic microphones, the Shure Unidyne B and the AKG D222. The D222 uses two separate pickups for bass and treble giving a very extended response.

3
AKG D190 - all is not what it seems. Good for snare drums and roto-toms in spite of what AKG say.

4
Shure SM58. Often used vocal microphone although frequency response is hardly flat.

5
AKG D12. Bass drummers idol.

6
Top range capacitor - the fairly recently introduced Shure SM81, but at £150 it had better be good.

A selection of microphones discussed in the text.

phone is designed to operate into. This is important because a wrong impedance load will not only alter the levels, but also affect the frequency response. Most professional microphones have quoted impedances of 200 ohms or 600 ohms. This means that they should be plugged into a tape recorder or mixer with an imput 'resistance' of about 600 ohms, the difference between 600 and 200 not being critical. Most tape recorders are not satisfactory as they stand having input impedances of about 50k ohm and a matching transformer should really be purchased, although the trick of connecting a 680 ohm resistor across each input jack often works.

Wiring Up

Some care is necessary in order to obtain the best results. Most professional microphones employ balanced line outputs (a full description of which appears elsewhere in this issue) and use cannon connectors, although ¼ inch jacks are sometimes seen. It is essential that all microphones are connected up in the same phase so that a positive sound pressure produces a positive voltage on the same input connector pins irrespective of the microphone used. If this is not observed the final sound will be very hollow, and lack bass, due to phase cancellation of signals from oppositely wired mics. If all the microphones are from one manufacturer no problem will exist, but it is worth the time to check if a mixture of makes are used.

The cable used to connect the microphones up should be of a high quality, preferably with a proper braided screen, and of the low noise type designed specially for microphones. This sort of cable employs a semi-conducting screen between the braid and the core insulator (Figure 8) this must be stripped well back out of the way since it exhibits a fairly low resistance and will affect the operation of the microphone. It is false economy to use plastic jack plugs since they are very unreliable - buy decent metal ones, preferably the sort with integral cable clamp.

One from the Hundreds?

It can be very hard to choose the correct microphone, much advice given is misleading, and some of it simply wrong. In general it is best to go to a good dealer, who will let you test the microphone in the environment for which it is intended. Under no circumstances buy a microphone without listening to it first.

Firstly it is necessary to decide on the polar pattern required, followed by the decision about the frequency response. For example, recording a chamber orchestra needs an extended top with a flat response, an obvious candidate for capacitor types, as would be a hi-hat cymbal. However vocal work through such a microphone would probably sound rather flat, indicating a 'presence' peak may be required.

Other problems emerge as the microphone is tested, most particularly susceptability to stray noise such as wind, pops and handling bangs. Pops are caused by close miking vocals when like letters 'P' or 'B' start the word. The rush of air causes a nasty popping sound to occur. Wind noise is only a problem outside (or near big air conditioners?) and simply results from the noise created by the airflow around the microphone. Both these may be reduced by fitting a pop shield - a sleeve of foam over the top of the microphone. Handling noise is only relevant if the microphone will not remain in its stand all night. A solid 'clunk' as the artist removes or replaces the microphone in its stand is not a very desirable effect. All these factors should be taken into account, and most of them can only be explored by using the microphone in question.

Most manufacturers quote applications for much of their range. Inevitably these applications are a little stretched since the manufacturer wants to convince the buyer that his microphones are more universal than those made by other people. Exceptions do exist - AKG modestly refer to the D190 as for 'General semi-professional use, movie sound and announcer studios'. In fact, the 190 is not a particularly good vocal microphone being very susceptible to popping, but it is blessed with a considerable transient response and is used in several rigs and studios for snare drums and roto-toms, and sometimes on cymbals, although it has a tendency to sound a bit 'splashy' at times.

This section can be simply summarised however with two words, 'try it', but you may need to find an understanding dealer first.

One final note: It is not worth buying cheap microphones and an expensive tape recorder, better results will be obtained by putting half the available funds on a tape machine and splitting the rest between two microphones. On no account buy several cheaper ones, since in general two good microphones will last a lifetime, as well as sounding a great deal better. **E&MM**

GET ORGANISED!

Ken Lenton-Smith

Readers of this new magazine are bound to be constructors by nature. The field of electronics is vast and there are myriads of ideas to whet the appetite in its application. Where music is concerned, more than the usual care is demanded if the result is to be acceptable, even to the layman. Electro-music has to be very much more than a simple go/no-go situation and a great deal of thought should go into the planning of major projects such as synthesiser or organ.

The idea of building a musical instrument will stem either from an interest in electronics or because the potential constructor already has good musical knowledge and wishes to have his own instrument. Both categories will have a lot to learn in the process as very few people possess both high musical and electronic abilities. Possibly learning to play well is more difficult than putting the components together correctly!

The first essential part of the planning is to know exactly what is required, and this is not as simple as it may sound. Many gadgets that can produce music are loosely called 'organs' - indeed, you can buy one in Woolworths these days. Commercial organs often bristle with so many facilities and frills that it is difficult to know whether they are orchestras, synthesisers or organs. The use to which the completed instrument will be put will shape the plan to a large degree, taking into account the amount of cash the constructor is prepared to spend.

Unless well endowed musically, it is a good idea to enlist the help of a friend experienced in music and together look at and listen to commercial instruments that appear to fill the bill. There are excellent organ kits on the market today - Maplin, Wersi and several others - where a number of the basic decisions have already been made by the designers but the customer still has options as to the scale and cost of the instrument. With both these and commercial instruments generally, it is a little difficult to know exactly what you do require until experienced in playing that particular model.

COMPASS

Whether the organ is to be built from a kit or self designed, one of the first decisions to be made will involve the size of the instrument.

The single manual version can hardly be termed an organ as, although the keyboard may be 'split' to allow playing of both solo and accompaniment simultaneously, the arrangement has many limitations. The players usually appear to prefer to stand (at least saving the cost of a bench!) as part of a group of instrumentalists and are mainly involved in providing harmonic and rhythmic backing to the lead instruments. If 'pop group' orientated, the single manual instrument is probably sufficient and does at least have the advantage of portability. The output may well be pre-amplified only, with its signal feeding one of the channels of a common amplifier system.

The 'spinet' organ is in the midway category and is possibly the most popular size of organ for use at home. This type of small entertainment organ will have two keyboards and probably 13 stub pedals. Contrasting tone-colours can be used between the solo (upper manual) and accompaniment (lower) and all of the normal organ departments are represented. The staggered keyboards are shorter than usual - about 3½ octaves - but this limitation can be overcome to some extent by careful choice of pitches.

If classical music is the aim, the short keyboards of the 'spinet' are a serious disadvantage, as is also the short compass of the pedal clavier. Those aspiring to serious organ music must settle for no less than two full 5-octave manuals and a 25 or 32 note pedal clavier as otherwise it will be impossible to play works scored for the King of Instruments. It is perfectly feasible to design a light music organ on this scale but naturally the larger manuals and pedalboard will influence the size of the console in the home.

CONSOLE

Organ kits take the console into account but if the instrument is to be self-designed and used in the home, remember to consult the Household Management! The organ will be a piece of furniture - possibly the centrepiece - and should be built accordingly. Take a tape measure when visiting an organ studio or church. There is no real standard for console measurements but it is worth remembering that one of the joys of having completed an instrument is to hear it played skilfully by someone else.

If you wish to retain that friendship, make sure that the controls are recognisable and accessible. Touch switches and postage stamp sized buttons may look smart but are not easy to cope with when concentrating on music at speed. A reasonable sized tab or rocker is a much better proposition. Study the tab layout of several organs, noting any colour coding used. The final plan can then incorporate the best of these, though I would advise against a rainbow display of tabs if possible. Normal practice is to use white for flutes, red for reeds, yellow for strings and black for non-speaking controls.

Some standardisation is necessary if you expect anyone to sit down and play the beast! Imagine getting into a car where the brake and clutch pedals had been transposed. While in this vein, the relative positions of manuals and pedals are important: the top C of a 13 note pedalboard is usually below middle E on the bottom manual. The height of the bench above the pedals should be some 21" for comfortable playing.

PITCHES

In this particular article we are ignoring the electronic aspects as the general plan must first be laid. Another consideration, which may depend on the method of tone generation in mind, is the number of pitches to employ.

The electronic organ still copies its pipe counterpart in many ways, including the matter of pitch. The ability to bring in a number of these together has always given the organ that full and regal sound. Although a rank of 61 organ pipes (covering one stop over the 5-octave manual) may be displayed out of chromatic order for decorative purposes above the console, the longest pipe produces the lowest note and the shortest the highest. If the longest pipe is 8' long, that particular stop is known as 8' pitch (the exception being closed pipes, such as Tibia Clausa and Stopped Diapason). A 4' pipe will produce a note one octave above an 8' pipe and a 16' pipe will be one octave lower.

'Footage' is an organ term that has crept into our terminology but pitch is the better word. The pipeless organ we are considering will be capable of producing various pitches, including mutation stops: these are dissonant tones based on odd harmonics of the fundamental or 8' pitch and are extremely useful in building up brassy tones. The original Hammond system employed nine pitches (and is still used by Hammond and imitators of its drawbar system) and all of these are useful though the limitation in building is often financial.

The upper (solo) manual should be provided with as many pitches as the pocket will stand. The table shows nine pitches and the notes that would be heard on playing middle 'C' with given pitches switched in.

In all probability, the number will be much less than this. A suitable but comprehensive set of pitches would be 16', 8', 4', 2-⅔' and 2' for the upper manual. The lower (accompaniment) manual will not require 16' pitch and probably 8' and 4' stops will be quite sufficient. At the same time, the self-designed instrument should be capable of expansion and modification at a later date in this respect. The pedal section is normally equipped with 16' and 8' pitches.

I should perhaps emphasise that pitch only refers to the frequency of the note heard and has nothing to do with tone-colour. An organ may well have several 8' or 16' stops, for example, but each will sound different because the tabs control filters that impart tonal variation. Mixing different voices at various pitches is, of course, one of the pleasures of playing organ.

Summarising our prior thoughts on the instrument in mind, the musical destination will predetermine both size and compass of the instrument. The console must accord with the room concerned and its controls be instantly recognisable. The choice of the number of pitches envisaged can only be verified by experimenting with instruments in the organ showroom. Commercial organ kits will cater for a number of options and will no doubt include the suggestions made here.

Building an instrument is a fairly long process, so there is no point in rushing these important preliminaries. Take plenty of time and make plenty of notes before laying down the keel. It is only too easy to find that you have ended up with something not ideal!

E&MM

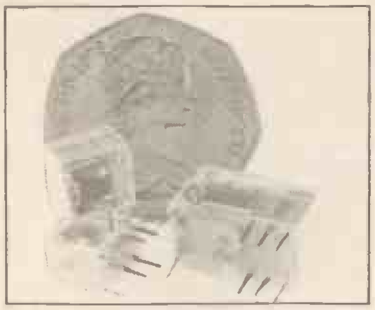
PITCH: Middle 'C' keyed at various pitches.

Pipe Pitch	16'	8'	5⅓	4'	2⅔	2'	1⅗	1⅓	1'
Scale Pitch	—	Fundamental	5th	8th	12th	15th	17th	19th	22nd
Typical Stop	Bass	Principal	Quint	Octave	Nazard	Flute	Tierce	Larigot	Piccolo
	C*	C*	D*	C*	D*	C*	D*	D*	C*

(C* Consonant pitches) (D* Dissonant pitches)

NEW PRODUCTS

MINI-RELAYS



A new range of miniature printed circuit board relays are being introduced by Ambit. They are available from stock with 10-12V DC, 320R coils and to special order with operating voltages from 3 to 24V. The life expectancy for the mechanics is quoted at 10^7, with a contact life of 10^5 at maximum ratings. Two types are available; the RBU is flux resistant and has two-pole changeover contacts with a 2A at 24V DC rating, and the smaller RCU type has single-pole changeover contacts rated 2A at 100V AC or 24V DC. Price for the RBU is £1.85 and for the RCU is £1.65, in single quantities. Available from AMBIT INTERNATIONAL, 200 North Service Road, Brentwood, Essex CM14 4SG.

HI-FI DISTRIBUTION BOXES

A very neat way of tidying up all those cables behind the hi-fi gear. The box screws onto the back of the shelf and is unobtrusive and slim enough to fit into a small space. Units are available with four or six European style 6A sockets.

There is a neon indicator for mains on indication and the units are supplied with over 2m of 6A mains lead. A neat and relatively inexpensive solution if you are using separate hi-fi units.

Maplin Electronic Supplies Ltd., P.O. Box 3, Rayleigh, Essex.

CHEAP BOXES

West Hyde Developments Ltd have announced price cuts by more than 25 per cent on their Bocon cases which are manufactured in Western Germany. They are claimed to be superbly engineered and precision moulded in the widest range of colours and sizes available from any top quality supplier.

This scale of price reduction, together with very generous quantity discounts on all orders for ten items or more allows significant savings. For further information contact Chris Long, West Hyde Developments Ltd, Unit 9, Park Street Industrial Estate, Aylesbury, Bucks.

McKENZIE SPEAKERS

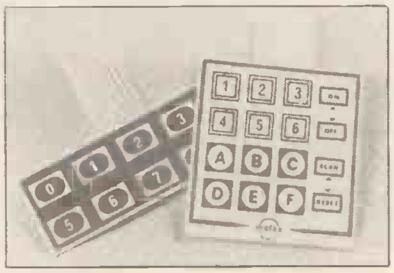
McKenzie Acoustic Ltd now have available a new 'STUDIO SERIES' of instrument and disco loudspeakers. The technical data quotes 'High specifications coupled with a superb standard of presentation makes them highly desirable pieces of equipment which competes and even betters all the best types currently available'.

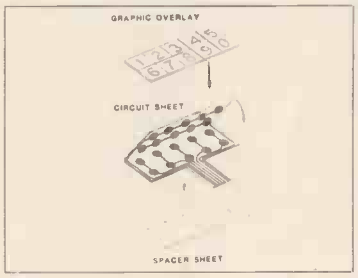
These first two models are C12-125 GP and C12-125 TC, both 12 inch and rated at 125 watts. Model C12-125 GP is a general purpose unit suitable for guitar, keyboard etc. Model C12-125 TC is a dual cone extended response version, which is useful for P.A. use or indeed for any application where a response extending up to around 14kHz and high power handling is desired.

Typical sensitivity has been measured, with an input of 1 watt at 1kHz sine from one metre on axis, at 101dB. With broad band noise input 1 watt at one metre, 104dB is present and at their rated power, in excess of 120dB is quoted.

These units which are built on pressure diecast aluminium chassis incorporate a finned heatsink over the anisotropic magnet assembly. They are claimed by the manufacturers to be capable of superb sound and excellent sensitivity operating for long periods in the toughest conditions, with a high standard of finish attained by using a durable gold coloured stoved epoxy for the chassis and satin black for the finned magnet cover.

They are to retail at around £49 and £52 respectively, including VAT.



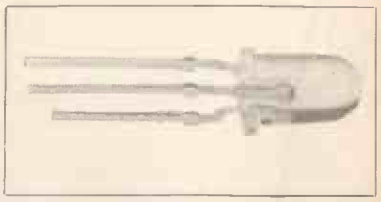


FLAT SWITCH

A bank of 16 or more switches in a thin flexible sheet with an adhesive back that simply sticks on to a metal or plastic front panel has been developed by Molex Electronics Ltd. A thin layer of silver is deposited as a polymer ink onto two sections of a flexible polyester sheet and a thin insulating layer with openings to create a contact gap is sandwiched between them. The connecting wires which can be two for each switch or X-Y matrix etc are brought out as a flat flexible strip. After passing the cable through a slot cut in the front panel, the flat cable is simply pushed into a special connector and plugged onto a pcb. Although at present only available in large quantities to customers' own designs, Molex are planning to produce standard designs which will probably be available through component retailers. Selling at around £3 for a 16-switch bank, they offer a low-cost easy-to-use alternative to ordinary switches.

Molex Electronics Ltd, Holder Road, Aldershot, Hampshire.

MULTICOLOUR LED

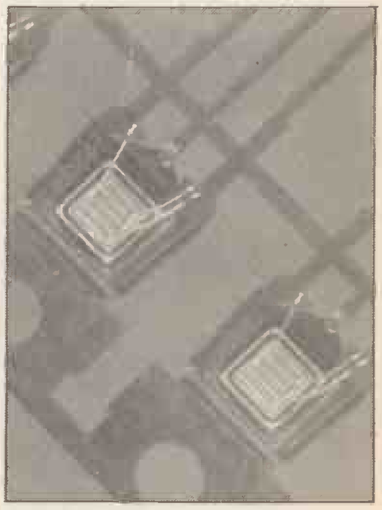


A new idea in light emitting diodes have a green and a red chip encapsulated in a clear epoxy package. Unlike other red/green LED's, this device has three leads enabling both the red and the green to be driven simultaneously. It is therefore very easy to control the drive current to each, to give different levels of brightness of the red and green, and this enables the effective output to be any colour in the spectrum between green (565nm) and red (700nm).

The output light beam, although bright is very narrow and the device is considerably enhanced by using a clear "Cliplite" LED cover also available from this supplier.

Maplin Electronic Supplies Ltd, P.O. Box 3, Rayleigh, Essex.

THYRISTOR WITH GATE TURN-OFF



BTW58's awaiting encapsulation.

A new device to be known as a GTO (gate turn-off switch) is available from Mullard. Like a thyristor, the GTO can be turned on by positive gate drive, but unlike a thyristor if the gate is taken negative the device will switch off. To be known as the BTW58, they will be available with repetitive peak off-state voltages of 1000V, 1300V or 1500V, and an on-state DC current of 5A.

Prices range from about £3 each for the 1000V version and at this price the device should prove very popular, because it combines the high overcurrent capability and high blocking voltage of the thyristor with the ease of gate drive and fast switching associated with bipolar transistors and darlingtons.

Mullard Ltd, Torrington Place, London.

MUSIC MAKER EQUIPMENT SCENE

There is a vast array of equipment on the market at present, and 1981 should bring major innovations at affordable prices. On the keyboard side we are seeing many digital/analogue hybrids, the Prophet 10 from Sequential Circuits features two 61-note keyboards, with 10 complete voices, each keyboard having its own programmer so two completely different sounds can be played at once.

The Roland Jupiter 8 is an 8 voiced programmable unit with a 64 patch storage capability, with one of its special features being an arpeggiator. Oberheim also have some new models in this field, these are the OB-SX, available in 4 or 6 voice configurations. The OB-SX is a preset version of their very popular OB-X.

Going down market slightly, the Moog Opus 3 is worth checking out, with full polyphonic capabilities including Strings/Organ and Brass. It is still able to produce strong polyphonic or lead synth tones.

Introduced into the UK are two new models from Korg, the LP-10 is an electric piano with six way EQ, 3 preset tones which can be mixed and also an inbuilt speaker system. Korg have also introduced the BX3 which is the big brother of the CX3 single manual organ. The BX3 has two 61 note keyboards, full drawbar principles and features an electronic rotary speaker effect.

A very useful unit around at present is the Sescom CT-1A. This is a cable tester in a small pedal type unit allowing you to pinpoint faults in XLR, phono or jack cables.

The guitar manufacturers keep on maintaining the huge quantities of models that we see in our music stores.

Several companies are using famous names, pickups and hardware to expand their ranges. You can now buy "Handbuilt Guitars" from Mighty Mite, there are two models, a lead and bass variation with a one piece mahogany body, solid maple neck with brass bridges/nuts and fittings.

Westbury also feature Di Marzio pickups on their ever increasing range of guitars. Pignose, once known only for their small practice amp have added the 150R Crossmix to their range, the 150R has two complete channels which can be preset to different tones and volumes, allowing the player to switch from channel 1 to channel 2 or being able to crossmix both channels together.

Since Vox amplification was bought over a year ago by Rose-Morris it has been given a new lease of life particularly with a very widely accepted range of FX pedals. The pedals, of which there are seven, come in a newly designed V shape and are very competitive in price.

Morley have increased their pedal scope, a very interesting unit is the Electro-Pik percussion pedal, this allows control of both decay and timbre, the attack can also be manipulated allowing drawn bow effects such as violin, cello and even flute and synthetic sounds are available. The Morley pedals will all act as volume pedals too.

Finally this month, if you are interested in sound and communications equipment encompassing Amps / Mics / Speakers / PA / Studio Equipment and much more, then take a trip to the Sound 81 International Exhibition at the Cunard International Hotel from the 17th-19th February 1981. E&MM

AMERICA

Ian Waugh

This is a monthly column spotlighting the electro-music developments taking place in America, where a lot of major research into electronics and music was pioneered. In spite of ever-increasing advances in this field being made by other countries, America can still offer a few surprises to the electronic music maker. All specifications are based on manufacturers information and should not be constituted as a review.

Probably the most significant development since the 'chip' is the application of digital technology to musical instruments and although such applications have been around since the mid-sixties we are only now seeing such developments in commercial units.

Just to belie the title of this column (and who wants to be pigeon-holed anyway?) one of the most comprehensive designs in the application of digital technology comes from an Australian company called Fairlight Instruments. Their unit is called the Fairlight C.M.I. (Computer Musical Instrument) and the design concept is that any sound can be played in a musical fashion.

Eight waveform memories can hold waveforms of sounds inputted via a microphone or originally defined in terms of harmonics and their envelopes by the synthesist, using a light pen and VDU screen. These can be played independently, or each memory can be given the same sound for 8-note homogenous polyphonic keyboard playing. Since these waveforms can be stored on disc, then modified or blended with others, the system allows a fascinating insight into the nature of sound to be gained by the synthesist and theoretically any sound forms or characteristics can be achieved by a combination of direct and reproductive synthesis.

The keyboard is velocity sensitive and this parameter, along with the positions of various pedal and switch type performance controls, can be assigned to control aspects of the sound such as volume, attack, vibrato etc.

A built-in sequencer facility allows real time recording of music played in from the keyboard, including velocity information, and up to seven tracks can play along with the one being recorded, allowing complex multi-voice compositions to be assembled.

Also included in the system is 'The Composer', a programming language allowing music to be entered via an alphanumeric keyboard and then manipulated in score form using the 'Screen Based Editor'. The language can also compose music directly, in accordance with general rules defined by the programmer/musician.

Capabilities are determined by the programs which are loaded via two floppy diskettes. These can be updated as new programs become available or as the user writes his own.

Con Brio have produced their ADS 100 digital synthesiser with a view to interesting the 'live' musician. It has capabilities for 64 digital oscillators each with independent amplitude and frequency control, and also 128 envelope generators. Information is stored on an 8-inch floppy disc which provides immediate recall of previously determined patches and the disc will also store any previously-played keyboard sequence or alternative tunings. Each oscillator can be individually modulated by envelope generators which consist of 16 separate segments. A video display of the envelopes is provided. Additional voicings for the ADS 100 are available from Con Brio.

Rocky Mount Instruments have launched their DK-20 which is described as a digital combo keyboard designed to meet the demands of the club musician. Factory presets include guitar, piano, flute and clavinet and the sounds can be altered with digital envelope and filter controls. The DK-20 uses digital tone generation in order to produce an extra clean sound. A special feature is polyphonic timbre modulation which puts each note played through complex timbre changes during its envelope. A 'transient' button gives a biting edge to the initial timbre-changing stages to make each note stand out even during heavy chords. It would, perhaps, help prevent the keyboards getting lost behind mountains of guitar amps and speakers. Also included is a built-in mixer for sound blending and stereo output mixing.

New England Digital are now busy promoting their Synclavier II in America and abroad with the phrase 'Synclavier II - its the last synthesiser you'll ever need'. Certainly it appears nearer the musicians concept of a synthesiser than some of the other computer based systems available, since all synthesis functions, and those of the integral 16-track digital recorder, can be controlled directly from the front panel. A button is pushed for the control to be changed, and a single 4-digit numerical display shows the value of the function selected while a large knob is used to increase or decrease it.

A new method of synthesis called partial timbres, along with frequency modulation, immediate recall of stored sounds (including 64 factory presets), and a host of special effects make it an exceptionally powerful live-performance instrument. The Synclavier II is also very compact - the keyboard unit, which holds all the controls, is lighter than a Minimoog and can be carried under one arm. The computer unit is less than 19 inches square and can be sited away from the main console along with the disc drive.

Next month: what you can buy for around $69,000,00 (whoever said, 'Another day, another dollar' *must* have been a musician), plus what's new in some other areas of musical and electronic development in America.

Companies and manufacturers mentioned:

Con Brio, 975 San Pasqual St., Suite 313, Pasadena, CA 91106;

Rocky Mount Instruments, Macungie, PA 18062;

New England Digital, Main St, Norwich, VT 05055.

Fairlight and Synclavier II distributed by Syco Systems (UK) Ltd, 20 Conduit Place, London W2. **E&MM**

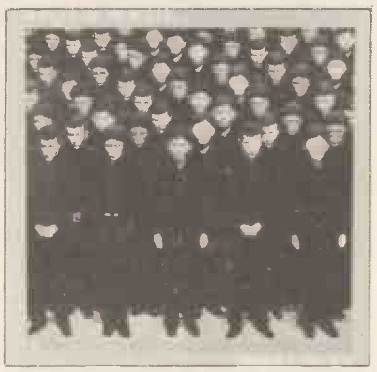
RECORD REVIEWS

X00 Multiplies
by the Yellow Magic Orchestra
A & M AMLH 68518

The latest 'technopop' to invade England from Japan. Since Japan is so busy exporting the latest in electronic technology it is not surprising that its musical exports should also be state of the art. Unlike previous electronic music from Japan, for example Isao Tomita, the Yellow Magic Orchestra's material is original and not just interpretations of well established classical works. Haruomi ('Harry') Hosono, bass and synthesiser player with the Y.M.O., describes their music as a kaleidoscope involving danceable rhythms, heart-piercing melodies and 'a metallic concept meant to massage the frontal lobes'. What the album lacks in musical imagination is compensated by technical production. The Yellow Magic Orchestra produce a clean powerful sound with polyphonic synthesisers and some interesting vocal treatments with vocoders and echo units. Short repeating sequences combined with heavy pulsating drums are often used.

The Yellow Magic Orchestra have fallen into the trap of labelling their compositions with suggestive futuristic titles such as 'Solid State Survivor' (could this be about a transistor which survived a soldering iron placed on its can?) 'Citizens of Science' and 'Technopolis'.

Side One begins with a "Fozzy Bear" voice introducing track 2 with "YMO are ready to lay on ya — 'Nice Age'," which turns out to be a repetitive track featuring vocals reminiscent of M's Pop Music over a very western discorock beat, and with interesting use of time-axis-modulated echo on the harmony vocals. In England the album is released by A&M and is accompanied by a free single but whether it becomes as successful as the work of Isao Tomita is doubtful.



Nevertheless it is well worth a listen, if only to find out what electronic two tone is like and to give your frontal lobes a massage!
Graham Hall.

Short Stories
by Jon and Vangelis
Polydor Deluxe POLD 5030

NOT many people who have followed the development of Jon Anderson and Vangelis could have imagined that the uniting of two talented musicians could produce such imaginative and individual music; both retain their identities yet complement each other so suc-

cessfully.

Short stories is an incomplete overture, stretching sound and tempo in every conceivable direction, leaving one in anticipation of what is to come.

Vangelis seems to have returned to earth, using suggestive melodies, he is able to create extraordinary emotion within his playing, the precise use of the synthesiser and an in depth knowledge of the capabilities of his instrument give him a totally productive nuance, which until now I did not believe he had. Vangelis' importance of exact timing in respect to falling filters, noise modulation and the like makes this a well produced and engineered record with dynamic precision.

All tracks have their own story to tell, the use of sequencing is quite apparent but laid knowingly to produce heaven or hell; very subtle modulations and the sometimes extravagant usage of percussion leads one to listen for the technique involved. I found this difficult due to losing oneself in the images produced.

The music complements the lyrics and vice-versa, Jon Anderson sings with his heart, a distinct empathy and etheral quality emits, he is able to add complex harmonics and rhythm where they should not exist.

Each piece is beyond analysis, it will mean something different to all, the synthesiser has made music here, gone are the long, monotonous free form sound effects that we thought electronic music consisted of, we have here the complete spectrum of sound in pure musical notation. I'm waiting for the next one!
Vince S. Hill.

Travelogue
by The Human League
Virgin V2160

The Human League's second L.P. on Virgin records is an exciting collection of ten tracks characterised by decaying filtered timbres of synthesisers and the strict rhythm created by synthesised drums and cymbals. Philip Oakey's expressive voice stands out from the background of synthesisers putting the emphasis as much on the lyrics as the melodies. Only two of the tracks are strictly instrumental - they are 'Toyota City' and 'Gordons Gin'. Toyota City uses gentle synthesised chimes to invoke an oriental flavour and Gordons Gin

is an electronic version of the catchy theme used to advertise glistening green bottles of a well known spirit!

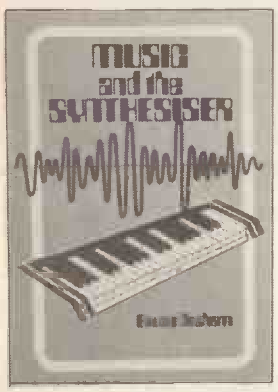
There is a part of The Human League's performance that cannot be gleaned from listening to their albums - their stage act uses slides and video films to enhance the music. Adrian Wright, the visual director, is considered as a member of the band rather than a stage crew tehnician which illustrates the importance of the visual side of their act. An original outfit amongst a new generation of groups producing electronic music - if you cannot get to see them live listening to this album is the next best thing.
Graham Hall.

BOOK REVIEWS

Music and the Synthesiser
by Bruce Graham
Published by Argus Books Ltd.
Price £4.25

The unfortunate thing for anybody writing a book concerning synthesisers is, that by the time the research is completed, the manuscript edited and then published, some parts of the book become out of date. This is what has happened to Music And The Synthesiser, not only has the author taken his base-line from synthesisers that are not readily available and purchased on the open market but he has neglected the Japanese syndrome which was quite apparent and increasing when he researched this project.

If, as Mr Graham implies the book is 'written with the beginner in mind' the transition of relating his ideas to those instruments that a virgin synthesist could understand yet afford would be a very tedious process.



That is not to say however, that this manual is without its merits. The author glides through the history and the explanations of the synthesiser with comparative ease. He then begins to develop further the basic elements of synthesis and their physical relationships. When advancing to the chapter regarding Patching, Signals, Voltage Control and Notation, we are attaining a much higher level than proposed, mainly because there are no synthesisers commercially available which use this type of pin patching, unless second hand. In addition to this, the synthesiser notation used is not seen in today's owners manuals and setting charts, though the explanation of modules in the next chapter seems useful.

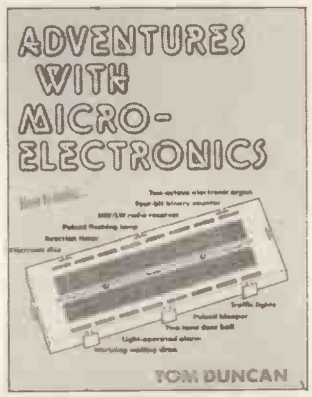
Mr Graham writes also on peripheral units, the use of tape recorders with a synthesiser, this being an extremely important and viable concept today and a helping hand to the newcomer in synthesis. The remaining chapters are all useful in guiding the beginner and intermediate in relating electronics to musical form.

Music And The Synthesiser is a good guide but not mentor, the explanations are valid, healthy and correct, yet the author lets himself down terribly in his glossary, which should be one of the most important parts of a book such as this, when he states that a flanger is 'an electronic phaser'.

Vince S. Hill.

Adventures with Microelectronics
by Tom Duncan
Published by John Murray Ltd.
Price £3.25

It has often been said that book critics only draw attention to an author's shortcomings, totally failing to point out the attributes and unprecedented parts of the text, but with this book that is impossible. Tom Duncan has made a perfect job in both the layout and description of each project represented. The book is aimed at the non-technical but again the author has not been frightened to use up-to-date devices (in particular CMOS IC's) which, as the title suggests, are the theme of the book. A good start is made by giving a brief resume of all the components necessary to construct the circuits given as examples in each chapter. All the circuits are constructed on Bimboard Building Blocks, a description of which is given in the



second chapter. This is followed by a chapter analysing in laymans terms the anatomy and uses of the silicon chip. Each of the ensuing chapters revolves around a different electronic project all of which are cheap and simple to construct.

The format which Tom Duncan uses to represent each project is particularly good. A list of the components required follows a short description of the circuit. This is succeeded by the circuit diagram which is quite graphic in its representation. Next comes a step by step guide to construction leaving no room for error. Notably explicit is the overlay of the circuit on the Bimboard again ruling out the possibility of making a mistake.

The book's only real 'let down' can be found in the section of text entitled 'How It Works'. This tends to be a common misgiving in books designed for the uninitiated - perhaps the beginner would grasp the subject faster and progress to a more technical level if more attention to detail was paid in describing how the circuit really operates. It is only fair to say though that this section does improve progressively throughout the book. Each chapter ends with a few ideas to try out and some suggested alterations to the original designs. These are not fully defined leaving enough detective work for the readers appetite to be whetted but not satiated.

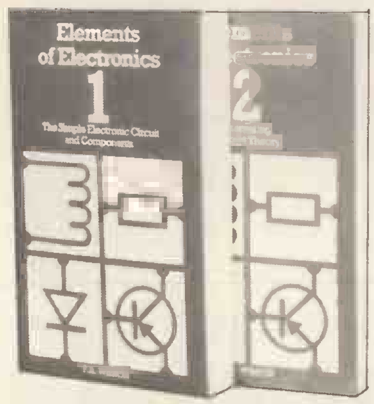
Nigel Fawcett.

Element of Electronics
A set of four books by F. A. Wilson
Published by B. Babani Ltd
Books 1, 2, 3 Price £2.25 each
Book 4 Price £2.95

Having read these books, one's immediate impression is that they are out of the paperback class. They really constitute the sort of invaluable textbook that can be relied upon in every situation and contain much of the information necessary to generate a deeper understanding of all that crops up in the electronics field.

Individually the four books describe the simple electronic circuit and components, alternating current theory, semiconductor technology, and microprocessing systems and circuits.

My initial complaint, having read the books, was that the author has overrated the powers of the microprocessor, and underrated the powers of the



human brain. However, although this is still my indictment, in retrospect the series as a whole will certainly find a home in my bookcase. The abundance of correct formulae and notation throughout the text provides useful reference information.

In brief, the books progress through from; an explanation of the electron and electric current, the sources of electricity, how this applies to the simple electronic circuit, the forces at work within this circuit, the relationships between the components in the circuit, what happens to the circuit if any part of it is altered, waveforms and their effects, time constants, the atom, diodes, transistors and the uses thereof, computers, computer systems, and what makes the computer tick.

Each book is well equipped with appendices, all delving deeply into the mathematics required to elucidate the preceding chapters. All the books are adequately cross-referenced, which by scanning the index, is infinitely helpful for those with a poor memory for theorems.

As previously mentioned, every chapter is armed with enough trigonometry or calculus to dissuade the casual observer from making a purchase. However, my advice is add these books to your collection, for they will undoubtedly provide you with a greater insight into the complex and often difficult subject of electronics.

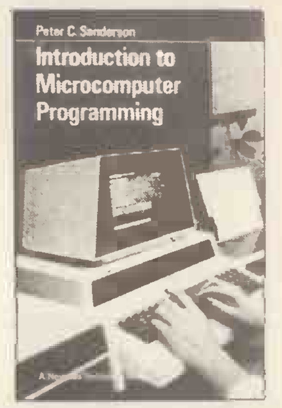
Nigel Fawcett.

Introduction to Microcomputer Programming
by Peter C. Sanderson
Published by Newnes
Price £4.05

This book is aimed at the complete beginner and starts off with an introduction along those lines including one of the best flow charting explanations I have seen.

After basics, the book proceeds to 'Choosing a Computing Programming Language'. This area could have been dealt with a little better, but the determined reader should gain some idea of a suitable language for his programs: Machine code, Assembly language, COBOL, FORTRAN, Pascal, ALGOL, PL/1, APL, and of course BASIC are all covered, although the higher level ones only briefly.

The next four chapters are taken up with a 'crash course' in BASIC. The construction of programs is described in a clear and concise manner and a description of possible differences in



system commands from machine to machine is included. At various stages exercises (with solutions) are provided.

Chapter 7 is a quick guide to types of BASIC, under headings such as: Integer Only, Matrix Instructions, Graphics Facilities etc. Included here is a worthwhile comparison chart covering the BASIC instruction sets of various machines.

The next two chapters deal with Assembly Language and Machine Code programming. Obviously the most difficult area to convey to beginners — this is a brave attempt but without some other publication to explain in greater depth the use of hex, octal and binary, the beginner will start to flounder. On the plus side all examples are shown using the four most popular processors (8080, 6800, 6502, Z80).

The final section deals with program development and testing, explaining how to avoid making errors and find any that do occur.

In summary I would recommend this book to anybody who is considering buying a machine but is not sure whether he is going to be able to compile and write his own programs. If you do purchase a machine it will prove a useful reference book, unlike many others which you may grow out of. In fact the machine code sections you may well grow into.

Graham Daubney.

Patent Place

Patent Place is a regular feature that will describe patents of particular interest to the electronics or electro-music enthusiast, especially where they relate to or offer improvements over existing devices or design techniques, present some totally new idea, or offer scope for further experimentation by the hobbyist.

Many attempts have been made to duplicate the sound of rotating speaker systems for organs using solid-state circuitry to mimic the amplitude and phase modulation effects produced by rotating directional sound sources. Most take the form of signal processors that drive a single amplifier and speaker system, but the invention described by the Roland Corporation in patent specification 1522850 uses a multiple speaker arrangement and modulates the apparent location of the sound source in order to produce a more complete simulation of the rotating speaker sound.

Three speakers are used, equally spaced along a straight line facing the listener. Each speaker has its own power amplifier and voltage controlled amplifier so that the signal level of each can be separately modulated. The centre channel is fed with the input signal directly, while the other two receive a frequency modulated version from a voltage controlled delay element (3 in Figure 1). The VCA's and delay are controlled by signals from the modulation section, which consists of a 0.2 to 10Hz sine wave oscillator (2) and two phase shift networks (P_1 & P_2). Since the modulating signals for the outer channels are 180° apart, and the signal for the centre channel is 90° from each, the modulated signals from the three speakers give the effect of a rotating sound source (Figure 2) with an overall tremolo effect. The delay element is modulated by the same signal as the centre channel VCA, causing the pitch of the tone to be increased as the sound moves towards the listener and decreased as it moves away, simulating Doppler shift and producing vibrato.

A simplified system where the centre signal is mixed with the outer signals for reproduction via two speakers is also described. Both systems were used in the Roland Revo tone cabinets where in three models the speakers were arranged in a single 'Leslie' - type enclosure.

In patent specifications 1510416, the Sansui Electric Company Ltd describe a mechanical reverberation system using a number of tunable vibration elements rather than a spring or plate-type delay device.

The vibration chords are made of magnetic material and are held under tension over two moving iron transducers. A driver amplifier takes the input signal and feeds it to the input transducer (see Figure 3). The chords are simultaneously driven according to the input signal, and the output transducer picks up the vibrations for amplification. The resultant signal is mixed with the original to yield what Sansui call a "chordally emphatic, musically rich reverberation effect". Only the chords having resonant frequencies which correspond to components of the input signal continue to vibrate after the input stops: the other chords stop immediately.

As Figure 4 shows, the chords are held at one end by pegs which can be rotated to tune the vibration frequencies. They are also dependent upon the material of the chords so the resonances can be separated to give a more even reverb effect.

An arrangement is also proposed which uses a similar arrangement of transducers and piano wires fixed at one end only as the vibration elements. In addition alternatives using piezoelectric or electrostatic methods to achieve the same effect are also covered by the patent.

The sounds produced by such devices would be similar to that of a 12/6-string double-neck electric guitar with the volume of one neck turned up while the other is played, or the sympathetic vibration effect of a piano played with the sustain pedal held down. Whether such an effect would be useful for a compound musical signal is doubtful, but it could find application in portable and home organs. **E&MM**

Copies of Patent specifications can be obtained from:

Patent Office.
(Sales Branch),
St. Mary Cray,
Orpington,
Kent,
BRS 3RD

Price £1.45 each

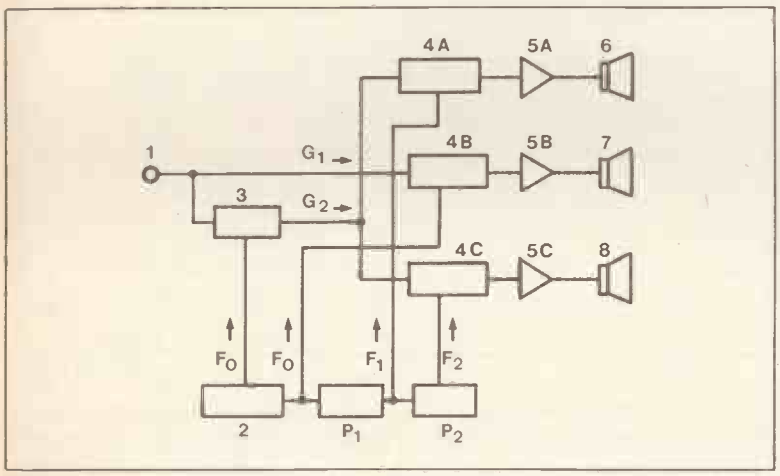


Figure 1.

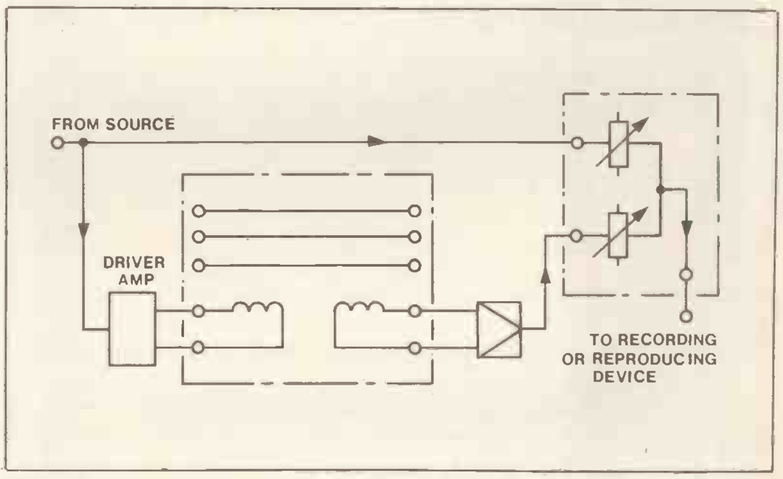


Figure 3.

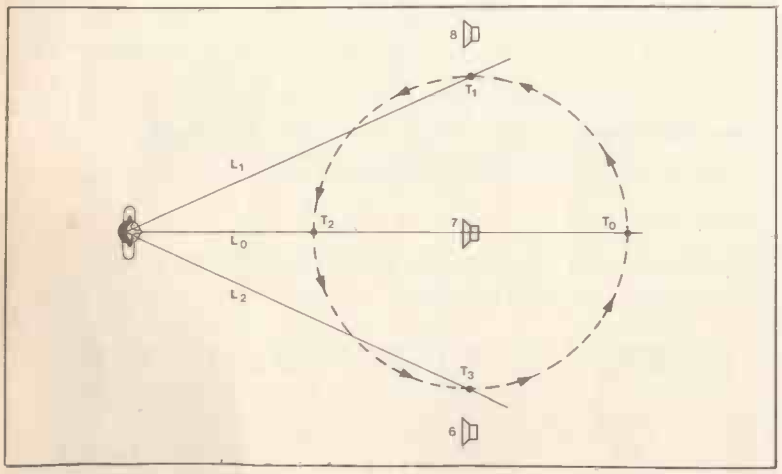


Figure 2.

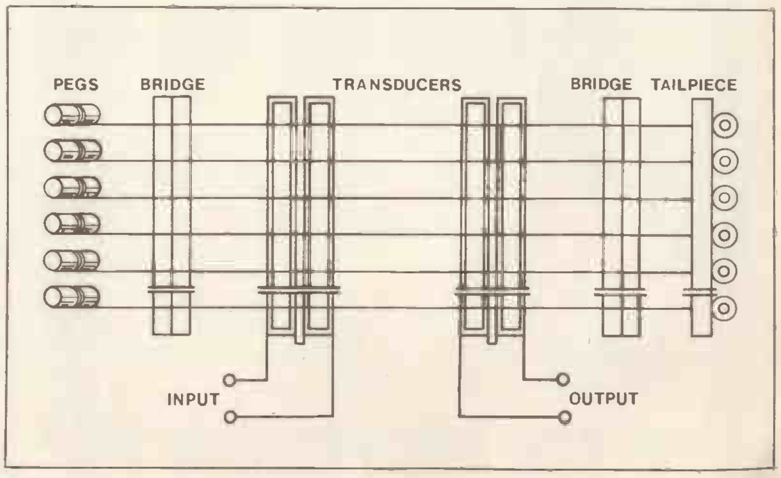


Figure 4.

Electronics & Music Maker looks to the future by choosing projects that use up-to-date technology and features that inform its readers of the latest developments in electronics and electro-music.

Education in its broadest sense is therefore one of the key aspects of this magazine.

It is also exciting that it will be read by teachers and pupils alike through its wide circulation in this country and many subscriptions abroad.

To begin with we are devoting a specific page to education each month so that a 'forum' for teachers and possibly pupils may be established. It is in the teaching of electronics, computing and music that we are most interested to have your views.

From our overwhelming pre-publication correspondence, we have found that many readers have offered to write on subjects that could be of great potential value in secondary and further education.

With the increasing use of electronics in music, the music teacher needs to be aware of developments and ideas that will keep him or her up-to-date. Traditional methods and concepts are not to be ignored, simply expanded to bring the subject in line with the enormous changes occurring — especially in the use of computers to make music and the VDU as a music notation 'blackboard'. Presentation of music appreciation can be enhanced by aural and visual improvements as well.

Similarly, the science classroom can only benefit from staff and pupils willing to provide electronics projects of low cost and yet incorporating the latest circuit devices. Although the teaching of computing does not necessitate knowing how a microcomputer works internally, it is obviously valuable to have practical knowledge for adding peripherals and making improvements.

We shall be interested to hear from anyone who has a short article for publication related to music, computing or electronics.

EDUCATION

You have a problem?

Computers are used in the real world to help solve problems. The trouble is that usually it is a big problem in itself to get a computer set on the right road in this task! In the classroom it is also a problem to know how to start off in the right direction (for *both* pupil and teacher) in tackling *problem solving*.

The computer studies teacher has faced this situation for some time. Now more teachers ought to be involved. This is so because information (or knowledge) is becoming more and more available, so much so that it seems nonsense to cram *facts* into people's heads all the time when they can get hold of those facts at the touch of a few buttons (as is increasingly the case). If you are shocked at this idea, just think. What use is it just to regurgitate facts, rules, and so on in isolation? All too often we hear of people learning something under the heading of, say, 'mathematics' but are unable to apply what they have learned in a closely related subject such as 'physics'. We need to start developing the skills of problem solving across the whole curriculum so that we all may cope with a dangerously complex world somewhat better than we appear to be doing now. Perhaps computing may be used to that end.

Let us think, then, 'how can we learn to solve problems?' Let us start with the computer and ask, 'how do I start programming a computer to help to solve problems?' One approach is to use the idea of 'successive refinement' - or 'top-down development'. With this approach we start with the idea of the problem itself and begin to chop it up into smaller units - or *modules* - tackling each module as we can by further breaking it down into yet more modules until we come to the bare bones of the problem. These bare bones we can then implement on the computer. Flow charting is an essential aid in program development - *and* problem solving.

Figure 1a states that 'we have a problem', and is a form of breaking the ice. Then, for every problem we have associated data - or 'input'; and for every problem we require results - or 'output' (Figure 1b). Can we identify the data? Can we talk of the required results? If we can begin to answer both or just one of these then we may be getting closer to solving the problem.

Every problem has one or more 'keys'; these are principal parts of the problem to solve - and therefore to identify! Can we split 'the problem' into one or more keys? Can we split these keys into smaller units (see Figure 2). If we can split up a problem into these keys and smaller units then we may begin to link them together with a flow chart.

These keys may be regarded as problem modules in their own right. The idea of *feedback* is often incorporated into the problem solving scheme: this is where the various stages of problem solution may be evaluated - it is a little like repeatedly asking a question 'how am I doing now?' (see Figure 3).

In future notes I hope to illustrate this in practice, but not only in traditional computing areas. Control technology and real time processing of information is becoming increasingly important. These, and other notes for guidance, I hope will be of potential use to both teachers and pupils alike.

Steve Leverett. **E&MM**

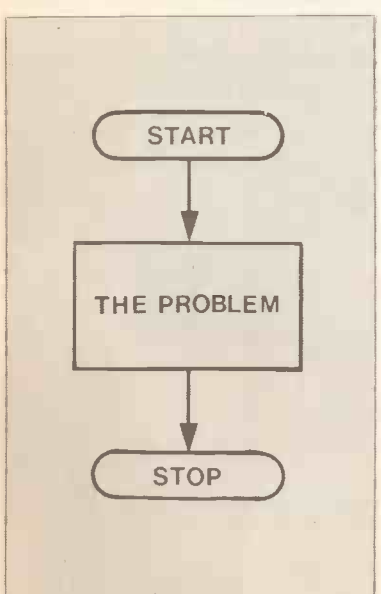


Figure 1a

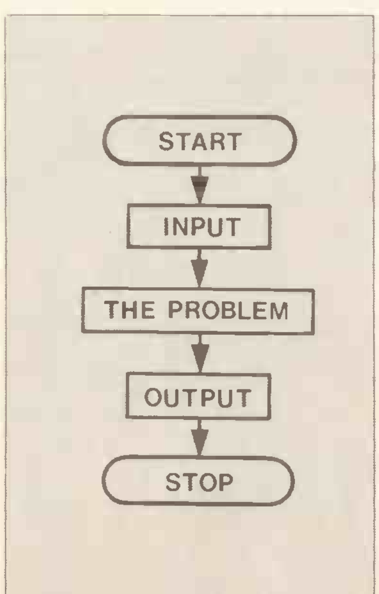


Figure 1b

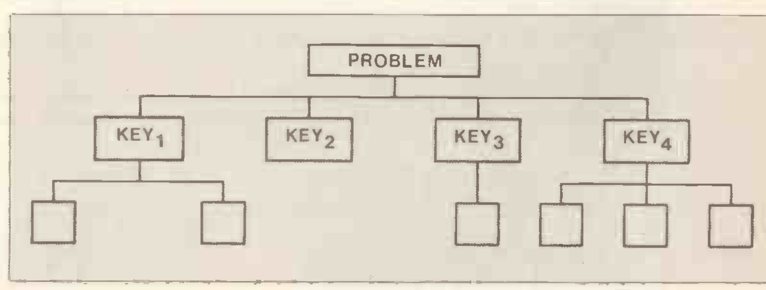


Figure 2

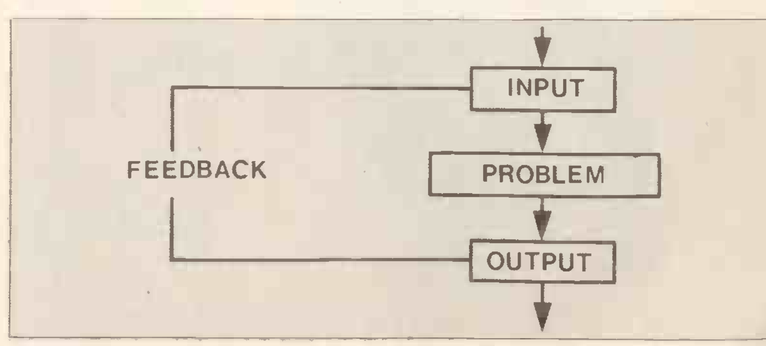


Figure 3


be complete
with
ANTEX
240 V – 15 W
All ANTEX soldering irons have bits which slide easily on and off stainless steel shafts. Inside these shafts are the heating elements for maximum efficiency of heat transfer. There are no screws or screw threads to corrode and stick to shaft. Bits are heavily Iron plated for long life.
Model C
ST3 Stand
A strong chromium plated, steel spring screwed into a plastic base of high grade insulating material provides a safe and handy receptacle for all ANTEX models soldering irons.
Model X25 – 25 watts
A general purpose iron also with a ceramic and steel shaft to give you toughness combined with near-perfect insulation. Fitted with 1/8" bit.
Model SK3 Kit
Contains both the model CX230 soldering iron and the stand ST3. It makes an excellent present for the radio amateur or hobbyist.
Model SK1
This kit contains a 15 watt miniature soldering iron, complete with 2 spare bits, a coil of solder, a heat sink and a booklet, "How to Solder".
SOLDERING KIT
MODEL CX
ANTEX
New Handy Repair Kit
Model CX –17 watts
A miniature iron with the element enclosed first in a ceramic shaft, then in stainless steel. Virtually leak-free. Only 7½" long. Fitted with a 3/32" bit.
the DESIGN CENTRE
how to solder 2
comment souder page 11
lötverbindungen seite 22
Model SK4 Kit
With the model X25/240 general purpose iron and the ST3 stand, this kit is a must for every toolkit in the home.
Model MLX Kit
The soldering iron in this kit can be operated from any ordinary car battery. It is fitted with 15 feet flexible cable and battery clips. Packed in a strong plastic envelope it can be left in a car, a boat or a caravan ready for soldering in the field.
A N T E X
ANTEX (Electronics) Limited Mayflower House, Plymouth, Devon. Telephone (0752) 67377/8

Breadboard Exhibition

A record number of people visited the Breadboard 1980 exhibition at the Royal Horticultural Halls, Westminster, with an increase in attendance of over 50% on last year.

A good time was had by all and everyone we spoke to commented on how smoothly the show ran and how pleased they were with the response to their exhibits. Many of the larger suppliers elected not to sell components on their stands this year, giving their space over to some very impressive projects; ranging from an organ at £23,000 down to an electronic timer for a few pounds. However, components were still extensively supplied by the smaller companies, some of whom reported good sales of scrap PCBs, "dead boards" and bargain packs.

What follows is a brief look around some of the stands.

AURA SOUNDS

Many of the 'Wersi' organs were on show on the main stand, and in the demonstration room Mick Leary put the Wersi 'Helios' through its paces.

CHROMASONIC ELECTRONICS

Although components were on sale, this company was very computer orientated. On show were the U.K. 101, the Video Genie and, of course, Pets.

VERO ELECTRONICS

Ever popular as usual, all Vero products were on show and for sale. Indeed judging by the crowds selling well. A competition was on each day at this stand, with of course Vero products as prizes. Of particular note were a number of small beginners projects, a new area for this company.

BERNARD BABANI (PUBLISHING) LTD

Babani had their extensive range of books on show, which were also on sale. Michael Babani commented: "It was good to get out and meet readers." Throughout the week a number of their authors called in at the stand.

ELECTROVALUE LTD

Computers were much in evidence on this stand with both Nascom and the new Gemini systems being demonstrated. A brisk sale of components was reported and it was interesting to note an on-line computer terminal, allowing customers to place orders direct from the stand.

N.I.C. MODELS

N.I.C. displayed the TRS 80 model 3 computer. The first time this machine has been seen in the U.K. They reported good sales of computer games and games books. At times all you could see of their stand was bobbing heads and flashing lights!

CLEF PRODUCTS

Mr Bootham was on hand to answer any constructors' questions and demonstrate his latest programmable rhythm unit, which was very compact and impressive. The usual range of electronic pianos were also on demonstration, as was an electronic rotor for use with organs or piano.

A. MARSHALL(LONDON) LTD

This was one of the larger companies who elected not to sell components from their stand this year, but they were still present in force featuring among other things a miniature metal detector, the 'Leader' range of test gear and many printed circuit board accessories. Catalogues were available at half price.

MAPLIN ELECTRONIC SUPPLIES LTD

Maplin had a commanding view of the show, with the majority of their exhibits on the stage area of the hall. Atari were in the limelight with their system 800 computer and its amazing 'Star Raiders' plug-in ROM. This was the first time this computer had been on general exhibit in the U.K. Many of the musical projects were being demonstrated, including the new Matinee organ. Books and leaflets were on sale, as was the new 1981 catalogue.

J.P.S.

Featured on the J.P.S. stand were Nascom and Sinclair products. Sales of accessories and components flourished and special discounts were offered on a number of items.

ELEKTOR PUBLISHERS LTD

One of the main attractions on this stand was a programmable TV game. Also, of course, back issues of the magazine, along with a plentiful supply of boards for the projects contained within them. For those who haven't seen Elektor boards, they are the best we've seen.

E&MM's stand attracted a lot of attention, too!

Just a few of the thousands who attended Breadboard.

BOSS INDUSTRIAL MOULDINGS LTD

This company launched a new microprocessor breadboard which will be backed up by instruction on how to build a micro on one board. Their normal range of boxes etc were also on show.

WATFORD ELECTRONICS

Microprocessors were in evidence on the Watford stand, and they also offered a laser kit for under £200. Superboard II was there as was the Video Genie, and there was a special offer on the Base 2 Printer. They were pleased to note people coming from long distances to visit the show.

PRACTICAL WIRELESS

The main feature of this stand was an amateur radio station, which generated an enormous amount of interest. Practical Wireless T-shirts could also be purchased. On one particular day an appearance was made by Mr Brian Rix, who contrary to popular rumour was in fact a guest of Practical Wireless.

T. J. BRINE ASSOCIATES

On demonstration was the new Road-Runner wiring system for use in logic circuit board wiring. This is their own development and features extremely low profile connections that can be made up to five times faster than with conventional wire wrap techniques.

CONTINENTAL SPECIALIST CORPORATION (UK) LTD

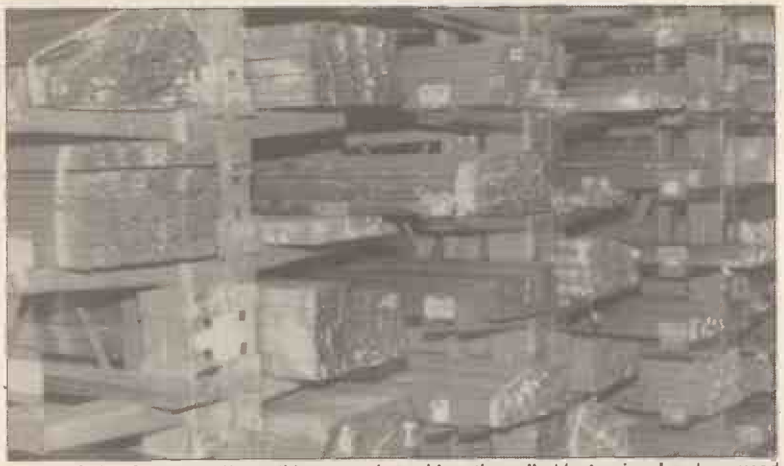
This company made a colourful appearance with a range of their well-known breadboards, both on sale and being demonstrated. Also featured were many items of test equipment. To cater for the many younger people at this exhibition several games and competitions were held on the stand. Mrs Knight told us that their only criticism of the show was the noise level created by the multitude of musical instruments and electronic games. Many other exhibitors also considered this a problem.

AMBIT INTERNATIONAL

Emphasised on this stand were radio components and tuners, with a demonstration of some very up-to-the-minute VHF equipment, which has been described in various magazine articles. DVMs and frequency meter modules could also be seen.

It was particularly nice to see some clubs getting involved. The Association of London Computer Clubs had a stand, as did the British Amateur Electronics Club, and many Electronic Organ Constructors' Society members were present looking for bargains.

It is, of course, not possible to review every stand individually but we hope the above cross-section will give our readers some idea of just what went on. This was the third Breadboard exhibition and without a doubt the best to date. **E&MM**

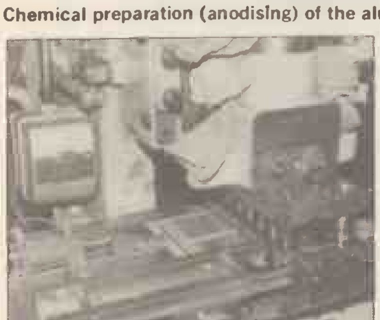


Ingots of aluminium are 'forced' into pre-shaped lengths called 'extrusions' and are used for pillars, box edges etc.

Part of the large factory area for preparing metalwork.

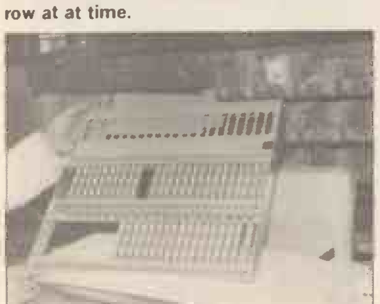
One of the huge presses that cut the sheet aluminium.

Chemical preparation (anodising) of the aluminium to give its high quality finish.

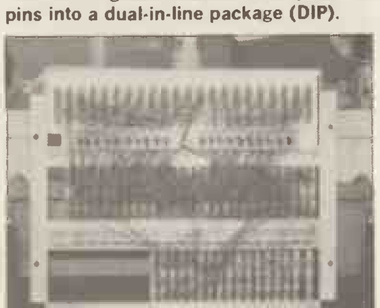


Veroboard holes are machine punched one row at at time.

This rotating drum automatically inserts pins into a dual-in-line package (DIP).



A complex panel of sockets with numbering added as well.



Here's the same panel after wire-wrapping!

INDUSTRY PROFILE

Vero Electronics Limited

To the electronics constructor, the name of Vero must be a very familiar one. It was in 1961 that Vero Electronics was first formed by Mr G. Verdon-Roe (son of the famous aviation pioneer, Sir Alliott Verdon) to manufacture Veroboard, the first commercially available breadboard for use with transistors. With very little competition at the time the demand for Veroboard was high, as it enabled designs to be quickly prototyped and tested.

During the 60's, Vero established its main factories in the UK near Southampton and opened three overseas companies in Long Island, America, in Paris, France and Bremen, Germany.

Since then many different breadboarding sizes and types that have been introduced for industrial use have been made available to the hobbyist.

In 1979 the company was taken over by B.I.C.C. and today its main UK plant has over 500 employees and is divided into 3 product divisions - Card Frames, Circuit Boards, and Enclosures.

At the Card Frame Division are a wide range of facilities for manufacturing card and module frame assemblies and in 1977 a large, automated anodising plant was installed. The Circuit Board Division produces Veroboard, DIP boards, pins, DIP sockets and other accessories. Production tools are also designed and made in the engineering section.

Both metal and plastic cases are manufactured at the Enclosure Division and their output includes numerous boxes for housing constructors' projects.

Some of the more recent cases include sloping fronts, moulded-in battery compartments, flip-tops, keyboard enclosures, tilt legs, two-tone finish, front panel displays, VDU's and 19" card frames for computer boards.

For the microprocessor designer, special prototyping boards with separate multiway connectors, rack power supplies and heatsinks are produced.

If you prefer to etch a PCB yourself, you can use Vero's etch-resist transfers.

Vero Systems is a sister company in the group that produces rechargable wire-wrap guns. This wire-wrap method of connection was developed to cope with the complex wiring of micro-circuit boards. It requires no soldering and uses insulated wire that can be simply routed straight across the board from one point to the next. If you make a wrong connection, the Verowrap gun will also 'unwrap' it for you.

The photographs give you a glimpse of my days visit to the factories based near Southampton. What they don't show is the warm hospitality I received and the enthusiasm which Vero's management have for their products. Because Vero's standards are aimed at industrial level, they pay a lot of attention to the finish and general care of materials at each point of production. Eg. etching takes place in a dust-free room, the powder painting process eliminates unpainted areas on panels and items are often wrapped and unwrapped several times during the assembly of a case.

Some of their most recent developments include 'through-plating' of circuit boards, VDU cases (such as the Research Machines 380Z), cloth textured panels, small pillars made from a single sheet and silk screened panels.

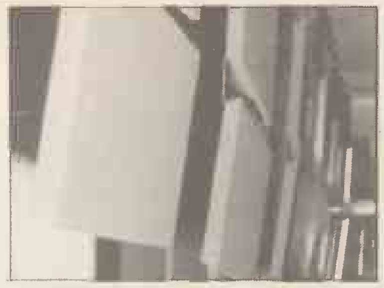
Despite all the technology available, I was surprised to find that Veroboard is mechanically made. Holes are punched out in rows of clear copper coated board. The grooves are then cut to make the track run in one direction.

Most of the metal is anodised. This in fact can insulate, unless a self-tap screw is inserted - so don't always assume a whole metal chassis is earthed from one point! Another process - alochroming - ensures electrical contact between panels.

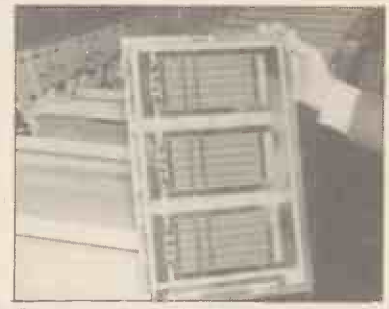
Vero have a strong interest in the hobby market and have a range of Hobbykits for you to build. Their 'Products for the Electronics Hobbyist' book at 40p is a useful reference guide, and their sales staff provides a personal service to retail shops and individual customers to ensure that we get suitable high quality products for our building projects.

If you've never used Veroboard (or already like using it), then make sure you order your copy of Electronics & Music Maker, May Issue when we offer a free board on which you can build any of the specially designed electro-music circuits included.

Mike Beecher. **E&MM**



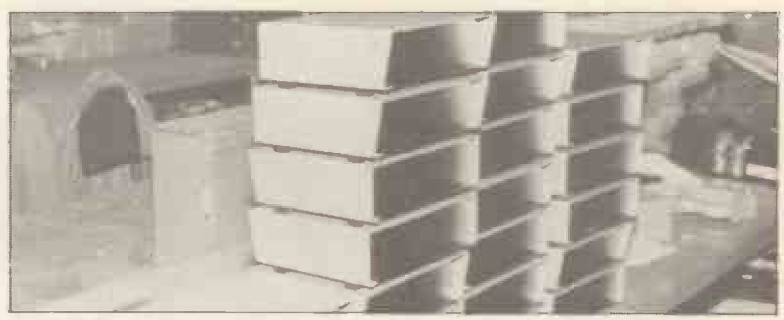
A special painting process where powder is deposited on panels by electrostatic attraction.



Through-plating of Industrial circuit boards is one of Vero's new developments.

A 19" card frame being assembled.

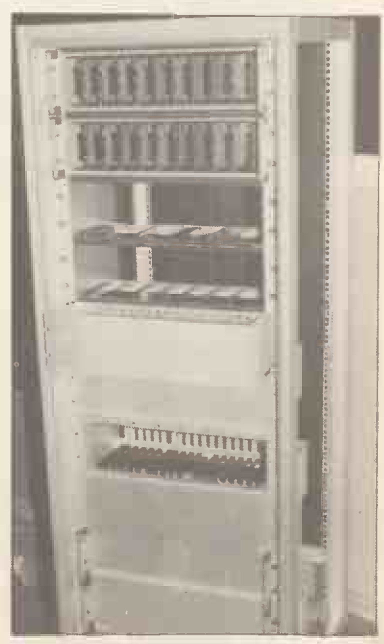
Fitting together the 'G' range cases.



Finished 'G' range cases that have all round accessibility and sloping visor.

Some of the larger boxes including VDU cases.

Mike Humphrey (l) Retail Sales Manager, and John Burns (r) Commercial Sales Manager.



A 'Verorak' kit assembled in 30 minutes, yet as strong and rigid as a welded structure.

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- **Input socket for electric instruments.**
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KORG

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Sharp Electronics (UK) Ltd., Sharp House, Thorp Road, Newton Heath, Manchester M10 9BE.

Citizens Band

This column will be given to news and views on CB and other short range two-way communications, including news of amateur radio.

Let's start this month by introducing CB. This stands for Citizens Band radio which is a radio system for everybody, except in Britain. It started in 1947 in U.S.A. when people had hand held ex-U.S.A.F. walkie-talkies. They were made during the war for intelligence agents who carried them and conveyed information through a special aircraft system called The Joan-Eleanor Project. It consisted of a very small transceiver (transistors were not invented then, so it was valves all the way) on the ground and in the aircraft. The message was transmitted and recorded, then flown back and decoded, and proved to be a successful technique. 260MHz was occasionally used, thus allowing small aerials to be used on the ground based transceiver.

After the war people carried these sets everywhere - then came the guy with the car! This was no problem for he simply fitted a transceiver onto the dashboard. This was the first mobile CB system. After 10 years there were hundreds of thousands of licenced users in the U.S.A.

In 1958 the American F.C.C. brought in the Class D Citizens System. This was on 27MHz and that is where CB as we know it started. It is at present illegal in the U.K. to import, manufacture or use 27MHz for speech modulated transmission. In other words, to make it easy, if you own and use a CB transceiver you are liable to get a £400 fine and/or three months in prison.

At this point, I must say that neither the K.E.B.A. Club (Kent and Essex Breakers' Association) nor Electronics & Music Maker condone the illegal use of 27MHz transmitters at all. We hope in the near future to be able to say "see you on channel!" but at the moment nobody knows if and when this will become possible in this country.

Next month we will bring some news and views of other clubs around Britain and give you more information on the K.E.B.A.'s activities. Let people in your area know about CB (not with T.V.I.) by sending your club's name and phone number where you can be contacted, and we will do our best to help you to help CB.

Till next month stay clean and green.

10-10
The Elf
K.E.B.A.

EVENTS

Feb 17th-19th	'SOUND' 81 INTERNATIONAL EXHIBITION. Cunard Hotel, London (See Music Maker Equipment Scene page)
Mar 2nd-5th	AUTOQUIP EXHIBITION, Wembley Conference Centre, London Car equipment and accessories including in-car-entertainment.
Mar 8th-15th	INTERNATIONAL AUDIO EXHIBITION CIT, Porta-Maillott, Paris
Mar 11th, 13th	MICROSYSTEMS '81 EXHIBITION, Wembley Conference Centre, London Exhibition covers all aspects of microprocessor systems, i.e., Hardware, Software & Peripherals.
Mar 12th-16th	'HOME VIDEO SHOW', Cunard International Hotel, London
Mar 17th-19th	COMPUTERMARKET, Albany Hotel, Glasgow. Aimed at senior management, executives and directors of organisations using or considering the use of computers.
Mar 24th-26th	COMPUTERMARKET, New Centry Hotel, Manchester
Mar 31st	ELECTRONIC TEST & MEASURING INSTITUTE EXHIBITION, Wythenshaw Forum, Manchester
Mar 31st-Apr 2nd	COMPUTERMARKET, Albany Hotel, Birmingham
Apr 1st-2nd	NATIONAL ELECTRONIC CIRCUITS & MICRO ELECTRONICS EXHIBITION, Dallas, U.S.A.
Apr 7th-9th	COMPUTERMARKET, West Centre Hotel, London

We shall be pleased to publish news of forthcoming electronic and electro-music exhibitions, clubs — also special electronic music concerts.

S-2020TA STEREO TUNER/AMPLIFIER KIT

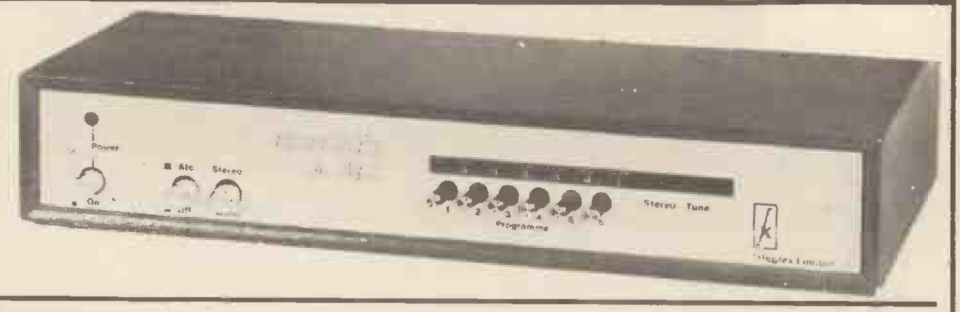
NEW HIGH PERFORMANCE TUNER

A high-quality push-button FM Varicap Stereo Tuner with pilot cancel decoder combined with a 24W r.m.s. per channel Stereo Amplifier, using Bifet op. amps.

Brief Spec. Amplifier Low field Toroidal transformer, Mag. input. Tape In/Out facility (for noise reduction unit, etc.) THD less than 0·1% at 20W into 8 ohms. **High Slew Rate.** Low noise op amps used throughout. Power on/off FET transient protection All sockets, fuses, etc., are PC mounted for ease of assembly. Tuner section uses UM 1181 FET module requiring no RF alignment, ceramic IF INTERSTATION MUTE, and phase-locked IC pilot cancel, stereo decoder, LED tuning and stereo indicators. Tuning range 88-108MHz 30dB mono S/N @ 0.7μV. THD 0.3%

PRICE: £69.95 + VAT

NELSON-JONES Mk. 2 STEREO FM TUNER KIT



A very high performance tuner with dual gate MOSFET RF and Mixer ready built front end, triple gang varicap tuning, linear phase I.F. and 3 state MPX decoder.

PRICE: £74.95 + VAT

NRDC-AMBISONIC UHJ SURROUND SOUND DECODER

The **first ever** kit specially produced by Integrex for this British NRDC backed surround sound system which is the result of 7 years' research by the Ambisonic team W W July, Aug., '77
The unit is designed to decode not only UHJ but virtually all other 'quadrophonic' systems (Not CD4), including the new BBC HJ. 10 input selections.
The decoder is linear throughout and does not rely on listener fatiguing logic enhancement techniques. Both 2 or 2 input signals and 4 or 6 output signals are provided in this most versatile unit
Complete with mains power supply, wooden cabinet, panel, knobs, etc.

Complete kit, including licence fee **£57.70** + VAT or ready built and tested **£76.95** + VAT

S5050A STEREO AMP

Very high performance kit

50 watts rms-channel. 0 015% THD. S/N 90 dB, Mags/n 80 dB. Output device rating 360w per channel.
Tone cancel switch 2 tape monitor switches. Metal case + comprehensive heatsinks.

Complete kit only **£69.95** + VAT

(Also available our 20w/ch BIFET S2020 Amp)

INTRUDER 1 Mk. 2 RADAR ALARM

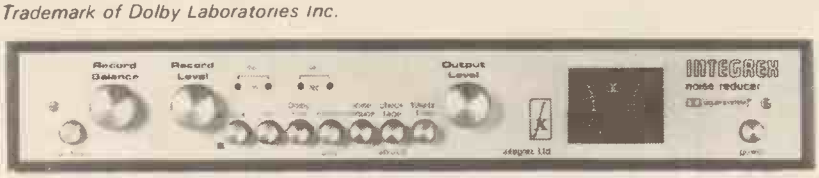
With Home Office Type approval

The original "Wireless World" published Intruder 1 has been re-designed by Integrex to incorporate several new features, along with improved performance. The kit is even easier to build. The internal audible alarm turns off after approximately 40 seconds and the unit re-arms. 240V ac mains or 12V battery operated. Disguised as a hard-backed book. Detection range up to 45 feet. Internal mains rated voltage free contacts for external bells etc.

Complete kit **£52.50** plus VAT, or ready built and tested **£68.50** plus VAT.

Wireless World Dolby noise reducer

Trademark of Dolby Laboratories Inc.



Typical performance
Noise reduction better than 9dB weighted
Clipping level 16 5dB above Dolby level (measured at 1% third harmonic content)
Harmonic distortion 0.1% at Dolby level typically 0.05% over most of band, rising to a maximum of 0 12%
Signal-to-noise ratio: 75dB (20Hz to 20kHz, signal at Dolby level) at Monitor output
Dynamic range >90dB
30mV sensitivity

Complete Kit **PRICE: £49.95** + VAT (3 head model available)

Also available ready built and tested .... **Price £67.60** + VAT
Calibration tapes are available for open-reel use and for cassette (specify which) .... **Price £2.75** + VAT
Single channel plug-in Dolby (TM) PROCESSOR BOARDS (92 x 87mm) with gold plated contacts and all components .... **Price £10.50** + VAT

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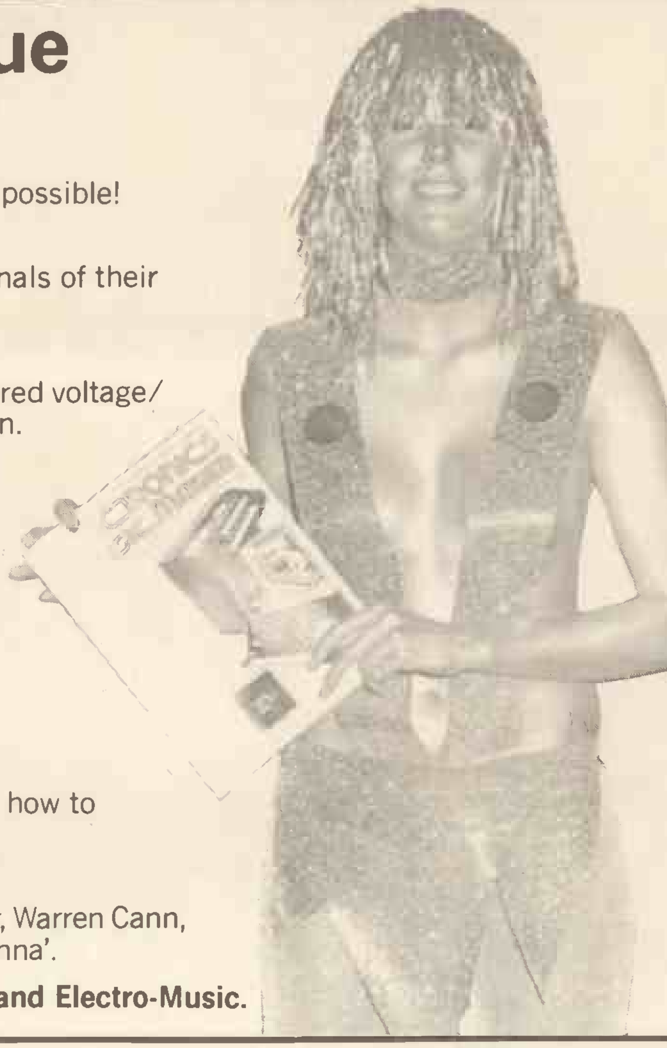
NEXT MONTH – April Issue

on sale at your newsagent from March 12th



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An ideal accessory for the car workshop.

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A versatile unit with applications in the home or workshop.

MATINEE ORGAN
SPECTRUM SYNTHESISER
Continuing these exciting electro-music projects.

STARTING POINT
Part 2 of this informative practical series shows the beginner how to build an invaluable high impedance voltmeter.

ULTRAVOX
A special look at the electronics and music of Ultravox's drummer, Warren Cann, with one of next month's offers including the group's latest LP 'Vienna'.

Plus all our regular articles covering Electronics, Computing and Electro-Music.

FIRST ISSUE SPECIAL OFFERS

Each month, Electronics & Music Maker will be giving special offers to its readers that represent a substantial saving on normal retail prices. Items will be selected that are useful in our specialist area — electro-music.

The LP record BBC Radiophonic Workshop 21 (REC 354) is a real collectors item that introduces the sounds of the BBC Radiophonic Workshop.

Price £2.85
Normally £3.99!

The record selects some interesting music and effects used on radio and television productions, from the Workshop's first electronic music creations to experiments using synthesisers and multi-track recording at the present time.

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1 pr. Insulated Long-Nose Pliers (length 130mm). Perfect for bending and forming fine wire.

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All prices shown include VAT, postage and packing.

QUO ZOG?
by STICHOS

The pattering primordial rain
Made Zog the Caveman think again
That Life was brutish, short and dull,
So, with defiant rebel shout,
Two bones he seized and then beat out
Bold rhythms on an unfleshed skull.

Now Zog the Minstrel tunes his strings
And with his harp a Saga sings
In vaulted, firelit Viking Hall
Telling of Heroes' feats of arms
Opposing Gods with magic Charms
Whilst holding Cowardice in thrall.

Tending his flocks in Greece, Zog knew
Cloven imprints where willows grew
That marked the passing tread of Pan;
But, with syrinx-aided travel,
Sought, by piping, to unravel
The God-given Destiny of Man.

The choleric clang of sword on shield
To Legionary Zog appealed,
And Cohorts thought him worth his salt
Because his need for rhythmic beat
Was satisfied by marching feet,
With contrapuntal cries of 'Halt'.

The world of Zog the Brit seemed good
So he - as true-blue chappie would -
Takes God as Partner without qualms,
Takes rosin-tortured gut and plays
Bland tunes, (near swamped by clatt'ring trays),
Beneath the shade of indoor Palms.

Zog - as a slave - laden with gyves -
In a strange land - 'mid stranger lives -
Blew soft on reed with poignant art
And made the golden surface-gloss
O'er ride the silver pain of Loss,
As Music can - played from the heart.

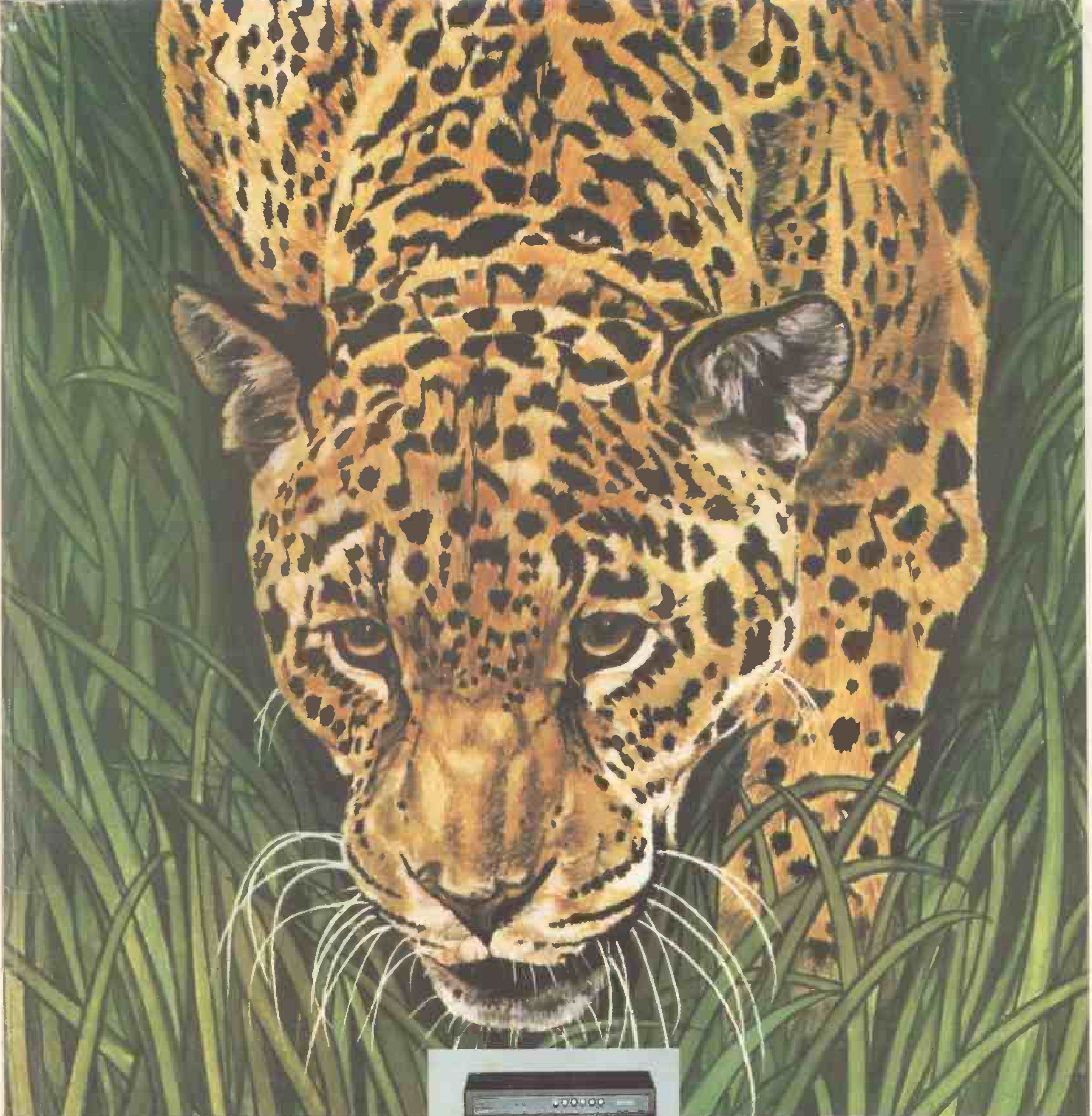
Compuphonic Zog the Euro
Screams defiance in crescendo
Unfearful of a Wrath Divine,
While the searing Laser's flicker,
And drum-beats made forever quicker,
Means the skull that's pounded now - is mine!

Thus we skim the mellifluous pages
Of Mankind's music through the ages;
But, as we end the present text -
We wonder what will happen next?

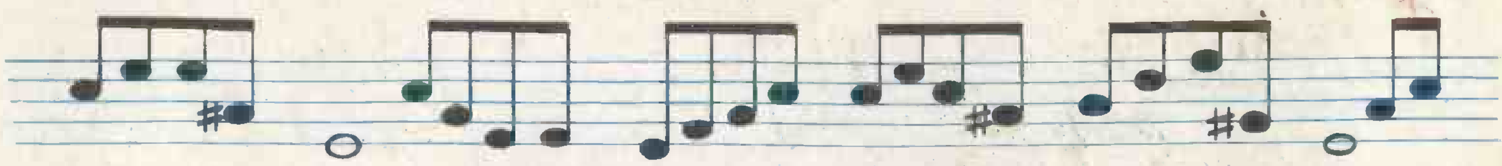
ADVERTISERS INDEX

The symbol above will represent Electronics & Music Maker and portrays our aim to bring together electronics and music — through its bold 'E' on an oscilloscope grid and its double 'M' sound waveform that begins with a suggestion of traditional notation.

It is your assurance that projects and circuit boards have been carefully prepared, tested and approved and is your guarantee that our magazine provides informative and accurate editorial for the electronics and music maker.



Make it for a Song!



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Full construction details start in this issue of Electronics & Music Maker.

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