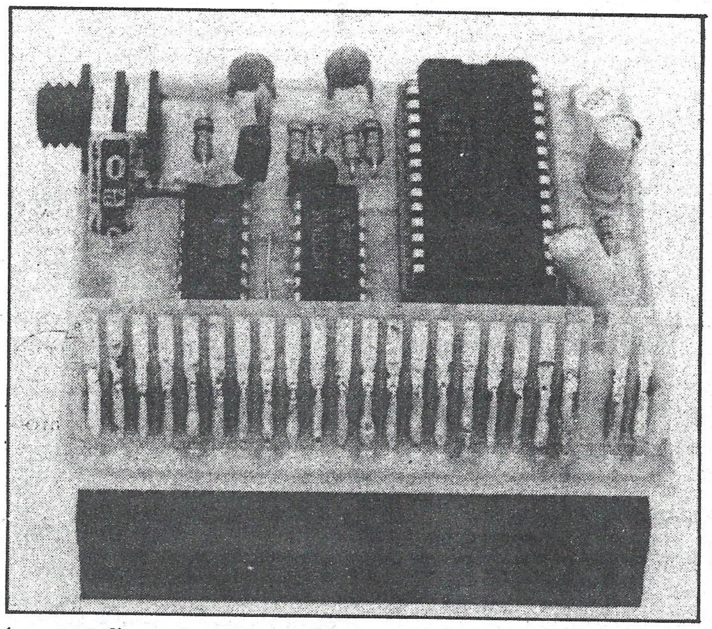
Speech Synthesizer Project For Sinclair Computers

Now hear this: Computers can talk back!

Mike Lord

This article describes an add-on speech synthesiser for the ZX81 or Spectrum. It is compatible with the Sinclair 16K RAM Pack, ZX printer, and Microdrive/Net interfaces. Add-ons from other manufacturers may also be used as long as they do not use I/O addresses with A7=0. The board is also compatible with the software produced by Timedata for use with their ZX speech add-ons.



The hardware produces a range of 'Allophones', which are the basic sounds used when we speak. By programming the correct sequence of allophones, you can make the board 'speak' virtually any English word, as well as many foreign ones. It can also produce some strange sound effects to give a lively background for games programs!

This technique doesn't produce as high a quality of speech as can be obtained from fixed vocabulary synthesisers which produce complete words or phrases, like the one fitted in the BL Maestro. But it is more flexible, and so more suitable for the experimenter.

To keep the cost low, we haven't fitted an audio amplifer or loudspeaker. The board has an 0V.5 output signal which can drive a high impedance (eg crystal) earpiece, or can be connected to a normal audio amplifier.

The Circuit

Is quite straightforward, as can be seen from **Figure 1.** Most of the work is done by the speech synthesiser chip, IC3.

To start it speaking an allophone, the $\overline{ALD}$ input to IC3 should be pulsed low while the appropriate code number (0-63) is present on the computer data lines D0-D5. Because there are only 64 possible codes, the other two data lines (D6 and D7) are not connected.

Once it has been started in this way, the speech chip will carry on by itself to produce the allophone sound. It has two outputs which the computer can look at: SBY which is high while the allophone is being produced; and $\overline{LRQ}$ which goes low when the chip is ready to accept a new allophone. These two signals are routed to the two data lines D4 and D3 respectively through the tri-state buffers in IC2.

Because we wanted the board to work with either the ZX81 or the Spectrum without modification, it is 'I/O' mapped. That is, it appears in the computer's I/O address space rather than in the memory address space. It has also been designed to use a 23+23 way bus connector which is suitable for both computers, rather than the 28+28 way Spectrum connector which cannot be used with the ZX81.

To avoid conflict with Sinclair peripherals such as the ZX printer, address line A7 is used to select the board. ICI decodes the state of the $\overline{RD}$, $\overline{WR}$, $\overline{IORQ}$ and A7 lines from the computer so that when the computer is writing to an I/O address with A7 low, the $\overline{ALD}$ input of the speech chip is pulsed low. When the computer reads from an I/O address with A7 low, ICI enables the tri-state buffers IC2 to put the state of the SBY and $\overline{LRQ}$ signals onto the data bus.

R7 and C10 reset the speech chip when power is applied; although a reset signal is available from both the ZX81 and the Spectrum, it appears in different positions on the connectors for the two machines.

L1 and the small capacitors around it form a tuned circuit resonant at about 3MHz. This is used by an oscillator in IC3 to generate the basic clock for the speech chip. Altering the values of the inductor or the capacitors will affect the 'pitch' of the voice output signal.

This voice signal comes out of pin 24 of IC3 as a pulse width

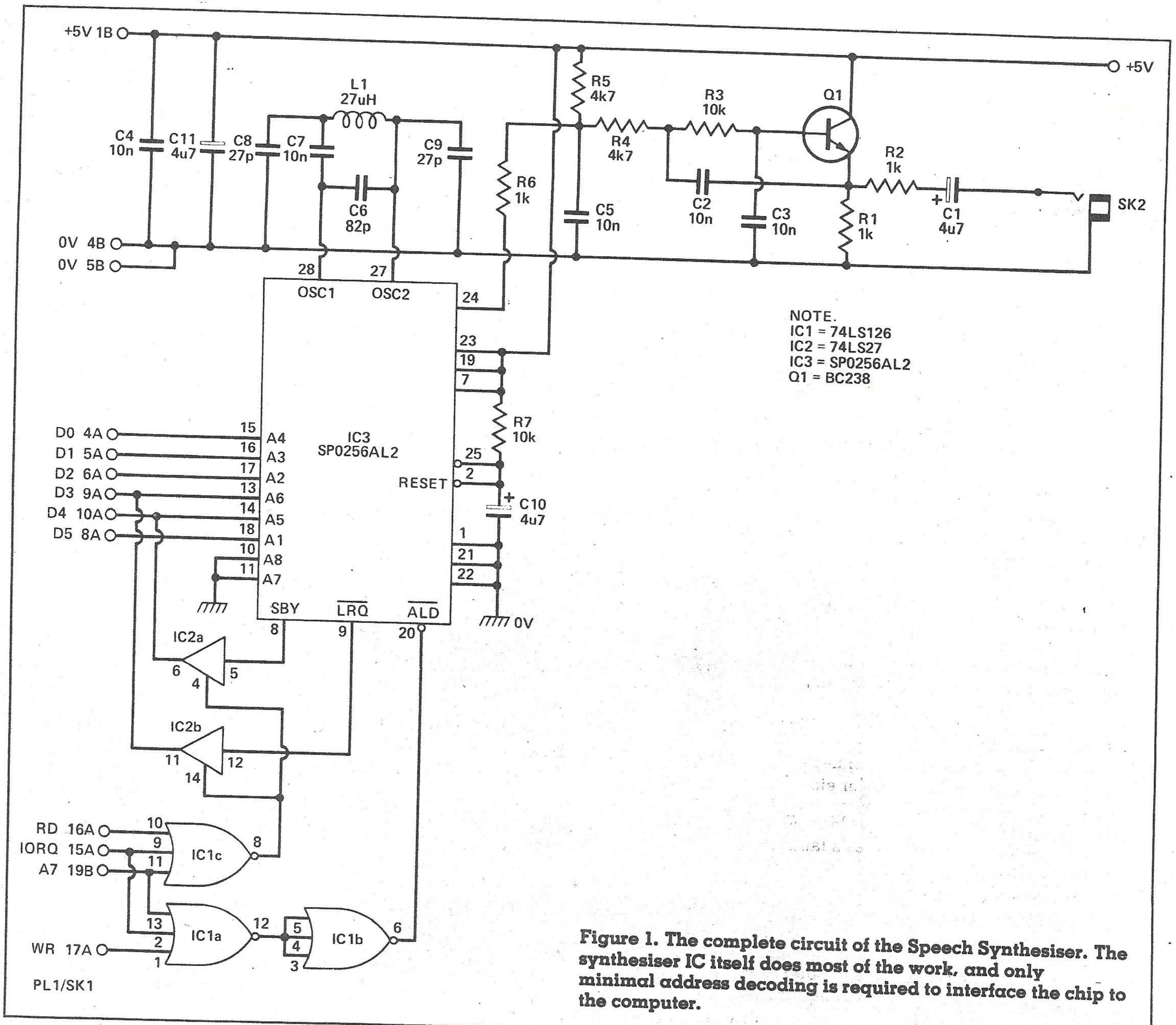


Figure 1. The complete circuit of the Speech Synthesiser. The synthesiser IC itself does most of the work, and only minimal address decoding is required to interface the chip to the computer.

modulated square wave, at approximately 20kHz. If you were to connect an amplifier directly to this output, it would probably be grossly overloaded by the very high level of 20kHz, as well as annoying all the dogs and young people in the neighbourhood! So a three pole active filter — comprising Q1 and its surrounding resistors and capacitors — has been added between the speech chip and the output of the board.

Construction

The component layout is shown in **Figure 2.** A single-sided board has been used to keep the cost low, but this means that two wire links have to be added as shown.

Provided that the components you are using are reasonably small, there should be no problem, in fitting them to the PCB. But take care when soldering as, in a few places, the tracks run very close to IC pads and it is only too easy to make an unwanted connection! And make sure that the electrolytic capacitors (C1, C10 & C11) are put in the right way round. Note that **Figure 2** shows which side the positive lead of these capacitors should be, but many electrolytics only have the negative lead marked on the case.

Q1 might cause some confusion. The case is 'D' shaped as shown, but individual manufacturers seem to have their own ideas about which way round the 'D' should go. Luckily they all form the leads into a pattern which will only fit into the PCB one way round. The collector lead goes into the hole nearest to ICs 1 & 2.

It is worth using an IC socket for the speech chip IC3 because it is expensive, and using a socket means that you don't actually have to fit the IC until the very last moment. Whether you use sockets for the other two ICs really depends on how confident you are about being able to solder them in the right positions and the right way round first time!

Once you have soldered all of the components onto the main PCB it is time to fit the computer bus connectors PL1 and SK1.

SK1 should be fitted first, positioned so that its body is on the track side of the board, spaced about 0.5 cm from the board. Solder a couple of

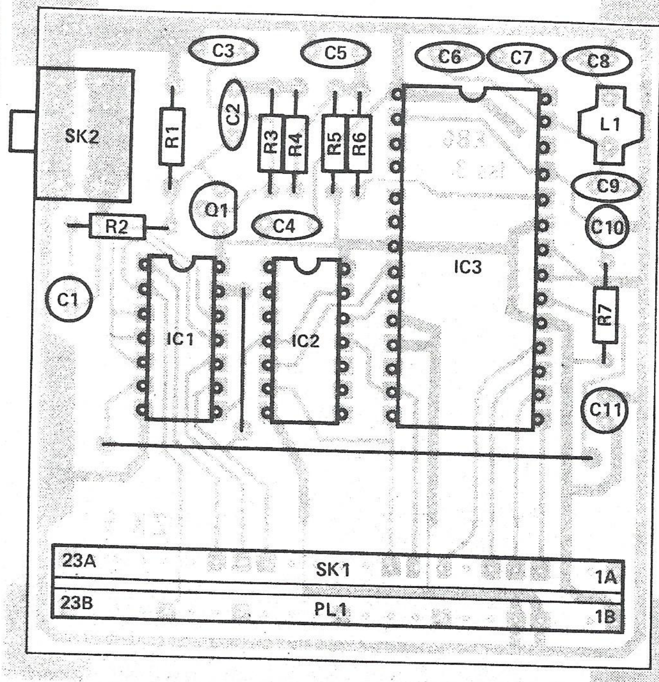
Parts List

RESISTORS
(All 1/4 watt 5%)
R1,2,6 .... 1k
R3,7 .... 10k
R4,5 .... 4k7

CAPACITORS
C1,10,11 .... 4u7 25V radial electro
C2,3,4,5,7 .... 10n miniature ceramic or polyester
C6 .... 82p min. ceramic
C8,9 .... 27p min. ceramic

SEMICONDUCTORS
Q1 .... BC238 NPN transistor
IC1 .... 74LS126 quad tri-state buffer
IC2 .... 74LS27 triple 3-input NOR
IC3 .... SP0256AL2 speech synthesiser

MISCELLANEOUS
L1 .... 27uH inductor
SK1: 23+23 way 0.1" ZX81 edge connector socket with wire-wrap terminals and polarising key in pos'n 3.
SK2 .... 3.5mm PC mounting jack socket
SK3 .... 28 way DIL socket
PL1: 23+23 way 0.1" ZX81 edge connector plug with polarising slot in pos'n 3. PCB, wire, solder etc.



NOTE. SK1 IS MOUNTED ON THE SOLDER SIDE SEE PHOTO

Figure 2. The printed circuit board and component overlay. PL1 is needed if the speech synthesiser is to be used in conjunction with other add-ons for the Sinclair computer(s).

corner pins onto the square pads on the board first then check that the connector body is absolutely 'square' to the PCB before soldering to the remaining pads.

PL1, which is a double sided PCB type, should be fitted last. The ends of the SK1 terminals which project through the component side of the main board have to bent in and soldered to the matching tracks on PL1. Again, it is best to solder the end connections first and check that PL1 is absolutely square to the main PCB (and that its polarising slot is at the right end) before soldering the bulk of the connections.

Testing It

Before doing anything rash, check carefully to make absolutely sure that the right components are fitted the right way round, and that there are no short-circuits caused by solder splashes or excessive solder. This is most important, as a fault on the speech board could damage your computer.

Then remove power from the computer, plus the board in, then re-apply power. If the computer doesn't start up as normal, turn the power off quickly and check your work again.

Once you are sure that the computer still works properly with the board fitted, connect it to an audio amplifier so that you can hear the sounds it will be making.

If you have a Spectrum, then you can give the board a quick test by entering:
OUT 127,18
which would give a continuous 'ey' sound. Use OUT 127,0 to stop it. If you have a ZX81, then load and run the 'ZX81 Output Routine' then enter:
LET S$=CHR$ 18+CHR$ 64
RAND USR 16514
to produce a short 'ey' sound.

Allophone Speech Synthesis

The speech chip used can generate 64 different allophones (including some silent 'pauses' of varying lengths), as shown in **Table 1.**

To make it say a complete word or phrase, you have first to choose a suitable sequence of allophones. For example, the word 'Hello' can be produced reasonably well by the four allophones:

HH,U,L,OW

Then the code for each allophone in turn has to be sent to the speech chip. For 'Hello', the four codes would be:

53 39 43 58

Different allophones last for different times (see **Table 1**), so the speech board tells the computer when it has finished with the current allophone code and is ready for the next. With most allophones, the speech chip will actually carry on giving an audible output after the allophone has 'officially' finished. This covers over any gap until the computer can load the next code into the speech board, but does mean that you must deliberately turn the sound off at the end of a word or phrase by sending one of the silent (pause) codes to the board.

How intelligible the resulting speech output is depends mainly on the choice of allophones. For example, if you look at **Table 1** you will see that there are three 'G' sounds; 'GI', and 'GU'. It is always worth experimenting to see which sounds best in a particular word.

The allophones marked with a '*' in Table 1 can be repeated to lengthen and give emphasis to those sounds, as the doubled 'E' sound in 'Ten':

T,E,E,NN

Short pauses between allophones, particularly before the sounds 'b', 'c', 'ch', 'd', 'g', 'p' and 't', can make a considerable improvement to the quality of the speech output, as can using differing length pauses between words to give a more natural 'rhythm'.

Programming

The ZX81 and Spectrum Output Routines given with this article put a machine code program into the REM line 1.

When called (by a statement like RAND USR LOC) it looks for the first variable in the Variables area; this must be the character array S$, since that is the first variable to be used in the BASIC program. It then sends the code of each character in S$ to the speech board, in turn, waiting each time for the synthesiser to finish speaking the previous allophone. When it reaches a character in S$ which has the code 64, it turns the synthesiser off and returns to BASIC.

So, to make it speak the word 'Hello', first put the appropriate codes into S$ with a statement like:

```
LET S$=CHR$ 53+CHR$
        39+CHR$ 43+CHR$
                58+CHR$ 64
```

(Don't forget the 'end' code 64)

Then RAND USR LOC will call the machine code routine to speak the word. S$ is dimensioned in the routines to hold up to 21 allophone codes (including the end code 64);

ZX81 Output Routine

```
1 REM 1234567890123456789012345
2 DIM S$(21)
3 LET LOC=16514
4 LET A$="0106002A104009017FF
F7EED79FE40C8ED78CB5F20FA2318F1
5 FOR X=LOC TO LOC+24
6 POKE X,16*CODE A$+CODE A$(2
)-476
7 LET A$=A$(3 TO)
8 NEXT X
```

When run this routine loads the REM statement in line 1 with the machine code routine;

```
START  LD BC,0006    Point S$
       LD HL,(4010)   to start
       ADD HL,BC      of S$
NUCD   LD A,(HL)     Send next
       OUT (C),A      code
       CP 64         Quit if it
       RET Z          was 64
LOOP   IN A,(C)      Wait while
       BIT 3,A        allophone
       JR NZ,LOOP     is spoken
       INC HL        Then get
       JR NUCD        next one
```

Spectrum Output Routine

```
1 REM 1234567890123456789012345
2 DIM S$(21)
3 LET loc=5+PEEK 23635+256*PE
EK 23636
4 DATA 1,6,0,42,75,92,9,1,127
,255,126,237,121,254,64,200,237
120,203,95,32,250,35,24,241
5 FOR x=loc TO loc+24
6 READ a
7 POKE x,a
8 NEXT x
```

Table 1

Mnemonic	Code	Time (mS)	Example
A	21	80*	hAt
AIR	47	250	hAIR
AH	17	60*	cOme
AR	61	200	fARm
AY	18	200	trAY
B	63	60	Big
BU	19	40	taBle
C	13	120	Can
CH	28	150	CHurCH
D	50	50	baDly
DU	40	80	Do
E	38	50*	bEt
EAR	27	250	hEAR
EE	52	170	sEE
EL	31	140	tabLE
ER	26	210	hER
F	9	110*	Food
G	12	120	doG
GI	10	80	Guest
GU	59	80	Green
H	57	130	Hoe
HH	53	90	He
I	3	50*	sIt
IE	6	170	skY
IR	60	110	fIR
J	5	100	Jet
K	1	80	Comb
KU	41	140	speaK
L	43	80	Lie
M	16	180	Milk
N	25	140	No
NG	11	200	aNchor
NN	37	170	thiN
O	54	70*	hOt
OO	23	70*	fOOt
OOO	55	170	mOOn
OR	29	240	stORE
OU	8	250	OUt
OW	58	170	snOW
OY	34	290	tOY
P	33	150	Pit
R	46	80	gReat
RR	7	130	Read
S	62	60*	beSt
SH	42	120	SHip
T	48	80	parT
TH	20	50	THey
THH	51	130*	THin
THU	30	180	baTHE
TT	35	100	ToTal
U	39	50*	bUtter
UH	22	60	sOOty
V	44	130	Very
W	15	140	Will
WH	24	250	WHen
Y	56	90	You
YU	49	130	Yes
Z	45	150	Zoo
ZH	14	130	aZure
P1	0	10	(pause)
P2	32	30	''
P3	4	40	''
P4	36	100	''
P5	2	200	''

* These allophones can be repeated to lengthen them.

Table 1. Allophone codes for the ZX Speech Synthesiser.

Spectrum Voice Synthesiser

Until recently a voice synthesiser attachment to a microcomputer would have cost at least £200. With the introduction of the General Instrument SPO256 chip a good synthesiser can be built for as little as £15. In this article Robert Harvey outlines the construction and use of just such a device for the Sinclair Spectrum.

The system to be described is intended for connection to a ZX SPECTRUM but the circuit can easily be interfaced to any Z80 based micro and as the driver software is written in BASIC, this too should be transportable with little modification.

The circuit can be easily constructed on VERO VQ board using a wiring pen (also from VERO) or a PCB can be used. The dual 28 way edge connector can be soldered directly to the board and thus the finished unit (with the speaker mounted on the board) can plug in and stand up behind the Spectrum. The circuit includes a five volt power supply for the logic and it is recommended that this be used because the SP0256 chip alone uses around 90mA and it is well known that the Spectrum's own internal power supply will not stand much more loading!

The main circuit consists of three parts: Computer interface, Voice synthesiser chip and the filter amplifier circuit.

Interface

The synthesiser is interfaced to work on one of the Z80 I/O ports: When writing to this port, data is transferred to the SP0256 which then begins pronunciation. When reading the port the Busy (ie. Currently talking) signal is presented on bit 7. The actual address of the port can be changed to any of seven different addresses so that the circuit can be accommodated with any other devices connected to the computer. The three address bits A5, A6 & A7 not used within the Spectrum are used to select this port address. The software assumes port 159 is used.

The Synthesiser

This section of the circuit consists of the SP0256 chip and an oscillator made from two gates of a TTL quad NOR gate IC. GI recommend that a 3.12 MHz crystal be used and provision has been made within the chip to connect this directly without the need for external circuitry. Although, by using a separate oscillator (eliminates the need for an expensive crystal) the pitch of the synthesised voice can be changed to give the most pleasing results. The crystal, if required, can be connected between pins 27 and 28 of the SP0256. The chip itself contains all the logic to convert the allophone codes into digital speech.

The Filter/Amplifier

The output of the chip consists of a high frequency pulse width modulated signal which must be passed through a low pass filter in order to remove the high modulation frequency and obtain an analogue signal. This circuit uses a second order Butterworth filter with a cutoff frequency of 5KHz and is made from a CA3140 MOSFET operational amplifier. The signal from this is then amplified to drive a loudspeaker by an LM380 power amplifier in a standard configuration.

Allophones

This type of speech synthesiser utilises parts of the spoken word known as allophones. These are the actual sounds that go to make up speech. The synthesiser board will pronounce fifty nine allophones and in theory it should be possible to synthesise any word in the English language. Obviously though the words produced, while being understandable, will not match those produced by the human vocal tract, which has the capability of producing many more than fifty nine speech sounds!

Conversion of text to speech using allophones requires a small amount of experimentation in order to produce realistic sounds. The amount of effort depends on the composition of the word: Words with nasal and fricative sounds are harder to set right than words that contain mostly just vowels and consonants, but this is just a general guide and it is worth remembering that the sounds of different groups of letters change depending on their position within a word, and that some groups of letters have quite complicated allophone combinations. The allophone table (**Fig 2**) gives allophone numbers in decimal and a guide to their use and should help in the formation of allophone speech.

Programming The Synthesiser

The synthesiser takes a six bit code representing an allophone and generates the corresponding sound. The actual process of sending allophone codes to the synthesiser is simplicity itself and consists of just waiting for the chip to finish what it was last doing and then sending it the new code. This can be done with the following extract of BASIC code:

```
1000 IF IN 159>127 THEN GO TO
     1000
1010 OUT 159,DATA
```

Thus the following program can be used to test a sequence of allophones:

```
 10 RESTORE 100
 20 IF IN 159>127 THEN GO TO 20
 30 READ N: OUT 159,N
 40 IF N THEN GO TO 20
 50 STOP
100 DATA 42,15,16,9,49,22,13,51,0
```

In this example the word spoken will be "COMPUTER" (KK,AX,MM,PP,YY, UW,TT2,ER in allophones!) but any sequence of codes can be put as data at line 100 terminated by a zero value.

For more examples of words made from allophones (some better than others!) a program will be given next month which prints what it says just in case it is not understood!

Another area of experimentation would be to use the synthesiser to produce sound effects for games, something it could do without much computer intervention as the synthesiser will continue a sound until it receives a pause code. The next step up from the example programs would be one that converts allophone input as text into numeric strings to be sent to the synthesiser – this would go some way towards simplifying the text to allophone conversion process. Then perhaps a program could be written to convert English text directly into allophone codes.

So to conclude, this synthesiser gives one the opportunity to add speech to almost any program very cheaply. Let your computer answer back!

Next Month: PCB and Software.

PARTS LIST

Resistors		**Capacitors**			
R1	10k	C1	10u	IC3	7805
R2, 7, 8	330R	C2, 5, 9	220u	IC4	74LS32
R3, 4	100R	C3	220p	IC5	74LS00
R5, 6	1k0	C4	820p	IC6	CA3140
R9	10k	C6, 7, 8	100n	IC7	LM380
R10	18k	**Semiconductors**		**Miscellaneous**	
RV1	5k	IC1	74LS42	Speaker, PCB, IC sockets, connecting wire etc.	
		IC2	SPO256-AL2		

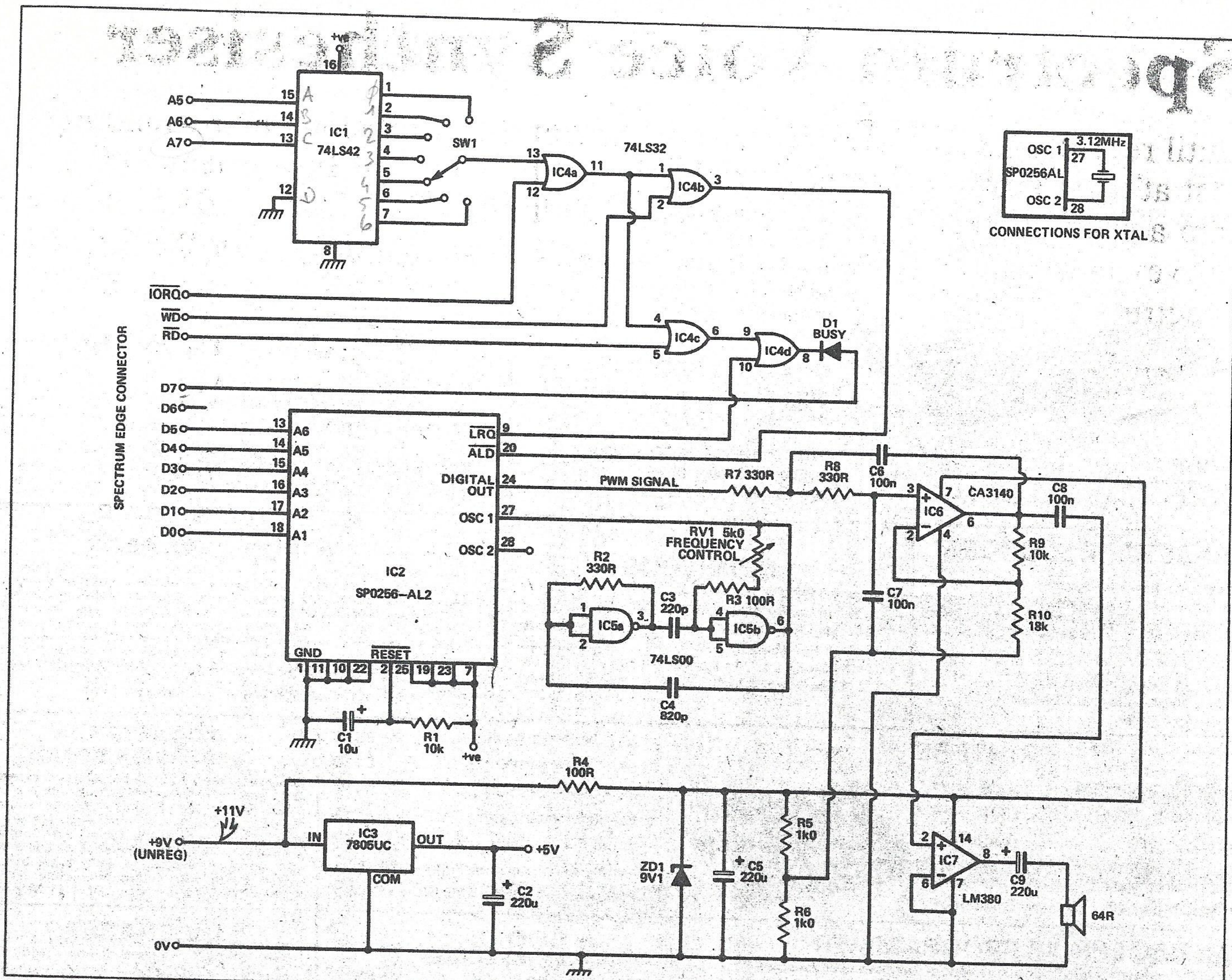


Figure 1. Full circuit diagram.

Allophone Table

Pauses

0 PA1 (10 mS) – use before voiced stops and affricates
1 PA2 (30 mS) – use before voiced stops and affricates
2 PA3 (50 mS) – before voiceless stops and voiced fricatives also between words
3 PA4 (100mS) – Between clauses and sentences
4 PA5 (200mS) – Between clauses and sentences

Short Vowels – These can be repeated

7	EH	E	– bend
12	IH	I	– fitting
15	AX	U	– succeed
23	AO	AU	– aught
24	AA	O	– cot
26	AE	A	– fat
30	UH	OO	– cook

Long Vowels

5	OY	OY	– toy
6	AY	Y	– sky
19	IY	E	– see
20	EY	EA	– great
22	UW	O	– to
31	UW2	OO	– food
32	AW	OU	– out
53	OW	OW	– snow
62	EL	L	– angle

R-Coloured Vowels

47	XR	AI	– hair
51	ER	ER	– computer
52	ER2	IR	– bird (monosyllables)
58	OR	OR	– store
59	AR	AR	– farm
60	YR	R	– clear

Resonants

14	RR	R	– read
39	RR2	R	– brain
49	YY	U	– computer
25	YY2	Y	– yes
45	LL	L	– luck
46	WW	W	– wool

Voiced Fricatives

18	DH	TH	– they
54	DH2	TH	– bathe
35	VV	V	– even
43	ZZ	Z	– zoo
38	ZH	GE	– beige

Voiceless Fricatives

29	TH	TH	– thin
40	FF	F	– fire
55	SS	S	– sat

(29, 40, 55 double for initial positions)

27	HH	H	– he
57	HH2	H	– hoe
37	SH	SH	– shirt
48	WH	WH	– whig

Voiced Stops

28	BB	B	– rib
63	BB2	B•	– big
21	DD	D	– could
33	DD2	D	– do
36	GG	GU	– guest
61	GG2	G	– go
34	GG3	IG	– wig

Voiceless Stops

17	TT	T	– its
13	TT2	T	– to
42	KK	C	– computer
41	KK2	K	– sky
8	KK3	C	– crane
9	PP	P	– pub

Affricates

10	JH	J	– jury
50	CH	CH	– church

Nasal

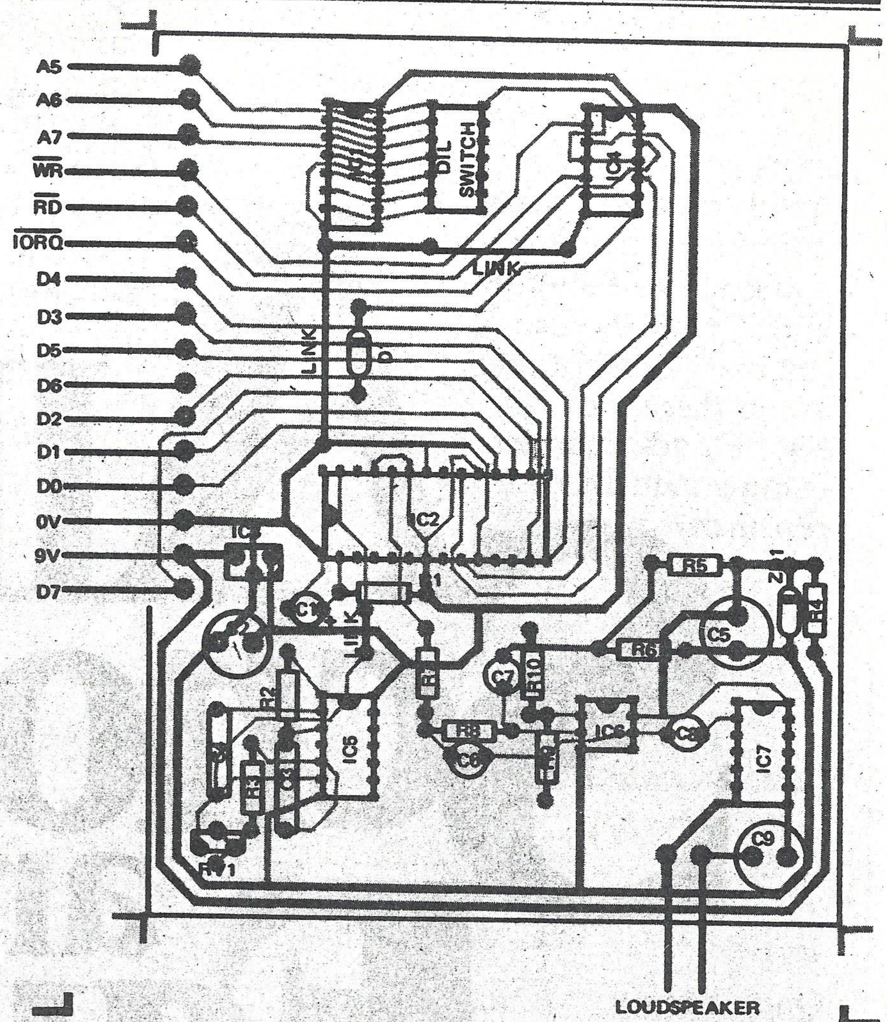
16	MM	M	– milk
11	NN	N	– earn
56	NN2	N	– no
44	NG	NG	– bans

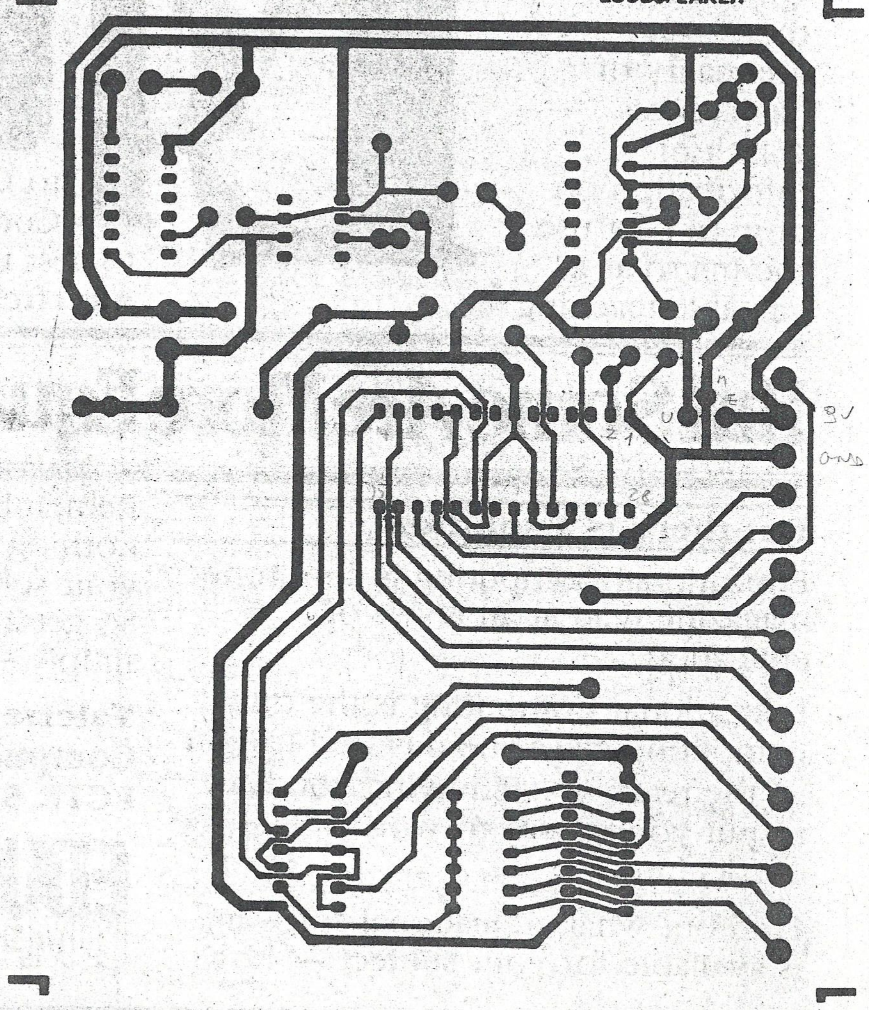
Spectrum speech synthesiser

In Part 2 of Robert Harvey's project to build a £15 speech synthesiser, the software and PCB details are given.

To recap, the speech synthesiser is based on the General Instrumenmt SPO256 chip. While the board is designed with the Spectrum specifically in mind, it can easily be interfaced to any Z80 based micro, and as the software is written in BASIC, this too should be transportable with little modification.

The circuit is easily constructed on Vero VQ Board using a wiring pen, or by using a PCB. The dual 28-way connector can be soldered directly to the board and thus the finished unit (with speaker mounted on the board) can plug in and stand up behind the Spectrum. The circuit includes a 5V power supply for the logic and it is recommended that this be used because the SPO256 alone uses around 90mA, and it is well known that the Spectrum's own internal power supply will not stand much more loading. The software is shown below in Listing 1. ■





LISTING 1

```
10   PRINT "I AM A ZX SPECTRUM COMPUTER"
20   LET X=300: GO SUB 1000:, REM *** NOW SAY IT
30   PAUSE 50
40   PRINT "PLEASE ENTER A NUMBER"
50   LET X=310: GO SUB 1000
60   LET A$=INKEY$: IF A$<"0" OR A$>"9" THEN GO TO 60
70   LET A=VAL A$
80   PRINT "THE NUMBER IS ";A
90   LET X=320: GO SUB 1000
100  LET X=A+200: GO SUB 1000
110  PAUSE 25
120  GOTO 40


199  REM **** NUMBERS ONE TO
     NINE IN ALLOPHONES
200  DATA 43,12,12,39,53,0: REM ZERO
201  DATA 46,23,11,0: REM ONE
202  DATA 13,31,0: REM TWO
203  DATA 40,14,19,0: REM THREE
204  DATA 40,58,0: REM FOUR
205  DATA 40,6,40,0: REM FIVE
206  DATA 55,12,2,41,55,0: REM SIX
207  DATA 55,7,35,7,11,0: REM SEVEN
208  DATA 20,2,13,0: REM EIGHT
209  DATA 56,6,11,0: REM NINE


299  REM **** SENTENCES IN ALLOPHONES (See PRINTs)
300  DATA 6,3,26,16,3,20,3,43,7,7,21,4,7,1,41,55,3,55
301  DATA 9,7,41,17,14,15,16,3,42,15,16,9,49,22,13,51,0
310  DATA 9,45,19,43,3,7,11,2,13,51,3,20,3,11,15,16,1
311  DATA 28,51,0
320  DATA 18,52,3,11,15,16,1,28,51,3,12,12,55,4,0
999  REM **** SUBROUTINE TO SPEAK A PHRASE
1000 RESTORE X
1010 READ IN
1020 IF IN 159>127 THEN GO TO 1020
1030 OUT 159,N
1040 IF N THEN GO TO 1020
1050 RETURN
```

33 D

34 ~~G (GATTO)~~ → G finale (quasi C)

35 V

36 GHE ?

37 SC

38 → GE (BEIGE)

39 → R di BRAIN

40 F

41 CH (in CHE)

42 → CH più dolce

43 → Z inglese

44 N nasale di ANGOLO

45 L

46 → W

47 → EAR

48 → WHO

49 → JI

50 C di CI

51 R → TER

52 → BIRD

53 → SNOW

54 → THE

55 S

56 → NO

57 → HOE

58 → OR

59 → ARE

60 → CLEAR

61 G dura

62 ~~ɛ~~ → EL

63 B

6 = AI
7 = È
8 = C (CASSA)
9 = P
10 = G (GIU)
11 = N (NASALE)
12 = E (STRETTA)
13 T (TAVOLO)
14 = ⟶ R IN INGLESE
15 = ⟶ U IN BUT
16 M
17 = ⟶ TS per fare la Z italiana
18 = ⟶ TH
19 = I
20 = EI
21 = ⟶ D/T in could
22 = ⟶ U in TO
23 = O
24 = A
25 = IE
26 = ⟶ A/E in FAT
27 = ⟶ H in HE ?
28 = B
29 = ⟶ TH in Thin
30 = U
31 = ⟶ EU in FOOD
32 = AU

A	24	
B	28,19	BI
C	50,19	CI
D	33,19	DI
E	12	
F	7,40,40,7	EFFE
G	10,19	GI
H	24,1,41,24	A SP1 K A
I	19	
L	7,62,7	ELE
M	7,16,7	EME
N	7,44,7	ENE
O	23	
P	9,19	PI
Q	8,30	QU
R	7,7,51,2,7	EER SP2 E
S	7,55,55,7	ESSE
T	17,19	TI
U	30	
V	35 30	VU
Z	17,55,7,13,24	TSETA

TAVOLA = 17, 24, 24, 35, 23, 62, 24, ∅
ANNO = 24, 24, 1, 44, 44, 23, 23, ∅
BIANCO = 28, 19, 24, 44, 8, 23, ∅
CASSA = 41, 24, 55, 55, 24, ∅
CIELO = 50, 7, 7, 62, 23, ∅
DADO = 33, 1, 24, 24, 2, 33, 1, 23, 23, ∅

Spectrum Voice Synthesiser

Until recently a voice synthesiser attachment to a microcomputer would have cost at least £200. With the introduction of the General Instrument SPO256 chip a good synthesiser can be built for as little as £15. In this article Robert Harvey outlines the construction and use of just such a device for the Sinclair Spectrum.

The system to be described is intended for connection to a ZX SPECTRUM but the circuit can easily be interfaced to any Z80 based micro and as the driver software is written in BASIC, this too should be transportable with little modification.

The circuit can be easily constructed on VERO VQ board using a wiring pen (also from VERO) or a PCB can be used. The dual 28 way edge connector can be soldered directly to the board and thus the finished unit (with the speaker mounted on the board) can plug in and stand up behind the Spectrum. The circuit includes a five volt power supply for the logi and it is recommended that this be used because the SP0256 chip alone uses around 90mA and it is well known that the Spectrum's own internal power supply will not stand much more loading!

The main circuit consists of three parts: Computer interface, Voice synthesiser chip and the filter amplifier circuit.

Interface

The synthesiser is interfaced to work on one of the Z80 I/O ports: When writing to this port, data is transferred to the SP0256 which then begins pronunciation. When reading the port the Busy (ie. Currently talking) signal is presented on bit 7. The actual address of the port can be changed to any of seven different addresses so that the circuit can be accommodated with any other devices connected to the computer. The three address bits A5, A6 & A7 not used within the Spectrum are used to select this port address. The software assumes port 159 is used.

The Synthesiser

This section of the circuit consists of the SP0256 chip and an oscillator made from two gates of a TTL quad NOR gate IC. GI recommend that a 3.12 MHz crystal be used and provision has been made within the chip to connect this directly without the need for external circuitry. Although, by using a separate oscillator (eliminates the need for an expensive crystal) the pitch of the synthesised voice can be changed to give the most pleasing results. The crystal, if required, can be connected between pins 27 and 28 of the SP0256. The chip itself contains all the logic to convert the allophone codes into digital speech.

The Filter/Amplifier

The output of the chip consists of a high frequency pulse width modulated signal which must be passed through a low pass filter in order to remove the high modulation frequency and obtain an analogue signal. This circuit uses a second order Butterworth filter with a cutoff frequency of 5KHz and is made from a CA3140 MOSFET operational amplifier. The signal from this is then amplified to drive a loudspeaker by an LM380 power amplifier in a standard configuration.

Allophones

This type of speech synthesiser utilises parts of the spoken word known as allophones. These are the actual sounds that go to make up speech. The synthesiser board will pronounce fifty nine allophones and in theory it should be possible to synthesise any word in the English language. Obviously though the words produced, while being understandable, will not match those produced by the human vocal tract, which has the capability of producing many more than fifty nine speech sounds!

Conversion of text to speech using allophones requires a small amount of experimentation in order to produce realistic sounds. The amount of effort depends on the composition of the word: Words with nasal and fricative sounds are harder to set right than words that contain mostly just vowels and consonants, but this is just a general guide and it is worth remembering that the sounds of different groups of letters change depending on their position within a word, and that some groups of letters have quite complicated allophone combinations. The allophone table (**Fig 2**) gives allophone numbers in decimal and a guide to their use and should help in the formation of allophone speech.

Programming The Synthesiser

The synthesiser takes a six bit code representing an allophone and generates the corresponding sound. The actual process of sending allophone codes to the synthesiser is simplicity itself and consists of just waiting for the chip to finish what it was last doing and then sending it the new code. This can be done with the following extract of BASIC code:

```
1000 IF IN 159>127 THEN GO TO
     1000
1010 OUT 159,DATA
```

Thus the following program can be used to test a sequence of allophones:

```
 10 RESTORE 100
 20 IF IN 159>127 THEN GO TO 20
 30 READ N: OUT 159,N
 40 IF N THEN GO TO 20
 50 STOP
100 DATA 42,15,16,9,49,22,13,51,0
```

In this example the word spoken will be "COMPUTER" (KK,AX,MM,PP,YY, UW,TT2,ER in allophones!) but any sequence of codes can be put as data at line 100 terminated by a zero value.

For more examples of words made from allophones (some better than others!) a program will be given next month which prints what it says just in case it is not understood!

Another area of experimentation would be to use the synthesiser to produce sound effects for games, something it could do without much computer intervention as the synthesiser will continue a sound until it receives a pause code. The next step up from the example programs would be one that converts allophone input as text into numeric strings to be sent to the synthesiser – this would go some way towards simplifying the text to allophone conversion process. Then perhaps a program could be written to convert English text directly into allophone codes.

So to conclude, this synthesiser gives one the opportunity to add speech to almost any program very cheaply. Let your computer answer back!

Next Month: PCB and Software.

PARTS LIST

Resistors

R1	10k
R2, 7, 8	330R
R3, 4	100R
R5, 6	1k0
R9	10k
R10	18k
RV1	5k

Capacitors

C1	10u
C2, 5, 9	220u
C3	220p
C4	820p
C6, 7, 8	100n

Semiconductors

IC1	74LS42
IC2	SPO256-AL2
IC3	7805
IC4	74LS32
IC5	74LS00
IC6	CA3140
IC7	LM380

Miscellaneous

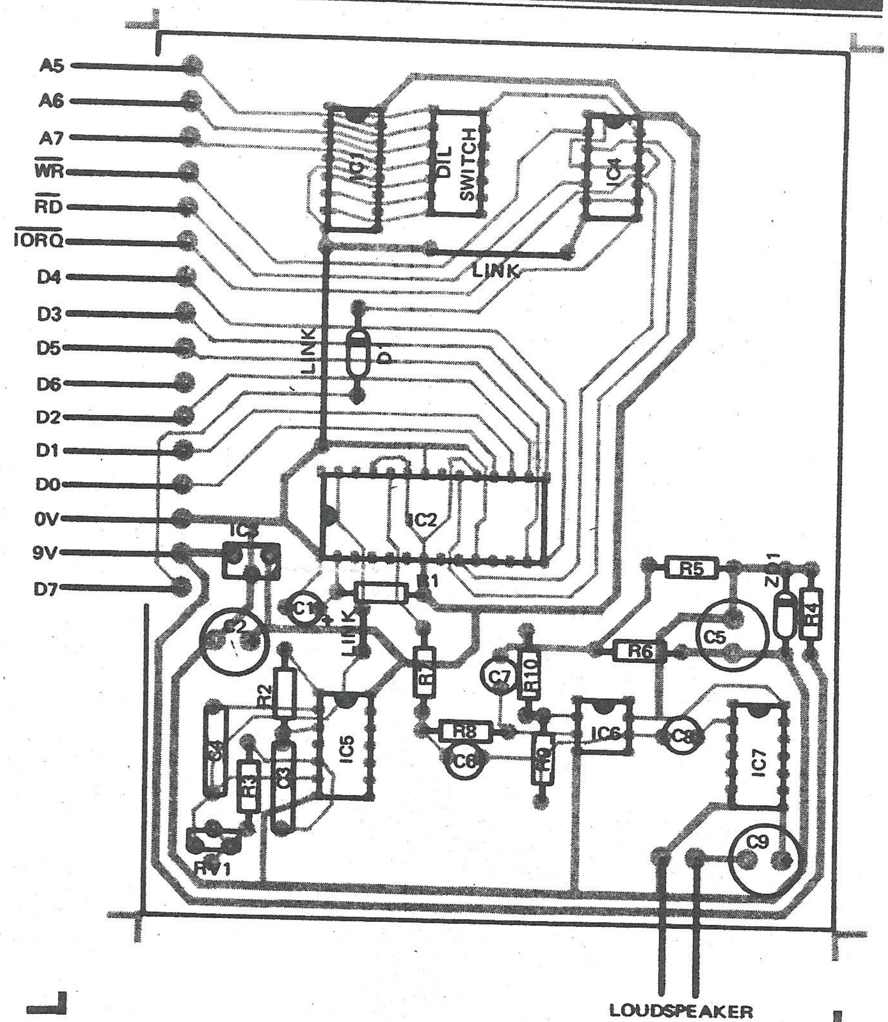
Speaker, PCB, IC sockets, connecting wire etc.

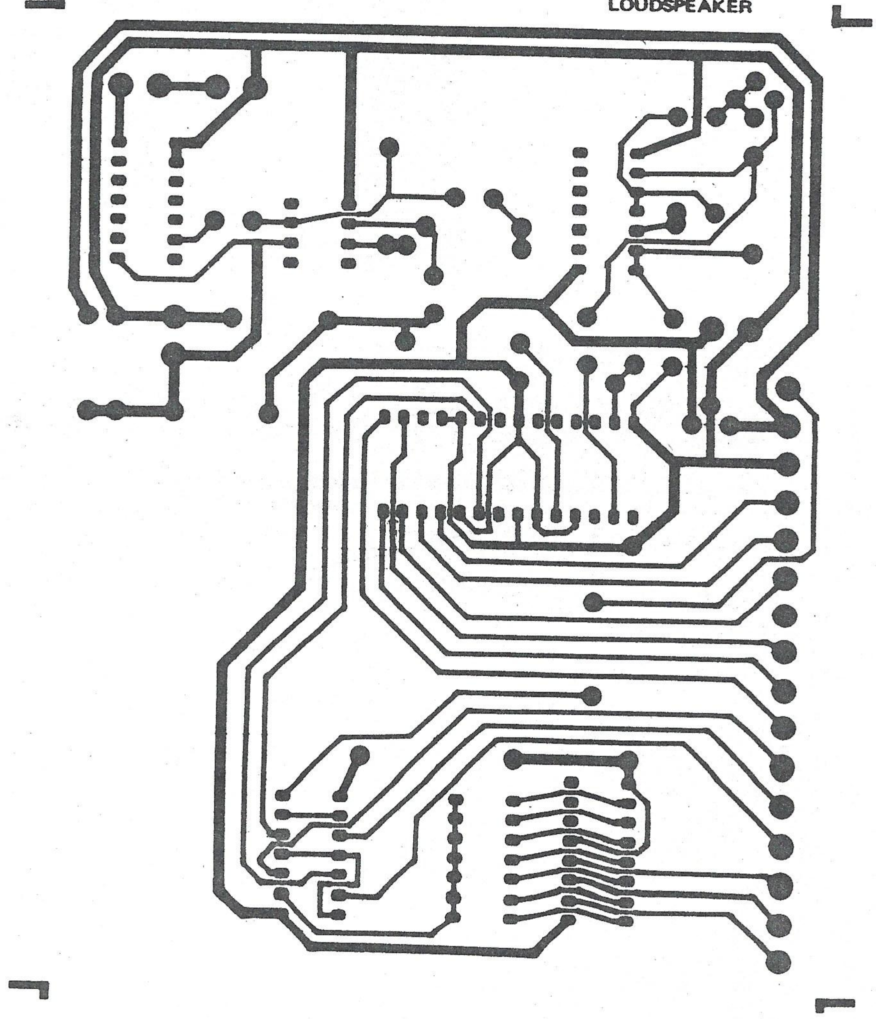
Spectrum speech synthesiser

In Part 2 of Robert Harvey's project to build a £15 speech synthesiser, the software and PCB details are given.

To recap, the speech synthesiser is based on the General Instrumenmt SPO256 chip. While the board is designed with the Spectrum specifically in mind, it can easily be interfaced to any Z80 based micro, and as the software is written in BASIC, this too should be transportable with little modification.

The circuit is easily constructed on Vero VQ Board using a wiring pen, or by using a PCB. The dual 28-way connector can be soldered directly to the board and thus the finished unit (with speaker mounted on the board) can plug in and stand up behind the Spectrum. The circuit includes a 5V power supply for the logic and it is recommended that this be used because the SPO256 alone uses around 90mA, and it is well known that the Spectrum's own internal power supply will not stand much more loading. The software is shown below in Listing 1. ■





LISTING 1

```
10    PRINT "I AM A ZX SPECTRUM COMPUTER"
20    LET X=300: GO SUB 1000:. REM *** NOW SAY IT
30    PAUSE 50
40    PRINT "PLEASE ENTER A NUMBER"
50    LET X=310: GO SUB 1000
60    LET A$=INKEY$: IF A$<"0" OR A$>"9" THEN GO TO 60
70    LET A=VAL A$
80    PRINT "THE NUMBER IS ";A
90    LET X=320: GO SUB 1000
100   LET X=A+200: GO SUB 1000
110   PAUSE 25
120   GOTO 40


199   REM **** NUMBERS ONE TO
      NINE IN ALLOPHONES
200   DATA 43,12,12,39,53,0: REM ZERO
201   DATA 46,23,11,0: REM ONE
202   DATA 13,31,0: REM TWO
203   DATA 40,14,19,0: REM THREE
204   DATA 40,58,0: REM FOUR
205   DATA 40,6,40,0: REM FIVE
206   DATA 55,12,2,41,55,0: REM SIX
207   DATA 55,7,35,7,11,0: REM SEVEN
208   DATA 20,2,13,0: REM EIGHT
209   DATA 56,6,11,0: REM NINE


299   REM **** SENTENCES IN ALLOPHONES (See PRINTs)
300   DATA 6,3,26,16,3,20,3,43,7,7,21,4,7,1,41,55,3,55
301   DATA 9,7,41,17,14,15,16,3,42,15,16,9,49,22,13,51,0
310   DATA 9,45,19,43,3,7,11,2,13,51,3,20,3,11,15,16,1
311   DATA 28,51,0
320   DATA 18,52,3,11,15,16,1,28,51,3,12,12,55,4,0
999   REM **** SUBROUTINE TO SPEAK A PHRASE
1000  RESTORE X
1010  READ IN
1020  IF IN 159>127 THEN GO TO 1020
1030  OUT 159,N
1040  IF N THEN GO TO 1020
1050  RETURN
```

TECHNICAL DATA

AN EXCLUSIVE RADIO SHACK SERVICE TO THE EXPERIMENTER

SP0256-AL2 Voice Synthesizer

Features

- Natural Speech
- Stand Alone Operation with Inexpensive Support Components
- Wide Operating Voltage
- Word, Phrase, or Sentence Library, ROM Expandable
- Expandable to 491K of ROM Directly
- Simple Interface to Most Microcomputers or Microprocessors
- Supports L.P.C. Synthesis: Formant Synthesis: Allophone Synthesis

Description

The SP0256 (Speech Processor) is a single chip N-Channel MOS LSI device that is able, using its stored program, to synthesize speech or complex sounds.

The achievable output is equivalent to a flat frequency response ranging from 0 to 5kHz, a dynamic range of 42dB, and a signal-to-noise ratio of approximately 35dB.

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- A software programmable digital filter that can be made to model a VOCAL TRACT.
- A 16K ROM which stores both data and instructions (THE PROGRAM).
- A MICROCONTROLLER which controls the data flow from the ROM to the digital filter, the assembly of the "word strings" necessary for linking speech elements together, and the amplitude and pitch information to excite the digital filter.
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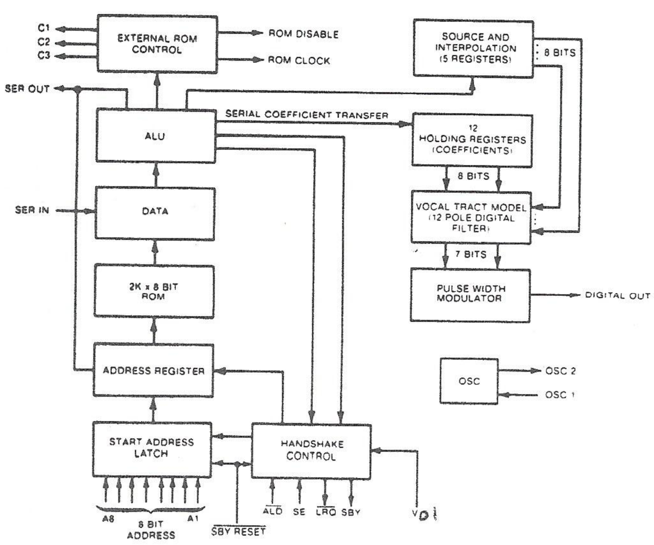
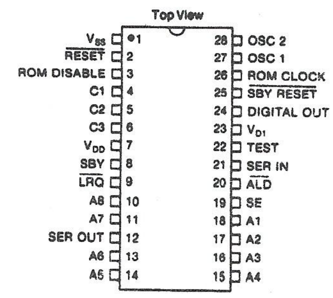
Applications

- Telecommunications
- Appliances
- Computer Peripherals
- Automotive
- Personal Computers
- Toys/Games
- Educational Aids
- Warning Systems
- Security Systems
- Electronic Musical Instruments
- Aids to the Blind
- Narrow Bandwidth
- Communication Systems



BLOCK DIAGRAM FOR SP0256

PIN CONFIGURATION
28 LEAD DUAL IN LINE



Absolute Maximum Ratings

V_{D1} V_{DD} . . . . −0.3V to +12V
Storage Temperature . . . . −25°C to +125°C
Clock Crystal Frequency 3.12MHz

DC CHARACTERISTICS

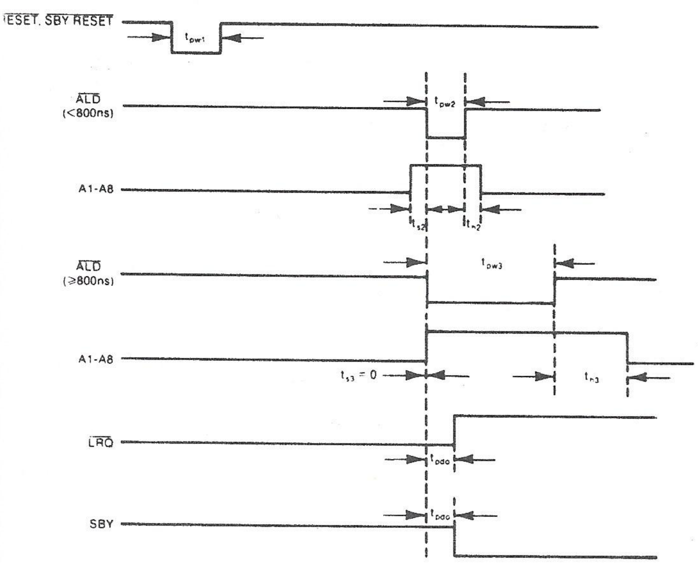
Operating Temperature T_A = 0°C to +70°C

Characteristics	Sym	Min	Max	Units
Primary Supply Voltage	V_{DD}	4.6	7	V
Standby Supply Voltage	V_{D1}	4.6	7	V
Primary Supply Current	I_{DD}	—	90	mA
Standby Supply Current	I_{D1}	—		mA
Inputs A1-A8, ALD, SER IN, TEST, SE				
Logic 0	V_{IL}	0	0.6	V
Logic 1	V_{IH}	2.4	V_{D1}	V
Capacitance	C_{IN}	—	10	pf
Leakage	I_{LC}	—	± 10	μA
RESET, SBY RESET Logic 0	V_{IL1}	0	0.6	V
Logic 1	V_{IH1}	3.6	V_{D1}	V
Oscillator Leakage OSC 1 (7.0V, no load)	—	1.0	10	μA
Outputs SBY, DIGITAL OUT, C1, C2, C3, LRQ, ROM DISABLE, ROM CLOCK, SER OUT Logic 0 (0.72mA load)	V_{OL}	0	0.6	V
Logic 1 (−50μA load)	V_{OH}	3.5	V_{D1}	V

AC CHARACTERISTICS

Operating Temperature: $T_A = 0°C$ to $+70°C$

Characteristics	Sym	Min	Max	Units
Clock Frequency, 3.120 MHz	–	–	–	MHz
$\overline{\text{Reset}}$, $\overline{\text{SBY Reset}}$	t_{pw1}	100	–	μs
$\overline{\text{ALD}}$ (<800ns)	t_{pw2}	200	800	ns
A1-A8 Set Up	t_{s2}	160	–	ns
A1-A8 Hold	t_{h2}	160	–	ns
$\overline{\text{ALD}}$ (≥800ns)	t_{pw3}	800	–	ns
A1-A8 Set Up	t_{s3}	0	–	ns
A1-A8 Hold	t_{h3}	1200	–	ns
$\overline{\text{LRQ}}$	t_{pd0}	–	640	ns
SBY	t_{pd0}	–	640	ns



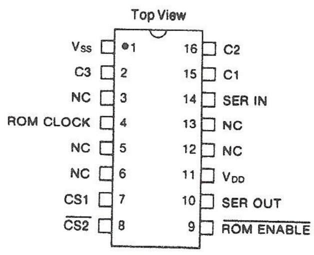
TIMING DIAGRAM

Vocabulary List

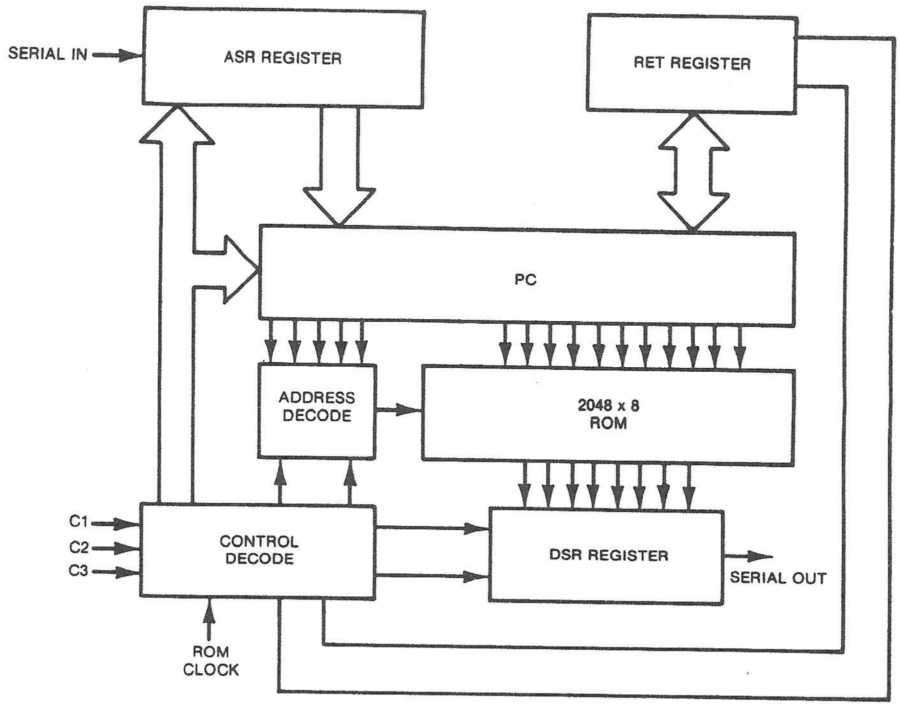
Address	Word	Address	Word
0	Oh	18	Eighteen
1	One	19	Nineteen
2	Two	20	Twenty
3	Three	21	Thirty
4	Four	22	Forty
5	Five	23	Fifty
6	Six	24	It Is
7	Seven	25	A.M.
8	Eight	26	P.M.
9	Nine	27	Hour
10	Ten	28	Minute
11	Eleven	29	Hundred Hour
12	Twelve	30	Good Morning
13	Thirteen	31	Attention Please
14	Fourteen	32	Please Hurry
15	Fifteen	33	Melody A
16	Sixteen	34	Melody B
17	Seventeen	35	Melody C

PIN FUNCTIONS

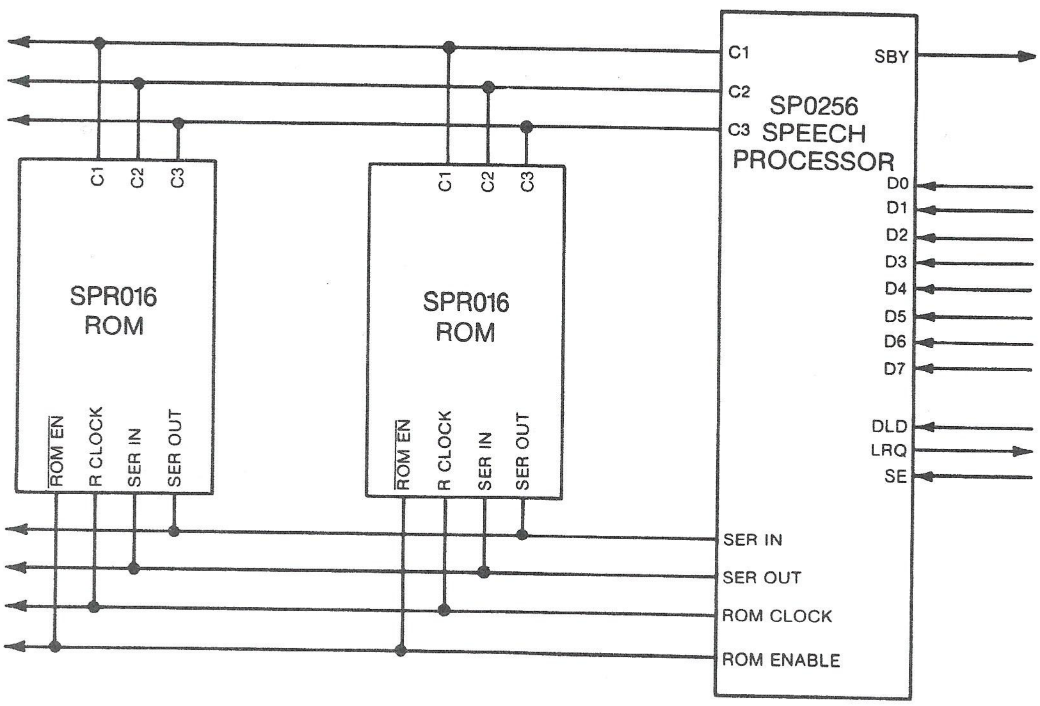
Pin Number	Name	Function
1	V_{SS}	Ground
2	$\overline{\text{RESET}}$	A logic 0 resets the SP. Must be returned to a logic 1 for normal operation.
3	ROM DISABLE	For use with an external serial speech ROM. A logic 1 disables the external ROM.
4,5,6	C1,C2,C3	Output control lines used by an external serial speech ROM.
7	V_{DD}	Primary power supply.
8	SBY	STANDBY. A logic 1 output indicates that the SP is inactive (i.e. not talking) and V_{DD} can be powered down externally to conserve power. When the SP is reactivated by an address being loaded. SBY will go to logic 0.
9	$\overline{\text{LRQ}}$	$\overline{\text{LOAD REQUEST}}$. $\overline{\text{LRQ}}$ is a logic 1 output whenever the input buffer is full. When $\overline{\text{LRQ}}$ goes to a logic 0, the input port is loaded by placing the 8 address bits on A1-A8 and pulsing the $\overline{\text{ALD}}$ input.
10,11,13, 14,15,16, 17,18	A8,A7,A6,A5, A4,A3,A2,A1	8-bit address which defines any one of 256 speech entry points.
12	SER OUT	SERIAL ADDRESS OUT. This output transfers a 16-bit address serially to an external speech ROM.
19	SE	STROBE ENABLE. Normally held in a logic 1 state. When tied to ground, ALD is disabled and the SP will automatically latch in the address on the input bus approximately 1μs after detecting a logic 1 on any address line.
20	$\overline{\text{ALD}}$	$\overline{\text{ADDRESS LOAD}}$. A negative pulse on this input loads the 8 address bits into the input port. The leading edge of this pulse causes $\overline{\text{LRQ}}$ to go high.
21	SER IN	SERIAL IN. This is an 8-bit serial data input from an external speech ROM.
22	TEST	A logic 1 places the SP in test mode. This pin should normally be grounded.
23	V_{D1}	Standby power supply for the interface logic and controller.
24	DIGITAL OUT	Pulse width modulated digital speech output which, when filtered by a 5kHz low pass filter and amplified, will drive a loudspeaker.
25	$\overline{\text{SBY RESET}}$	STANDBY RESET. A logic 0 resets the interface logic. Normally should be a logic 1.
26	ROM CLOCK	1.56MHz clock for an external serial speech ROM.
27	OSC 1	XTAL IN. Input connection for a 3.12MHz crystal.
28	OSC 2	XTAL OUT. Output connection for a 3.12MHz crystal.



Pin Configuration for SPR016



BLOCK DIAGRAM FOR SPR016



Simple Interface of SPR016s to SP0256

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583-LWC

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TECHNICAL DATA

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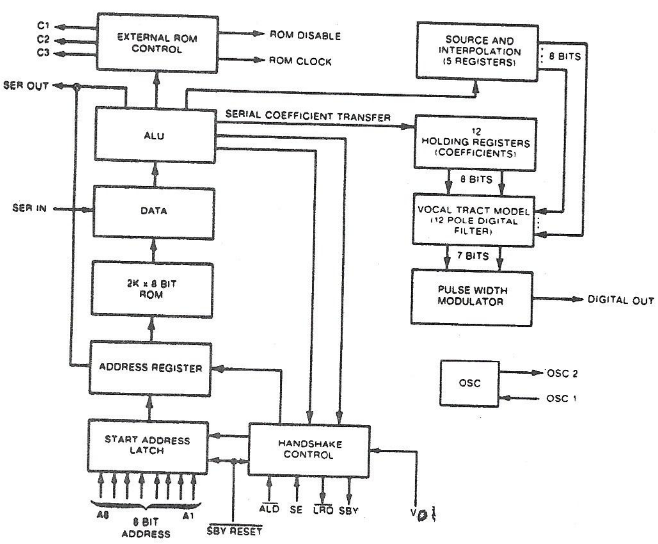
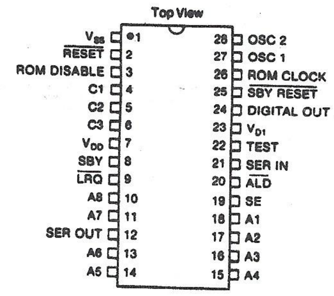


BLOCK DIAGRAM FOR SPO256

PIN CONFIGURATION
28 LEAD DUAL IN LINE



Absolute Maximum Ratings

V_{D1} V_{DD} . . . . –0.3V to +12V
Storage Temperature . . . . –25°C to +125°C
Clock Crystal Frequency 3.12MHz

DC CHARACTERISTICS

Operating Temperature T_A = 0°C to +70°C

Characteristics	Sym	Min	Max	Units
Primary Supply Voltage	V_{DD}	4.6	7	V
Standby Supply Voltage	V_{D1}	4.6	7	V
Primary Supply Current	I_{DD}	–	90	mA
Standby Supply Current	I_{D1}	–		mA
Inputs A1-A8, ALD, SER IN, TEST, SE				
Logic 0	V_{IL}	0	0.6	V
Logic 1	V_{IH}	2.4	V_{D1}	V
Capacitance	C_{IN}	–	10	pf
Leakage	I_{LC}	–	± 10	μA
RESET, SBY RESET				
Logic 0	V_{IL1}	0	0.6	V
Logic 1	V_{IH1}	3.6	V_{D1}	V
Oscillator Leakage OSC 1 (7.0V, no load)	–	1.0	10	μA
Outputs SBY, DIGITAL OUT, C1, C2, C3, LRQ, ROM DISABLE, ROM CLOCK, SER OUT				
Logic 0 (0.72mA load)	V_{OL}	0	0.6	V
Logic 1 (–50μA load)	V_{OH}	3.5	V_{D1}	V

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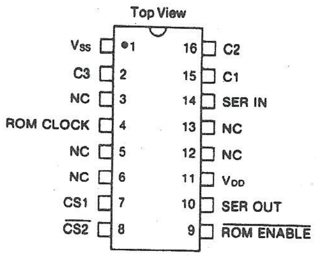
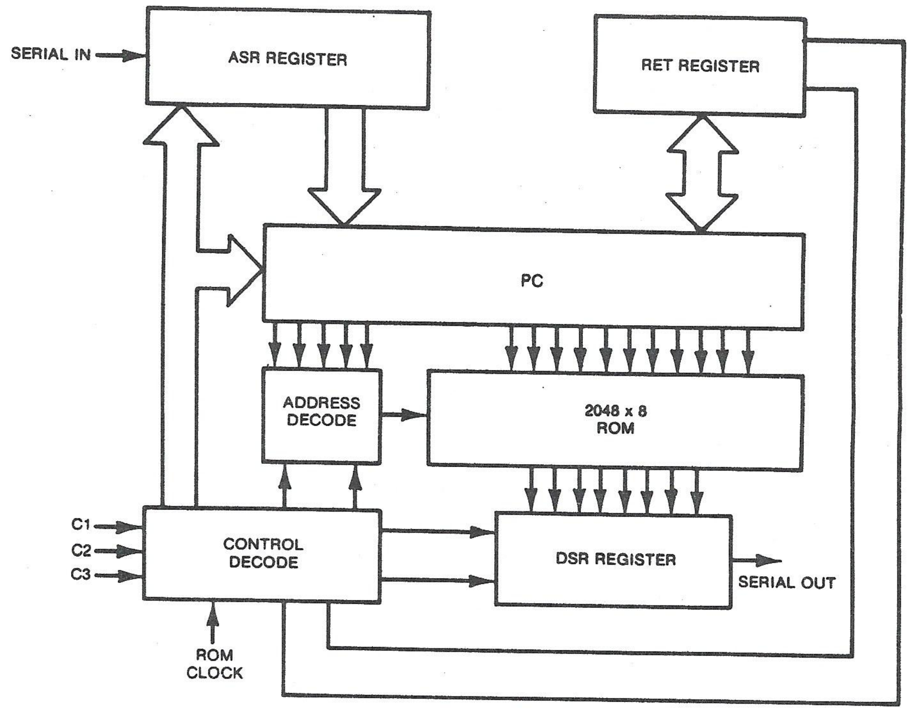
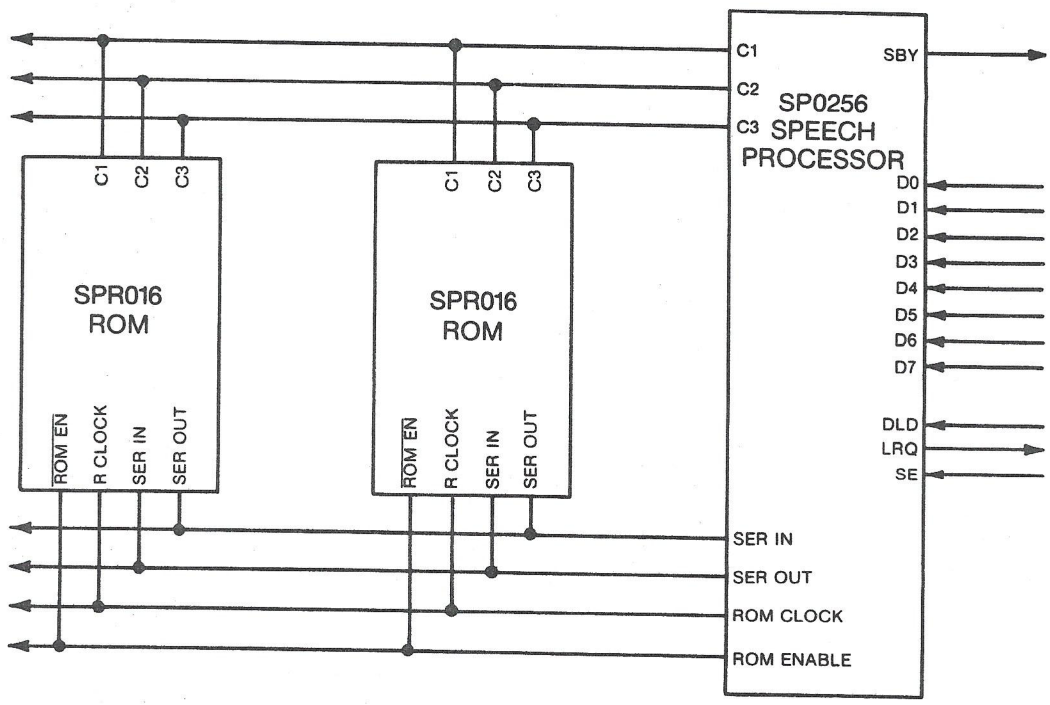


Pin Configuration for SPR016



BLOCK DIAGRAM FOR SPR016



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Clock Frequency, 3.120 MHz	–	–	–	MHz
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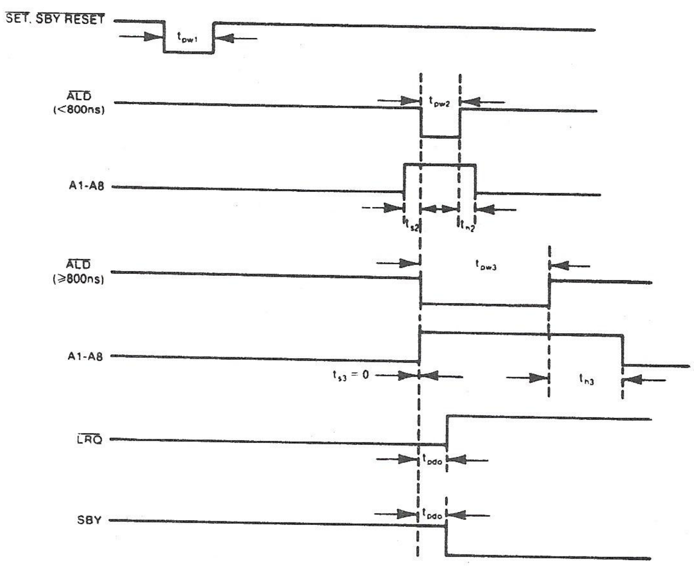
$\overline{\text{ALD}}$ (< 800ns)	t_{pw2}	200	800	ns
A1-A8 Set Up	t_{s2}	160	–	ns
A1-A8 Hold	t_{h2}	160	–	ns
$\overline{\text{ALD}}$ (≥ 800ns)	t_{pw3}	800	–	ns
A1-A8 Set Up	t_{s3}	0	–	ns
A1-A8 Hold	t_{h3}	1200	–	ns
$\overline{\text{LRQ}}$	t_{pd0}	–	640	ns
SBY	t_{pd0}	–	640	ns



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8	Eight	26	P.M.
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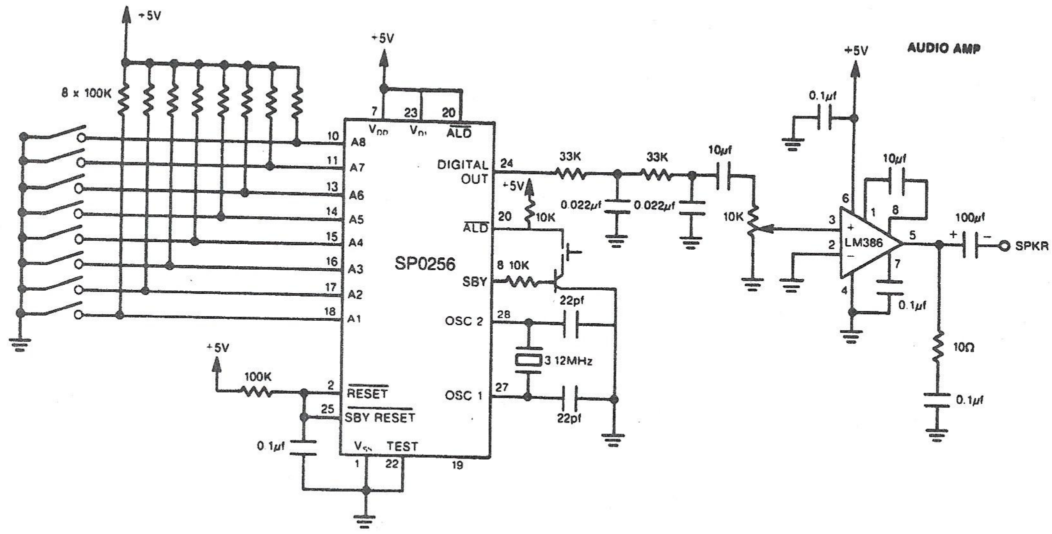
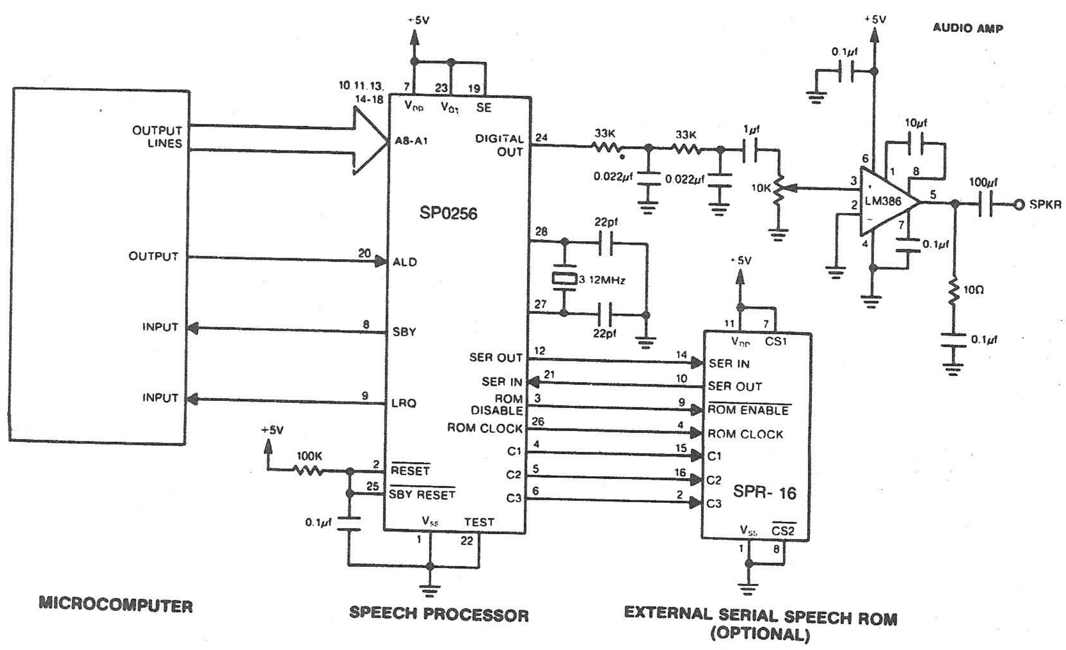
9	$\overline{\text{LRQ}}$	LOAD REQUEST. $\overline{\text{LRQ}}$ is a logic 1 output whenever the input buffer is full. When $\overline{\text{LRQ}}$ goes to a logic 0, the input port is loaded by placing the 8 address bits on A1-A8 and pulsing the $\overline{\text{ALD}}$ input.
10,11,13, 14,15,16, 17,18	A8,A7,A6,A5, A4,A3,A2,A1	8-bit address which defines any one of 256 speech entry points.
12	SER OUT	SERIAL ADDRESS OUT. This output transfers a 16-bit address serially to an external speech ROM.
19	SE	STROBE ENABLE. Normally held in a logic 1 state. When tied to ground, ALD is disabled and the SP will automatically latch in the address on the input bus approximately 1μs after detecting a logic 1 on any address line.
20	$\overline{\text{ALD}}$	ADDRESS LOAD. A negative pulse on this input loads the 8 address bits into the input port. The leading edge of this pulse causes $\overline{\text{LRQ}}$ to go high.
21	SER IN	SERIAL IN. This is an 8-bit serial data input from an external speech ROM.
22	TEST	A logic 1 places the SP in test mode. This pin should normally be grounded.
23	V_{D1}	Standby power supply for the interface logic and controller.
24	DIGITAL OUT	Pulse width modulated digital speech output which, when filtered by a 5kHz low pass filter and amplified, will drive a loudspeaker.
25	SBY $\overline{\text{RESET}}$	STANDBY RESET. A logic 0 resets the interface logic. Normally should be a logic 1.
26	ROM CLOCK	1.56MHz clock for an external serial speech ROM.
27	OSC 1	XTAL IN. Input connection for a 3.12MHz crystal.
28	OSC 2	XTAL OUT. Output connection for a 3.12MHz crystal.

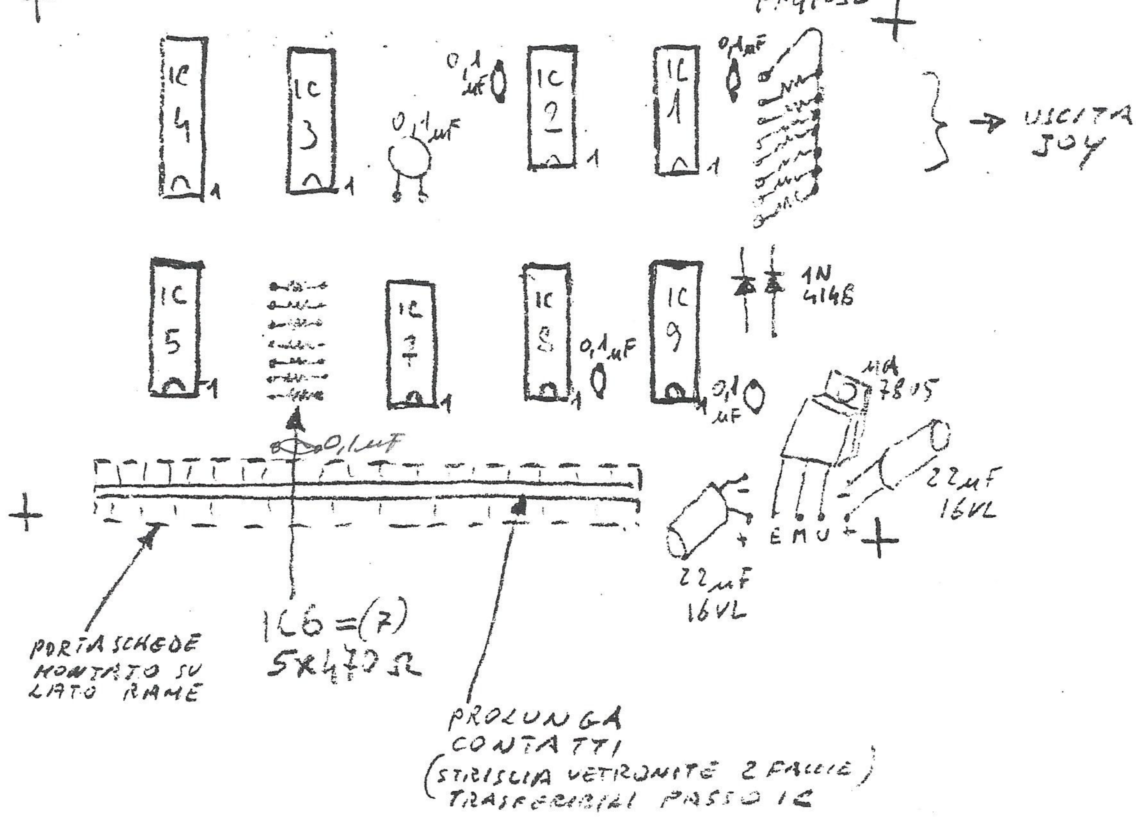


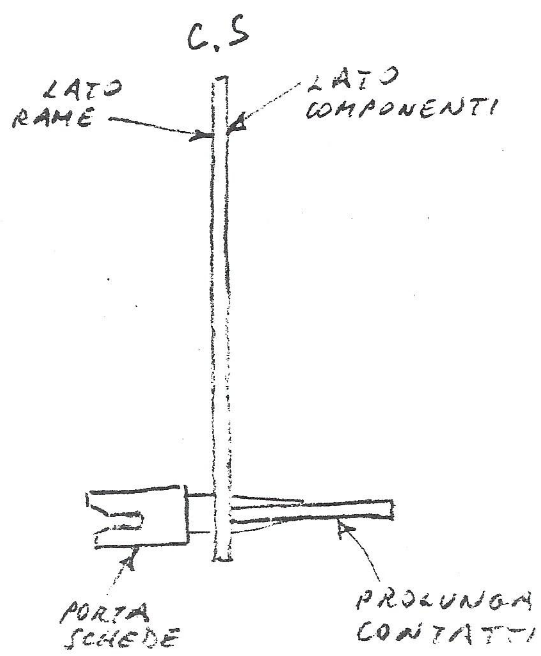
TYPICAL APPLICATION STAND ALONE CONFIGURATION



TYPICAL APPLICATION MICROCOMPUTER INTERFACE

VISTA LATO COMPONENTI



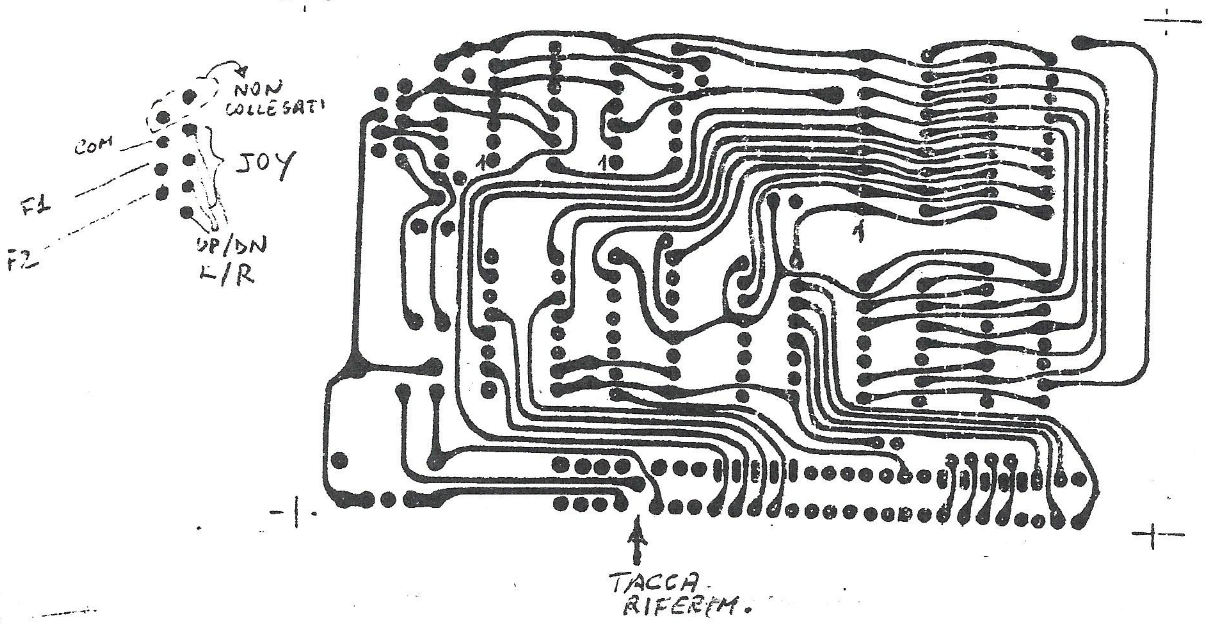


Elenco Compon.

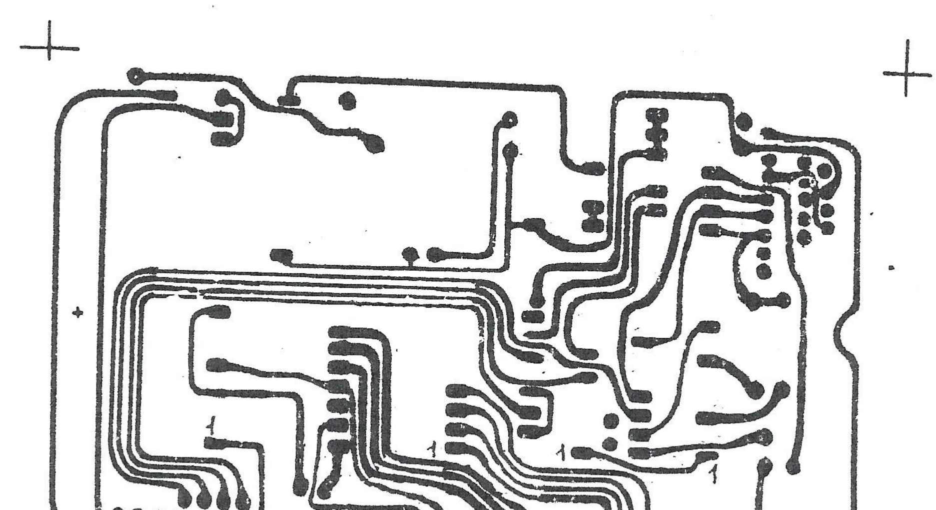
IC1 = 74LS260
IC2 = 74LS00
IC3 = µPD 2114 } MEMOR.
IC4 = " "
IC5 = 74LS365
(IC6) = (Resist. 470Ω)
IC7 = 74LS148
IC8 = 74LS157
IC9 = " "

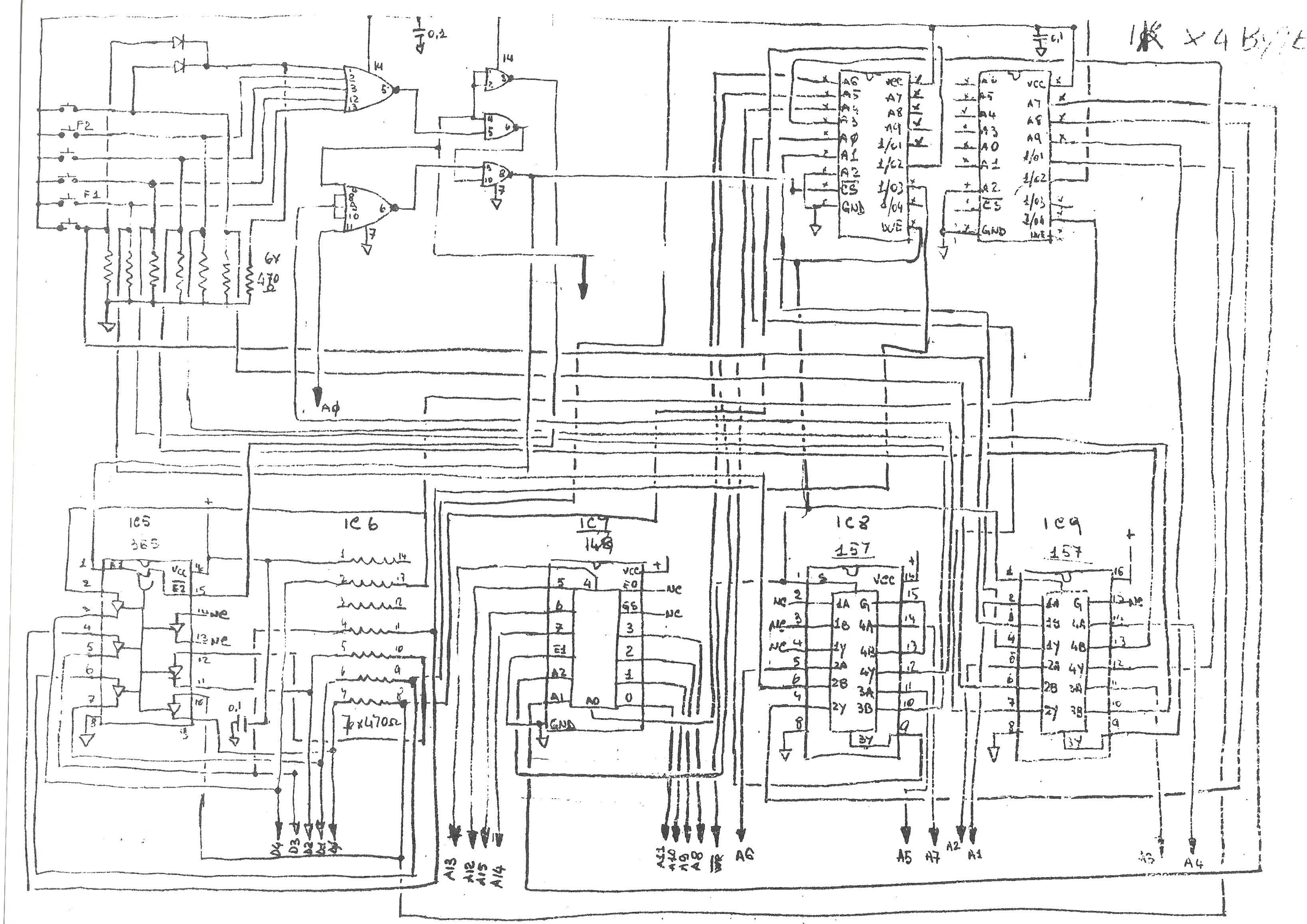
2) Elettrolitici 22µF 16VL
1) µA 7805
2) 1N4148
6) Cond. 0.1µF
13) 470 Ω 1/4 w
1) Portaschede
1) Jack a vaschetta

LATO RAME

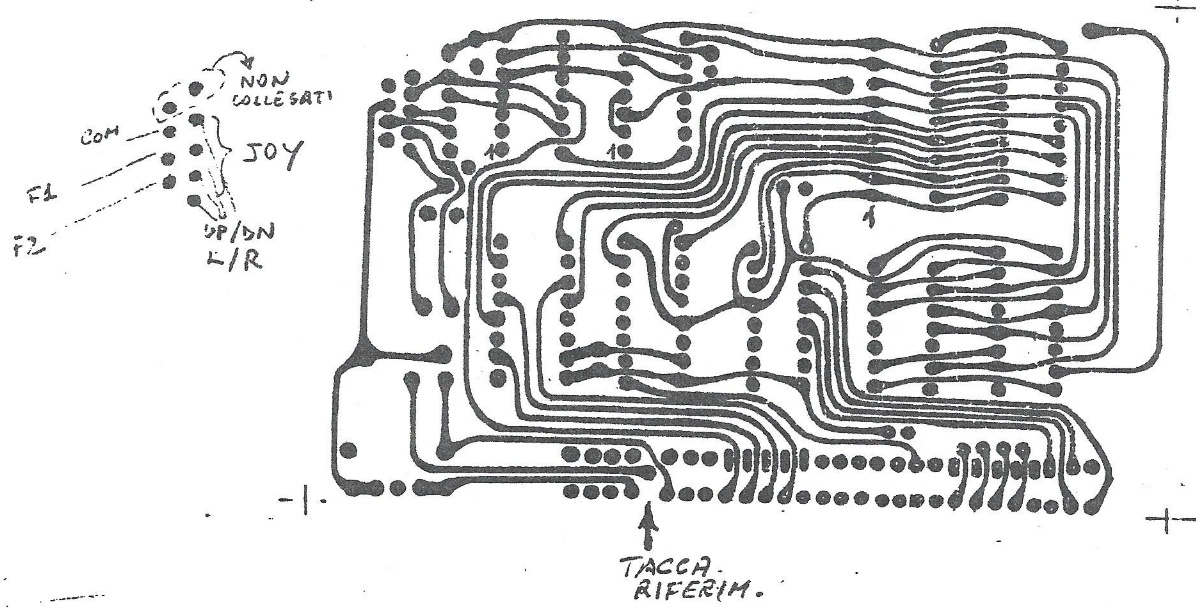


LATO COMPONENTI

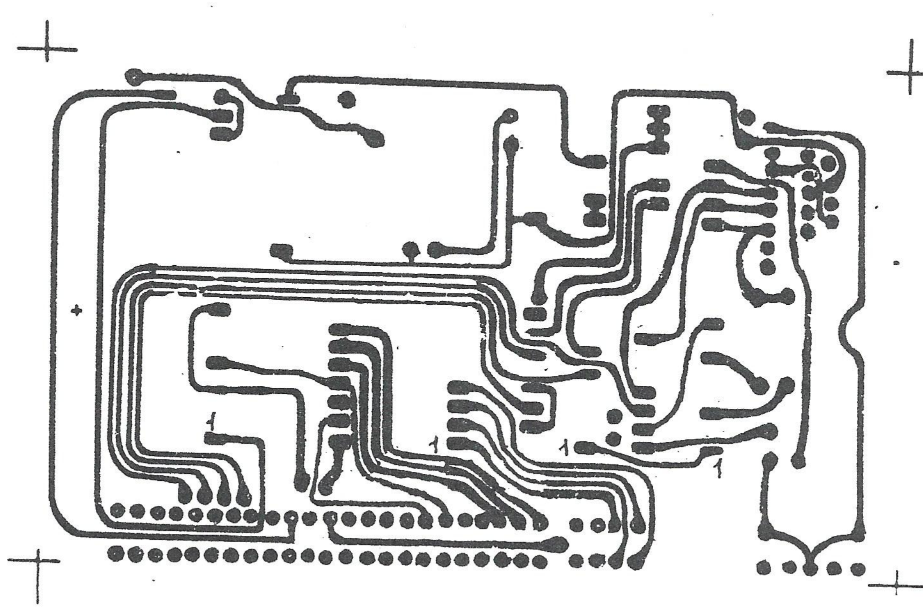



1K x 4 Byte
IC5
365
IC6
7x470Ω
IC7
148
IC8
157
IC9
157
F1
F2
6x 470
A0
A13
A12
A15
A14
A11
A10
A9
A8
A6
A5
A7
A2
A1
A3
A4
D4
D3
D2
D1
D0

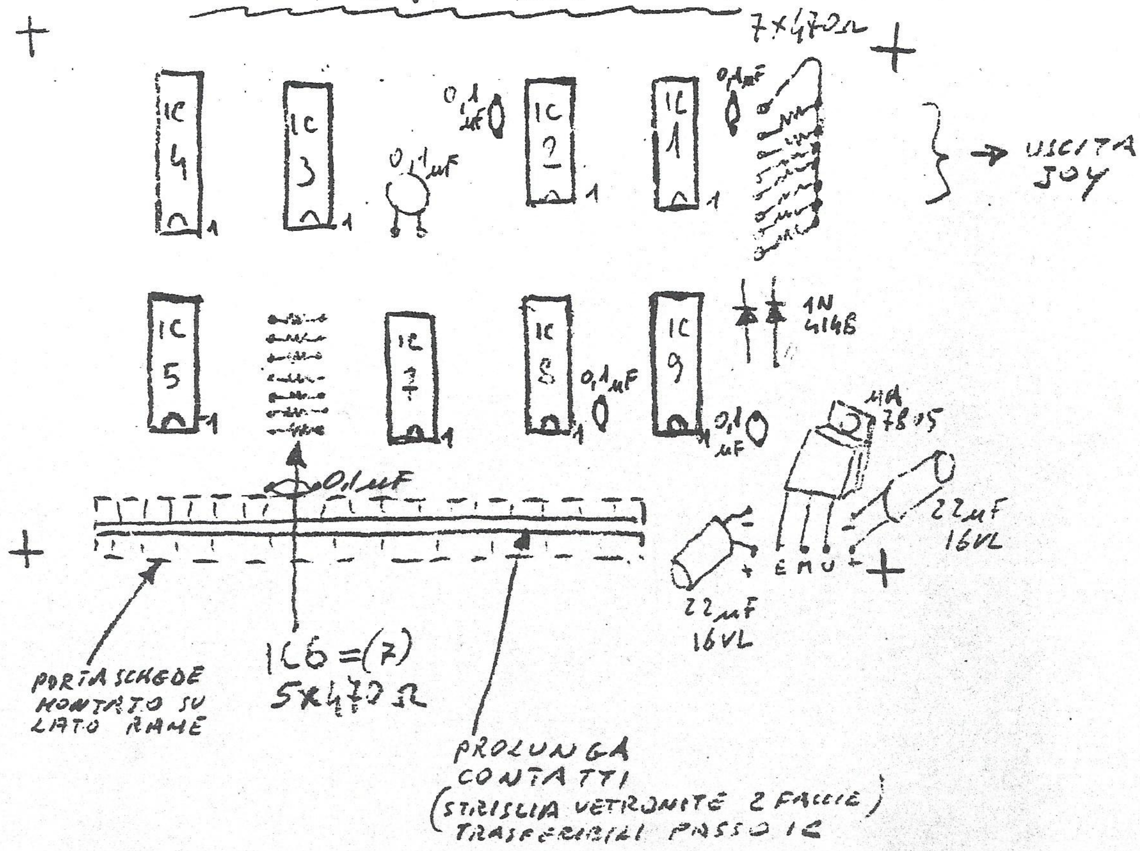
LATO RAME

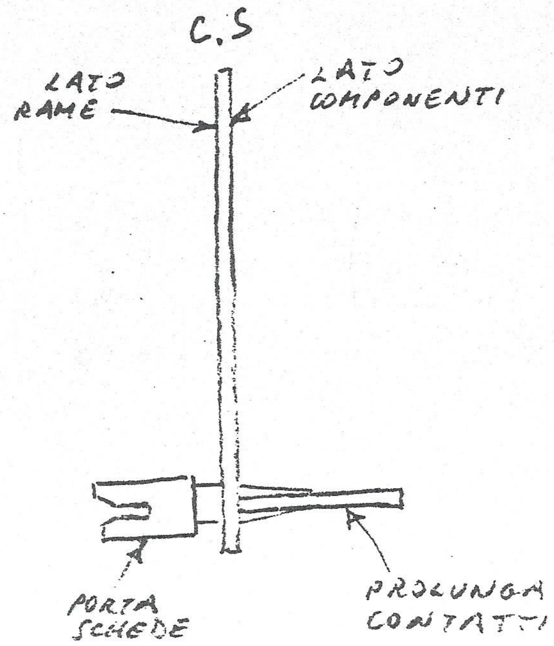


LATO COMPONENTI



VISTA LATO COMPONENTI





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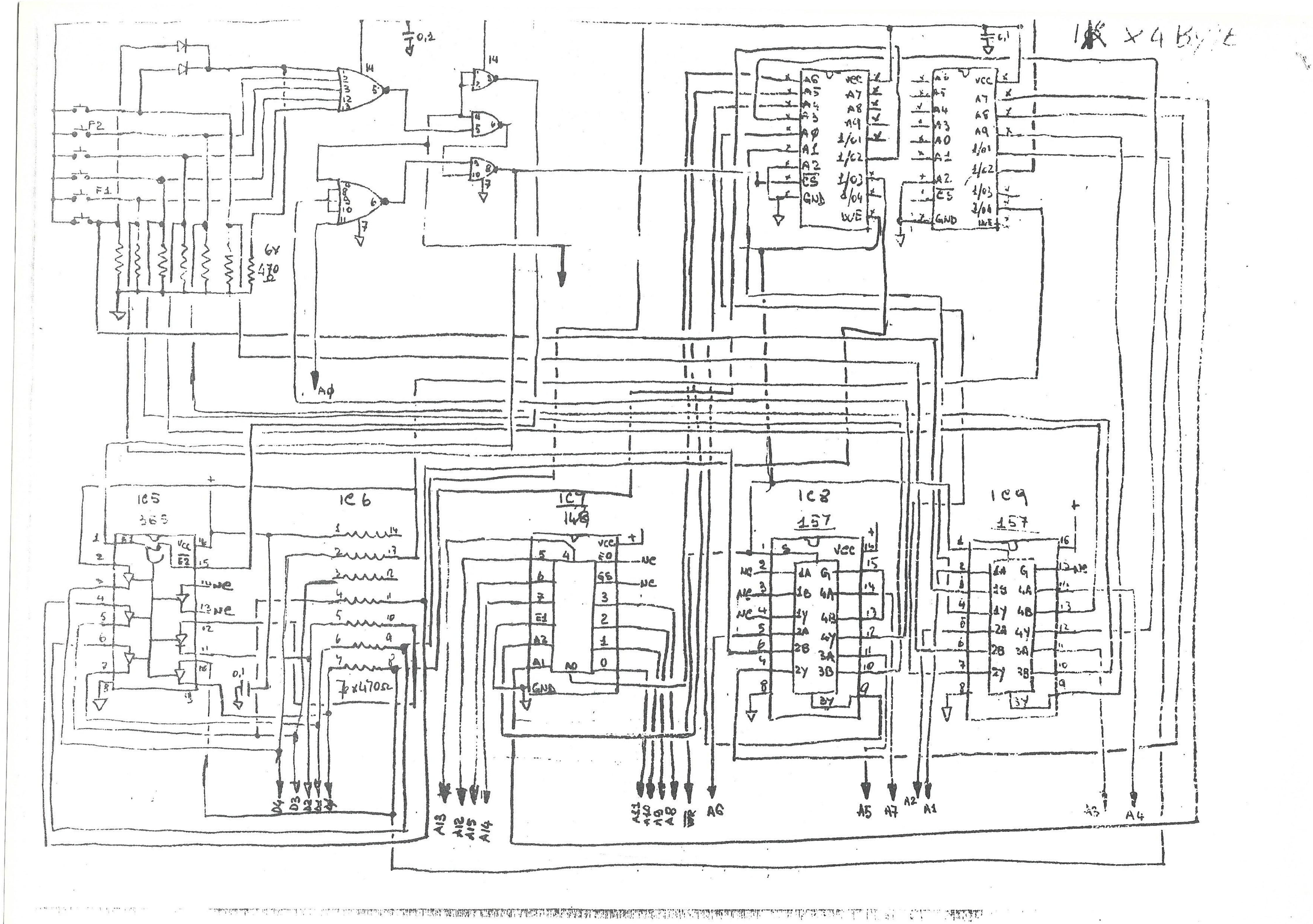
30578



1K x 4 Byte
IC5
365
IC6
7 x 470Ω
IC7
148
IC8
157
IC9
157
F1
F2
6 x 470
A0
D4
D3
D2
D1
A13
A12
A15
A14
A11
A10
A9
A8
AB
A6
A5
A7
A2
A1
A3
A4

Spectrum Voice Synthesiser

Until recently a voice synthesiser attachment to a microcomputer would have cost at least £200. With the introduction of the General Instrument SPO256 chip a good synthesiser can be built for as little as £15. In this article Robert Harvey outlines the construction and use of just such a device for the Sinclair Spectrum.

The system to be described is intended for connection to a ZX SPECTRUM but the circuit can easily be interfaced to any Z80 based micro and as the driver software is written in BASIC, this too should be transportable with little modification.

The circuit can be easily constructed on VERO VQ board using a wiring pen (also from VERO) or a PCB can be used. The dual 28 way edge connector can be soldered directly to the board and thus the finished unit (with the speaker mounted on the board) can plug in and stand up behind the Spectrum. The circuit includes a five volt power supply for the logic and it is recommended that this be used because the SP0256 chip alone uses around 90mA and it is well known that the Spectrum's own internal power supply will not stand much more loading!

The main circuit consists of three parts: Computer interface, Voice synthesiser chip and the filter amplifier circuit.

Interface

The synthesiser is interfaced to work on one of the Z80 I/O ports: When writing to this port, data is transferred to the SP0256 which then begins pronunciation. When reading the port the Busy (ie. Currently talking) signal is presented on bit 7. The actual address of the port can be changed to any of seven different addresses so that the circuit can be accommodated with any other devices connected to the computer. The three address bits A5, A6 & A7 not used within the Spectrum are used to select this port address. The software assumes port 159 is used.

The Synthesiser

This section of the circuit consists of the SP0256 chip and an oscillator made from two gates of a TTL quad NOR gate IC. GI recommend that a 3.12 MHz crystal be used and provision has been made within the chip to connect this directly without the need for external circuitry. Although, by using a separate oscillator (eliminates the need for an expensive crystal) the pitch of the synthesised voice can be changed to give the most pleasing results. The crystal, if required, can be connected between pins 27 and 28 of the SP0256. The chip itself contains all the logic to convert the allophone codes into digital speech.

The Filter/Amplifier

The output of the chip consists of a high frequency pulse width modulated signal which must be passed through a low pass filter in order to remove the high modulation frequency and obtain an analogue signal. This circuit uses a second order Butterworth filter with a cutoff frequency of 5KHz and is made from a CA3140 MOSFET operational amplifier. The signal from this is then amplified to drive a loudspeaker by an LM380 power amplifier in a standard configuration.

Allophones

This type of speech synthesiser utilises parts of the spoken word known as allophones. These are the actual sounds that go to make up speech. The synthesiser board will pronounce fifty nine allophones and in theory it should be possible to synthesise any word in the English language. Obviously though the words produced, while being understandable, will not match those produced by the human vocal tract, which has the capability of producing many more than fifty nine speech sounds!

Conversion of text to speech using allophones requires a small amount of experimentation in order to produce realistic sounds. The amount of effort depends on the composition of the word: Words with nasal and fricative sounds are harder to set right than words that contain mostly just vowels and consonants, but this is just a general guide and it is worth remembering that the sounds of different groups of letters change depending on their position within a word, and that some groups of letters have quite complicated allophone combinations. The allophone table (**Fig 2**) gives allophone numbers in decimal and a guide to their use and should help in the formation of allophone speech.

Programming The Synthesiser

The synthesiser takes a six bit code representing an allophone and generates the corresponding sound. The actual process of sending allophone codes to the synthesiser is simplicity itself and consists of just waiting for the chip to finish what it was last doing and then sending it the new code. This can be done with the following extract of BASIC code:

```
1000 IF IN 159>127 THEN GO TO
     1000
1010 OUT 159,DATA
```

Thus the following program can be used to test a sequence of allophones:

```
 10 RESTORE 100
 20 IF IN 159>127 THEN GO TO 20
 30 READ N: OUT 159,N
 40 IF N THEN GO TO 20
 50 STOP
100 DATA 42,15,16,9,49,22,13,51,0
```

In this example the word spoken will be "COMPUTER" (KK,AX,MM,PP,YY, UW,TT2,ER in allophones!) but any sequence of codes can be put as data at line 100 terminated by a zero value.

For more examples of words made from allophones (some better than others!) a program will be given next month which prints what it says just in case it is not understood!

Another area of experimentation would be to use the synthesiser to produce sound effects for games, something it could do without much computer intervention as the synthesiser will continue a sound until it receives a pause code. The next step up from the example programs would be one that converts allophone input as text into numeric strings to be sent to the synthesiser – this would go some way towards simplifying the text to allophone conversion process. Then perhaps a program could be written to convert English text directly into allophone codes.

So to conclude, this synthesiser gives one the opportunity to add speech to almost any program very cheaply. Let your computer answer back!

Next Month: PCB and Software.

PARTS LIST

Resistors

R1	10k
R2, 7, 8	330R
R3, 4	100R
R5, 6	1k0
R9	10k
R10	18k
RV1	5k

Capacitors

C1	10u
C2, 5, 9	220u
C3	220p
C4	820p
C6, 7, 8	100n

Semiconductors

IC1	74LS42
IC2	SPO256-AL2
IC3	7805
IC4	74LS32
IC5	74LS00
IC6	CA3140
IC7	LM380

Miscellaneous

Speaker, PCB, IC sockets, connecting wire etc.

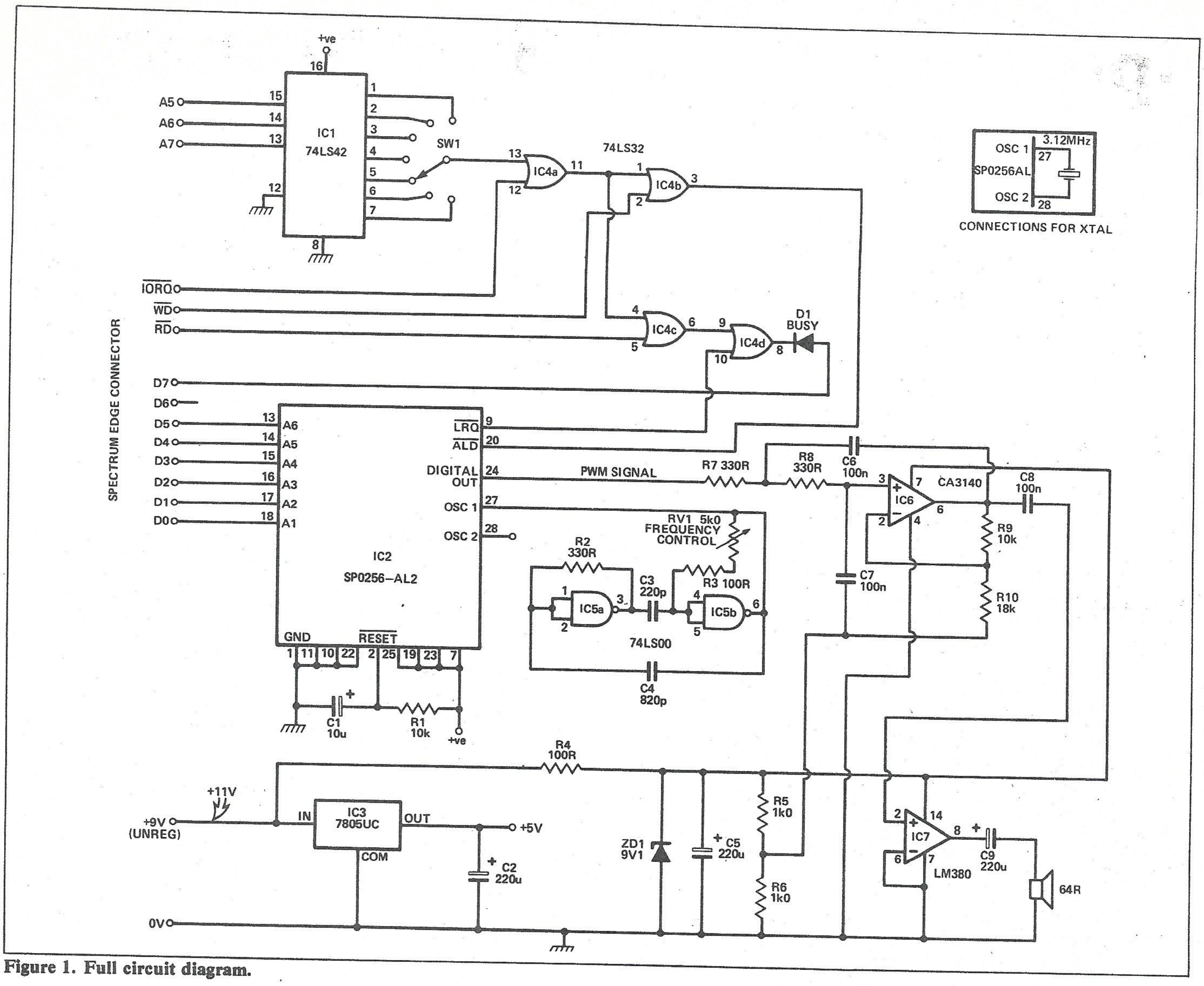


Figure 1. Full circuit diagram.

Allophone Table

Pauses

0	PA1 (10 mS)	use before voiced stops and afficates
1	PA2 (30 mS)	use before voiced stops and afficates
2	PA3 (50 mS)	before voiceless stops and voiced fricatives also between words
3	PA4 (100mS)	Between clauses and sentences
4	PA5 (200mS)	Between clauses and sentences

Short Vowels – These can be repeated

7	EH	E	bend
12	IH	I	fitting
15	AX	U	succeed
23	AO	AU	aught
24	AA	O	cot
26	AE	A	fat
30	UH	OO	cook

Long Vowels

5	OY	OY	toy
6	AY	Y	sky
19	IY	E	see
20	EY	EA	great
22	UW	O	to
31	UW2	OO	food
32	AW	OU	out
53	OW	OW	snow
62	EL	L	angle

R-Coloured Vowels

47	XR	AI	hair
51	ER	ER	computer
52	ER2	IR	bird (monosyllables)
58	OR	OR	store
59	AR	AR	farm
60	YR	R	clear

Resonants

14	RR	R	read
39	RR2	R	brain
49	YY	U	computer
25	YY2	Y	yes
45	LL	L	luck
46	WW	W	wool

Voiced Fricatives

18	DH	TH	they
54	DH2	TH	bathe
35	VV	V	even
43	ZZ	Z	zoo
38	ZH	GE	beige

Voiceless Fricatives

29	TH	TH	thin
40	FF	F	fire
55	SS	S	sat
27	HH	H	he
57	HH2	H	hoe
37	SH	SH	shirt
48	WH	WH	whig

(29, 40, 55 double for initial positions)

Voiced Stops

28	BB	B	rib
63	BB2	B	big
21	DD	D	could
33	DD2	D	do
36	GG	GU	guest
61	GG2	G	go
34	GG3	IG	wig

Voiceless Stops

17	TT	T	its
13	TT2	T	to
42	KK	C	computer
41	KK2	K	sky
8	KK3	C	crane
9	PP	P	pub

Affricates

10	JH	J	jury
50	CH	CH	church

Nasal

16	MM	M	milk
11	NN	N	earn
56	NN2	N	no
44	NG	NG	bans

Spectrum speech synthesiser

In Part 2 of Robert Harvey's project to build a £15 speech synthesiser, the software and PCB details are given.

To recap, the speech synthesiser is based on the General Instrumenmt SPO256 chip. While the board is designed with the Spectrum specifically in mind, it can easily be interfaced to any Z80 based micro, and as the software is written in BASIC, this too should be transportable with little modification.

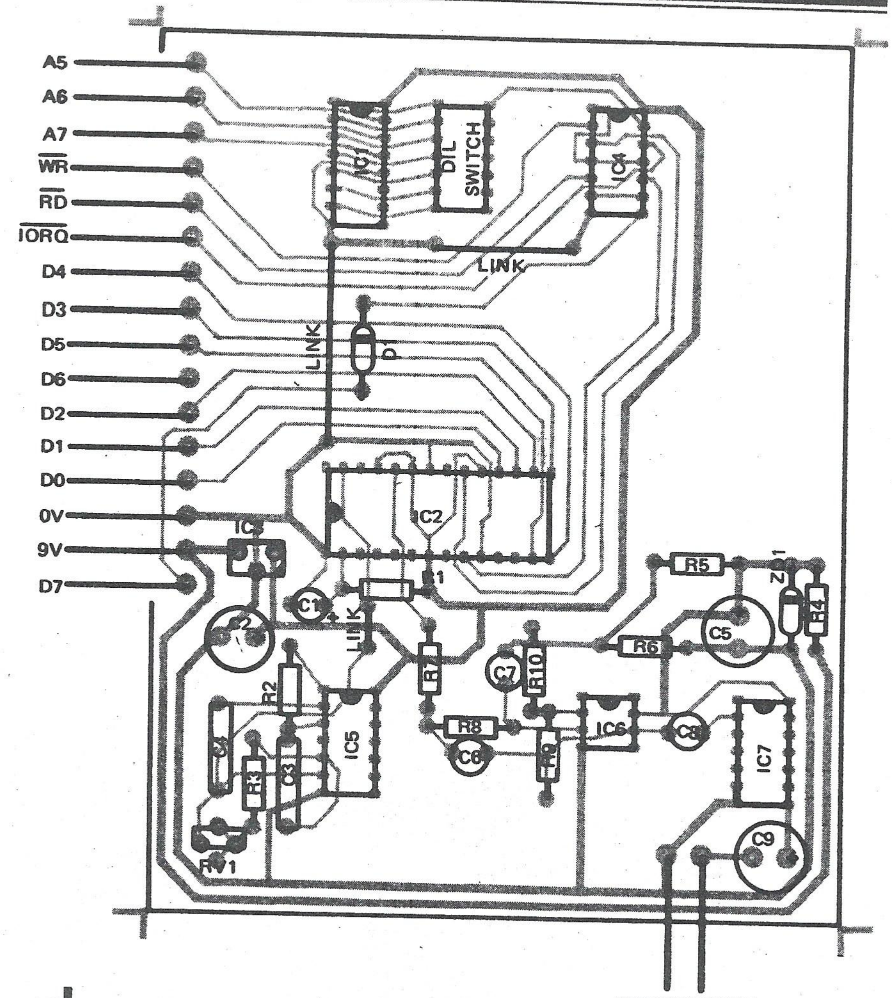
The circuit is easily constructed on Vero VQ Board using a wiring pen, or by using a PCB. The dual 28-way connector can be soldered directly to the board and thus the finished unit (with speaker mounted on the board) can plug in and stand up behind the Spectrum. The circuit includes a 5V power supply for the logic and it is recommended that this be used because the SPO256 alone uses around 90mA, and it is well known that the Spectrum's own internal power supply will not stand much more loading. The software is shown below in Listing 1. ■

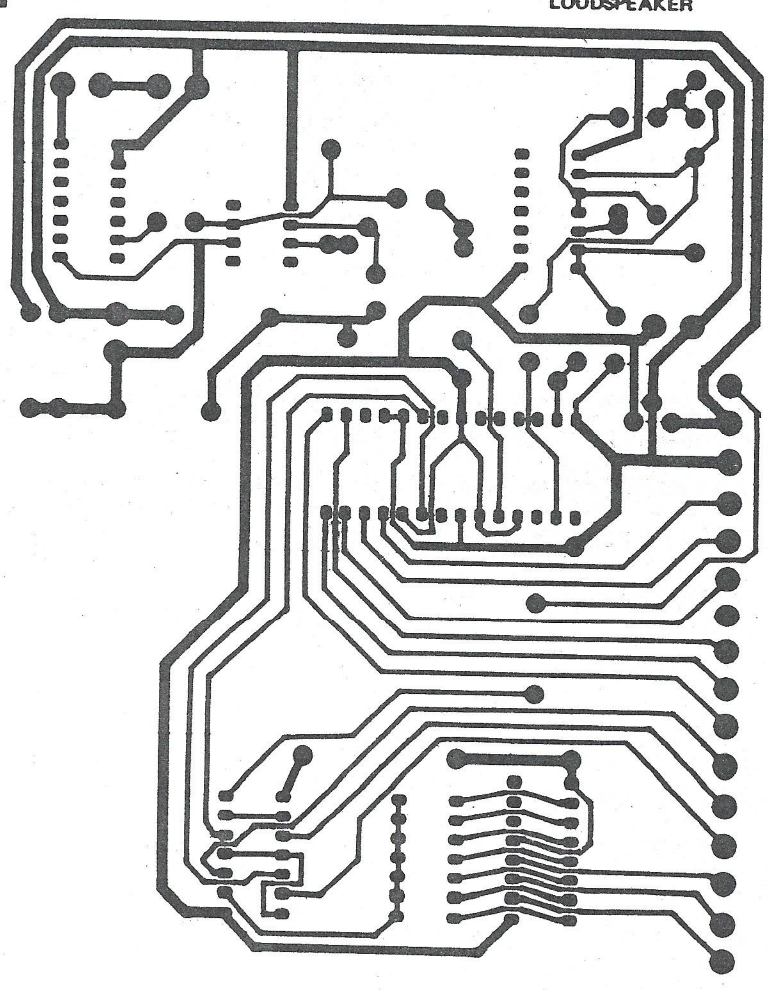
LISTING 1

```
10   PRINT "I AM A ZX SPECTRUM COMPUTER"
20   LET X=300: GO SUB 1000:. REM *** NOW SAY IT
30   PAUSE 50
40   PRINT "PLEASE ENTER A NUMBER"
50   LET X=310: GO SUB 1000
60   LET A$=INKEY$: IF A$<"0" OR A$>"9" THEN GO TO 60
70   LET A=VAL A$
80   PRINT "THE NUMBER IS ";A
90   LET X=320: GO SUB 1000
100  LET X=A+200: GO SUB 1000
110  PAUSE 25
120  GOTO 40


199  REM **** NUMBERS ONE TO
     NINE IN ALLOPHONES
200  DATA 43,12,12,39,53,0: REM ZERO
201  DATA 46,23,11,0: REM ONE
202  DATA 13,31,0: REM TWO
203  DATA 40,14,19,0: REM THREE
204  DATA 40,58,0: REM FOUR
205  DATA 40.6.40.0: REM FIVE
206  DATA 55,12,2,41,55,0: REM SIX
207  DATA 55,7,35,7,11,0: REM SEVEN
208  DATA 20,2,13,0: REM EIGHT
209  DATA 56,6,11,0: REM NINE


299  REM **** SENTENCES IN ALLOPHONES (See PRINTs)
300  DATA 6,3,26,16,3,20,3,43,7,7,21,4,7,1,41,55,3,55
301  DATA 9,7,41,17,14,15,16,3,42,15,16,9,49,22,13,51,0
310  DATA 9,45,19,43,3,7,11,2,13,51,3,20,3,11,15,16,1
311  DATA 28,51,0
320  DATA 18,52,3,11,15,16,1,28,51,3,12,12,55,4,0
999  REM **** SUBROUTINE TO SPEAK A PHRASE
1000 RESTORE X
1010 READ IN
1020 IF IN 159>127 THEN GO TO 1020
1030 OUT 159,N
1040 IF N THEN GO TO 1020
1050 RETURN
```





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TECHNICAL DATA

AN EXCLUSIVE RADIO SHACK SERVICE TO THE EXPERIMENTER

SP0256-AL2 Voice Synthesizer

Features

- Natural Speech
- Stand Alone Operation with Inexpensive Support Components
- Wide Operating Voltage
- Word, Phrase, or Sentence Library, ROM Expandable
- Expandable to 491K of ROM Directly
- Simple Interface to Most Microcomputers or Microprocessors
- Supports L.P.C. Synthesis: Formant Synthesis: Allophone Synthesis

Description

The SP0256 (Speech Processor) is a single chip N-Channel MOS LSI device that is able, using its stored program, to synthesize speech or complex sounds.

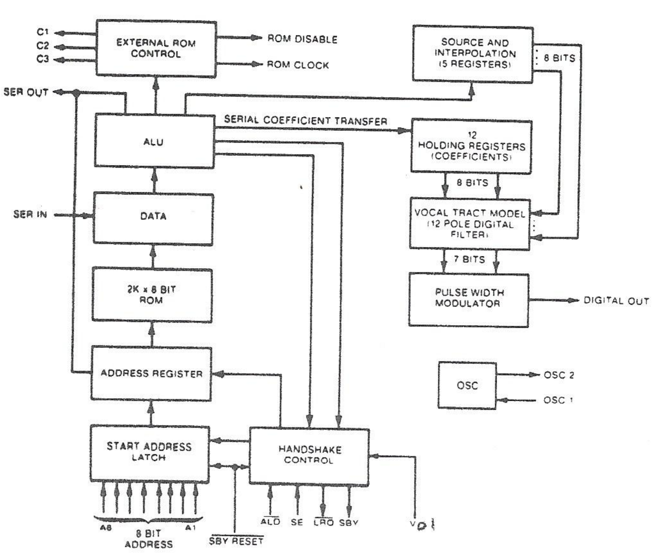
The achievable output is equivalent to a flat frequency response ranging from 0 to 5kHz, a dynamic range of 42dB, and a signal-to-noise ratio of approximately 35dB.

The SP0256 incorporates four basic functions:

- A software programmable digital filter that can be made to model a VOCAL TRACT.
- A 16K ROM which stores both data and instructions (THE PROGRAM).
- A MICROCONTROLLER which controls the data flow from the ROM to the digital filter, the assembly of the "word strings" necessary for linking speech elements together, and the amplitude and pitch information to excite the digital filter.
- A PULSE WIDTH MODULATOR that creates a digital output which is converted to an analog signal when filtered by an external low pass filter.

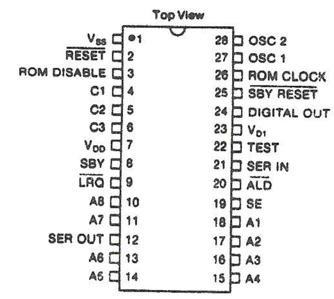
Applications

- Telecommunications
- Appliances
- Computer Peripherals
- Automotive
- Personal Computers
- Toys/Games
- Educational Aids
- Warning Systems
- Security Systems
- Electronic Musical Instruments
- Aids to the Blind
- Narrow Bandwidth
- Communication Systems



BLOCK DIAGRAM FOR SP0256

PIN CONFIGURATION
28 LEAD DUAL IN LINE



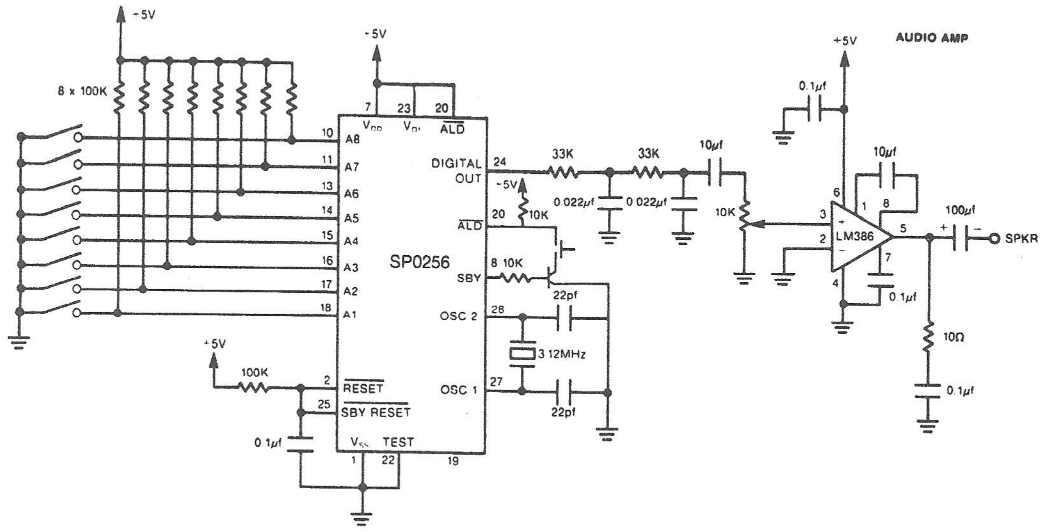
Absolute Maximum Ratings

V_{D1} V_{DD} . . . . −0.3V to +12V
Storage Temperature . . . . −25°C to +125°C
Clock Crystal Frequency 3.12MHz

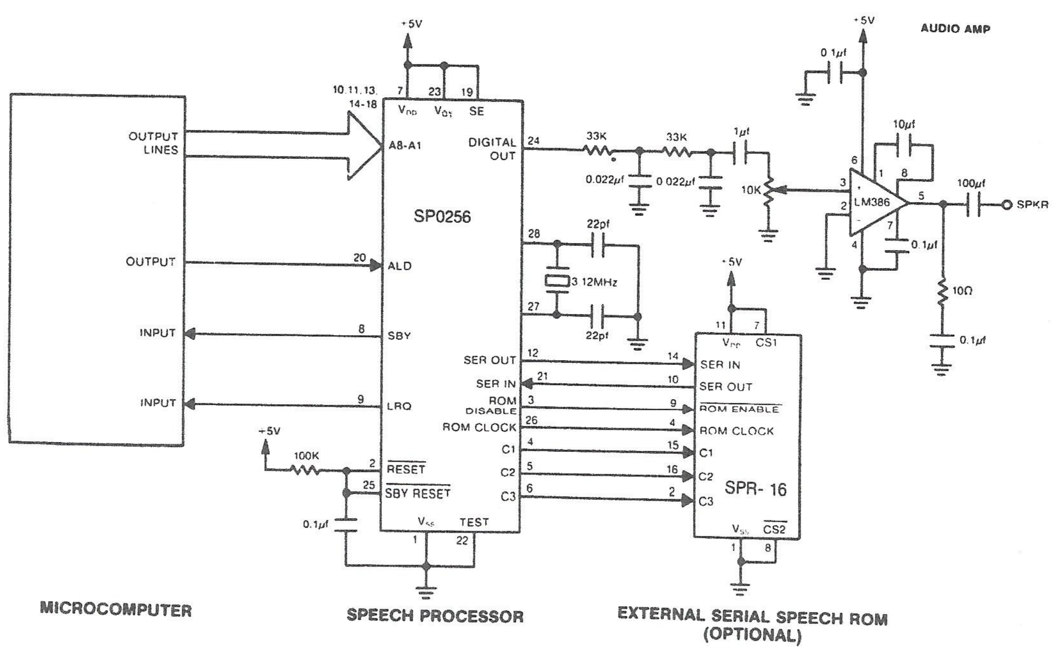
DC CHARACTERISTICS

Operating Temperature T_A = 0°C to +70°C

Characteristics	Sym	Min	Max	Units
Primary Supply Voltage	V_{DD}	4.6	7	V
Standby Supply Voltage	V_{D1}	4.6	7	V
Primary Supply Current	I_{DD}	–	90	mA
Standby Supply Current	I_{D1}	–		mA
Inputs A1-A8, ALD, SER IN, TEST, SE				
Logic 0	V_{IL}	0	0.6	V
Logic 1	V_{IH}	2.4	V_{D1}	V
Capacitance	C_{IN}	–	10	pf
Leakage	I_{LC}	–	± 10	µA
RESET, SBY RESET				
Logic 0	V_{IL1}	0	0.6	V
Logic 1	V_{IH1}	3.6	V_{D1}	V
Oscillator Leakage OSC 1 (7.0V, no load)	–	1.0	10	µA
Outputs SBY, DIGITAL OUT, C1, C2, C3, LRQ, ROM DISABLE, ROM CLOCK, SER OUT				
Logic 0 (0.72mA load)	V_{OL}	0	0.6	V
Logic 1 (−50µA load)	V_{OH}	3.5	V_{D1}	V



TYPICAL APPLICATION STAND ALONE CONFIGURATION

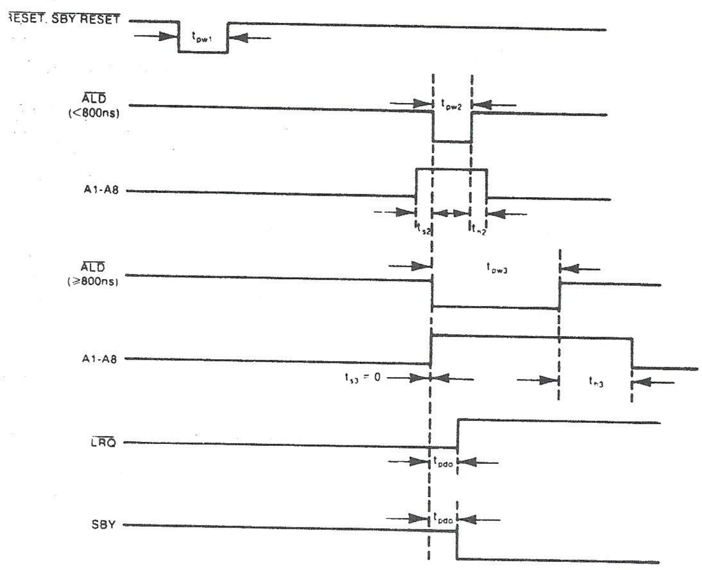


TYPICAL APPLICATION MICROCOMPUTER INTERFACE

AC CHARACTERISTICS

Operating Temperature: T_A = 0°C to +70°C

Characteristics	Sym	Min	Max	Units
Clock Frequency, 3.120 MHz	–	–	–	MHz
$\overline{\text{Reset}}$, $\overline{\text{SBY Reset}}$	t_{pw1}	100	–	μs
$\overline{\text{ALD}}$ (< 800ns)	t_{pw2}	200	800	ns
A1-A8 Set Up	t_{s2}	160	–	ns
A1-A8 Hold	t_{h2}	160	–	ns
$\overline{\text{ALD}}$ (≥ 800ns)	t_{pw3}	800	–	ns
A1-A8 Set Up	t_{s3}	0	–	ns
A1-A8 Hold	t_{h3}	1200	–	ns
$\overline{\text{LRQ}}$	t_{pd0}	–	640	ns
SBY	t_{pd0}	–	640	ns



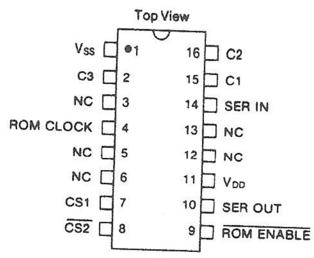
TIMING DIAGRAM

Vocabulary List

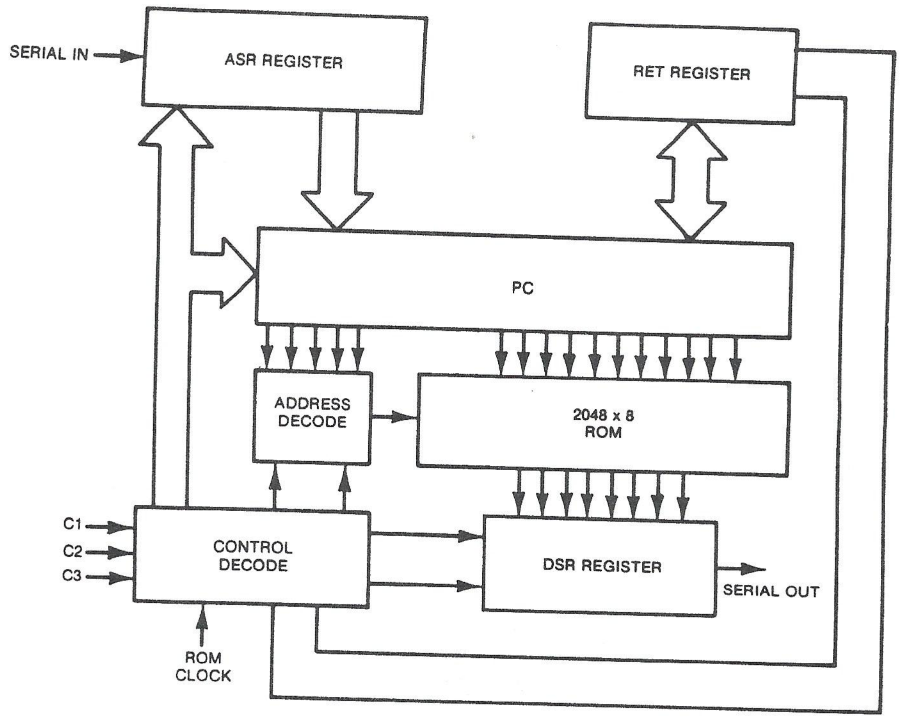
Address	Word	Address	Word
0	Oh	18	Eighteen
1	One	19	Nineteen
2	Two	20	Twenty
3	Three	21	Thirty
4	Four	22	Forty
5	Five	23	Fifty
6	Six	24	It Is
7	Seven	25	A.M.
8	Eight	26	P.M.
9	Nine	27	Hour
10	Ten	28	Minute
11	Eleven	29	Hundred Hour
12	Twelve	30	Good Morning
13	Thirteen	31	Attention Please
14	Fourteen	32	Please Hurry
15	Fifteen	33	Melody A
16	Sixteen	34	Melody B
17	Seventeen	35	Melody C

PIN FUNCTIONS

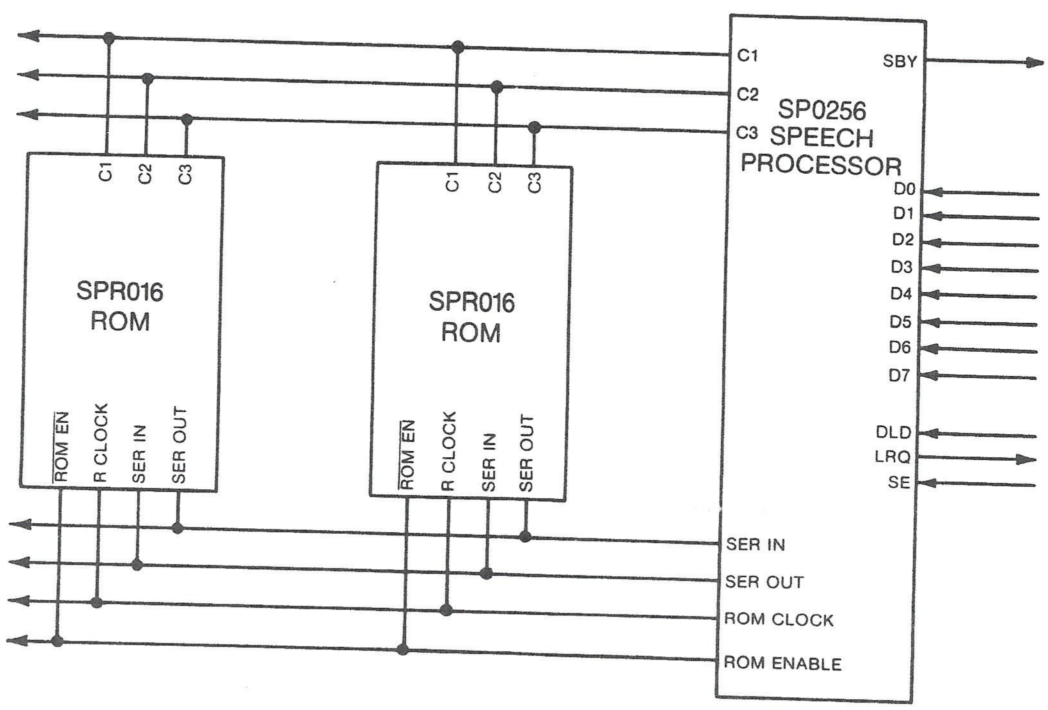
Pin Number	Name	Function
1	V_{SS}	Ground
2	$\overline{\text{RESET}}$	A logic 0 resets the SP. Must be returned to a logic 1 for normal operation.
3	ROM DISABLE	For use with an external serial speech ROM. A logic 1 disables the external ROM.
4,5,6	C1,C2,C3	Output control lines used by an external serial speech ROM.
7	V_{DD}	Primary power supply.
8	SBY	STANDBY. A logic 1 output indicates that the SP is inactive (i.e. not talking) and V_{DD} can be powered down externally to conserve power. When the SP is reactivated by an address being loaded. SBY will go to logic 0.
9	$\overline{\text{LRQ}}$	LOAD REQUEST. $\overline{\text{LRQ}}$ is a logic 1 output whenever the input buffer is full. When $\overline{\text{LRQ}}$ goes to a logic 0, the input port is loaded by placing the 8 address bits on A1-A8 and pulsing the $\overline{\text{ALD}}$ input.
10,11,13, 14,15,16, 17,18	A8,A7,A6,A5, A4,A3,A2,A1	8-bit address which defines any one of 256 speech entry points.
12	SER OUT	SERIAL ADDRESS OUT. This output transfers a 16-bit address serially to an external speech ROM.
19	SE	STROBE ENABLE. Normally held in a logic 1 state. When tied to ground, ALD is disabled and the SP will automatically latch in the address on the input bus approximately 1μs after detecting a logic 1 on any address line.
20	$\overline{\text{ALD}}$	ADDRESS LOAD. A negative pulse on this input loads the 8 address bits into the input port. The leading edge of this pulse causes $\overline{\text{LRQ}}$ to go high.
21	SER IN	SERIAL IN. This is an 8-bit serial data input from an external speech ROM.
22	TEST	A logic 1 places the SP in test mode. This pin should normally be grounded.
23	V_{D1}	Standby power supply for the interface logic and controller.
24	DIGITAL OUT	Pulse width modulated digital speech output which, when filtered by a 5kHz low pass filter and amplified, will drive a loudspeaker.
25	$\overline{\text{SBY RESET}}$	STANDBY RESET. A logic 0 resets the interface logic. Normally should be a logic 1.
26	ROM CLOCK	1.56MHz clock for an external serial speech ROM.
27	OSC 1	XTAL IN. Input connection for a 3.12MHz crystal.
28	OSC 2	XTAL OUT. Output connection for a 3.12MHz crystal.



Pin Configuration for SPR016



BLOCK DIAGRAM FOR SPR016



Simple Interface of SPR016s to SP0256

RADIO SHACK, A DIVISION OF TANDY CORPORATION

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NOTE SU SPEECH SYNT.

- PUÒ ESSERE ALIMENTATO ANCHE CON 6V
- IL DIP SWITCH DEVE ESSERE TUTTO SU ON PER LO Ø E VANNO MESSI SU OFF GLI INDIRIZZI CHE SI VOGLIONO SENTIRE.
- ALL'ACCENSIONE OCCORRE A VOLTE DARE IL RESET CORTOCIRCUITANDO IL 2 CON 1 DELL' SPØ256