VOCODER

Change sex or orchestrate yourself (same thing, really) with the ETI Vocoder, designed by Richard Becker of Powertran.

A vocoder could be simply defined as a device which will, in real time, superimpose the spectral characteristics of one signal upon another. To leave it at that, however, would result in many a yawn and a few skipped pages. In fact vocoders are anything but boring! Put speech and the output of an instrument into a vocoder and the instrument, not the operator, appears to be doing the talking or singing! Use the internal excitation oscillators, change the frequency and the speaker suddenly changes sex. Use the noise generator and there is whispering in the breeze. Use the output of a cassette deck and the London Symphony Orchestra recites the Karma Sutra! Just a few of the possibilities!

Human speech is built up from two basic components — the sound from the vocal chords which buzz when air is passed over them and the sound of air rushing past the teeth. These sounds are used to produce voiced and unvoiced speech respectively. By opening and closing the mouth and the nasal cavity, and by moving the tongue, thereby adjusting the resonances, the basic sounds are modified in amplitude and harmonic content. If the variations in amplitude and harmonic content can be analysed and applied to suitable electronic control circuitry then the basic sounds of speech can be substituted for by almost anything and this is just what a vocoder does.

The first part of a vocoder is a spectrum analyser producing control signals which are a measure of the strength of the speech signal in each of the frequency bands (14 in this design). The substitution (excitation) signal is also split into a number of frequency bands (using identical filters to those used for analysis) and each of these signals is passed through a voltage controlled amplifier whose gain is determined by the control signals. The sum of the outputs of these amplifiers is the vocoder output.

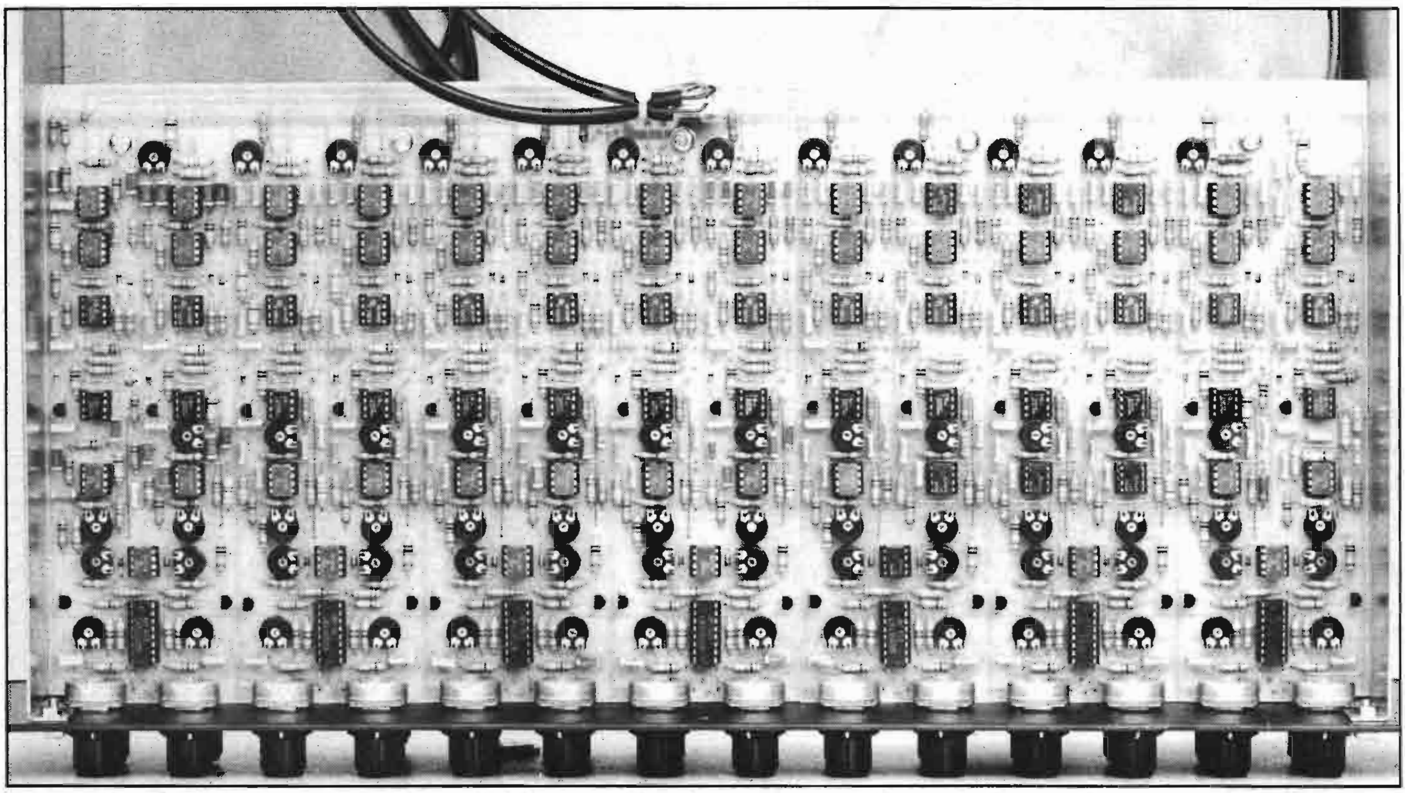
The system

The speech signal, after passing through the pre-amplifier and tone control stages, is separated into 14 bands by bandpass filters, a low pass filter and a high pass filter. The bandpass filters are double tuned that is to say each of the two stages has a slightly different resonant frequency. The effect of this is to broaden the band of accepted frequencies and give the response curve a flattened top. A high Q makes the filters cut off rapidly out of the pass bands.

The envelope followers consist of an active full wave rectifier and a low pass filter, the output of which is the control signal for the synthesiser section. The control signal passes through a sample and hold stage which is used to freeze the music, by means of a footswitch, at any required point of articulation. The stage is also used for slewing rate control which smooths out the control signals for slower and smoother changes in spectral balance and amplitude resulting in speech being changed into singing or chanting.

Holy Responses

In the synthesis section there is a filter bank identical to that of the analysis section. Voltage controlled amplifiers modulate the outputs of these with the control signals from the analysis section. The outputs are then summed to produce the output signal. Alternate channel outputs are inverted since there is a change in phase as a signal is swept through the resonant frequency of the filter. Therefore, at the midpoint between adjacent bands phase cancellation will occur producing deep holes in the overall frequency response. By having adjacent channels outputs inverted with respect to each other there is addition instead of subtraction at the midpoints.



The analysis/synthesis board occupies the front half of the case. All the potentiometers are PCB mounting for ease of construction. The Power Supply Unit (to be described next month) is a respectable distance away, mounted on the rear panel.

SPECIFICATION

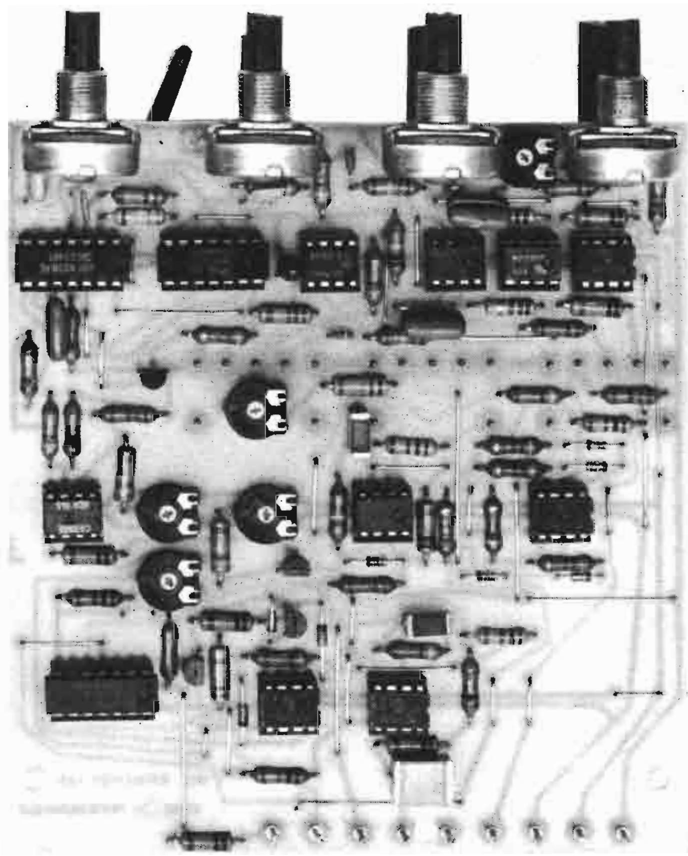
14 channel: Filters — 4th order with bandpass filters at ⅓ octave spacing.
LED Bar Display PPMs for both speech and excitation.
Speech input: amplifier:
mic input: sensitivity 1 mV
mic input: impedance 100k
line input: sensitivity 500 mV
line input: impedance 10k
tone control: ± 6 dB Treble boost — Bass cut/Bass Boost - Treble cut.
excitation input amplifier:
low input: sensitivity 10 mV
low input: impedance 100k
high input: sensitivity 500 mV
high input: impedance 10k
tone control: ± 6 dB Treble boost-Bass cut/Bass boost-Treble cut

Internal excitation:
pseudo-random counter noise generator
2 oscillators — range: 15 Hz-250 Hz
pulse width: fully variable

Slew rate control: 100:1 range. FREEZE by footswitch

Voice/unvoiced detector:
AGC on noise generator to follow excitation signal

Output amplifier:
mixing controls for vocoder, speech bypass and external excitation bypass
Output level: 1V



The internal excitation board.

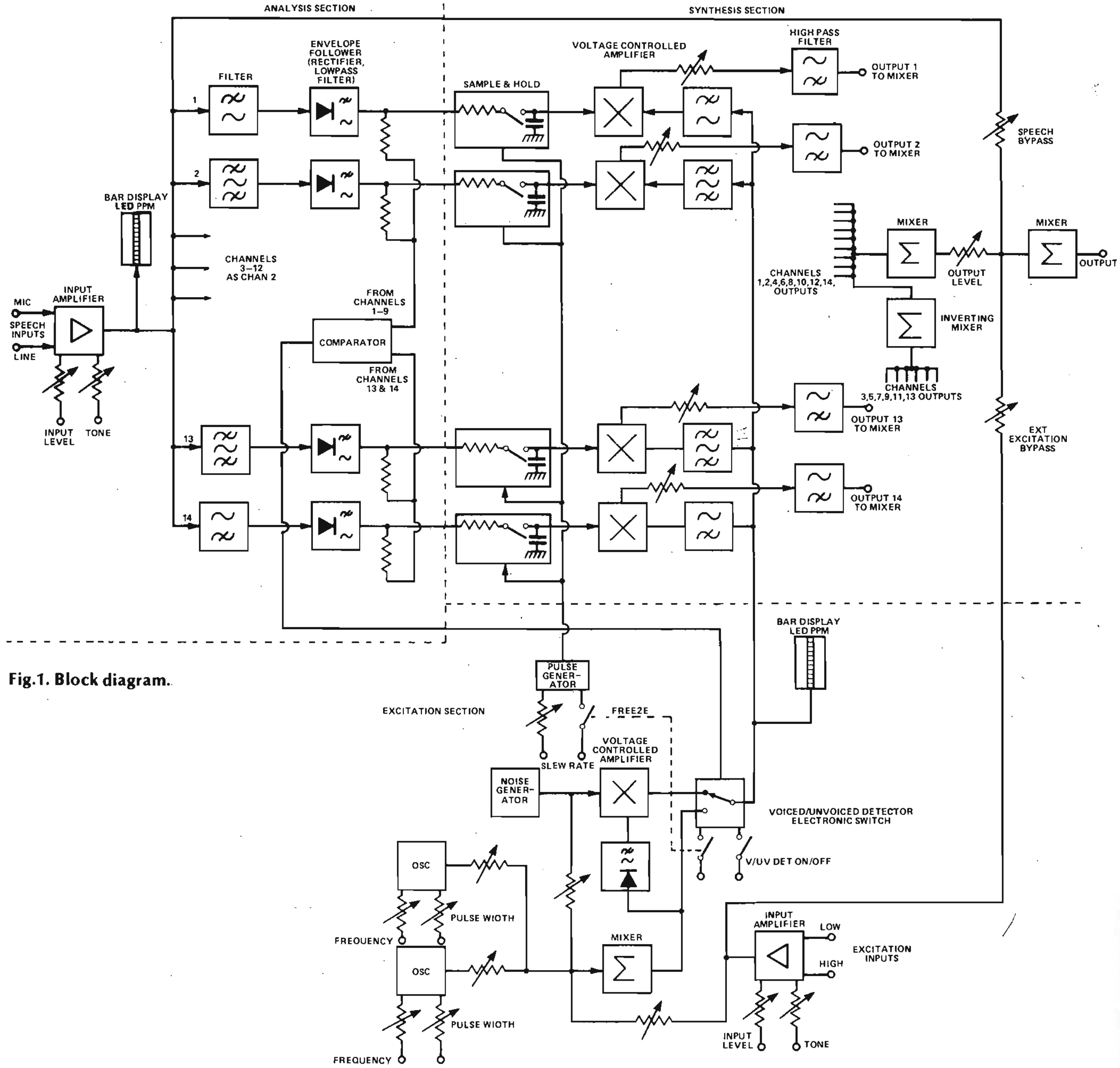
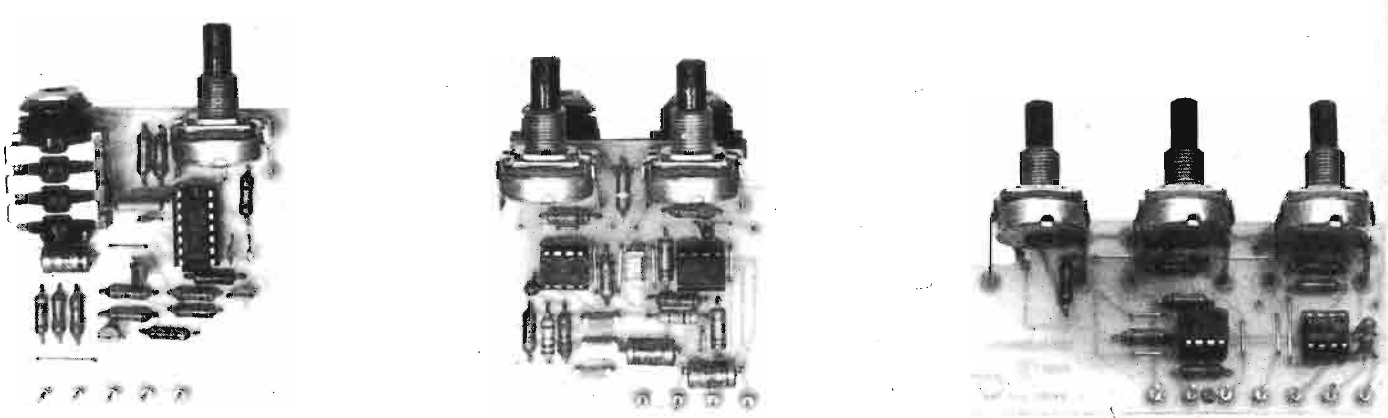
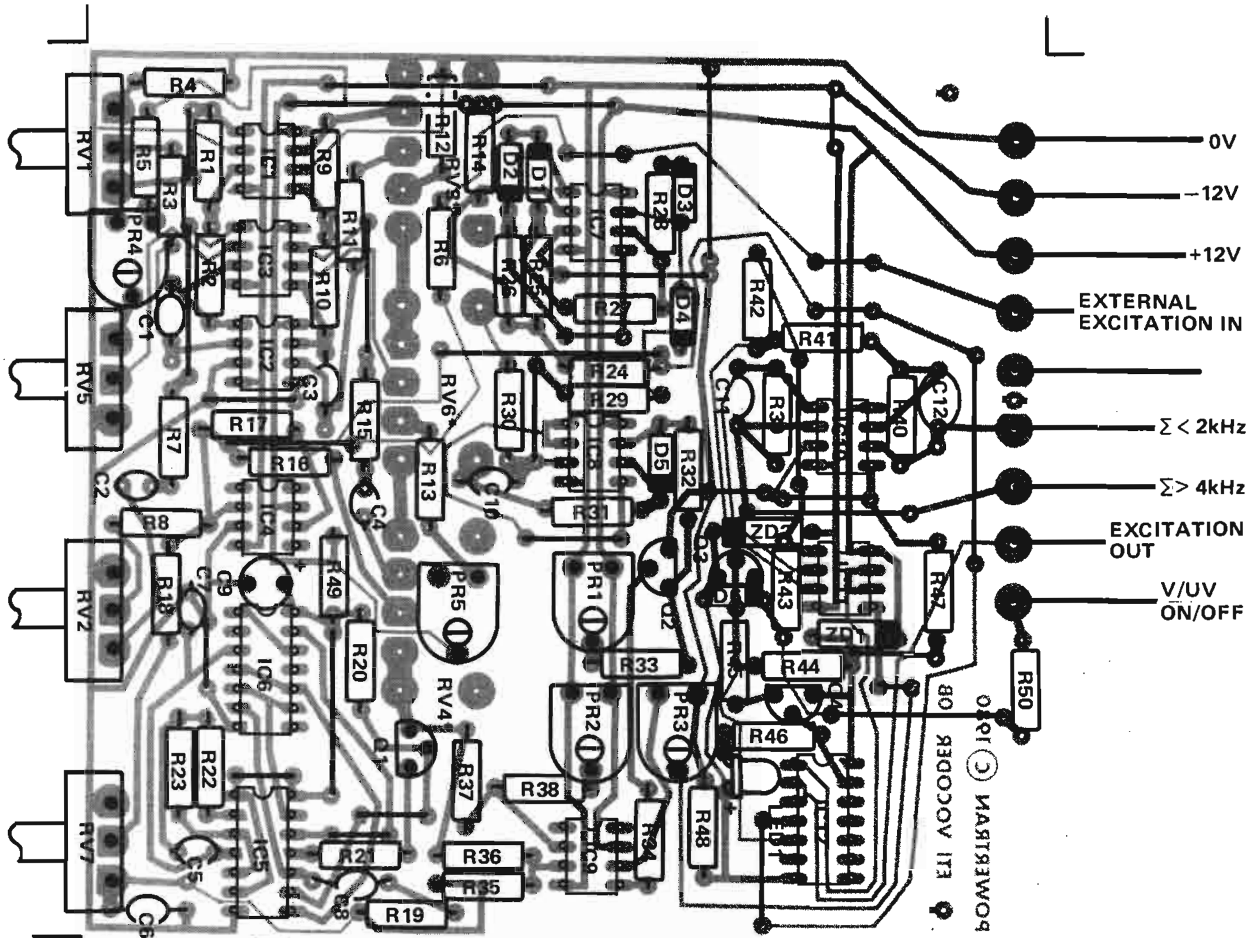


Fig.1. Block diagram.



Details of the smaller boards devoted to slew rate control (left), input amplifier (middle) and output amplifier (right) will be given in the concluding part of the Vocoder project next month.



NOTE:
*RV3, 4 & 6 ARE ON THE UNDERSIDE OF THE BOARD

Fig.2. Component overlay of the internal excitation board.

PARTS LIST

RESISTORS — ALL 2% METAL OXIDE

R1,9,29,34,40,44,45,50	10k
R2,10	5k6
R3,11	18k
R4,12	560R
R5,13	11k
R6,8,16,18,35,39,43	47k
R7,15	150k
R14,30,42	1M
R17	100k
R19	15k
R20,24,25,26,27,28	4k7
R21,32	22k
R22	330k
R23	27k
R31	3k9
R33,38	470k
R36,37,46	1k5
R41,47,48	1k
R49	3k3

POTENTIOMETERS

RV1,2,5,7	10k logarithmic
RV3,4,6	10k logarithmic
PR1,2	100k preset
PR3	220k preset
PR4,5	2k2 preset

CAPACITORS

C1,3	100n polyester
C2,4	10n ceramic
C5	220p ceramic
C6	33n polyester
C7	100p ceramic
C8	10n polyester
C9	10u 16V tantalum
C10	100n polycarbonate
C11	220n polycarbonate
C12	1u0 polycarbonate

SEMICONDUCTORS

IC1,2,7,10,11	1458
IC3,8	TL082 or LF353
IC4	741
IC5	4006
IC6	4030
IC9	CA3080
IC12	4016
Q1,3	BC182L
Q2,4	BC212L
ZD1,2	5V1 Zener
D1-D6	1N4148
LED 1	TIL209

MISCELLANEOUS

9 way connector and pins, IC sockets, terminal pins, rotary on/off switch.

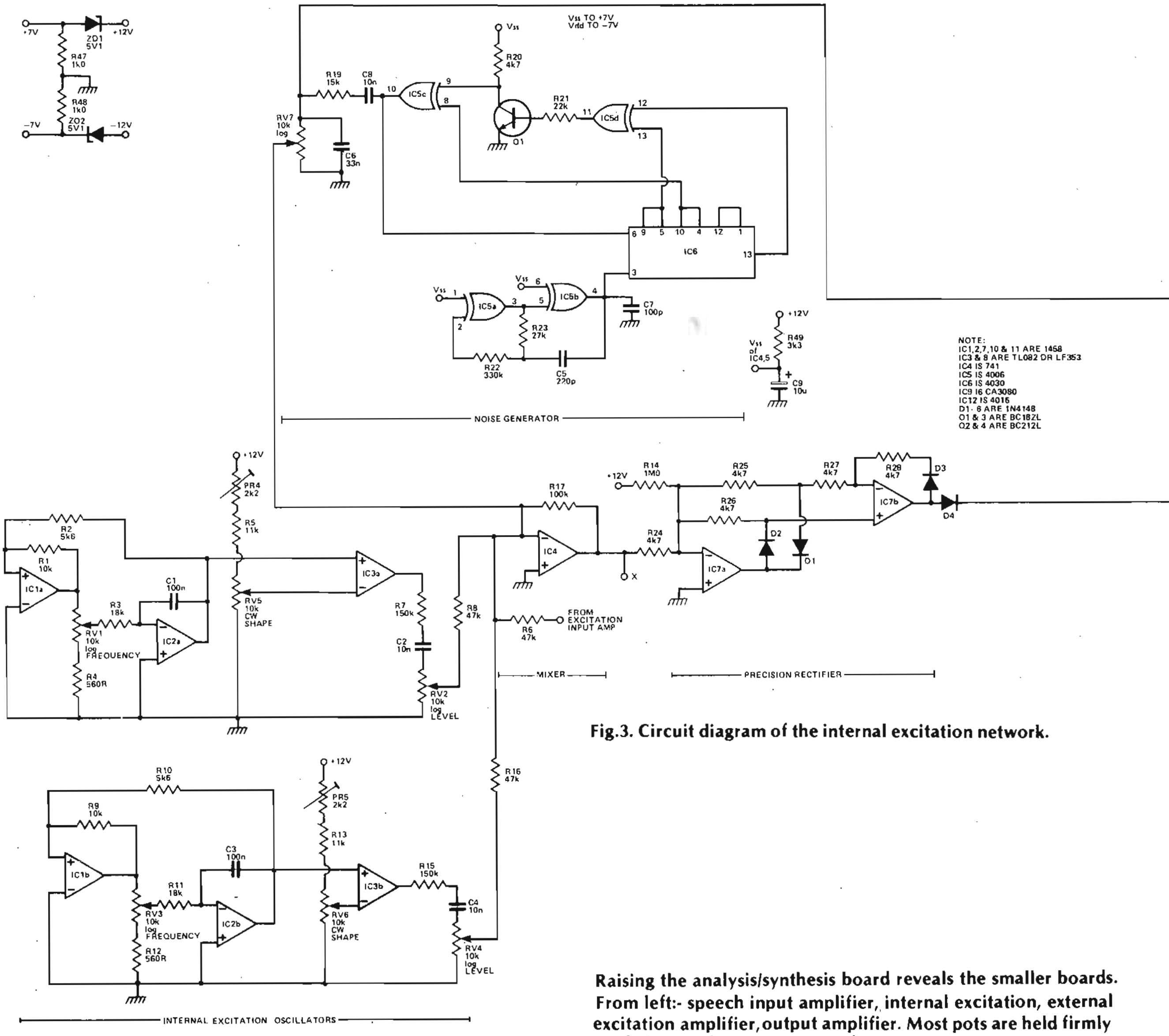
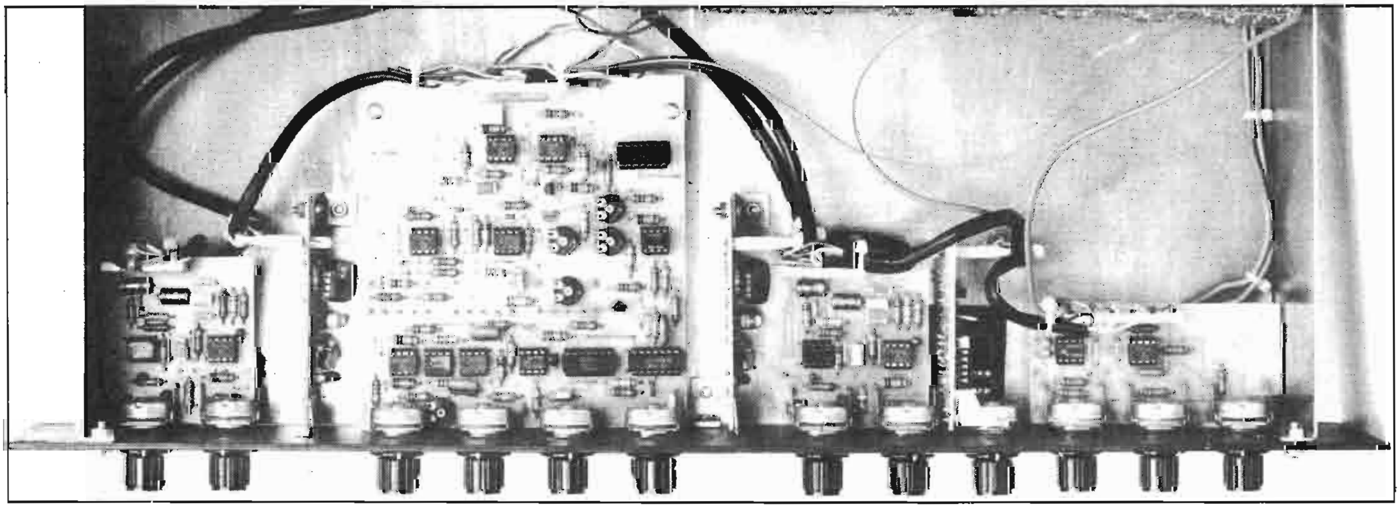
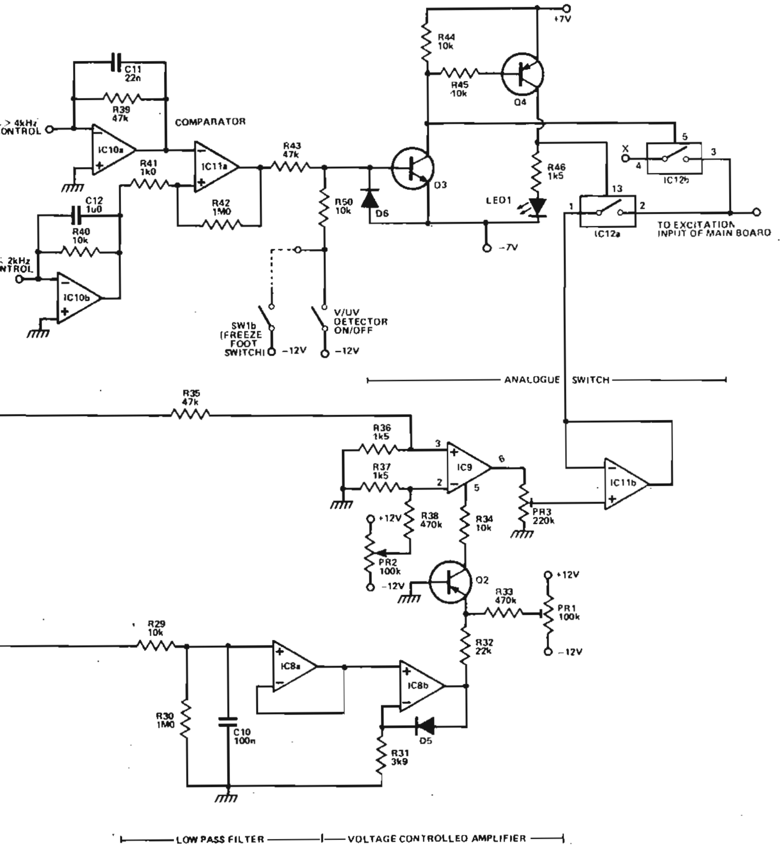


Fig.3. Circuit diagram of the internal excitation network.

Raising the analysis/synthesis board reveals the smaller boards. From left:- speech input amplifier, internal excitation, external excitation amplifier, output amplifier. Most pots are held firmly on their PCBs by pot mounting frames.





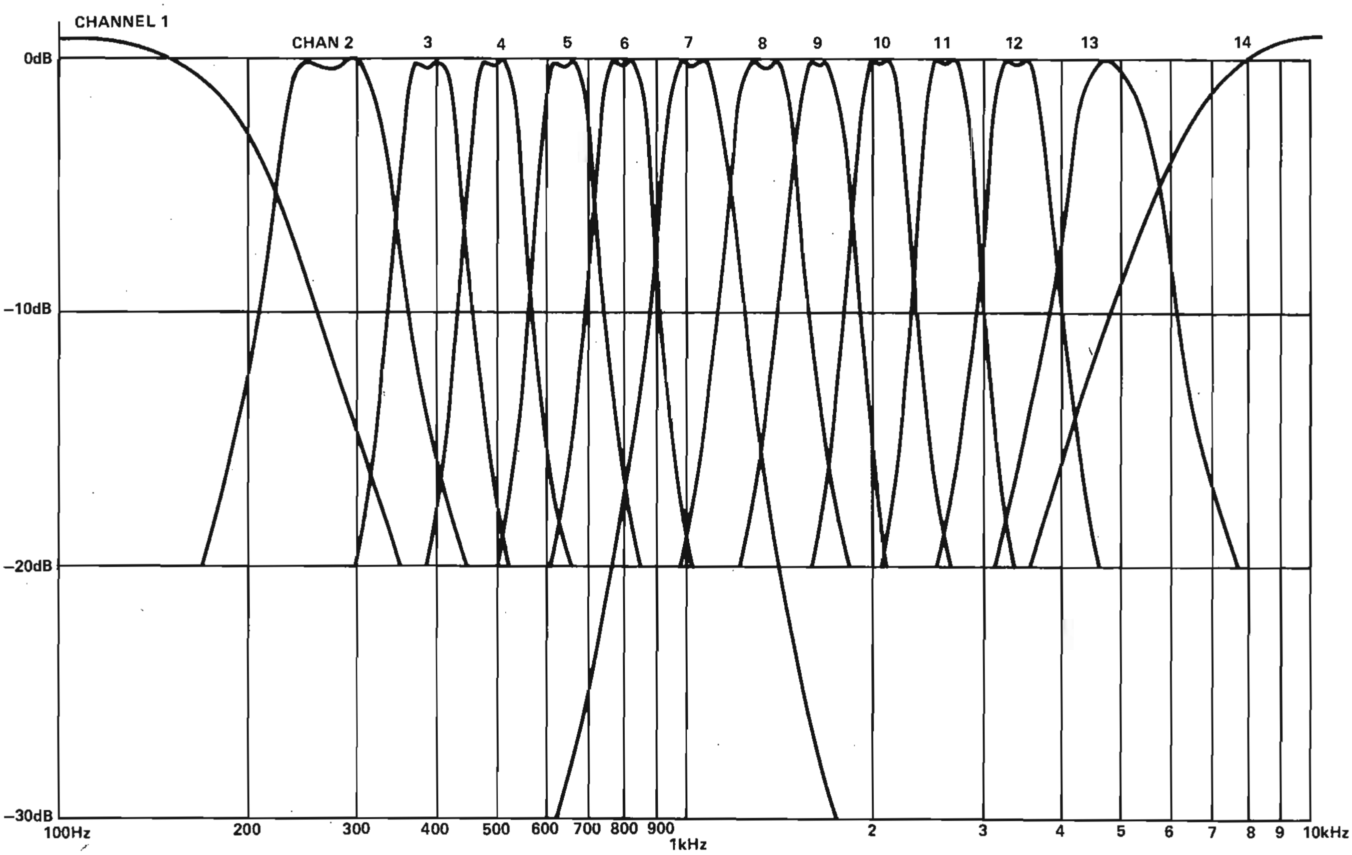
HOW IT WORKS

IC1, 2 form a pair of relaxation oscillators. IC2 is an integrator driven by the output of IC1. C1 is charged until it reaches about one third of the supply line voltage when the Schmidt trigger (IC1) changes state and C1 starts discharging until it reaches about one third of the supply line voltage in the opposite direction, making IC1 change state again. The output of IC2 is a triangular waveform which is compared with an adjustable DC voltage by IC3 to produce a pulse output of adjustable mark/space ratio. The outputs of the two oscillators are mixed with the external excitation and the noise by IC4.

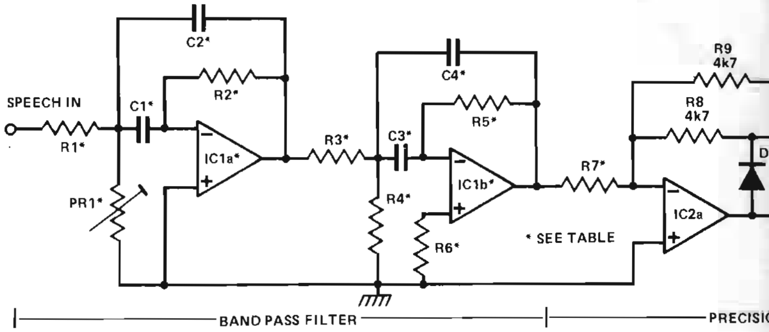
The noise generator is a pseudo-random counter. IC5a,b form an oscillator operator at about 40 kHz. This clocks IC6, which is an 18 stage shift register with feedback applied round it via IC5c, d and Q1. The output of IC5c is a complex pulse train, which, when filtered by C8, R19, C6 has the characteristics of random noise with a very even frequency response.

The key part of the voiced/unvoiced detector is the comparator IC11a, which compares the levels of the speech components over 4 kHz with those below 2 kHz. It is not necessary to use separate filters for this purpose as the control signals at the outputs of IC3 of the analysis section contain the necessary information and these are summed by IC10a, b before comparison. When voiced speech is present IC11a goes low, Q3 turns off, its collector goes high and the analogue switch IC12b is opened allowing the output of IC4 to pass to the synthesis section. To match the noise level to that of the excitation from IC4 there is AGC. IC7a is a full wave rectifier peak detector which is buffered by IC8a. IC8b and Q2 are a voltage to current converter to provide a control current for the OTA IC9 through which the noise is passed.

Fig.4.(below) Filter frequency response curves.



For external excitation, there is a pre-amplifier and tone control circuit similar to that used for speech. The output of this stage is mixed with the two oscillators (which generate pulses of variable width and frequency) and also with the output of the noise generator. The noise also passes through an AGC circuit to match its level to the excitation signals. This noise is then used to substitute for the other excitation signals by the voiced/unvoiced detector electronic switch when unvoiced speech is detected by the comparator which determines whether the majority of the energy in the speech is at low frequencies (2 kHz — voiced) or at high frequencies (4 kHz — unvoiced).



BUYLINES

Next month we conclude the Vocoder project with constructional details of the remaining boards and power supply, with notes on setting up and use.

HOW IT WORKS

IC1 in channels 2-13 is the analysis bandpass active filter. PR1 adjusts the first section in relation to the second. When correctly set up there is an overall voltage gain of 10. In channels 1, 14 IC1 is a low pass filter and a high pass filter respectively. IC2 rectifies the signal to demodulate it to convert it into a control signal for the VCA. IC3 is an active low pass filter with a cut off frequency of 200 Hz or one fifth of the frequency of the bandpass filter, whichever is the higher.

R14 takes the output of IC3 out for analysis by the voiced/unvoiced detector. IC4 is the slewing rate controller, Q1 and R15 acting as a variable resistor which, in conjunction with C7, forms an RC network adjustihe slewing rate controller, Q1 and R15 acting as a variable resistor, which, in conjunction with C7, forms an RC network adjusting the slewing rate of the stage. Being a FET Q1 could, on its own, be used as a variable resistor by simply varying the V_{GS}, but there are 14 of them to control simultaneously and without careful selection they would not track together. To deal with this Q1 is used instead as a switch which is turned on and off by a 1 kHz pulse signal of variable width. C7 is then charged and discharged at a rate dependent on the duty cycle of the pulse signal and R15. During the ON period V_{GS} is maintained at O by the feedback via R17.

IC5 and Q2 form a voltage to current converter, the gain of which is set by PR2 to compensate for variations in gain in IC6. For correct operation IC5's input must never go negative. To ensure that it doesn't, a bias voltage is applied via R15. This voltage together with the combined offset voltages of IC1-5 is nulled out by PR3.

IC6 is an OTA (operational transconductance amplifier), which could have been our old friend the CA3080, but a better device, the LM13600 is now available. It achieves very low distortion by having linearising diodes at the input. Bias current for these is supplied by R28. The gain is controlled by the current supplied to pin 1. The output of the OTA is taken to a volume control RV1 from where it goes back into IC6 to a buffer stage before being taken out via C12 and R30 to a virtual earth mixer. C12 and R30 serve as a high pass filter to remove breakthrough of the control signal. The excitation or music signal is applied to the OTA via IC7 which is a filter identical to that of IC1.

CHAN	PR1,5	R1,21	R2,22	R3,23	R4,24	R5,25	R6,26	R7	R12,13	C1,3,8,10	C2,4,9,11	C12	IC1,7
1	–	10k	10k	2k0	220R	10k	10k	4k7	68k	47n	150n	220n	TL082/LF353
2	2k2	2k0	82k	24k	910R	110k	110k	4k7	47k	68n	68n	47n	1458
3	1k0	6k2	180k	47k	560R	220k	220k	4k7	30k	39n	39n	33n	1458
4	1k0	6k2	180k	47k	430R	220k	220k	4k7	24k	33n	33n	27n	1458
5	1k0	6k2	180k	47k	430R	220k	220k	3k6	18k	27n	27n	22n	1458
6	1k0	6k2	180k	47k	430R	220k	220k	3k0	15k	22n	22n	18n	1458
7	1k0	6k2	180k	47k	560R	220k	220k	2k4	12k	15n	15n	15n	1458
8	1k0	6k2	180k	47k	560R	220k	220k	1k8	12k	12n	12n	12n	1458
9	1k0	6k2	180k	47k	510R	220k	220k	1k5	12k	10n	10n	10n	1458
10	1k0	6k2	180k	47k	470R	220k	WIRELINK	1k2	12k	8n2	8n2	8n2	TL082/LF353
11	1k0	6k2	180k	47k	430R	220k	WIRELINK	1k2	12k	6n8	6n8	6n8	TL082/LF353
12	1k0	6k2	180k	47k	560R	220k	WIRELINK	1k2	12k	4n7	4n7	4n7	TL082/LF353
13	2k2	2k0	82k	24k	1k1	110k	110k	1k2	12k	3n3	3n3	4n7	1458
14	--	13k	43k	2k0	220R	43k	13k	1k2	12k	1n0	1n0	4n7	1458

Table 1. Component values for the 14 channels of the analysis/synthesis section.

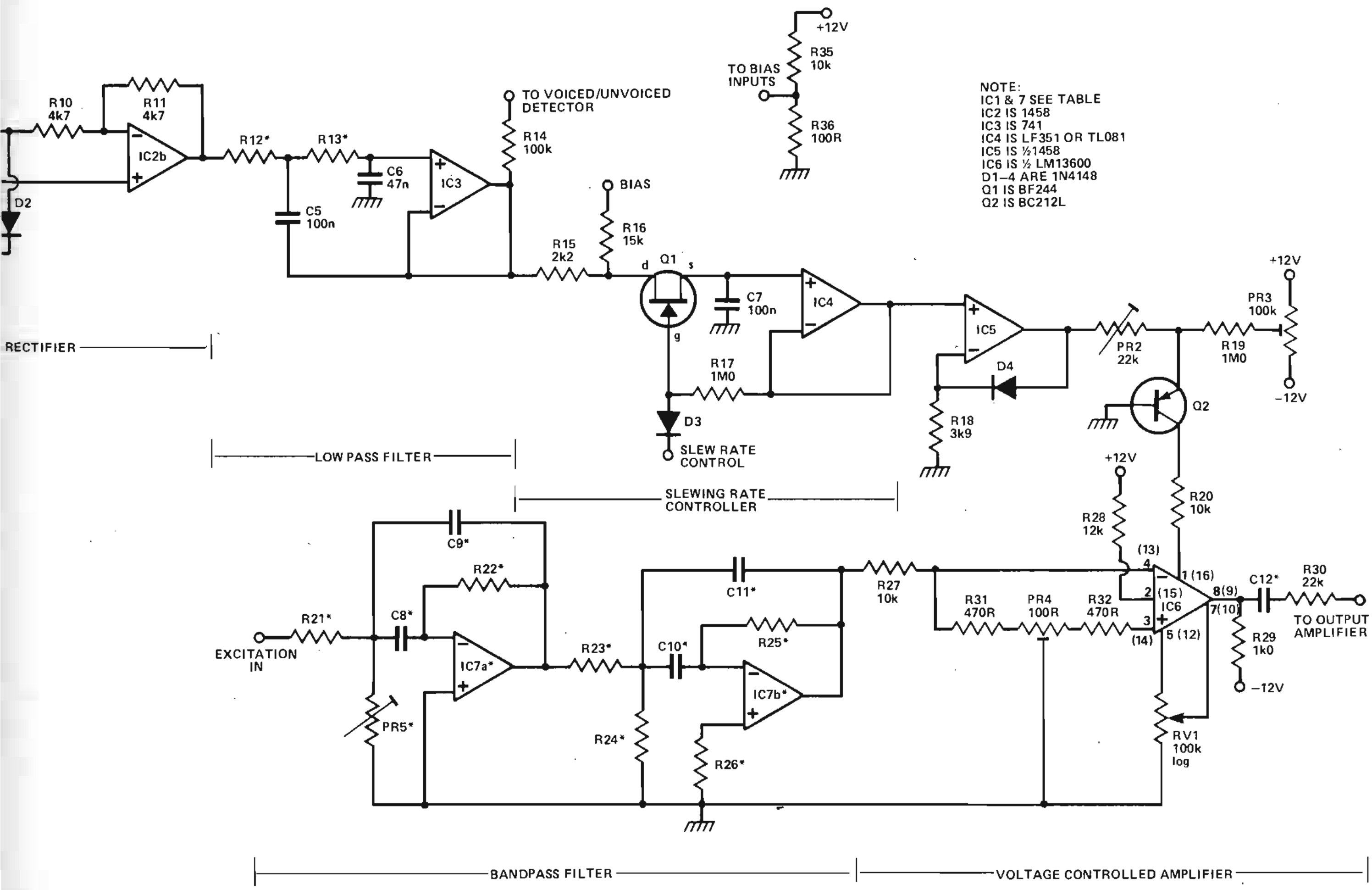


Fig.5a(above). Circuit diagram of analysis/synthesis section.

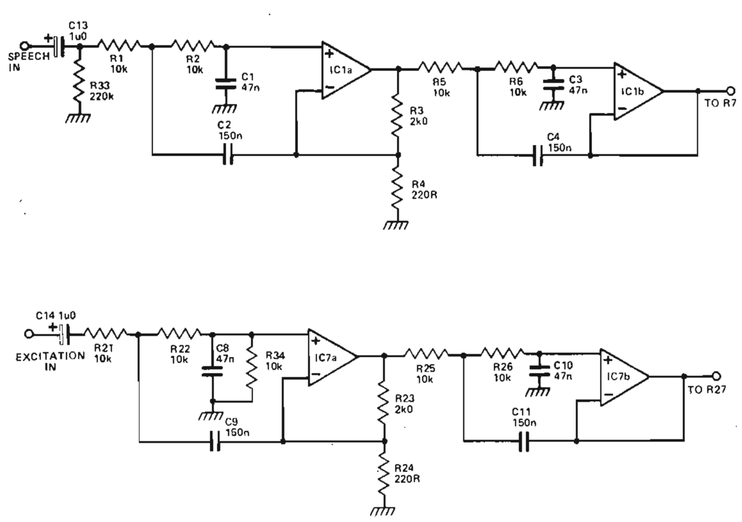


Fig.5b. In channel 1 band pass filters are replaced by the low pass filters shown above.

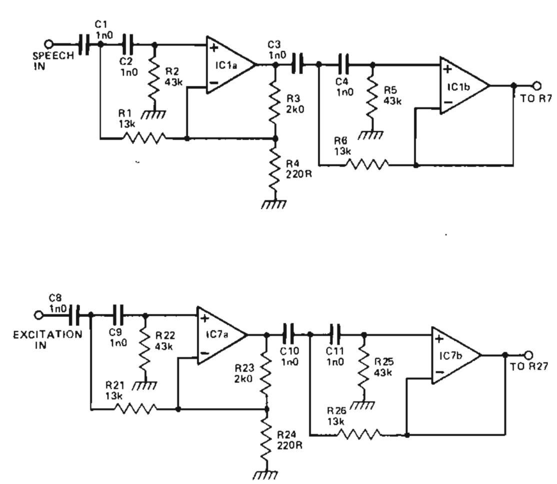


Fig.5c. In channel 14 band pass filters are replaced by the high pass filters above.

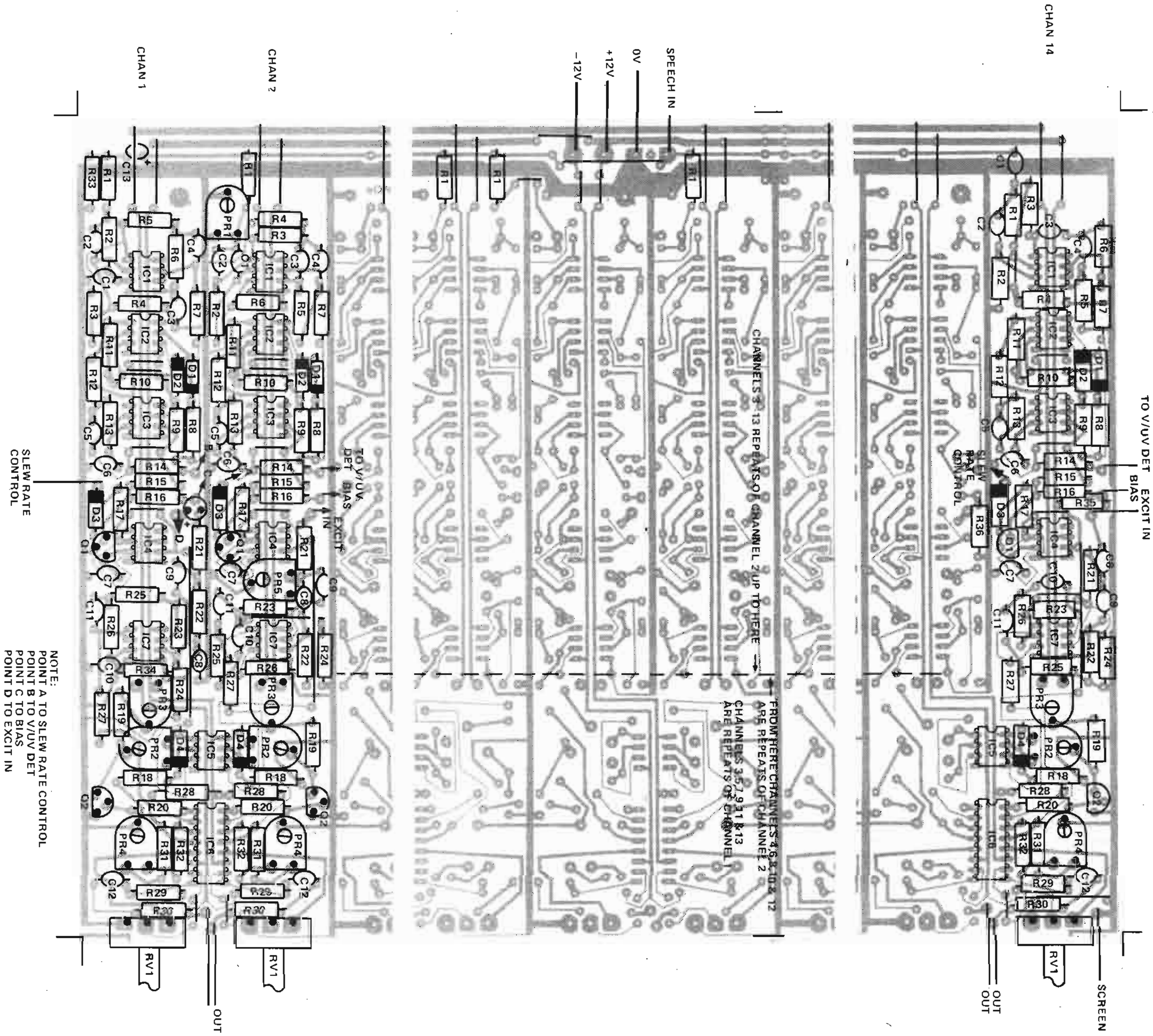


Fig.6. Component overlay of the analysis/synthesis section. We haven't shown the whole board, as the channels are very similar. The three parts of the board (above) show channels 1, 2 and 14 and the power connections in the middle.

PARTS LIST

PARTS COMMON TO ALL CHANNELS

RESISTORS ALL 2% METAL OXIDE

R1-7, 21-26	see Table 1
R8,9,10,11	4k7
R12,13	see Table 1
R14	100k
R15	2k2
R16	15k
R17,19	1M
R18	3k9
R20,27	10k
R28	12k
R29	1k
R30	22k
R31,32	470R

POTENTIOMETERS

RV1	100k logarthmic
PR1,5	see Table 1
PR2	22k preset
PR3	100k preset
PR4	100R preset

CAPACITORS

C1-4,8-12	see Table 1
C5,7	100n polycarbonate
C6	47n polycarbonate

SEMICONDUCTORS

IC1,7	see Table 1
IC2,5*	1458
IC3	741
IC4	TL081 or LF351
IC6*	LM13600
D1-4	1N4148
Q1	BF233C
Q2	BC212L

*only ½ of IC used in each channel

PARTS SPECIFIC TO CHANNEL 1

R33,34	220k
C13,14	1u0 tantalum

PARTS SPECIFIC TO CHANNEL 14

R35	10k

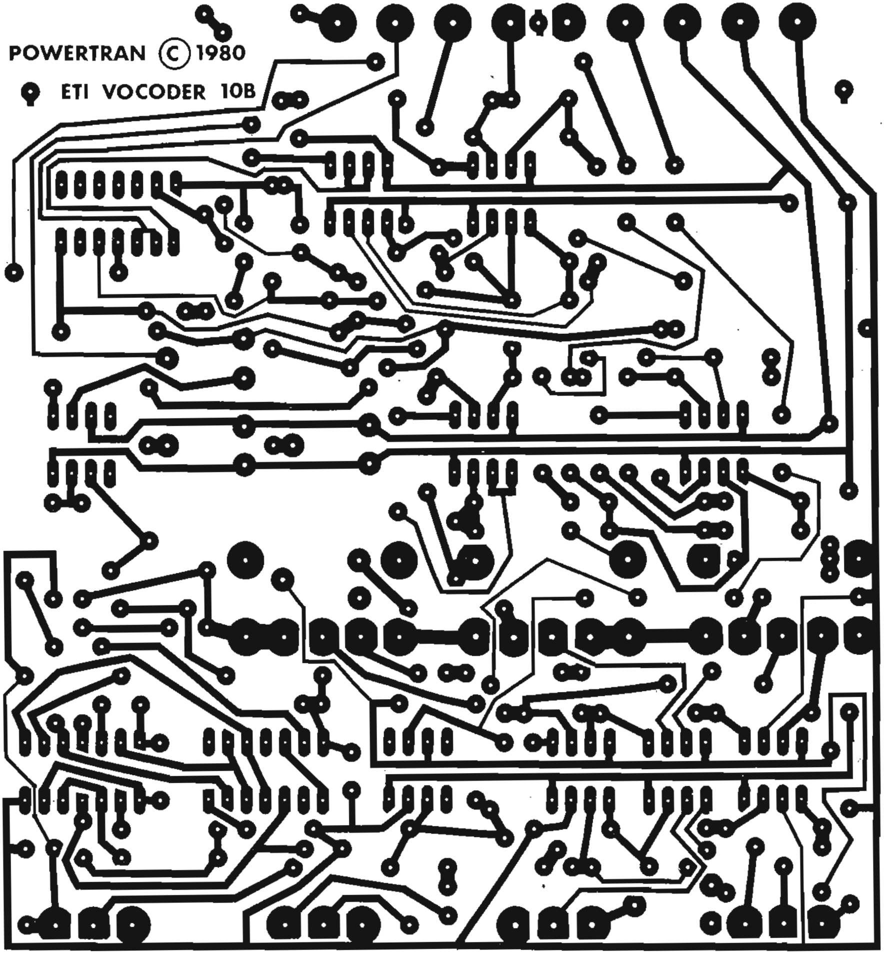
PARTS SPECIFIC TO CHANNEL 13

R36	100R

MISCELLANEOUS

IC sockets, 4 way connector, connector pins.

Below: Vocoder board B. The large PCB is not shown here as it is *too* large to go on the page. An SAE to Modmags will secure a copy.



VOCODER

In the concluding part of the ETI Vocoder, Richard Becker deals with construction and setting up

Start construction with the power supply PCB and bolt this onto the rear panel with mica washers between the panel and transistors, which are on the underside of the board. Silicone grease will keep the washers in place during fitting. Wire up and check all is well when operating into 1k0 resistors as temporary loads.

Build up the rest of the boards. Use insulation on any links which touch the leads of components. On the LED PPM boards, fit the connector pins for the connector to the component side of the board for the excitation meter and the non-component side for the speech meter. Where there are jack sockets, solder short lengths of bare wire to the boards and fit both board and socket to the front panel before soldering the wires to the sockets, which then become firmly attached parts of the board assemblies. On the internal excitation board of the three controls with mounting frames fit to the underside of the board. The other four controls fit on the top side of the board. To get the correct spacing between the top and bottom controls the top ones are soldered to pins such that the tags just touch the top of the board.

Split Supply

The analysis/synthesis board is split in two halves to simplify manufacture. When the two halves are completed, fit the boards to the panel by means of the controls. Fit wire links between the boards and solder the two halves together by use of a bared length of wire along the joint. Fit the spacers to the back of the board and drop it into the chassis so that it can sit

PARTS LIST • Slew Rate Control

Resistors all 2% metal oxide	
R1, 2	15k
R3, 6, 8	2k2
R4, 5, 7	10k
R9, 10	47R
R11	220R
R12	470R
R13	1k0
Potentiometer	
RV1	1M0 log with mounting frame
Capacitors	
C1, 5	10n ceramic
C2,	33n polyester
C3	100p ceramic
C4	560p ceramic
C6, 7	22u 25V
Semiconductors	
IC1	556
Q1	2N3904
Q2	2N3906
D1	1N4148
LED1	TIL220
Miscellaneous	
Footswitch, Footswitch box, stereo jack plug and socket, 5 way connector, IC socket	

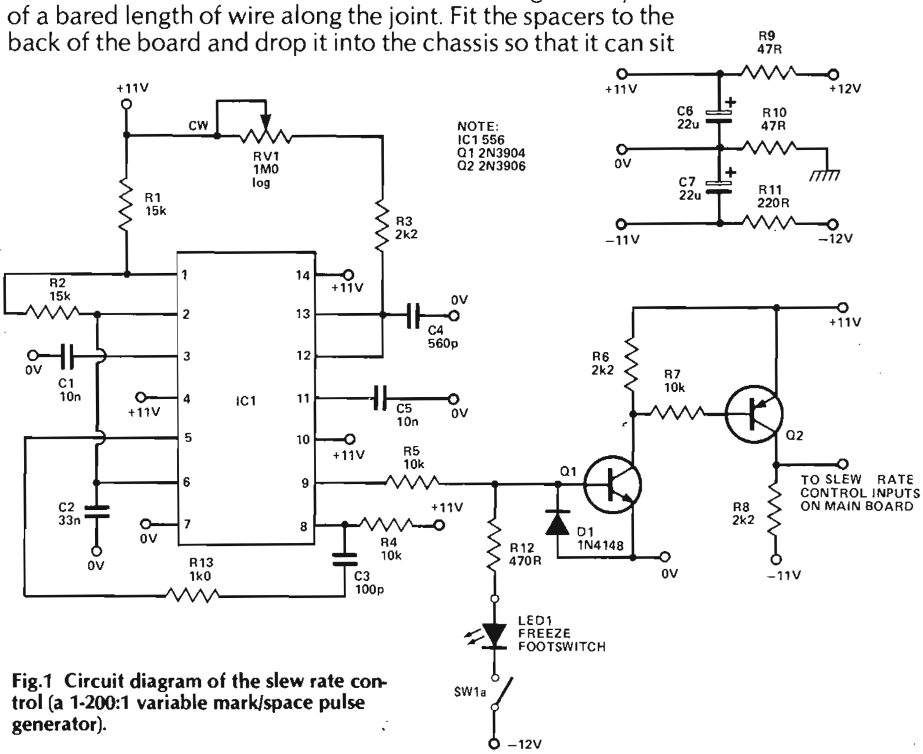
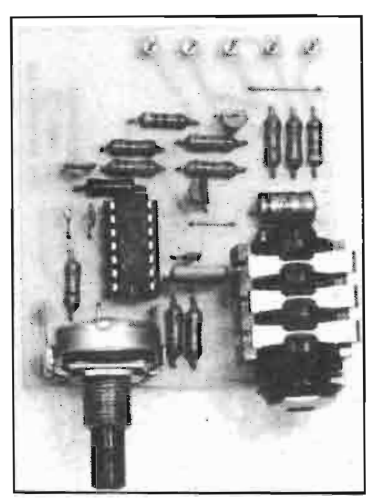


Fig.1 Circuit diagram of the slew rate control (a 1-200:1 variable mark/space pulse generator).



Slew rate control board.

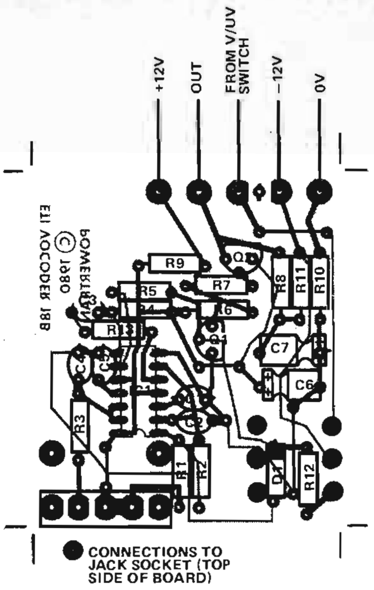


Fig.2 Component overlay of the slew rate control board.

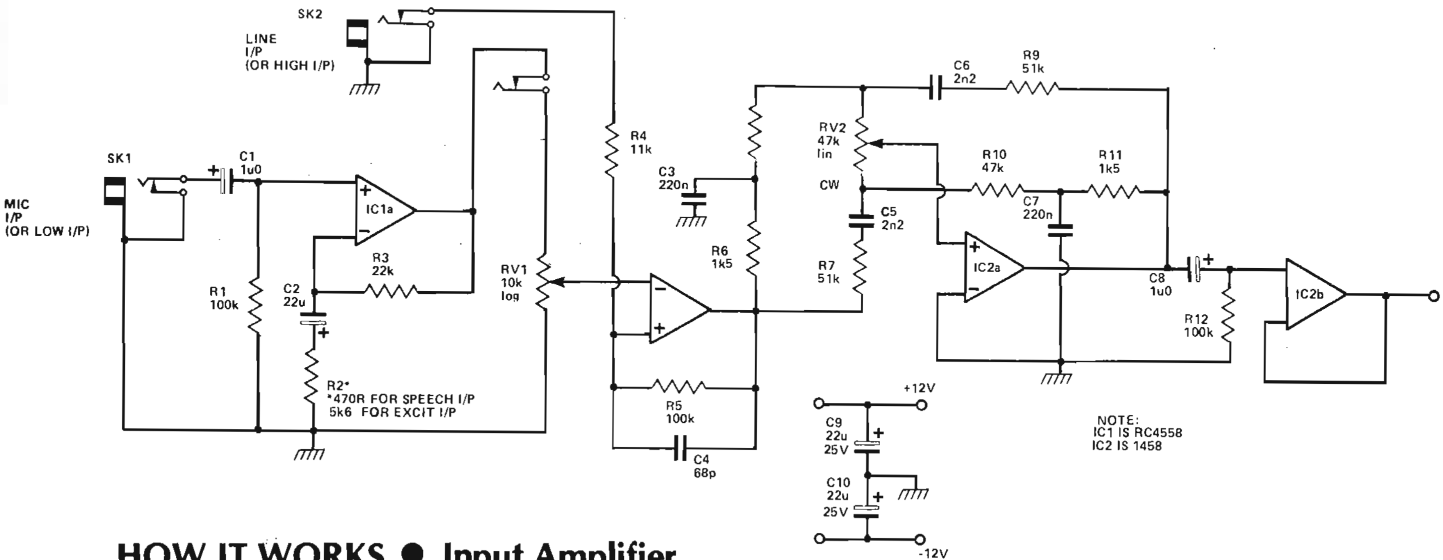
on its back edge whilst wiring up and setting up. Link together with a stretched length of wire on the back of the board all the excitation input pins and also the other inputs and outputs (a total of seven rails).

Make up the wiring loom and connect up all the boards.

HOW IT WORKS ● Slew Rate Control

This is a pulse generator of variable mark/space ratio. IC1 is a 556 which is a dual timer. Pins 1-6 form a 1 kHz 2:1 mark/space ratio pulse generator, its frequency being determined by R1, R2, C2. Its output is used to trigger via C3 and a monostable built round pins 8-13. The width of the output pulse is determined by C4, resistors R3, RV1. The output is buffered by Q1. Q2 is the output driver, switching from + 11 V to − 11 V. The freeze switch forces the output to − 11 V thereby turning off all the FETs of the analysis/synthesis section. To isolate the heavy switching surges on the power rails from the rest of the machine the rails are decoupled by R9, 10, 11 and C6, 7.

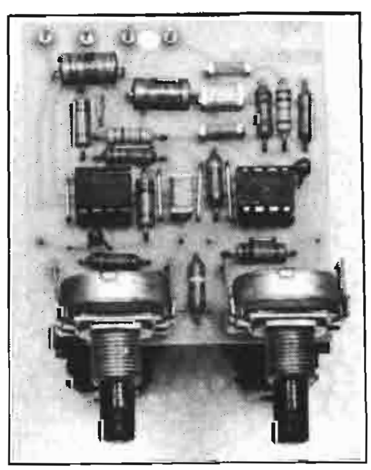
Fig.3 Circuit diagram of the input amplifier



HOW IT WORKS ● Input Amplifier

The preamplifier uses an RC4558, which is a low noise version of the 1458, for IC1. The overall gain of the stage is dependent on which input is used, being unity for SK2 and for SK1 it is 500 (speech) or 50 (excitation). The gain is distributed between IC1a and IC1b. If SK1 is used and SK2 is not, then amplified signal from IC1a is connected to RV1 via the switched contact SK2. Also R4 is connected to ground, through the other switched contact of SK2, giving IC1b a voltage gain of ten. If SK2 is used then IC1a is isolated and R4 is disconnected from ground making IC1b now have unity gain.

IC2 is a rather complex tone control stage giving, with a single control knob, treble boost with bass cut or bass boost with treble cut. R7, C5 and R9, C6 form high pass filters whilst R6, C3 and R11, C7 form low pass filters. When the wiper is clockwise the input of IC2 is connected to the input of the stage via C5, R7 whilst RV2 is in series with the feedback thereby boosting the gain at high frequencies. At the same time, bass from feedback path R11, C7, R10 is dominant over bass from the input, which has to pass through RV2. Therefore, the bass is cut. The opposite occurs when the wiper is anticlockwise.



Input amplifier board.

Setting Up

Check the power lines are still correct when all the boards are connected, set all presets to the centre of their travel and apply a sinusoidal signal to the speech line input. (If no oscillator is available use the cheap little circuit shown.) Set the level to where the sixth LED up just flickers, corresponding to 400 mV. Measure the AC voltage on pin 6 of IC1 channel 2. Adjust the frequency until the voltage reaches a peak, turn PR1 fully clockwise and turn it back slowly until 4 V RMS is measured at the resonant peak of the filter. Repeat this for the other analysis filters.

Connect a 56R resistor between the bias rail and +12 V, turn the slewing rate control fully clockwise, check the pulse generator is operating by listening for a whistle when the input jack of an amplifier is placed near the slew rate control board, switch off the unvoiced detector, plug the oscillator into the external excitation HIGH input and set up channel 2 excitation filter as for the analysis filters (except that now the point to measure is pin 1 of IC7 and the potentiometer to adjust is PR5). With RV1 fully clockwise adjust PR2 so that 4 V RMS is also at the output of the OTA buffer (IC6 pin 8). Repeat this for the other filters including channels 1, 14 where there is only PR2 to adjust.

Plug the vocoder into an amplifier, turn up all channel volume controls and the vocoder output control. Turn down the speech and the excitation inputs. Turn up one of the oscillators and adjust RV5 or RV6, as appropriate, so that the signal is heard to just disappear when the width control is anticlockwise. Repeat for the other oscillator.

PARTS LIST • Input Amplifier

Resistors all ¼ W 5%	
R1, 5, 12	100k
R2 (speech)	470R
R2 (excitation)	5k6
R3	22k
R4	11k
R6, 11	1k5
R7, 9	1k
R8, 10	47k
Potentiometers	
RV1	10k log with mounting frame
RV2	47k lin with mounting frame
Capacitors	
C1, 8	1u0 16V tantalum
C2	22u 16V tantalum
C3, 7	220n polycarbonate
C4	68p ceramic
C5, 6	2n2 polycarbonate
C9, 10	22u 25V electrolytic
Semiconductors	
IC1	RC4558
IC2	1458
Miscellaneous	
5 way connector, connector pins, IC sockets, jack sockets.	

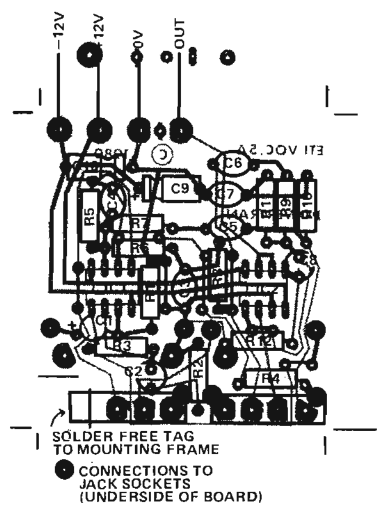


Fig.4 Component overlay of the input amplifier board.

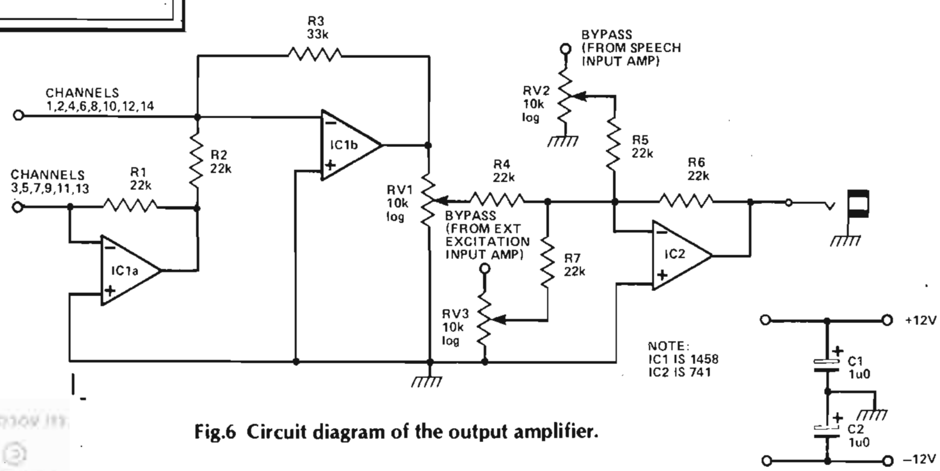
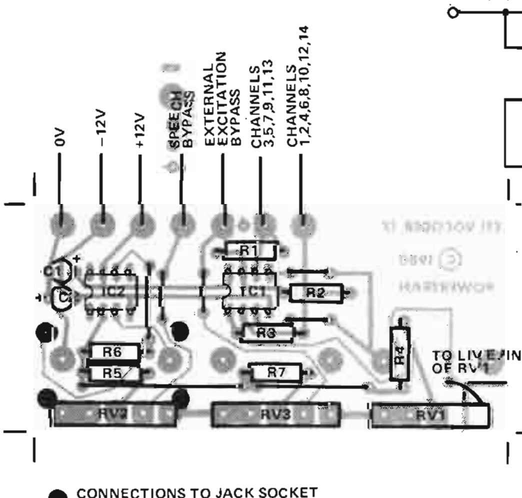


Fig.6 Circuit diagram of the output amplifier.

HOW IT WORKS • Output Amplifier

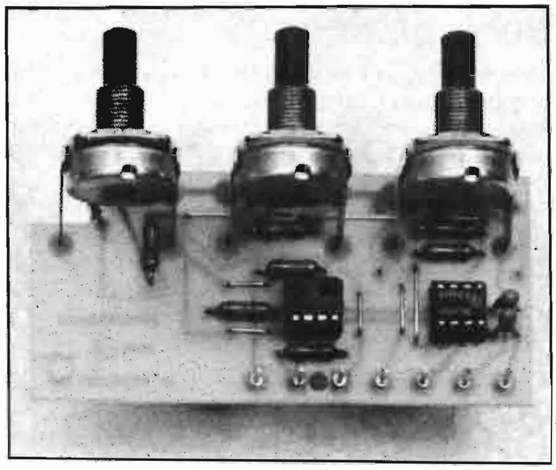
Outputs from channels 3, 5, 7, 9, 11, 13 are mixed by IC1a and the inverted output mixed with the outputs of channels 1, 2, 4, 6, 8, 10, 12, 14, by IC1b. The output of this is then mixed with the speech and external excitation signals by IC2.

Fig.5 (below) Component overlay of the output amplifier board.



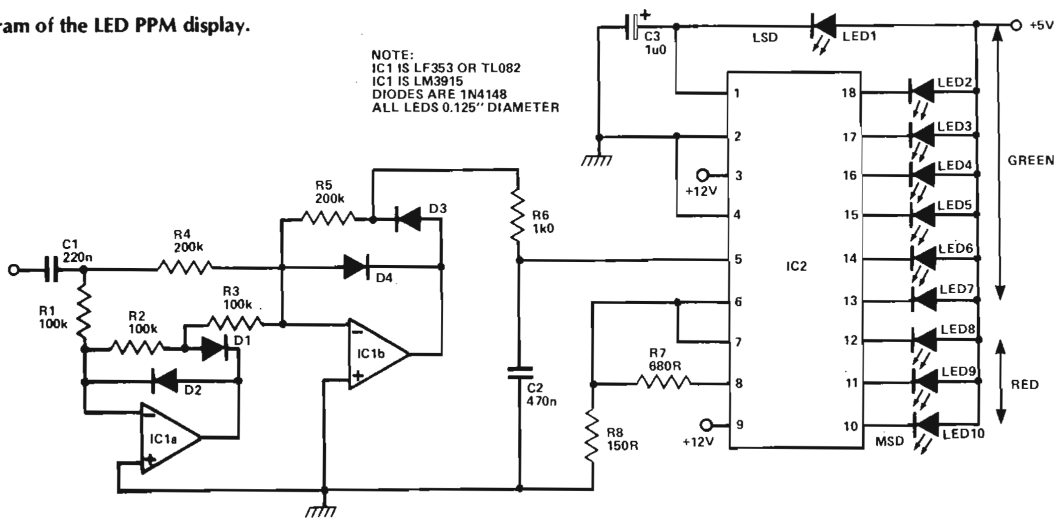
PARTS LIST ● Output Amplifier

Resistors ¼W 5%	
R1, 2, 4, 5, 6	22k
R3	33k
Potentiometers	
RV1, 2, 3	10k log with mounting frames
Capacitors	
C1, 2	1u0 16V tantalum
Semiconductors	
IC1	1458
IC2	741
Miscellaneous	
Jack socket, 7 way connector, connector pins, IC sockets.	



Output amplifier board.

Fig.7 Circuit diagram of the LED PPM display.



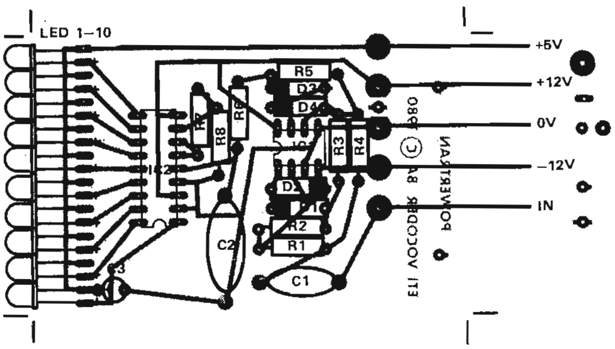


Fig.8 Component overlay of the LED PPM display board.

HOW IT WORKS ● LED PPM Display

IC1 is a full wave rectifier with peak detector charging C2 to the peak voltage of the input signal. IC1 is a logarithmic display driver, the sensitivity of which is determined by R7, 8. The LEDs are at 3 dB spacing. The red LEDs illuminate when the filters overload. The LEDs have their own power supply.

PARTS LIST ● LED PPM Display

Resistors ¼W 5%	
R1, 2, 3	100k
R4, 5	200k
R6	1k
R7	680R
R8	150R
Capacitors	
C1	220n polyester
C2	470n polyester
C3	1u0 16V tantalum
Semiconductors	
IC1	TL082 or LF353
IC2	LM3915
D1-4	IN4148
LED 1-7	TIL211 (green)
LED 8-10	TIL209 (red)
Miscellaneous	
5 way connector, connector pins, IC sockets.	

Noise Abatement

Remove the 56R resistor, turn down all the channel volume controls and the oscillators. Turn up the noise level to maximum, turn up channel 1 and adjust PR3 to the point just before the noise disappears. Repeat this for the other channels.

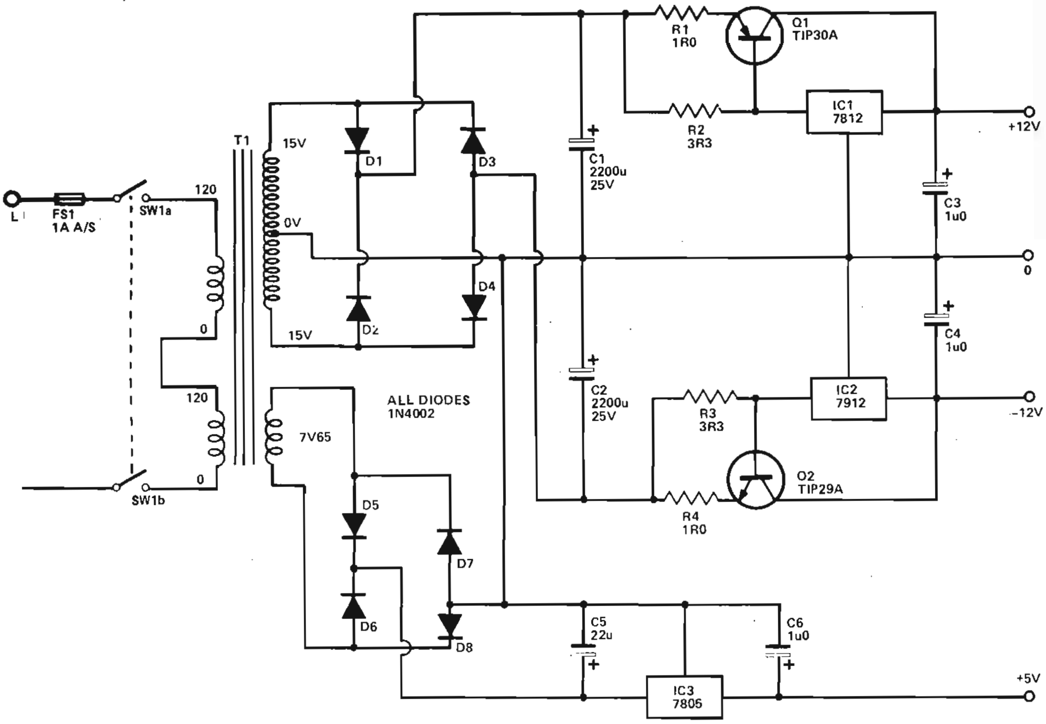
Disconnect the excitation and speech inputs from the analysis/synthesis board and temporarily connect the excitation to the speech input of the board so that noise can be applied to the analysis section. Turn up channel 1 and the noise control. Adjust PR4 for minimum breakthrough of the control signal which will be heard as a low rumble. Repeat this for the other channels and then re-connect the inputs.

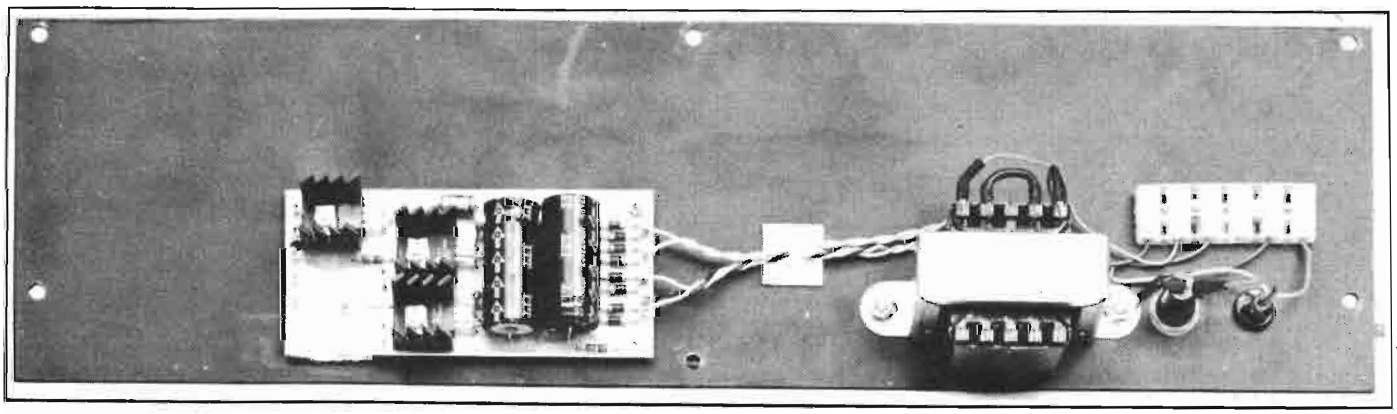
Turn on the voiced/unvoiced detector, apply a high frequency signal to the speech input and the V/UV LED will light up. Turn up all the channel volume controls and the noise control and noise will be heard. Adjust PR2 to halfway between the points where the noise is heard to start limiting. Turn down the noise control and adjust PR1 to the point where noise is just heard to disappear. Turn up the noise again and alter the frequency of the test oscillator. Adjust PR3 to where the noise level drops by about 6 dB, as indicated on the LED PPM, when the V/UV LED is illuminated.

HOW IT WORKS ● Power Supply

Raw positive DC is regulated by IC1. To reduce heat dissipation the current is shared with Q1 roughly in the proportion of R2 to R1. The negative supply is similar. The LEDs of the PPM meters have their own supply. This can be very raw indeed and smoothing capacitor C5 is very small. IC3 is used simply to limit the voltage and not regulate it.

Fig.9 Circuit diagram of the power supply unit.





The power supply unit mounted on the rear panel.

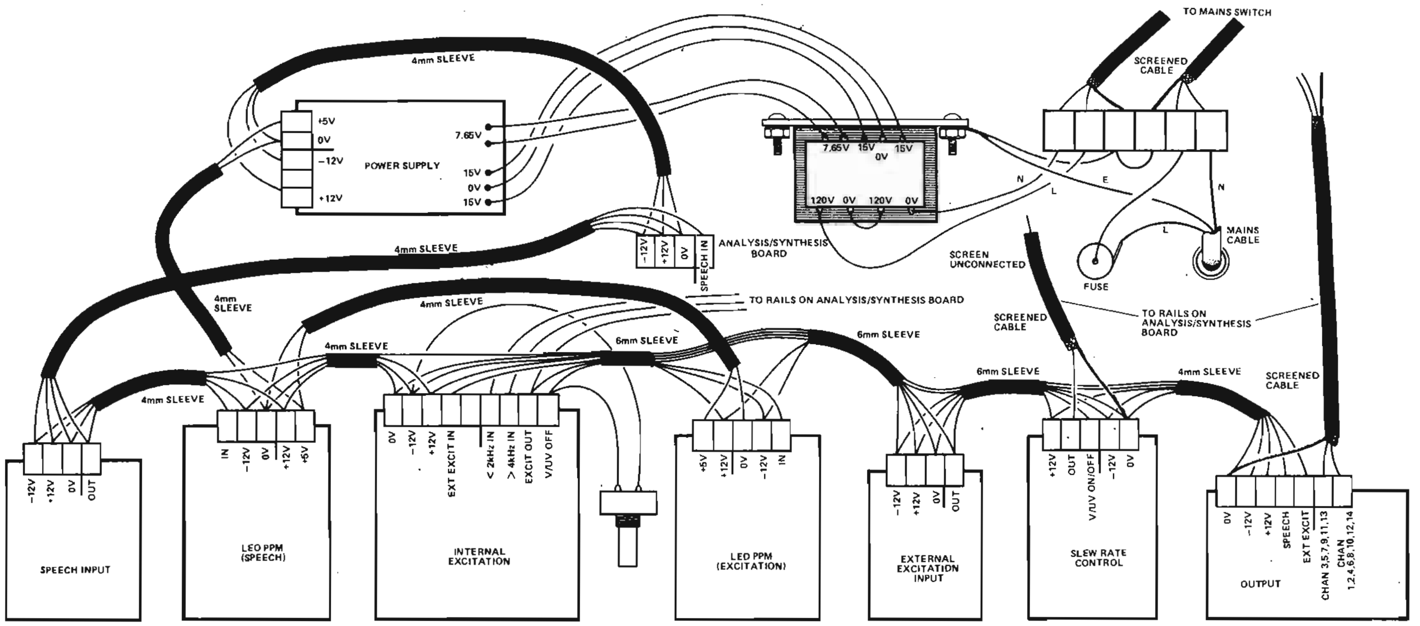


Fig.10 The job of wiring all the boards together is best tackled methodically and double checked by an impartial pair of eyeballs.

BUYLINES

Powertran Electronics, Portway Industrial Estate, Andover, Hampshire, are supplying a complete kit of parts for this project at £195.00 plus 15% VAT. Delivery by Securicor is £2.50 extra. Everything is included in the kit down to the last nut and bolt. They even give you a 'Freeze' footswitch and a test oscillator for setting it up!

PARTS LIST ● Power Supply

Resistors ½W metal glaze	
R1, 4	**1R0**
R2, 3	**3R3**
Capacitors	
C1, 2	**2200u 25V electrolytic**
C3, 4, 6	**1u0 tantalum**
C5	**22u 25V electrolytic**
Semiconductors	
D1-8	**1N4002**
IC1	**7812**
IC2	**7912**
IC3	**7805**
Q1	**TIP 30A**
Q2	**TIP 29A**

Miscellaneous
Transformer 15-0-15 V at 1 A, 7V65 at 0.4 A, 5 way connector, connector pins, finned heat sinks, mica washers.

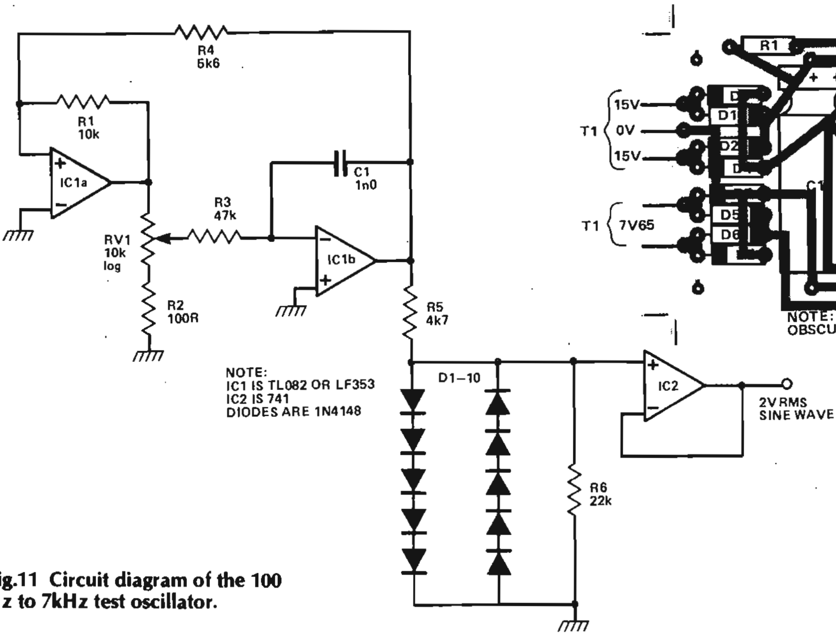


Fig.11 Circuit diagram of the 100 Hz to 7kHz test oscillator.

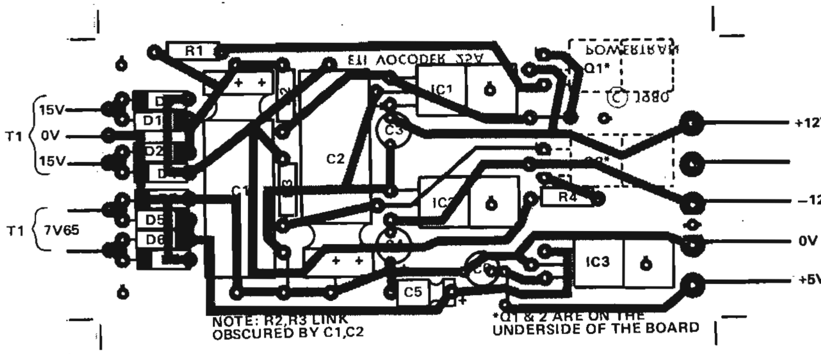
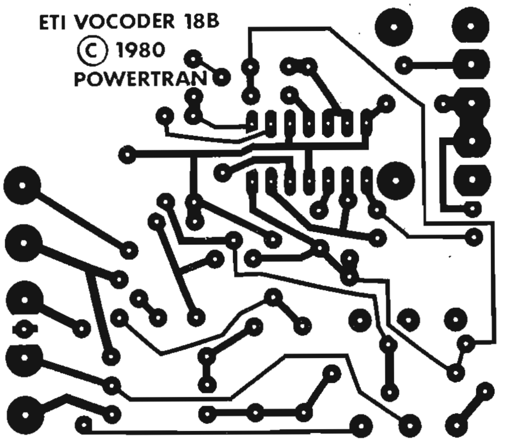
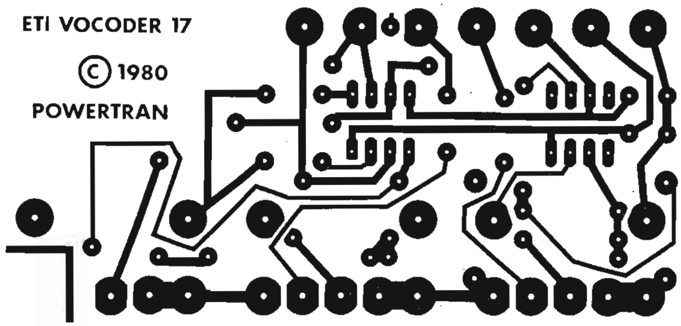


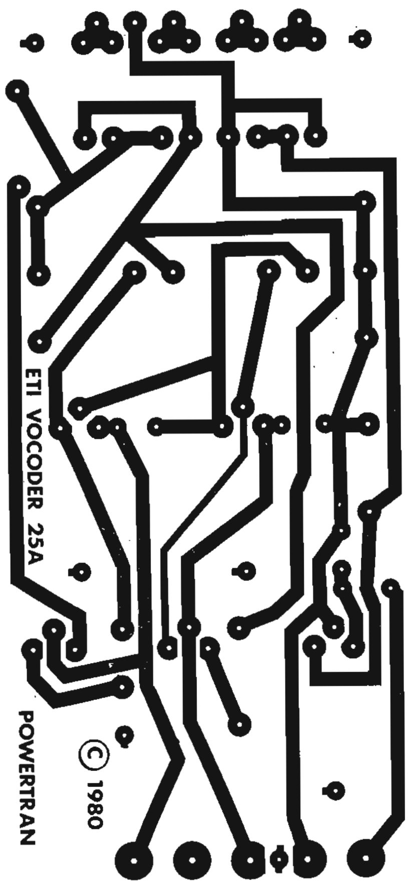
Fig.12 Component overlay of the power supply.



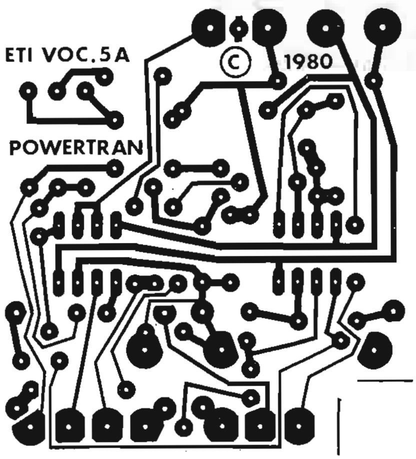
Vocoder Slew Rate Control Board



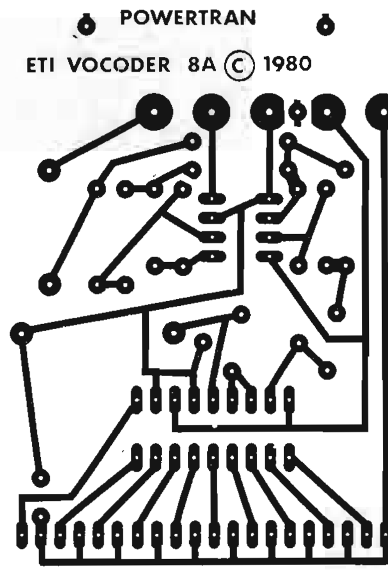
Vocoder Ouput Amplifer Board



Vocoder Power Supply Board



Vocoder Input Amplifier Board



Vocoder LED PPM Display Board