AN IMPROVED MICROCOMPUTER-BASED SPEECH RECOGNITION SYSTEM

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ABSTRACT

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The expansion of the vocabulary of a microcomputer-based speech recognition system is accompanied by a reduction in its rate of recognition. To retain a high standard of performance in increasing the vocabulary size to 36 words, the characteristics of the spoken word are used in addition to data samples representing formants 1, 2 and 3 and a zero-crossing detection taken at regular intervals through the duration of the word. Recognition of the spoken word is attained by matching data samples of the target word to a vocabulary made by the same speaker. The vocabulary is effectively reduced by prior consideration of the length of the word, whether it contains a stop and also the formant composition and zero-crossing detection at the beginning and the end of the word. A recognition rate of up to 90.8% is possible by the combination of these methods. The use of feedback given to the speaker and the importance of the words chosen for the vocabulary are discussed. The system was fabricated, tested and demonstrated with results.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND

Early investigation into the nature of speech involved experimental phonetics, the operation of the vocal tract in speech production and the identification of many of the acoustic parameters that are still the major concern in this area. Machine recognition of speech was the fruit of this research and the first automatic speech recognition is commonly accorded to Davis, Biddulph and Balashek (1) of the Bell Laboratories in 1952. These researchers, their contemporaries and their successors have used methods which are fairly similar but with large variations in emphasis.

Among the earliest of techniques has been the comparison and matching of speech sounds using spectrographic representation. The work of Potter, Kopp and Green (2) has been an important influence on speech research as is evidenced by the common use of pattern recognition techniques even without the use of the spectrograph. Other methods have incorporated the extraction of features such as a voiced/unvoiced classification, limitation of word or phoneme vocabulary, isolation of the word or phoneme, restriction to a single speaker and amplitude and time normalization of the speech sample.

1.2 SCOPE

The present study utilizes some of the methods established with large scale and sophisticated equipment and adapts these to a relatively low cost microcomputer system. This is a North Star Horizon equipped with a Z80 central processing unit, 64 kbyte random access memory, two floppy discs and a speech board made by Heuristics Inc. (Los Altos, California). The basic capability of this system is the recognition of ten isolated words through the matching of speech samples from a target word against a stored vocabulary, where the smallest difference found gives the key to the recognized word.

The extension of this system increases the vocabulary size to 36 words, retains a single speaker and employs some features of the words to prevent serious degradation of performance. The length of the word is one of its less variant features and is used to limit its comparison with only those vocabulary words of comparable length.

Data samples taken at the beginning and end of a word have been shown by Weiss (3) to have a considerable effect on the recognition of phonemes. The informational content of word extremities is used to qualify the comparisons made to the vocabulary. A stop which is contained in a word is among its most characteristic features and this gives an easily used criterion for rejection of the vocabulary matches of similar words which lack this feature.

the embedded stop.

The 36-word stored vocabulary is potentially available for matching against the target word, but is reduced in size by an initial comparison of the qualities of the target word with the total vocabulary. Each vocabulary word is tested to determine whether it qualifies for further comparison and is eliminated if this is not warranted. The vocabulary is reduced in this way for the target word and is called the relevant vocabulary for that target word.

The vocabulary is not built up with single samples as in the original system but over a number of consecutive samples. This not only provides a better data base, but affords the speaker practice of each word sound. The characteristics of the spoken word which are collected are displayed to the speaker in order that he obtains an objective assessment of his spoken word; enabling him to monitor and regulate his performance.

1.3 TERMS

It is not intended to cover the acoustic parameters extensively, such as has been done by Rabiner and Schafer (4) and Reddy (5), but to deal with those which have particular application to this study. Data samples are collected from particular bandwidths representing the amplitude of the speech signal, falling within the frequencies of the first three formants of the average vocal tract. The range of the filter pass-bands are used to define formant 1 as 150Hz to 900Hz, formant 2 as 900Hz to 2200Hz and formant 3 as 2200Hz to 5000Hz. These frequency values follow those outlined by Shafer and Rabiner (6).

A period of silence occurring within a word is taken to be a stop consonant which may be either voiced or unvoiced. Detection of a stop is made by the comparison of the stored data sample with a threshold value, such that the difference between two significant comparisons gives the duration of

CHAPTER II

THE SYSTEM CONFIGURATION

2.1 HARDWARE

2.1.1 Computer hardware

The North Star Horizon 2 (Fig. 2.1) is a S-100 bus microcomputer with a 10-slot mother board. The processor board interfaces the Z80A central processing unit to the S-100 bus carrying 8-bit data lines and 16-bit address lines. The processor is equipped with a crystal giving 2MHz operation clocking for memory compatibility. The system can support up to four disk drives, two serial ports, one parallel port and performs I/O operations through circuitry located on the mother board giving serial/parallel data conversions.

Auxiliary storage is available through two minifloppy disc drives (Shugart SA400) driven by the disc controller. The 5 1/4 in. discs are hard-sectored and double density, each giving approximately 179 kilobytes of storage and storing the Disc Operating System on track 0, sector 4 of the first disc, immediately following the first four sectors which are reserved for the directory. At run-up or reset time a bootstrap PROM on the disc controller loads the operating system from disc 1 into memory.

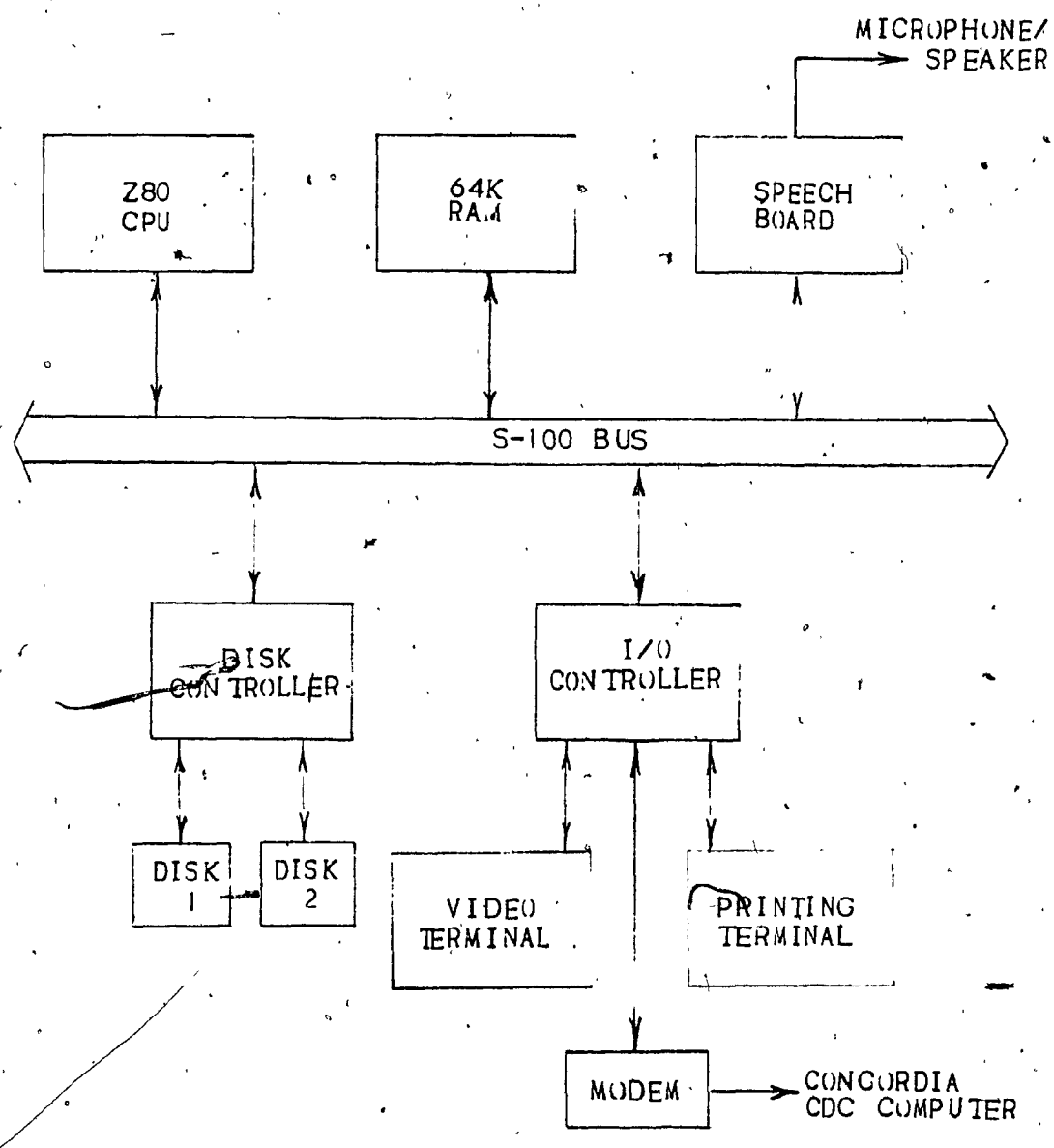

Fig. 2.1 : Schematic Diagram of Computer System

The equipment above was obtained assembled and tested and the remaining equipment was assembled from kit form by the author. A larger capacity memory than the original 16K North Star memory was substituted, this being a 64K dynamic random access memory (Expandoram). The parallel port is not used and the first serial port is configured for a 1200 baud rate serving an upper case terminal giving the major computer access. The second serial port is set to a 300 baud rate and usually interfaces a printing terminal (Terminet) giving not only advantages of hard copy, but affording also a lower case keyboard option. This port can also be changed to communicate with a modem, with the Horizon microcomputer assuming the role of a terminal. In this way, access to the Concordia CDC computer offers back-up opportunities of storage and printing.

2.1.2 Speech hardware

The speech board (Fig. 2.2) basically consists of some stages which pre-process the analog signal, an analog to digital converter and is controlled by digital logic. The latter routes analog signals, controls the A/D conversion and enables the interface of the board to the S-100 bus. The board was assembled and tested by the author and connected for compatibility with the Z80 clock signals and for appropiate port addresses. Three voltage reference levels were latched through the 8 to 1 analog multiplexor (M1) to

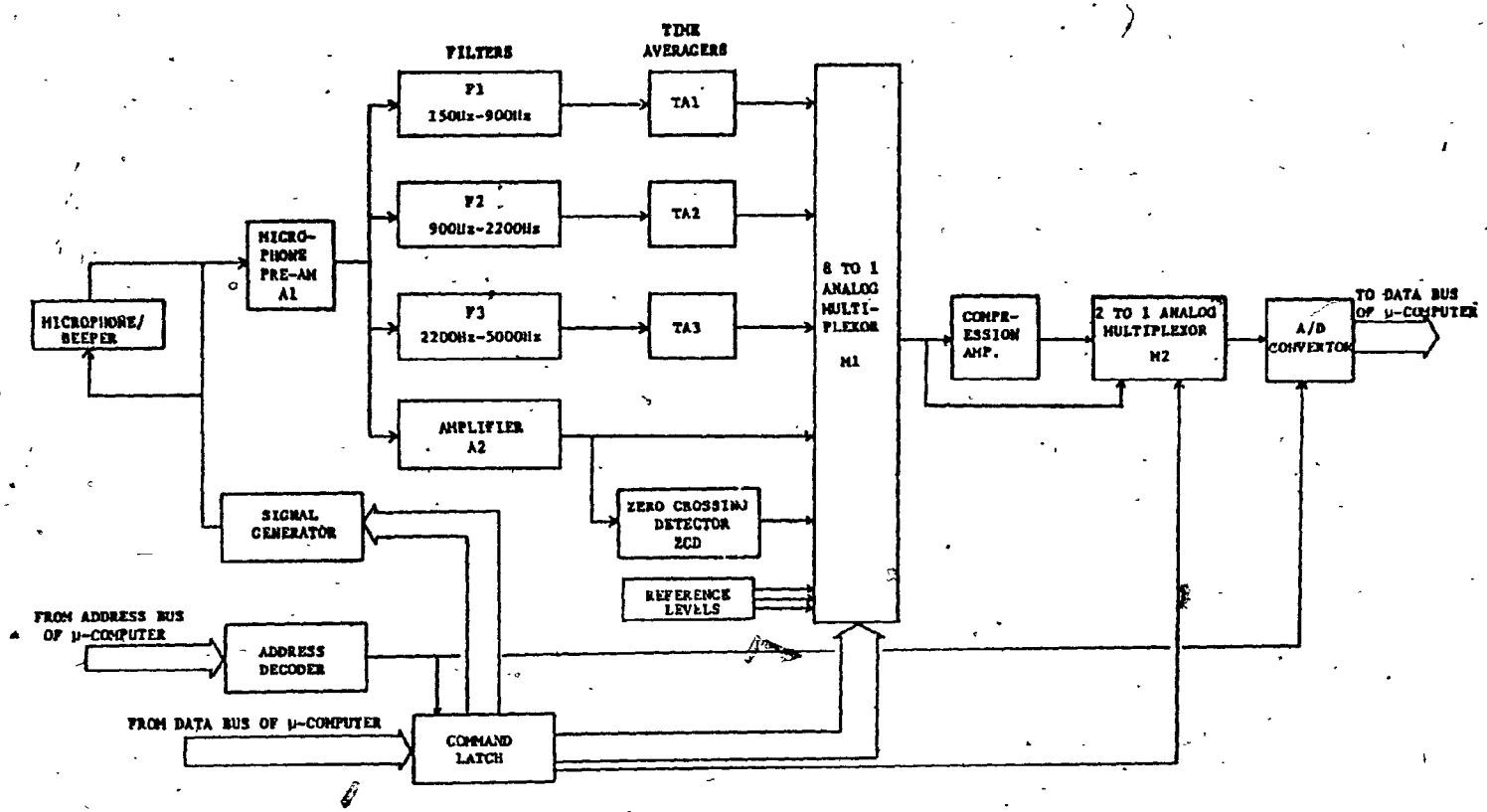

Fig. 2.1 : Schematic Diagram of Speech Board

the A/D converter, its output being directed into three memory buffers which were checked for proportionality with the reference levels. The gain of the microphone pre-amplifier (A1) was set, using a word spoken into the microphone, such that the filter outputs did not consistently saturate.

Vocal input is given at the microphone which is also used as a beeper when driven by the signal generator. A beep from the microphone provides a cue to the speaker when the signal generator is enabled. This beep, of 10ms duration, marks the beginning of the speech window and a second similar beep 1.5sec. later marks its end. The speech input is differentially amplified by the microphone preamplifier up to 5kHz to compensate for the greater energy found in the lower frequency components of speech. This pre-emphasis tends to balance the three formant values collected in the next stage and compensate for the attenuation of higher frequencies of the vocal tract.

Three band-pass filters receive the output of the preamplifier and extract the portion of the speech signal which falls within the frequency range of the filter. The filter values are chosen to approximate the frequencies of formants 1, 2 and 3 of the average vocal tract. The range of filter F1 is 150Hz to 900Hz, F2 is 900Hz to 2200Hz and F3 is 2200Hz to 5000hz. Each analog filter output is proportional to the microphone input within the filter passband and

varies about a level of 2 volts. A time averager (TA1, TA2 and TA3) follows each filter, detecting the peak of the input waveform and averages this over a fixed time period generating a voltage from 0 to 4 volts which is proportional to the signal within each band.

The amplified microphone output from the amplifier A1 is also applied to a second amplifier A2 where it is again emphasized up to 5kHz and its unfiltered waveform swings ±2 volts about a 2-volt rest level and is passed directly to the analog multiplexer M1. The output from A2 also passes to a zero-crossing detector (ZCD) which produces a voltage proportional to the number of times the amplified speech signal crosses its rest level in a given time and thus serves as an approximate measure of the frequency of the spoken input.

The outputs from the time averagers, the zero-crossing detector and three reference voltages which are used for testing the speech system are available at the 8 to 1 analog multiplexor. The selected output is passed either directly to the analog to digital converter or it is routed through a compression amplifier by a 2 to 1 analog multiplexor M2. The compression amplifier increases the low amplitude signals and reduces those of higher levels approximating a logarithmic gain of its output signal. This affords a means of compensating for the variation in the volume of repeated

speech.

The analog to digital conversion of the signal arriving from the multiplexor M2 is performed by a 6-bit ramp up-type converter using a ripple counter driven by the system clock and a voltage comparator. The ripple counter generates an increasing voltage to one input of a comparator, the other input being the processed speech signal. The comparator changes state when its inputs are equivalent and stops the counter when its contents are available to the system data bus as a digital representation of the converted analog signal.

2.2 SOFTWARE CONTROL

Program control of speech collection and conversion is attained through a word placed on a single input-output port (Fig. 2.3). The three lowest bits of this word select the input at the multiplexor M1 for conversion. Bit 3 of the control word passes to the multiplexor M2 where it is used as a switch control for possible use of the compression amplifier. Bit 4 is used to activate the signal generator to give the beep cues to the speaker and thus delineate the speech window. It may also be used in calibration and testing as the signal generator output contains frequencies in each of the filter passbands. The only remaining output port bit which is used is bit 5 which disables the

multiplexor M1 when the lowest three bits are changed. The input port provides the results of the analog to digital conversion in bits 0 to 5 (Fig. 2.4). Bit 6 is not used and is always zero and bit 7 signifies the completion of the analog to digital conversion when the conversion counter is stopped.

Bit	
0	-3-bit code selection
1	of 1 of 8 voltages for
2	multiplexor inout
3	-compressed/uncompressed selection
4	-beep control to signal generator
5	-multiplexor disable
6	-not used
7	-not used

Fig. 2.3 : Output Port

Bit	
0-5	6-bit analog to digital conversion output
6	not used
7	converter status

Fig. 2.4 : Input Port

CHAPTER III

THE RECOGNITION PROCEDURE

The speech recognition program is written in Z80 assembly language (Appendix A). It occupies approximately 25K bytes of memory space and uses Zilog code mnemonics, producing equivalent machine language code in approximately 7K bytes. The main program (Fig. 3.1) primarily directs the two basic stages of the recognition system. The first is termed the training mode (Fig. 3.2) which is primarily concerned with the construction of a working vocabulary. Following this is the performance mode (Fig. 3.7) in which the target word is matched to elements of the vocabulary, the best comparison determining the recognition decision.

3.1 TRAINING

3.1.1 Raw speech collection

When the training mode has been entered, the speaker types the identification of the word he intends to say and gives the corresponding vocal input at a microphone over a standard time interval. Speech collection is initiated by prompting the speaker with a 10 ms beep signalling the beginning of the speech window and a second beep 1.5 sec later marks its end. During this period 150 samples are taken every 10 ms, storing consecutive measures from the

Fig. 3.1 : Algorithm of Main Program

1. (Determination of mode/utility selection) Get input character into A reg.
2. If A reg = control B then output vocabulary and go to step 1.
3. If A reg = control C then go to monitor.
4. If A reg = control O then complement the output device flag and go to step 1.
5. If A reg = 'T' then call TRAIN and go to step 1.
6. If A reg = 'P' then call PERF.
7. Go to step 1.

Fig. 3.2 : Algorithm of the Training Mode

8. Initialize training sums.
9. Get word identification, save in WORD and initialize training sums.
10. Output word count.
11. Collect raw speech data (SPCH routine).
12. Find endpoints (ENDPTS routine). Establish beginning and ending samples, word length, stop containment, zero crossings detection with low formant data and output these results.
13. Get endings information (INFLD routine). Test corresponding bits in first two data samples against threshold 4 and also with the last two data samples. Load INFOWD bits as in Fig. 3.4.
14. Get 16 samples from raw speech buffer (GETSAM routine). Divide length of word by 16, interpolating data and load into sample buffer. Compute mean formant data and normalize sample buffer.
15. Input reject decision character. If 'R' go to step 10.
16. Print word report if requested from main program.
17. Collect cumulative statistics (STAT routine). Updates band sums, INFOWD sums vector, length sum and stop sum.
18. Increment word count and compare to word limit. If

three filters and the ZCD realized as integers ranging from 0 to 63 resulting from the 6-bit analog to digital conversion. The 600 data elements extracted in this way are stored in a raw speech buffer called BUF for subsequent analysis.

3.1.2 Analysis of the speech data

The word boundaries are located following the endpoint algorithm of Rabiner and Sambur (7). When the sum of the formant data for a sample exceeds a threshold of 5 this is taken as the word beginning, provided that the ZCD data is also above its threshold value of 1. If the latter is above its threshold the beginning point is lowered to an earlier sample with a level below its threshold. A similar technique with movement in the opposite direction finds the end of the word. A check is made on the validity of this endpoint by examining the following 25 samples as this may be a period of silence resulting from a stop consonant within the word. If the threshold is again exceeded the endpoint is rejected and a further examination is made from this point.

The difference between the endpoints gives the length of the word which is separated into 16 evenly spaced intervals by division to obtain 16 representative sets of samples. Linear interpolation is used to compute parameters corresponding to the filter bank and ZCD outputs for each sample set. The formant amplitudes of the selected samples

not zero go to step 10.

19. Calculate mean of all corresponding data (CALC routine). Load INFOWD and STOPWD vector elements.
20. Load sample buffer into vocabulary table (MOVE routine).
21. Output word data report (REP routine).
22. Return to main program.

are normalized by translation and each set is stored in a 16 X 4 array giving the 64 byte sample buffer SAM.

3.1.3 Collection of the word characteristics

As shown in Fig. 3.1 and Fig. 3.2, two bytes are used to store information about each spoken word. One is called the SIZE byte (Fig. 3.3) and contains the length of the word in bits 0 to 6 and bit 7 is used to mark the containment of a stop. This bit is set to 0 or 1 indicating the absence or presence respectively of a stop.

The INFO byte (Fig. 3.4) is loaded according to the beginning and ending characteristics of the word. The first and last two sets of samples in the raw speech buffer are examined to determine whether either of the corresponding formant and ZCD samples at each end of the word exceeds a threshold of 4. The lower four bits portray the beginning and the higher four bits the ending of the word.

3.1.4 Vocabulary formation

The data thus obtained is sufficient for the development of a vocabulary based on a single word training, but here successive samples (usually 10) are used, each sample set being added to cumulative sum storages for each data item. The mean of each is finally derived and loaded into the TABLE array which is of size n X 64 where n is the

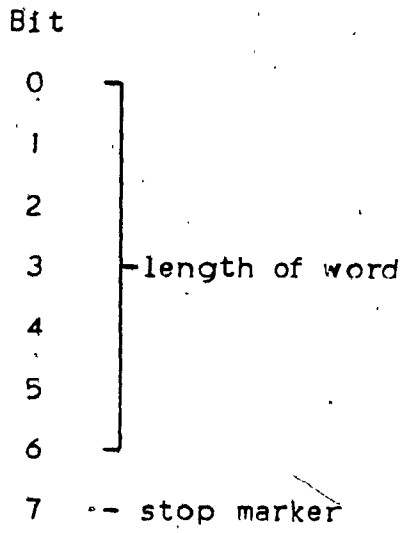

Fig. 3.3 : The SIZE Byte

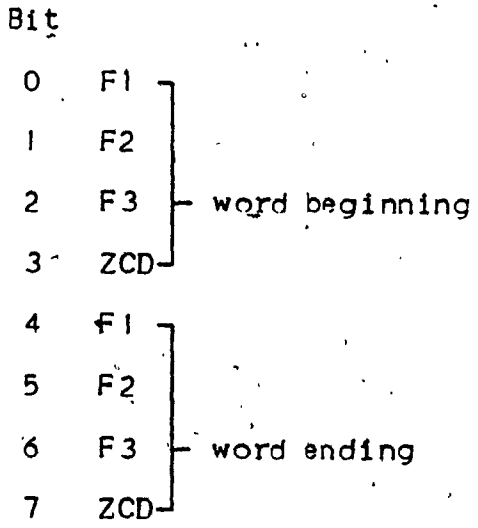

Fig. 3.4 : The INFO Byte

size of the vocabulary and 64 is the size of the sample buffer SAM. The most commonly used vocabulary employs the 36 alphanumeric samples which are linked to the SIZE and INFO vectors (Fig. 3.5). An alternate vocabulary of the same size utilizing the words of the International Civil Aviation Organization phonetic alphabet, yields the SIZE and INFO vectors shown in Fig. 3.6.

3.2 RECOGNITION

3.2.1 Target word data

The raw speech entered in the performance mode (Fig. 3.7) is collected as in the training mode and its analysis is performed in the same way, including the use of the same buffers. The characteristics of the target word are also derived similarly and they are stored in two bytes called SIOPWD which is similar to the SIZE vector elements and INFOWD which is similar to the INFO vector elements.

3.2.2 Qualification testing

Each element of the vocabulary obtained in the training procedure is tested to determine whether it shares minimal characteristics with that of the target word. Parameters are set so that the informational vocabulary storage may be used to test whether the vocabulary element qualifies for further

testing against the target word.

If the target word has a stop marked then only the vocabulary elements marked similarly will qualify for further comparison. Limits are placed upon the word length so that comparisons which exceed ± 25% of the target word length are eliminated. The beginning and ending information bytes stored for the remaining words in the vocabulary are used to perform an exclusive-OR operation with the corresponding target word information. Those vocabulary words with less than 6 out of 8 of the corresponding bits dissimilar are excluded. Though the original vocabulary is still available, these tests produce a smaller, relevant vocabulary for each target word.

3.2.3 Vocabulary comparison

The filter and ZCD data for the target word can now be used to compare with similar data for each of the elements of the relevant vocabulary. A minimum distance classification is performed between corresponding bytes of the target word and each of the relevant vocabulary words. This is done by storing absolute differences of each byte-pair in an n-element SUMS vector which is finally used to determine its minimum value entry. The position of this value is the key to the row number of the vocabulary TABLE and this can be interpreted for display as the result of the recognition. The SUMS vector may be output optionally to

present the proximities of the relevant vocabulary.

```
0 LENGTH = 058 INFO = 14 STOP
1 LENGTH = 029 INFO = 11
2 LENGTH = 025 INFO = 1F STOP
3 LENGTH = 034 INFO = 13 STOP
4 LENGTH = 040 INFO = 18 STOP
5 LENGTH = 057 INFO = 13 STOP
6 LENGTH = 063 INFO = 8C STOP
7 LENGTH = 052 INFO = 18 STOP
8 LENGTH = 051 INFO = 47 STOP
9 LENGTH = 040 INFO = 17 STOP
A LENGTH = 047 INFO = 17 STOP
B LENGTH = 050 INFO = 13 STOP
C LENGTH = 040 INFO = 1C
D LENGTH = 051 INFO = 1F STOP
E LENGTH = 045 INFO = 17 STOP
F LENGTH = 063 INFO = 13 STOP
G LENGTH = 021 INFO = 2C
H LENGTH = 052 INFO = 4F STOP
I LENGTH = 043 INFO = 13 STOP
J LENGTH = 031 INFO = 1C
K LENGTH = 032 INFO = 1F STOP
L LENGTH = 054 INFO = 1F STOP
M LENGTH = 022 INFO = 1F
N LENGTH = 056 INFO = 1F STOP
O LENGTH = 038 INFO = 13 STOP
P LENGTH = 025 INFO = 0F
Q LENGTH = 028 INFO = 13 STOP
R LENGTH = 059 INFO = 11 STOP
S LENGTH = 054 INFO = 87
T LENGTH = 019 INFO = 1F
U LENGTH = 018 INFO = 1B
V LENGTH = 013 INFO = 13
W LENGTH = 039 INFO = 33 STOP
X LENGTH = 056 INFO = 87 STOP
Y LENGTH = 036 INFO = 01
Z LENGTH = 053 INFO = 1C STOP
```

Fig. 3.5.1 36-Word Alphanumeric Vocabulary Information Storage

```
0 LENGTH = 081  INFO = 14 STOP
1 LENGTH = 029  INFO = 11
2 LENGTH = 025  INFO = 1F STOP
3 LENGTH = 034  INFO = 13 STOP
4 LENGTH = 045  INFO = 18 STOP
5 LENGTH = 067  INFO = 17 STOP
6 LENGTH = 063  INFO = 8C STOP
7 LENGTH = 034  INFO = 3C
8 LENGTH = 078  INFO = 47 STOP
9 LENGTH = 033  INFO = 17
A LENGTH = 046  INFO = 17 STOP
B LENGTH = 050  INFO = 13 STOP
C LENGTH = 040  INFO = 1C
D LENGTH = 062  INFO = 17 STOP
E LENGTH = 045  INFO = 17 STOP
F LENGTH = 075  INFO = C3 STOP
G LENGTH = 024  INFO = 1F STOP
H LENGTH = 067  INFO = 13 STOP
I LENGTH = 049  INFO = 4F STOP
J LENGTH = 063  INFO = 4E STOP
K LENGTH = 042  INFO = 1F STOP
L LENGTH = 037  INFO = 15 STOP
M LENGTH = 046  INFO = 23 STOP
N LENGTH = 059  INFO = 17 STOP
O LENGTH = 045  INFO = 11 STOP
P LENGTH = 038  INFO = 11 STOP
Q LENGTH = 061  INFO = 23 STOP
R LENGTH = 056  INFO = 11 STOP
S LENGTH = 054  INFO = 1C STOP
T LENGTH = 050  INFO = 1F STOP
U LENGTH = 048  INFO = 13 STOP
V LENGTH = 051  INFO = 17 STOP
W LENGTH = 036  INFO = 41 STOP
X LENGTH = 055  INFO = 27 STOP
Y LENGTH = 046  INFO = 47 STOP
Z LENGTH = 039  INFO = 1C STOP
```

Fig. 3.6 : 36-Word I.C.A.O. Vocabulary Information Storage

Fig. 3.7 : Algorithm of the Performance Mode

23. Collect raw speech data (SPCH routine).
24. Find endpoints (ENDPTS routine). Establish beginning and ending samples, word length, stop containment, zero crossings detection with low formant data and output these results.
25. Get endings information (INFLD routine). Test corresponding bits in first two data samples against threshold 4 and also with the last two data samples. Load INFOWD bits as in Fig. 3.4.
26. Compare target word with vocabulary storage (MATCH routine). Initialize SUMS vector, then blank each SUMS value if the corresponding vocabulary does not have a) the same stop value or b) a length within ±25% or c) endings information above a threshold when each is compared to the target word. SUMS defines the relevant vocabulary.
27. Get 16 samples from raw speech buffer (GETSAM routine). Divide length of word by 16, interpolate data and load into sample buffer. Compute mean formant data and normalize sample buffer.
28. Calculate absolute differences between target word and relevant vocabulary (CHEBY routine). Load these differences into corresponding SUMS elements. Find the position of the smallest value in SUMS and load into the A register.

29. Output recognized word character

30. Output relevant SUMS vector

31. Return to main program.

CHAPTER IV

THE SYSTEM EVALUATION

4.1 THE BASIC 10-WORD VOCABULARY

The digits 0 to 9 were used as words of the initial basic vocabulary as they enabled conveniently displayed results. The training mode was requested and a digit was entered from the keyboard followed by the spoken word during the speech window. The vocabulary was completed by providing the other digit words similarly, with a single input for each word.

The vocabulary was tested in performance mode by speaking each word and noting the frequency of confusion with other words. If the errors were large then the word was considered a poor sample and was replaced in the training mode with a substituted word. The vocabulary was re-tested with further replacements made as necessary. It should be noted that the empirical construction of a vocabulary in this way is time consuming.

When the vocabulary was finalized, it may be added that the speaker also was well-practised, and the testing was started by speaking each word in performance mode and recording the system response. Each word was spoken 50 times, enabling the construction of the confusion matrix (Fig. 4.1) and the derivation of the recognition rate of 95.4%.

OUTPUT / INPUT	0	1	2	3	4	5	6	7	8	9	ERRORS
0			2								2
1						2	1				3
2											0
3									2		2
4						2					2
5		2									2
6				1					1		2
7						2					2
8				1			2				3
9		2				1	1		1		5
ERRORS	0	4	2	2	0	7	4	0	4	0	23

Fig. 4.1 : 10-Word Vocabulary Confusion Matrix

This rate is at a sufficiently high level that the relatively few errors do not illustrate significant confusions, although some acoustic similarities may be seen. The 4 and the 5 words, for example, start with an unvoiced fricative and the 1 and 9 words end with a nasal consonant and a vowel.

4.2 THE EXTENDED 36-WORD ALPHANUMERIC VOCABULARY

The vocabulary was increased to 36 words using the 10 digit words as before and the literal words A to Z, with each word being a standard pronunciation of the alphanumeric character.

The three extensions used here incorporate the multiple-input training mode and the parameters of the length and the information collected on each word. During the training mode the speaker types the word identification and gives the first sample. He is given the opportunity to reject that word and he is prompted for another word. He is informed of the length of the word and the information it carried and also whether there was a zero crossing detection or a stop found (Fig. 4.2). When all samples are given, the computed word data and information are entered into the vocabulary and vocabulary information storage and the information entry is also displayed. In this procedure the speaker monitors his speech and is motivated to work to the reliable repetition of the system vocabulary.

The feedback of information to the speaker contrasts to the earlier basic system which lacked this facility. The presentation of results is continued in the performance mode, where similar details are displayed with the recognition result and data sums from the relevant vocabulary (Fig. 4.3). The confusion matrix (Fig. 4.4) was made using 25 samples of each word. The 146 errors recorded correspond to a recognition rate of 83.8%.

The recognition is maintained at this level by the extensions to the recognition procedure, since the expansion of the original 10-word vocabulary to 16 words resulted in a rate of approximately 70%. The 6 extra words corresponded to the letters A to F and this hexadecimal vocabulary produced confusions between the words corresponding to B, C, D, E and 3 which contain the /i/ sound. The alphanumeric vocabulary has this sound in words G, P, T and V also and although confusions of this type still exist there is a greater discrimination between words with similar sounds. Other confusions can be noted, such as the words 8 and H containing the /e/ vowel and 2 and Q which contain the /u/ vowel.

Examination of the recognition table shows some errors arising through mismatch of words on the basis of the containment of a stop. There are 22 such errors which may arise through variations in pronunciation. If the stop requirement was less stringent some errors would be eliminated, but this would be offset by the increase in the

```
T OR P ?
T
WORD 2
WORD 1
LENGTH = 25 INFO = 1F STOP
REJECT (R)?
WORD 2
LENGTH = 25 INFO = 1F STOP
REJECT (R)?
WORD 3
.
.
.
WORD 10
LENGTH = 27 INFO = 1E STOP

LENGTH = 25 INFO = 1F STOP
T OR P ?
```

Fig. 4.2 : Training Mode Display

```
T OR P ?
P
5 ZCD
8 ZCD
002 037 LENGTH = 36 INFO = 1C
RECOGNIZED 7
7 01256
C 02673
T OR P ?
```

Fig. 4.3 : Performance Mode Disolay

INPUT \ OUTPUT	0 1 2 3 4 5 6 7 8 9 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z	ERRORS
0	1 1	2
1	1	1
2	1 1	2
3	1 2	3
4	2 1 1	4
5	1 1	2
6	2	2
7	1	1
8	3 2	5
9	2 1 2	5
A	2 5	7
B	1 2	3
C	4	4
D	3	3
E	1 1 1 1	4
F	2 2	4
G	2 3 1	6
H	1 2 2 3	8
I	2 1 2 1	6
J	1	1
K	1 1 2 1	5
L	3 1	4
M	1 3 1 2	7
N	1 4	5
O	1 3 1	5
P	4 2 1	7
Q	1 1 2	4
R	4	4
S	1 1	2
T	3 1 1	5
U	3 1 1	5
V	2 4 1	7
W	2	2
X	1 2 3	6
Y	1 1	2
Z	1 2	3
ERRORS	3 3 5 1 1 3 2 5 4 0 1 3 4 8 0 4 8 6 3 0 5 8 2 6 6 1 6 2 0 9 2 3 7 6 8 1	146

Fig. 4.4 : 36-Word Alphanumeric Vocabulary Confusion Matrix

relevant vocabulary which would promote other errors.

4.3 THE EXTENDED 36-WORD I.C.A.O. VOCABULARY

The selection of the alphanumeric vocabulary was based on convenience in displaying results rather than on distinctive sounds. The later attribute is found in the International Civil Aviation Oganization phonetic alphabet (Appendix B) used in communications between pilots and controllers, and these words were substituted for a more representative test.

The digit words were used, but three were modified for greater distinction with the I.C.A.O. vocabulary. O was changed to "zeros", 8 was changed to "eighty-eight" and 9 was truncated to "nie". The training and testing was performed as with the alphanumeric vocabulary, taking 900 equally distributed samples. The confusion matrix (Fig. 4.5) shows 83 errors corresponding to a recognition rate of 90.8%.

The 7% improvement over the alphanumeric recognition rate does not adequately reflect the practical advantage of this vocabulary in respect of the reduced testing and practice time involved and the increased reliability it offers. The established sound patterns and the distinctive pronunciation of this vocabulary greatly promote a more constant repetition of these words. The errors noted in the recognition table appear to be more random than with the previous vocabularies through the more complex composition

OUTPUT / INPUT	0 1 2 3 4 5 6 7 8 9 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z	ERRORS
0		0
1		0
2	1 1 1	3
3	1 3	4
4	1 1	2
5	1 1	2
6	1 1	2
7	1	1
8	1 1 1	3
9	1	1
A	1 1 1	3
B	1 1 1	3
C	1	1
D	1 1	2
E	1 1	2
F	1 1 1	3
G	2 1	3
H	1	1
I	1 2	3
J	1 1 1	3
K	1 1 1	3
L	1 2	3
M	1 1 2	4
N	1	1
O	1 1	2
P	2 1	3
Q		0
R	1	1
S	2 1	3
T	1 1 2	4
U	1 2 1	4
V	1 2	3
W	1 1 2	4
X	1 1	2
Y	1 1	2
Z	1 1	2
ERRORS	2 3 3 4 0 1 1 2 2 4 2 4 2 0 2 1 1 1 2 2 3 3 0 4 4 4 2 5 2 2 6 0 1 4 2	83

Fig. 4.5 : 36-Word I.C.A.O. Vocabulary Confusion Matrix

of sounds in these words.

The preponderance of stops in the I.C.A.O. alphabet reduces the power of the stop reqirement as a discriminative factor. The vocabulary information storage (Fig. 3.4) shows there are only four words without an embeddded stop. Although this makes the words "one", "seven", "nie" and "charlie" among the most easily recognized, it would be preferable if half of the vocabulary was of each tyoe in order to start the recognition process with a single level binary sort.

CHAPTER V

THE SYSTEM IN APPLICATION

5.1 DEVELOPMENT

The vocabulary used initially was of 10 words, those being the digits 0 to 9. This small vocabulary was useful for the early experimental work and investigations into the potential of the system and was useful in the provision of a conveniently displayed result. The expansion of the vocabulary to 16 enabled the recognition of the words corresponding to the hexadecimal digits. When satisfactory recognition of this vocabulary was attained, though with a much reduced recognition rate, a model was made of the vocal input of machine language programs as reported by Webb, Menon and Suen (8). The execution was successful, but it was not efficient as it required two spoken words to form one byte. The spoken hexadecimal digits were loaded into a reserved area of memory under the speaker's control.

As a variation, non-hexadecimal words were spoken after the speaker typed the characters which form the word and these were loaded into a written vocabulary linked to the TABLE vocabulary which, as before, was of 16-word size. The written word was displayed as the recognition decision. This system did not use any of the modifications incorporated into the subsequent expanded system and still used single

training samples.

The last vocabulary expansion was made to 36, accomodating all the alphanumeric characters, while refining the procedure in order to maintain the performance. The use of the characteristics of each word have been important in the development of this recognition procedure, though the method of data collection used provides a valuable supporting role. In the training mode, the primary interest is in the provision of data samples and the construction of the vocabulary, but using multiple inputs for each word the speaker himself is undergoing an appreciable measure of self-training. Not only is he learning to repeat his words in the same way and so improving the statistical reliability of the data, but he is a controlling participator in its collection. He is able to see the display of the informational aspects of the word he has spoken and to reject it if he chooses. Consequently he is learning to reproduce previous sounds. The knowledge of results (9) is an important facet of learning and is an important contributing factor to the speaker's improvement.

The use of the I.C.A.O. vocabulary illustrates, through the improved recognition rate, the importance of a greater variety of sounds. The methods used with this vocabulary were identical to those used with the 36-word alphanumeric vocabulary. The greater variety of sounds it contains is beneficial to the speaker, since it makes his task more interesting, and to the system as there is a greater

distribution of word lengths which aid discrimination in the length qualification test. This advantage is partly countered by the large number of contained stops which reduce the effectiveness of this factor.

The contribution of the features of the word in the recognition process, using stops, lengths and endings is illustrated by the data from an output display (Fig. 5.1) in performance mode. The spoken word "five" is correctly recognized with 10 Chebychev sums output. The presence of the stop in the target word resulted in a relevant vocabulary of 20 words, and the length test eliminated a further 9 words. When the endings test is used with an exclusion based on less than 4 dissimilar corresponding bits, one extra word was removed giving a 10-word relevant vocabulary. To illustrate the effectiveness of a more stringent requirement of endings information similarity, the criterion was changed to less than 7 dissimilar corresponding bits. The program was run again using the same raw speech buffer contents, giving another correct recognition but only 3 sums were output (Fig. 5.2). The words "R" and "8" which were ranked second and third respectively in Fig. 5.1 were eliminated, making a greater distance between the first two words which can be considered as an indication of this being a stronger or clearer recognition. Normally a criterion of less than 6 dissimilar corresponding bits is used.

```
LENGTH=57 INFO=1B STOP
RECOGNIZED 5
0 2568
5 1263
7 2988
8 1803
H 2240
L 1939
N 2259
R 1424
X 2669
```

Fig. 5.1 : Output Sums with Information Threshold of 4

```
LENGTH=57 INFO=1B STOP
RECOGNIZED 5
5 1263
L 1939
N 2259
```

Fig. 5.2 : Output Sums with Information Threshold of 7

5.2 POTENTIAL

The word characteristics of length, stop and endings information which is primarily collected to improve recognition, become an important feedback to the speaker through their display. This secondary effect is an important one since it capitalizes on the interactive aspect of the system, stimulates the speaker and encourages him to maximize his performance. This aspect has been utilized in the use of the basic system as a speech therapy aid by Joost and Petry (10).

The value of the characteristics of the speech word in the formation of the small, relevant vocabulary greatly enhances the recognition process. This can be compared to the use by Cherry (11) to information, in referring to the content of information in the making of selections in communicative processes. The importance of the word endings has been noted, which raises a doubt as to relative value of the intermediate samples. The reference and discussion of redundancy by Shannon and Weaver (12) suggests a further investigation by collecting fewer samples, while retaining the word characteristics, to evaluate their worth.

Since the speech board is founded as an educational tool, it forms with its microcomputer host an excellent aid for introductory speech investigation. The microcomputer adds a powerful dimension to laboratory research by offering 'hands-on' capability with an on-line system and brings the

investigator into close proximity with his problem.

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```
0161  CD C5 04        0055          CALL  CRLF
0164  21 80 15        0056          LD    HL,MESS2  ; WORD ?
0167  CD A3 04        0057          CALL  WRITE
016A  CD 45 05        0058          CALL  WORDID    ; GET WORD ID
016D  32 AF 08        0059          LD    (WORD),A  ; SAVE WORD
0170  3C              0060          INC   A         ; WITHIN VOCABULARY ?
0171  47              0061          LD    B,A
0172  3A AC 08        0062          LD    A,(VOCSIZ)
0175  B8              0063          CP    B
0176  38 C3           0064          JR    C,WHAT    ; TOO LARGE
0178  3E 00           0065          LD    A,0
017A  32 73 15        0066          LD    (WORDC),A ; ZERO WORD COUNT
017D  CD C5 04        0067  TR1:    CALL  CRLF
0180  21 80 15        0068          LD    HL,MESS2  ; WORD
0183  CD A3 04        0069          CALL  WRITE
0186  3A 73 15        0070          LD    A,(WORDC)
0189  3C              0071          INC   A
018A  CD 38 06        0072          CALL  BCDA      ; PRINT WORD COUNT
018D  CD C5 04        0073          CALL  CRLF
0190  CD 0D 04        0074          CALL  SPCH      ; GET SPEECH
0193  CD A2 02        0075          CALL  ENDPTS    ; FIND ENDPOINTS
0196  CD A1 06        0076          CALL  INFLD     ; LOAD INFO WORD
0199  CD 94 05        0077          CALL  GETSAM    ; GET 16 SAMPLES
019C  CD C5 04        0078          CALL  CRLF
019F  21 99 15        0079          LD    HL,MESS6  ; REJECT (R)?
01A2  CD A3 04        0080          CALL  WRITE
01A5  CD 04 05        0081          CALL  INC
01A8  FE 52           0082          CP    'R'
01AA  28 D1           0083          JR    Z,TR1
01AC  CD 1B 02        0084          CALL  PREP
01AF  CD F3 07        0085          CALL  STAT      ; COLLECT STATISTICS
0182  3A 73 15        0086          LD    A,(WORDC) ; CHECK WORD COUNT
0185  3C              0087          INC   A
0186  32 73 15        0088          LD    (WORDC),A
0189  21 74 15        0089          LD    HL,WOROL
018C  BE              0090          CP    (HL)
018D  20 BE           0091          JR    NZ,TR1
018F  CD 42 08        0092          CALL  CALC      ; CALC MEAN STATS
01C2  3A AF 08        0093          LD    A,(WORD)  ; LOAD TRAIN SAMPLES
01C5  4F              0094          LD    C,A
01C6  16 40           0095          LD    D,64      ; ROW SIZE
01C8  CD 5A 04        0096          CALL  MULT      ; COMPUTE ROW
01CB  11 54 08        0097          LD    DE,TABLE  ; TABLE POINTER
01CE  CD 10 05        0098          CALL  ADD2      ; FORM ROW ADDRESS
01D1  50              0099          LD    D,B
01D2  59              0100          LD    E,C
01D3  21 BC 08        0101          LD    HL,SAM
01D6  06 40           0102          LD    B,64
01D8  7E              0103  MOVE:   LD    A,(HL)    ; LOAD TABLE
01D9  12              0104          LD    (DE),A
01DA  23              0105          INC   HL
01DB  13              0106          INC   DE
01DC  10 FA           0107          DJNZ  MOVE
01DE  CD 48 02        0108          CALL  LOAD      ; LOAD SIZE/INFO DATA
01E1  CD EC 01        0109          CALL  REP       ; PRINT WORD REPORT
```

APPENDIX A

PROGRAM LISTING

```
0100                        0001 ;
0100                        0002 ;
0100                        0003 ;
0100                        0004 ;
0100                        0005 ;
0100                        0006 ;
0100  CD C5 04              0007 START: CALL  CRLF
0103  21 77 15              0008        LD    HL,MESS1  ; I OR P ?
0106  CD A3 04              0009        CALL  WRITE
0109  CD 04 05              0010        CALL  INC       ; GET RESPONSE
010C  FE 03                 0011        CP    03H       ; ETX TO MONITOR
010E  CA 00 2D              0012        JP    Z,2D00H
0111  FE 02                 0013        CP    02H       ; STX PRINTS VOCAB
0113  CC 5D 02              0014        CALL  Z,VOCREP
0116  28 E8                 0015        JR    Z,START
0118  FE 11                 0016        CP    11H       ; DC1 CHANGES DEVICE
011A  20 07                 0017        JR    NZ,ST1
011C  3A 75 15              0018        LD    A,(DEVICE)
011F  2F                    0019        CPL
0120  32 75 15              0020        LD    (DEVICE),A
0123  FE 54                 0021 ST1:   CP    'T'       ; TRAIN ?
0125  20 08                 0022        JR    NZ,ST2
0127  32 AD 08              0023        LD    (MODE),A  ; STORE 'T' MODE
012A  CD 5A 01              0024        CALL  TRAIN
012D  18 D1                 0025        JR    START
012F  FE 50                 0026 ST2:   CP    'P'       ; PERFORM ?
0131  20 08                 0027        JR    NZ,WHAT
0133  32 AD 08              0028        LD    (MODE),A  ; STORE 'P' MODE
0136  CD 42 01              0029        CALL  PERF
0139  18 C5                 0030        JR    START
013B  3E 3F                 0031 WHAT:  LD    A,'?'     ; RESPONSE ERROR
013D  CD D7 04              0032        CALL  OUTC
0140  18 BE                 0033        JR    START
0142                        0034 ;
0142                        0035 ; PERFORMANCE MODE ROUTINE
0142                        0036 ;
0142  CD C5 04              0037 PERF:  CALL  CRLF
0145  CD 32 02              0038        CALL  SPEECH    ; GET RAW SPEECH
0148  F5                    0039        PUSH  AF
0149  CD C5 04              0040        CALL  CRLF
014C  21 AD 15              0041        LD    HL,MESS8  ; RECOGNIZED
014F  CD A3 04              0042        CALL  WRITE
0152  F1                    0043        POP   AF
0153  CD F8 04              0044        CALL  OUTWD     ; PRINT WORD IN ASCII
0156  CD 5F 07              0045        CALL  SUMOUT    ; PRINT SUMS TABLE
0159  C9                    0046        RET
015A                        0047 ;
015A                        0048 ; TRAINING MODE ROUTINE
015A                        0049 ;
015A  F5                    0050 TRAIN: PUSH  AF
015B  C5                    0051        PUSH  BC
015C  D5                    0052        PUSH  DE
015D  E5                    0053        PUSH  HL
015E  CD D5 07              0054        CALL  ZERO      ; INITIALIZE ALL SUMS
```

```
0463 1D          0495          DEC   E
0464 28 08       0496          JR    Z,MULT2
0466 78          0497          LD    A,B
0467 30 01       0498          JR    NC,MULTI
0469 82          0499          ADD   D
046A 1F          0500 MULTI:   RRA
046B 47          0501          LD    B,A
046C 18 F2       0502          JR    MULTO
046E D1          0503 MULT2:   POP   DE
046F F1          0504          POP   AF
0470 C9          0505          RET
0471             0506 ;
0471             0507 ; DIVIDE (B,C)/D GIVES C=QUOTIENT, B=REMAINDER
0471             0508 ;
0471 F5          0509 DIV:     PUSH  AF
0472 D5          0510          PUSH  DE
0473 1E 09       0511          LD    E,9
0475 78          0512          LD    A,B
0476 47          0513 DIVO:    LD    B,A
0477 79          0514          LD    A,C
0478 17          0515          RLA
0479 4F          0516          LD    C,A
047A 1D          0517          DEC   E
047B 28 0D       0518          JR    Z,DIV2
047D 78          0519          LD    A,B
047E 17          0520          RLA
047F 30 03       0521          JR    NC,DIV1
0481 92          0522          SUB   D
0482 18 F2       0523          JR    DIVO
0484 92          0524 DIV1:    SUB   D
0485 30 EF       0525          JR    NC,DIVO
0487 82          0526          ADD   D
0488 18 EC       0527          JR    DIVO
048A 17          0528 DIV2:    RLA
048B 5F          0529          LD    E,A
048C 3E FF       0530          LD    A,0FFH
048E A9          0531          XOR   C
048F 4F          0532          LD    C,A
0490 7B          0533          LD    A,E
0491 1F          0534          RRA
0492 D1          0535 DIV3:    POP   DE          ; ROUND QUOTIENT
0493 D5          0536          PUSH  DE
0494 CB 0A       0537          RRC   D
0496 30 01       0538          JR    NC,DIV4
0498 14          0539          INC   D
0499 CB BA       0540 DIV4:    RES   7,D
049B 78          0541          LD    A,B
049C BA          0542          CP    D
049D 38 01       0543          JR    C,DONE
049F 0C          0544          INC   C
04A0 D1          0545 DONE:    POP   DE
04A1 F1          0546          POP   AF
04A2 C9          0547          RET
04A3             0548 ;
04A3             0549 ; WRITE MESSAGE
```

```
0417  CD 49 04          0440            CALL   DELAY
041A  21 FC 08          0441            LD     HL,BUF      ; BUFFER ADDRESS
041D  1E 96             0442            LD     E,150       ; 150 SAMPLES
041F  16 00             0443 LOOP:      LD     D,0
0421  7A                0444 LOOPO:     LD     A,D
0422  FE 04             0445            CP     4
0424  28 08             0446            JR     Z,L1
0426  CD 3A 04          0447            CALL   SAMPL       ; GET 4 DATA SETS
0429  77                0448            LD     (HL),A      ; STORE DATA
042A  23                0449            INC    HL
042B  14                0450            INC    D
042C  18 F3             0451            JR     LOOPO
042E  3E 0A             0452 L1:        LD     A,10
0430  CD 49 04          0453            CALL   DELAY       ; INTER-SAMPLE DELAY
0433  1D                0454            DEC    E
0434  20 E9             0455            JR     NZ,LOOP
0436  CD 85 04          0456            CALL   BEEP
0439  C9                0457            RET
043A                    0458 ;
043A                    0459 ; COLLECT SAMPLE FROM SPEECH BOARD
043A                    0460 ;
043A  F6 20             0461 SAMPL:     OR     020H        ; RESET SPEECH BOARD
043C  D3 AF             0462            OUT    0AFH,A
043E  E6 DF             0463            AND    0DFH        ; CLEAR RESET BIT
0440  D3 AF             0464            OUT    0AFH,A      ; START CONVERSION
0442  DB AF             0465 SP1:       IN     A,0AFH
0444  17                0466            RLA                ; A/D CONVERTER STATUS
0445  38 FB             0467            JR     C,SP1
0447  1F                0468            RRA
0448  C9                0469            RET
0449                    0470 ;
0449                    0471 ; INTER SAMPLE DELAY TIME
0449                    0472 ;
0449  C5                0473 DELAY:     PUSH   BC
044A  FE 00             0474 DELO:      CP     0
044C  28 0A             0475            JR     Z,RETDEL
044E  06 69             0476            LD     B,105
0450  00                0477 DEL1:      NOP
0451  00                0478            NOP
0452  05                0479            DEC    B
0453  20 FB             0480            JR     NZ,DEL1
0455  3D                0481            DEC    A
0456  18 F2             0482            JR     DELO
0458  C1                0483 RETDEL:    POP    BC
0459  C9                0484            RET
045A                    0485 ;
045A                    0486 ; MULTIPLY C*D=(B,C)
045A                    0487 ;
045A  F5                0488 MULT:      PUSH   AF
045B  D5                0489            PUSH   DE
045C  06 00             0490            LD     B,0
045E  1E 09             0491            LD     E,9
0460  79                0492 MULTO:     LD     A,C
0461  1F                0493            RRA
0462  4F                0494            LD     C,A
```

```
03B8  21 FC 08          0385            LD    HL,BUF
03BE  16 40             0386            LD    D,64        ; ROW SIZE
03C0  0E 00             0387            LD    C,0         ; ZERO ROW NUMBER
03C2  3A B0 08          0388            LD    A,(BPT)     ; COLUMN INDEX
03C5  CD 30 05          0389            CALL  ADDR        ; GET ADDRESS TO (HL)
03C8  11 00 00          0390            LD    DE,0        ; S=0
03CB  0E 00             0391            LD    C,0
03CD  CD 62 05          0392 MD:        CALL  SUM         ; A = SUM OF BANDS 0 - 2
03D0  83                0393            ADD   E
03D1  5F                0394            LD    E,A
03D2  30 01             0395            JR    NC,M1
03D4  14                0396            INC   D
03D5  79                0397 M1:        LD    A,C         ; CHECK FOR END
03D6  B8                0398            CP    B           ; COMPARE TO LEN
03D7  20 F4             0399            JR    NZ,MD
03D9  D5                0400            PUSH  DE
03DA  51                0401            LD    D,C
03DB  C1                0402            POP   BC
03DC  CD 71 04          0403            CALL  DIV         ; COMPUTE MEAN INTO C
03DF  06 00             0404            LD    B,0
03E1  16 03             0405            LD    D,3
03E3  CD 71 04          0406            CALL  DIV         ; DIVIDE BY 3 FOR MEAN
03E6  79                0407            LD    A,C
03E7  32 AE 08          0408            LD    (AVER),A    ; STORE IN AVER
03EA  C9                0409            RET
03EB                    0410 ;
03EB                    0411 ; NORMALIZES AMPLITUDE BY TRANSLATION
03EB                    0412 ;
03EB  21 8C 08          0413 NORM:      LD    HL,SAM      ; BASE OF SAMPLE ARRAY
03EE  16 03             0414            LD    D,3         ; BAND COUNTER
03F0  06 40             0415            LD    B,64        ; SAMPLE BUFFER LENGTH
03F2  3A AE 08          0416            LD    A,(AVER)
03F5  96                0417 NRM1:      SUB   (HL)        ; AVERAGE - STORAGE
03F6  C6 20             0418            ADD   32          ; KEEP IT POSITIVE
03F8  77                0419            LD    (HL),A      ; RESTORE IT
03F9  15                0420            DEC   D           ; BAND COUNTER
03FA  28 06             0421            JR    Z,NRM2      ; SKIP ZCD ONLY
03FC  16 03             0422            LD    D,3
03FE  23                0423            INC   HL
03FF  05                0424            DEC   B
0400  28 04             0425            JR    Z,NRM3
0402  23                0426 NRM2:      INC   HL          ; NEXT SAMPLE
0403  05                0427            DEC   B
0404  20 EF             0428            JR    NZ,NRM1
0406  C9                0429 NRM3:      RET
0407                    0430 ;
0407  CD A3 04          0431 ERROR:     CALL  WRITE       ; WRITE ERROR MESSAGE
040A  C3 00 01          0432            JP    START       ; GET NEW COMMAND
040D                    0433 ;
040D                    0434 ; COLLECT RAW SPEECH DATA
040D                    0435 ;
040D  3E FA             0436 SPCH:      LD    A,250       ; SYSTEM NOISE DELAY
040F  CD 49 04          0437            CALL  DELAY
0412  CD B5 04          0438            CALL  BEEP        ; TURN BEEPER ON
0415  3E 96             0439            LD    A,150       ; BEEPER DELAY
```

```
037A 20 DE              0330            JR    NZ,CHO
037C CD 19 03           0331            CALL  MINDIG    ; FIND MIN DIFFERENCE
037F C9                 0332            RET
0380                    0333 ;
0380                    0334 ; INITIALIZE PARTIAL SUMS TABLE
0380                    0335 ;
0380 3A AC 08           0336 INTPAR: LD   A,(VOCSIZ)
0383 87                 0337         ADD  A          ; DOUBLE VOCSIZE
0384 4F                 0338         LD   C,A        ; WORD INDEX IN C
0385 3E 00              0339         LD   A,0
0387 21 56 14           0340         LD   HL,SUMS    ; BASE OF SUMS ARRAY
038A 77                 0341 IPS1:   LD   (HL),A
038B 23                 0342         INC  HL
038C 0D                 0343         DEC  C          ; GET NEXT ENTRY
038D 20 FB              0344         JR   NZ,IPS1
038F C9                 0345         RET
0390                    0346 ;
0390                    0347 ; UPDATE PARTIAL SUM
0390                    0348 ; SUMS(B) = SUMS(B) + ABS(A-SAM(E))
0390                    0349 ;
0390 E5                 0350 PRTSUM: PUSH HL
0391 D5                 0351         PUSH DE
0392 C5                 0352         PUSH BC
0393 F5                 0353         PUSH AF
0394 21 BC 08           0354         LD   HL,SAM     ; BASE OF SAMPLE BUFFER
0397 16 00              0355         LD   D,0
0399 19                 0356         ADD  HL,DE      ; ADDRESS OF SAMPLE (E)
039A 96                 0357         SUB  (HL)       ; A-SAM(E)
039B F2 A0 03           0358         JP   P,PS1
039E 2F                 0359         CPL             ; FORM 2'S COMP IF NEG
039F 3C                 0360         INC  A
03A0 57                 0361 PS1:    LD   D,A        ; SAVE A
03A1 78                 0362         LD   A,B
03A2 87                 0363         ADD  A
03A3 21 56 14           0364         LD   HL,SUMS    ; BASE OF SUMS ARRAY
03A6 4F                 0365         LD   C,A        ; INDEX TO C
03A7 06 00              0366         LD   B,0        ; ZERO HIGH ORDER BYTE
03A9 09                 0367         ADD  HL,BC      ; ADDRESS OF SUMS (B*2)
03AA 23                 0368         INC  HL
03AB 7A                 0369         LD   A,D        ; ADD TO SUMS(B)
03AC 86                 0370         ADD  (HL)
03AD 77                 0371         LD   (HL),A
03AE 30 02              0372         JR   NC,PS2
03B0 2B                 0373         DEC  HL
03B1 34                 0374         INC  (HL)
03B2 F1                 0375 PS2:    POP  AF
03B3 C1                 0376         POP  BC
03B4 D1                 0377         POP  DE
03B5 E1                 0378         POP  HL
03B6 C9                 0379         RET
03B7                    0380 ;
03B7                    0381 ; COMPUTE MEAN AMPLITUDE OF BANDS 0 - 2
03B7                    0382 ;
03B7 3A B2 08           0383 MEAN:   LD   A,(LEN)    ; LENGTH TO B
03BA 47                 0384         LD   B,A
```

```
031C  22 54 14          0275            LD    (MIN),HL
031F  3E 00             0276            LD    A,0
0321  32 AF 08          0277            LD    (WORD),A  ;STORE IN WORD
0324  3A AC 08          0278            LD    A,(VOCSIZ)
0327  3D                0279            DEC   A
0328  4F                0280            LD    C,A
0329  06 00             0281            LD    B,0
032B  C5                0282 MD1:       PUSH  BC
032C  79                0283            LD    A,C
032D  87                0284            ADD   A
032E  4F                0285            LD    C,A
032F  21 56 14          0286            LD    HL,SUMS
0332  09                0287            ADD   HL,BC
0333  46                0288            LD    B,(HL)
0334  23                0289            INC   HL
0335  4E                0290            LD    C,(HL)
0336  21 54 14          0291            LD    HL,MIN
0339  56                0292            LD    D,(HL)
033A  23                0293            INC   HL
033B  5E                0294            LD    E,(HL)
033C  CD 1F 05          0295            CALL  COM2      ; 2 BYTE COMPARISON
033F  38 07             0296            JR    C,NEWLO
0341  C1                0297            POP   BC
0342  0D                0298 MD2:       DEC   C
0343  FA 55 03          0299            JP    M,MD3
0346  18 E3             0300            JR    MD1
0348  21 54 14          0301 NEWLO:     LD    HL,MIN
034B  70                0302            LD    (HL),B
034C  23                0303            INC   HL
034D  71                0304            LD    (HL),C
034E  C1                0305            POP   BC
034F  79                0306            LD    A,C
0350  32 AF 08          0307            LD    (WORD),A
0353  18 ED             0308            JR    MD2
0355  3A AF 08          0309 MD3:       LD    A,(WORD)
0358  C9                0310            RET
0359                    0311 ;
0359                    0312 ; COMPUTE DIFFERENCES AND FIND NEAREST MATCH
0359  06 00             0313 CHEBY:     LD    B,0       ; ROW INDEX
035B  48                0314 CH0:       LD    C,B
035C  CD 8F 07          0315            CALL  NULIST    ; TEST FOR NULL WORD
035F  28 14             0316            JR    Z,CH2
0361  16 40             0317            LD    D,64      ; ROW SIZE
0363  3E 00             0318            LD    A,0       ; SAMPLE INDEX (COLUMN)
0365  5F                0319            LD    E,A
0366  21 54 08          0320 CH1:       LD    HL,TABLE  ; TABLE POINTER
0369  CD 40 05          0321            CALL  GETA      ; GET TABLE(C,A) TO A
036C  CD 90 03          0322            CALL  PRTSUM    ; UPDATE SUM
036F  1C                0323            INC   E
0370  7B                0324            LD    A,E
0371  FE 3F             0325            CP    63        ; TEMPLATE FINISHED ?
0373  20 F1             0326            JR    NZ,CH1
0375  04                0327 CH2:       INC   B         ; NEXT WORD
0376  3A AC 08          0328            LD    A,(VOCSIZ)
0379  B8                0329            CP    B
```

```
02B1  CD C9 07          0220            CALL    ZCHK        ; TEST ZCD DATA
02B4  30 08             0221            JR      NC,T1
02B6  79                0222            LD      A,C         ; TEST FOR BUFFER END
02B7  FE 96             0223            CP      150
02B9  20 EF             0224            JR      NZ,EP1
02BB  21 B9 15          0225            LD      HL,E1
02BE  C3 07 04          0226            JP      ERROR       ; PRINT 'NO SPEECH'
02C1  79                0227 T1:        LD      A,C         ; TENTATIVE START
02C2  3D                0228            DEC     A
02C3  32 B0 08          0229            LD      (BPT),A     ; BEGINNING POINTER
02C6  47                0230            LD      B,A
02C7  CD 62 05          0231 T10:       CALL    SUM         ; CONTINUE ANALYSIS
02CA  FE 06             0232            CP      6
02CC  30 05             0233            JR      NC,T11
02CE  CD C9 07          0234            CALL    ZCHK        ; DATA < THRESHOLD?
02D1  38 08             0235            JR      C,T2        ; TO T2 IF < THRESHOLD
02D3  79                0236 T11:       LD      A,C         ; END OF BUFFER CHECK
02D4  FE 96             0237            CP      150
02D6  20 EF             0238            JR      NZ,T10      ; GET MORE SPEECH
02D8  21 C3 15          0239 T12:       LD      HL,E2
02DB  C3 07 04          0240            JP      ERROR       ; 'SPEECH TOO LONG'
02DE  79                0241 T2:        LD      A,C         ; TENTATIVE ENDPOINT
02DF  3D                0242            DEC     A
02E0  3D                0243            DEC     A
02E1  32 B1 08          0244            LD      (EPT),A     ; SAVE ENDPOINT
02E4  90                0245            SUB     B
02E5  3C                0246            INC     A
02E6  32 B2 08          0247            LD      (LEN),A     ; SAVE LENGTH
02E9  3A B0 08          0248            LD      A,(BPT)     ; TEST BEGINNING
02EC  FE 01             0249            CP      1
02EE  28 E8             0250            JR      Z,T12       ; FOR ERROR MESSAGE.
02F0  0E 01             0251            LD      C,1         ; ENDING TEST
02F2  CD 62 05          0252 T3:        CALL    SUM         ; SILENCE IS A STOP ?
02F5  FE 06             0253            CP      6
02F7  30 0E             0254            JR      NC,STOP
02F9  CD C9 07          0255            CALL    ZCHK        ; TEST ZCD DATA
02FC  30 09             0256            JR      NC,STOP
02FE  79                0257            LD      A,C         ; TEST FOR STOP
02FF  FE 19             0258            CP      25
0301  20 EF             0259            JR      NZ,T3
0303  CD 77 06          0260            CALL    OUTLEN      ; PRINT LENGTH
0306  C9                0261            RET                 ; A GOOD WORD
0307  3A B2 08          0262 STOP:      LD      A,(LEN)     ; ADJUST BUFFER POINTER
030A  81                0263            ADD     C
030B  4F                0264            LD      C,A
030C  3A B0 08          0265            LD      A,(BPT)
030F  81                0266            ADD     C
0310  4F                0267            LD      C,A
0311  CD 90 06          0268            CALL    PCBCD       ; PRINT C REG IN BCD
0314  CD 1F 06          0269            CALL    STOPMK      ; MARK THE STOP
0317  18 AE             0270            JR      T10         ; CONTINUE ANALYSIS
0319                    0271 ;
0319                    0272 ; FIND MINIMUM NUMBER IN SUMS TABLE
0319                    0273 ;
0319  21 FF FF          0274 MINDIG:    LD      HL,0FFFFH   ; LARGEST NUMBER
```

```
024A  C9                  0165          RET
0248                      0166 ;
0248                      0167 ; LOADS TRAINING DATA INTO SIZE AND INFO
0248                      0168 ;
0248  CD 2D 06            0169 LOAD:    CALL  SZADD     ; SIZE ADDRESS IN HL
024E  3A E6 14            0170          LD    A,(STOPWD)
0251  77                  0171          LD    (HL),A    ; LOAD SIZE DATA
0252  21 C2 14            0172          LD    HL,INFO
0255  CD 30 06            0173          CALL  INFADD    ; INFO ADDRESS IN HL
0258  3A E7 14            0174          LD    A,(INFOWD)
025B  77                  0175          LD    (HL),A    ; LOAD INFO DATA
025C  C9                  0176          RET
025D                      0177 ;
025D                      0178 ; OUTPUT VOCABULARY REPORT
025D                      0179 ;
025D  3E FF               0180 VOCREP:  LD    A,0FFH
025F  32 76 15            0181          LD    (SWITCH),A
0262  06 00               0182          LD    B,0
0264  78                  0183 VOC1:    LD    A,B
0265  32 AF 08            0184          LD    (WORD),A
0268  CD F8 04            0185          CALL  OUTWD     ; PRINT WORD
026B  3E 20               0186          LD    A,20H
026D  CD D7 04            0187          CALL  OUTC
0270  3E 00               0188          LD    A,0
0272  32 E6 14            0189          LD    (STOPWD),A
0275  CD 2D 06            0190          CALL  SZADD     ; SIZE ADDRESS IN HL
0278  4E                  0191          LD    C,(HL)
0279  CB 79               0192          BIT   7,C
027B  28 07               0193          JR    Z,VOC2
027D  3E 80               0194          LD    A,80H
027F  32 E6 14            0195          LD    (STOPWD),A
0282  CB B9               0196          RES   7,C
0284  79                  0197 VOC2:    LD    A,C
0285  32 B2 08            0198          LD    (LEN),A
0288  21 C2 14            0199          LD    HL,INFO
028B  CD 30 06            0200          CALL  INFADD    ; INFO ADDRESS IN HL
028E  7E                  0201          LD    A,(HL)
028F  32 E7 14            0202          LD    (INFOWD),A
0292  CD EC 01            0203          CALL  REP       ; PRINT WORD REPORT
0295  04                  0204          INC   B
0296  3A AC 08            0205          LD    A,(VOCSIZ)
0299  B8                  0206          CP    B
029A  20 C8               0207          JR    NZ,VOC1
029C  3E 00               0208          LD    A,0
029E  32 76 15            0209          LD    (SWITCH),A
02A1  C9                  0210          RET
02A2                      0211 ;
02A2                      0212 ; FIND WORD BEGINNING/END COMPARING THRESHOLD
02A2                      0213 ;
02A2  0E 01               0214 ENDPTS:  LD    C,1       ; SPEECH BUFFER INDEX
02A4  CD A6 07            0215          CALL  INIT      ; ZERO STOP INFO
02A7  21 00 09            0216          LD    HL,BUF+4
02AA  CD 62 05            0217 EP1:     CALL  SUM       ; COMPUTE THRESHOLD
02AD  FE 06               0218          CP    6
02AF  30 10               0219          JR    NC,T1     ; IQ|T1 IF > THRESHOLD
```

```
01E4  CD 1B 02          0110          CALL  PREP
01E7  E1                0111          POP   HL
01E8  D1                0112          POP   DE
01E9  C1                0113          POP   BC
01EA  F1                0114          POP   AF
01EB  C9                0115          RET
01EC                    0116 ;
01EC                    0117 ; OUTPUT WORD REPORT IN T MODE
01EC                    0118 ;
01EC  21 88 15          0119 REP:     LD    HL,MESS4   ; LENGTH =
01EF  CD A3 04          0120          CALL  WRITE
01F2  3A B2 08          0121          LD    A,(LEN)
01F5  CD 38 06          0122          CALL  BCDA       ; PRINT DATA
01F8  21 A5 15          0123          LD    HL,MESS7   ; INFO =
01FB  CD A3 04          0124          CALL  WRITE
01FE  3A E7 08          0125          LD    A,(INFOWD)
0201  CD CB 06          0126          CALL  PAHEX      ; PRINT INFO IN HEX
0204  3E 20             0127          LD    A,20H
0206  CD D7 04          0128          CALL  OUTC
0209  3A E6 14          0129          LD    A,(STOPWD)
020C  CB 07             0130          RLC   A
020E  38 04             0131          JR    C,RI
0210  CD C5 04          0132          CALL  CRLF
0213  C9                0133          RET
0214  21 86 15          0134 RI:      LD    HL,MESS3   ; STOP
0217  CD A3 04          0135          CALL  WRITE
021A  C9                0136          RET
021B                    0137 ;
021B                    0138 ; PRINT REPORT TO DEVICE
021B                    0139 ;
0218  3A 75 15          0140 PREP:    LD    A,(DEVICE)
021E  FE 00             0141          CP    0
0220  C8                0142          RET   Z
0221  3E FF             0143          LD    A,0FFH
0223  32 76 15          0144          LD    (SWITCH),A
0226  CD EC 01          0145          CALL  REP
0229  3E 00             0146          LD    A,0
022B  32 76 15          0147          LD    (SWITCH),A
022E  CD 04 05          0148          CALL  INC
0231  C9                0149          RET
0232                    0150 ;
0232                    0151 ; GET AND PROCESS SPEECH
0232                    0152 ;
0232  C5                0153 SPEECH:  PUSH  BC
0233  D5                0154          PUSH  DE
0234  E5                0155          PUSH  HL
0235  CD 0D 04          0156          CALL  SPCH       ; GET SPEECH INPUT
0238  CD A2 02          0157          CALL  ENDPTS     ; FIND END POINTS
023B  CD A1 06          0158          CALL  INFLD      ; LOAD INFOWD
023E  CD 02 07          0159          CALL  MATCH      ; COMPARE VOCAB WORDS
0241  CD 94 05          0160          CALL  GETSAM     ; GET 16 SAMPLES
0244  CD 59 03          0161          CALL  CHEBY      ; FIND SMALLEST DIFF
0247  E1                0162          POP   HL         ; RESULT IN A
0248  D1                0163          POP   DE
0249  C1                0164          POP   BC
```

```
056E  C9              0715          RET
056F                  0716  ;
056F                  0717  ; INTERPOLATE
056F                  0718  ; B=V1, C=V2, D=FRAC*10
056F                  0719  ; REG A=V1+FRAC*(V2-V1)/10
056F                  0720  ;
056F  D5              0721  INTR:   PUSH  DE
0570  1E 00           0722          LD    E,0         ; SET FLAG
0572  79              0723          LD    A,C         ; V2 TO A
0573  90              0724          SUB   B           ; V2-V1
0574  F2 78 05        0725          JP    P,INTR1
0577  2F              0726          CPL               ; FORM 2'S COMP
0578  3C              0727          INC   A
0579  1E FF           0728          LD    E,0FFH      ; SET NEGATIVE FLAG
057B  C5              0729  INTR1:  PUSH  BC          ; SAVE (B,C)
057C  4F              0730          LD    C,A         ; SET UP MULTIPLY
057D  42              0731          LD    B,D         ; FRAC TO B
057E  CD 5A 04        0732          CALL  MULT
0581  16 0A           0733          LD    D,10        ; DIVIDE BY 10
0583  CD 71 04        0734          CALL  DIV         ; MAKES C QUOTIENT
0586  7B              0735          LD    A,E
0587  FE FF           0736          CP    0FFH        ; CHECK NEGATIVE FLAG
0589  20 04           0737          JR    NZ,INTR2
058B  79              0738          LD    A,C         ; COMP IF NEGATIVE
058C  2F              0739          CPL
058D  3C              0740          INC   A
058E  4F              0741          LD    C,A
058F  79              0742  INTR2:  LD    A,C
0590  C1              0743          POP   BC
0591  D1              0744          POP   DE
0592  80              0745          ADD   B           ; V1+FRAC*(V2-V1)/10
0593  C9              0746          RET
0594                  0747  ;
0594                  0748  ; GET 16 EVENLY SPACED SAMPLES FROM RAW SPEECH
0594                  0749  ; BUFFER AND MOVE THEM TO SAMPLE BUFFER
0594                  0750  ;
0594  21 BC 08        0751  GETSAM: LD    HL,SAM      ; BASE OF SAMPLE ARRAY
0597  22 B4 08        0752          LD    (SAMPT),HL  ; INIT SAMPT
059A  3A B2 08        0753          LD    A,(LEN)     ; FORM LEN*10
059D  4F              0754          LD    C,A
059E  16 0A           0755          LD    D,10
05A0  CD 5A 04        0756          CALL  MULT
05A3  16 10           0757          LD    D,16
05A5  CD 71 04        0758          CALL  DIV         ; COMPUTE INCREMENT*10
05A8  26 00           0759          LD    H,0
05AA  69              0760          LD    L,C
05AB  22 BA 08        0761          LD    (IND),HL    ; SAVE IT IN IND(EX)
05AE  21 00 00        0762          LD    HL,0
05B1  22 B8 08        0763          LD    (BUFPT),HL  ; INIT BUFFER POINTER
05B4  1E 10           0764          LD    E,16        ; NUMBER OF SAMPLES
05B6  D5              0765  GES1:   PUSH  DE
05B7  2A B8 08        0766          LD    HL,(BUFPT)  ; INDEX INTO BUFFER*10
05BA  44              0767          LD    B,H
05BB  4D              0768          LD    C,L
05BC  16 0A           0769          LD    D,10        ; DIVIDE BY 10
```

```
052A  79                  0660 COM21:  LD     A,C
052B  BB                  0661         CP     E
052C  3A 83 08            0662         LD     A,(TMP)
052F  C9                  0663         RET
0530                      0664 ;
0530                      0665 ; FIND BYTE ADDRESS
0530                      0666 ; (H,L)+(D*C)+A=:(H,L)
0530                      0667 ;
0530  F5                  0668 ADDR:   PUSH   AF
0531  C5                  0669         PUSH   BC
0532  D5                  0670         PUSH   DE
0533  CD 5A 04            0671         CALL   MULT
0536  09                  0672         ADD    HL,BC
0537  85                  0673         ADD    L
0538  6F                  0674         LD     L,A
0539  30 01               0675         JR     NC,ADDR1
053B  24                  0676         INC    H
053C  D1                  0677 ADDR1:  POP    DE
053D  C1                  0678         POP    BC
053E  F1                  0679         POP    AF
053F  C9                  0680         RET
0540                      0681 ;
0540  CD 30 05            0682 GETA:   CALL   ADDR
0543  7E                  0683         LD     A,(HL)
0544  C9                  0684         RET
0545                      0685 ;
0545                      0686 ; COLLECT WORD IDENTIFICATION
0545                      0687 ;
0545  CD 04 05            0688 WORDID: CALL   INC
0548  E6 7F               0689         AND    07FH
054A  FE 30               0690         CP     '0'
054C  DA 3B 01            0691         JP     C,WHAT
054F  FE 3A               0692         CP     '9'+1
0551  38 0C               0693         JR     C,WO1
0553  FE 41               0694         CP     'A'
0555  DA 3B 01            0695         JP     C,WHAT
0558  FE 5B               0696         CP     'Z'+1
055A  D2 3B 01            0697         JP     NC,WHAT
055D  D6 07               0698         SUB    07H
055F  D6 30               0699 WO1:    SUB    '0'
0561  C9                  0700         RET
0562                      0701 ;
0562                      0702 ; SUMS BANDS 0-2 IN REG A
0562                      0703 ; HL POINTS TO BUF(F1), RETURNS SUM IN A
0562                      0704 ;
0562  AF                  0705 SUM:    XOR    A          ; CLEAR A
0563  C5                  0706         PUSH   BC
0564  06 03               0707         LD     B,3
0566  86                  0708 SUM1:   ADD    (HL)
0567  23                  0709         INC    HL
0568  05                  0710         DEC    B
0569  20 FB               0711         JR     NZ,SUM1
056B  C1                  0712         POP    BC
056C  23                  0713         INC    HL         ; SKIP ZCD DATA
056D  0C                  0714         INC    C          ; UP SPEECH INDEX
```

```
04E2  47                0605            LD    B,A
04E3  CD 49 29          0606            CALL  2949H     ; PRINTER OUTPUT
04E6  C1                0607            POP   BC
04E7  C9                0608            RET
04E8                    0609 ;
04E8                    0610 ; PRINT WORD IN ASCII
04E8                    0611 ;
04E8  E6 7F             0612 OUTWD:     AND   7FH       ; MASK BIT 7
04EA  C6 30             0613            ADD   '0'
04EC  FE 3A             0614            CP    '9'+1
04EE  38 07             0615            JR    C,OUTC
0500  C6 07             0616            ADD   07H       ; 07H='A'-'0'-10
0502  18 03             0617            JR    OUTC
0504                    0618 ;
0504                    0619 ; GET CHARACTER
0504                    0620 ;
0504  DB 03             0621 INC:       IN    A,3
0506  E6 02             0622            AND   02H
0508  28 FA             0623            JR    Z,INC
050A  DB 02             0624            IN    A,2
050C  E6 7F             0625            AND   07FH
050E  18 C7             0626            JR    OUTC
0510                    0627 ;
0510                    0628 ; 16 BIT ADD
0510                    0629 ; ADD (B,C)+(D,E) = (B,C)
0510                    0630 ;
0510  EB                0631 ADD2:      EX    DE,HL
0511  09                0632            ADD   HL,BC
0512  EB                0633            EX    DE,HL
0513  42                0634            LD    B,D
0514  4B                0635            LD    C,E
0515  C9                0636            RET
0516                    0637 ;
0516                    0638 ; 16 BIT SUBTRACT
0516                    0639 ; (B,C)-(D,E)=(B,C)
0516                    0640 ;
0516  F5                0641 SUB2:      PUSH  AF
0517  79                0642            LD    A,C
0518  93                0643            SUB   E
0519  4F                0644            LD    C,A
051A  78                0645            LD    A,B
051B  9A                0646            SBC   D
051C  47                0647            LD    B,A
051D  F1                0648            POP   AF
051E  C9                0649            RET
051F                    0650 ;
051F                    0651 ; COMPARE 2 BYTES, (B,C),(D,E) ARE (HI,LO)
051F                    0652 ; (B,C) > (D,E) SETS COND CODE
051F                    0653 ;
051F  32 B3 08          0654 COM2:      LD    (TMP),A
0522  78                0655            LD    A,B
0523  BA                0656            CP    D
0524  28 04             0657            JR    Z,COM21
0526  3A B3 08          0658            LD    A,(TMP)
0529  C9                0659            RET
```

```
04A3                    0550 ; (H,L) =: MESS (ENDS WITH 0)
04A3                    0551 ;
04A3  7E                0552 WRITE:  LD   A,(HL)
04A4  FE 00             0553         CP   0
04A6  28 09             0554         JR   Z,WRI
04A8  FE 24             0555         CP   '
04AA  C8                0556         RET  Z          ; SUPPRESS CRLF
04AB  CD D7 04          0557         CALL OUTC
04AE  23                0558         INC  HL
04AF  18 F2             0559         JR   WRITE
0481  CD C5 04          0560 WRI:    CALL CRLF
0484  C9                0561         RET
0485                    0562 ;
0485                    0563 ; SOUND BEEPER CUE
0485                    0564 ;
0485  F5                0565 BEEP:   PUSH AF
0486  3E 10             0566         LD   A,10H
0488  D3 AF             0567         OUT  0AFH,A     ; ENABLE SIGNAL GEN
048A  3E 64             0568         LD   A,100
048C  CD 49 04          0569         CALL DELAY      ; BEEP FOR 100MS
048F  3E 00             0570         LD   A,0
04C1  D3 AF             0571         OUT  0AFH,A
04C3  F1                0572         POP  AF
04C4  C9                0573         RET
04C5                    0574 ;
04C5  F5                0575 CRLF:   PUSH AF
04C6  3E 0D             0576         LD   A,0DH
04C8  CD D7 04          0577         CALL OUTC
04CB  3E 0A             0578         LD   A,0AH
04CD  CD D7 04          0579         CALL OUTC
0400  3E 00             0580         LD   A,0
04D2  CD D7 04          0581         CALL OUTC
04D5  F1                0582         POP  AF
04D6  C9                0583         RET
04D7                    0584 ;
04D7                    0585 ; OUTPUT CHARACTER
04D7                    0586 ;
04D7  F5                0587 OUTC:   PUSH AF
04D8  DB 03             0588 OUTV:   IN   A,3
04DA  E6 01             0589         AND  01H
04DC  28 FA             0590         JR   Z,OUTV
04DE  F1                0591         POP  AF
04DF  D3 02             0592         OUT  2,A        ; VIDEO OUTPUT
04E1  F5                0593         PUSH AF
04E2  D5                0594         PUSH DE
04E3  3A 75 15          0595         LD   A,(DEVICE)
04E6  57                0596         LD   D,A
04E7  3A 76 15          0597         LD   A,(SWITCH)
04EA  A2                0598         AND  D
04EB  D1                0599         POP  DE
04EC  20 02             0600         JR   NZ,OUTP
04EE  F1                0601         POP  AF
04EF  C9                0602         RET
04F0  F1                0603 OUTP:   POP  AF         ; PRINTER OUTPUT
04F1  C5                0604         PUSH BC
```

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061B CD E8 03          0825          CALL  NORM
061E C9                0826          RET
061F                   0827 ;
061F                   0828 ; MARKS STOP IN T AND P MODES
061F                   0829 ;
061F E5                0830 STOPMK:  PUSH  HL
0620 3E 80             0831          LD    A,80H
0622 32 E6 14          0832          LD    (STOPWD),A: MARK STOP
0625 21 86 15          0833          LD    HL,MESS3    ; PRINT STOP
0628 CD A3 04          0834          CALL  WRITE
0628 E1                0835          POP   HL
062C C9                0836          RET
062D                   0837 ;
062D                   0838 ; GET SIZE ADDRESS OF DIGIT INTO HL
062D                   0839 ;
062D 21 9E 14          0840 SZADD:   LD    HL,SIZE
0630 16 00             0841 INFADD:  LD    D,0         ; ENTRY FOR INFO ADD
0632 3A AF 08          0842          LD    A,(WORD)
0635 5F                0843          LD    E,A
0636 19                0844          ADD   HL,DE
0637 C9                0845          RET
0638                   0846 ;
0638                   0847 ; PRINTS A/HL REG IN BCD, ALTERS HL REG
0638                   0848 ;
0638 26 00             0849 BCDA:    LD    H,0         ; A REG ENTRY
063A 6F                0850          LD    L,A
063B FD 21 71 06       0851          LD    IY,PIOTAB+4
063F 18 04             0852          JR    SKIP
0641 FD 21 6D 06       0853 BCDHL:   LD    IY,PIOTAB   ; HL REG ENTRY
0645 F5                0854 SKIP:    PUSH  AF
0646 D5                0855          PUSH  DE
0647 AF                0856 LOOP1:   XOR   A
0648 FD 5E 00          0857          LD    E,(IY+0)
0648 FD 56 01          0858          LD    D,(IY+1)
064E B7                0859 LOOP2:   OR    A
064F ED 52             0860          SBC   HL,DE       ; SUBTRACT POWER OF 10
0651 38 03             0861          JR    C,JUMP1
0653 3C                0862          INC   A
0654 18 F8             0863          JR    LOOP2
0656 19                0864 JUMP1:   ADD   HL,DE
0657 C6 30             0865          ADD   30H         ; ASCII CONVERSION
0659 CD D7 04          0866          CALL  OUTC        ; OUTPUT DIGIT
065C FD 23             0867          INC   IY
065E FD 23             0868          INC   IY
0660 3E 01             0869          LD    A,1
0662 BB                0870          CP    E           ; END OF TABLE ?
0663 20 E2             0871          JR    NZ,LOOP1
0665 3E 20             0872          LD    A,20H
0667 CD D7 04          0873          CALL  OUTC        ; PRINT SPACE
066A D1                0874          POP   DE
066B F1                0875          POP   AF
066C C9                0876          RET
066D 10 27             0877 PIOTAB:  DW    10000
066F E8 03             0878          DW    1000
0671 64 00             0879          DW    100
```

```
05BE  CD 71 04          0770          CALL  DIV
05C1  78                0771          LD    A,B         ; FRACTIONAL PART TO A
05C2  32 B6 08          0772          LD    (FRAC),A    ; SAVE IT
05C5  06 00             0773          LD    B,0         ; CLEAR FRACTION
05C7  3A B0 08          0774          LD    A,(BPT)
05CA  5F                0775          LD    E,A
05CB  16 00             0776          LD    D,0
05CD  CD 10 05          0777          CALL  ADD2        ; FORM BPT+IND
05D0  16 04             0778          LD    D,4
05D2  CD 5A 04          0779          CALL  MULT
05D5  21 FC 08          0780          LD    HL,BUF      ; BASE OF BUFFER
05D8  09                0781          ADD   HL,BC       ; BAND-0 BUFFER ADD
05D9  E5                0782          PUSH  HL          ; SAVE POINTER TO DATA
05DA  2A B4 08          0783          LD    HL,(SAMPT)
05DD  1E 03             0784          LD    E,3
05DF  2A B4 08          0785          LD    HL,(SAMPT)
05E2  E3                0786  GES2:   EX    (SP),HL
05E3  46                0787          LD    B,(HL)      ; V1 TO B
05E4  E5                0788          PUSH  HL          ; SAVE BUFPT
05E5  23                0789          INC   HL          ; NEXT SAMPLE SAME BAND
05E6  23                0790          INC   HL
05E7  23                0791          INC   HL
05E8  23                0792          INC   HL
05E9  4E                0793          LD    C,(HL)      ; V2 TO C
05EA  3A B6 08          0794          LD    A,(FRAC)
05ED  57                0795          LD    D,A         ; FRAC TO D
05EE  CD 6F 05          0796          CALL  INTR
05F1  E1                0797          POP   HL          ; RESTORE BUFPT=>V1
05F2  23                0798          INC   HL
05F3  E3                0799          EX    (SP),HL     ; SAMPT TO (H,L)
05F4  77                0800          LD    (HL),A      ; LOAD INTERP VALUE
05F5  23                0801          INC   HL          ; INC SAMPT
05F6  1D                0802          DEC   E           ; DEC BAND NUMBER
05F7  20 E9             0803          JR    NZ,GES2     ; NEXT BAND
05F9  E3                0804          EX    (SP),HL     ; POINT AT ZCR
05FA  7E                0805          LD    A,(HL)      ; GET IT TO A
05FB  E3                0806          EX    (SP),HL     ; GET SAMPT BACK
05FC  77                0807          LD    (HL),A
05FD  23                0808          INC   HL          ; INC SAMPT
05FE  22 B4 08          0809          LD    (SAMPT),HL  ; SAVE SAMPT
0601  E1                0810          POP   HL
0602  2A B8 08          0811          LD    HL,(BUFPT)  ; ADD INDEX TO BUFPT
0605  44                0812          LD    B,H
0606  4D                0813          LD    C,L
0607  2A BA 08          0814          LD    HL,(IND)
060A  54                0815          LD    D,H
060B  5D                0816          LD    E,L
060C  CD 10 05          0817          CALL  ADD2
060F  60                0818          LD    H,B
0610  69                0819          LD    L,C
0611  22 B8 08          0820          LD    (BUFPT),HL  ; RESTORE BUFPT
0614  D1                0821          POP   DE
0615  1D                0822          DEC   E
0616  20 9E             0823          JR    NZ,GES1
0618  CD B7 03          0824          CALL  MEAN
```

```
0673  0A 00          0880          DW    10
0675  01 00          0881          DW    1
0677                 0882 ;
0677                 0883 ; PRINTS LENGTHS IN BCD
0677                 0884 ;
0677  3A 80 08       0885 OUTLEN:  LD    A,(BPT)
067A  CD 38 06       0886          CALL  BCDA
067D  3A 81 08       0887          LD    A,(EPT)
0680  CD 38 06       0888          CALL  BCDA
0683  21 8B 15       0889          LD    HL,MESS4
0686  CD A3 04       0890          CALL  WRITE     ; PRINT 'LENGTH = '
0689  3A B2 08       0891          LD    A,(LEN)
068C  CD 38 06       0892          CALL  BCDA
068F  C9             0893          RET
0690                 0894 ;
0690                 0895 ; PRINT C REG (SPEECH INDEX) IN BCD
0690                 0896 ;
0690  E5             0897 PCBCD:   PUSH  HL
0691  3E 20          0898          LD    A,20H
0693  CD D7 04       0899          CALL  OUTC
0696  79             0900          LD    A,C
0697  CD 38 06       0901          CALL  BCDA
069A  3E 20          0902          LD    A,20H
069C  CD D7 04       0903          CALL  OUTC
069F  E1             0904          POP   HL
06A0  C9             0905          RET
06A1                 0906 ;
06A1                 0907 ; LOADS INFOWD IN T AND P MODES
06A1                 0908 ;
06A1  0E 00          0909 INFLD:   LD    C,0       ; ZERO C REG
06A3  3A 80 08       0910          LD    A,(BPT)
06A6  CD E3 06       0911          CALL  TEST      ; BEGIN INFO
06A9  3A 81 08       0912          LD    A,(EPT)
06AC  CD E3 06       0913          CALL  TEST      ; END INFO
06AF  3A 80 08       0914          LD    A,(BPT)
06B2  3C             0915          INC   A
06B3  CD E3 06       0916          CALL  TEST      ; BEGIN+4 INFO
06B6  3A 81 08       0917          LD    A,(EPT)
06B9  3D             0918          DEC   A
06BA  CD E3 06       0919          CALL  TEST      ; END-4 INFO
06BD  21 A5 15       0920          LD    HL,MESS7  ; INFO
06C0  CD A3 04       0921          CALL  WRITE
06C3  79             0922          LD    A,C
06C4  32 E7 14       0923          LD    (INFOWD),A; LOAD INFORMATION
06C7  CD C8 06       0924          CALL  PAHEX     ; PRINT INFO IN HEX
06CA  C9             0925          RET
06CB                 0926 ;
06CB                 0927 ; PRINTS A REG IN HEX
06CB                 0928 ;
06CB  CD CF 06       0929 PAHEX:   CALL  PA1
06CE  1F             0930          RRA
06CF  1F             0931 PA1:     RRA
06D0  1F             0932          RRA
06D1  1F             0933          RRA
06D2  1F             0934          RRA
```

```
06D3  F5              0935          PUSH  AF
06D4  E6 0F           0936          AND   0FH
06D6  FE 0A           0937          CP    10
06D8  38 02           0938          JR    C,PA2
06DA  C6 07           0939          ADD   7
06DC  C6 30           0940 PA2:     ADD   30H
06DE  CD D7 04        0941          CALL  OUTC
06E1  F1              0942          POP   AF
06E2  C9              0943          RET
06E3                  0944 ;
06E3                  0945 ; TEST DATA SAMPLE AND STORE INFORMATION
06E3                  0946 ;
06E3  CD F5 06        0947 TEST:    CALL  DATADD    ; DE=DATA ADDRESS
06E6  06 04           0948          LD    B,4       ; B=BAND COUNTER
06E8  1A              0949 TE1:     LD    A,(DE)
06E9  FE 04           0950          CP    4
06EB  38 02           0951          JR    C,TE2
06ED  CB C1           0952          SET   0,C
06EF  CB 09           0953 TE2:     RRC   C
06F1  13              0954          INC   DE
06F2  10 F4           0955          DJNZ  TE1
06F4  C9              0956          RET
06F5                  0957 ;
06F5                  0958 ; DATA SAMPLE ADDRESS IN DE, INCREMENT IN A
06F5                  0959 ;
06F5  E5              0960 DATADD:  PUSH  HL
06F6  26 00           0961          LD    H,0
06F8  6F              0962          LD    L,A
06F9  29              0963          ADD   HL,HL     ; *4 (BYTE INCREMENT)
06FA  29              0964          ADD   HL,HL
06FB  11 FC 08        0965          LD    DE,BUF
06FE  19              0966          ADD   HL,DE
06FF  EB              0967          EX    DE,HL
0700  E1              0968          POP   HL
0701  C9              0969          RET
0702                  0970 ;
0702                  0971 ; COMPARES TARGET WORD WITH VOCAB STORAGE OF
0702                  0972 ; LENGTH, STOP AND BAND INFORMATION
0702                  0973 ;
0702  CD 80 03        0974 MATCH:   CALL  INITPAR   ; INIT SUMS TABLE
0705  21 56 14        0975          LD    HL,SUMS   ; HL=SUMS ADDRESS
0708  DD 21 9E 14     0976          LD    IX,SIZE   ; IX=SIZE ADDRESS
070C  FD 21 C2 14     0977          LD    IY,INFO   ; IY=INFO ADDRESS
0710  3A E6 14        0978          LD    A,(STOPWD)
0713  4F              0979          LD    C,A       ; C=STOPWD
0714  3A AC 08        0980          LD    A,(VOCSIZ)
0717  47              0981          LD    B,A       ; B=VOCAB COUNTER
0718  DD 7E 00        0982 MA1:     LD    A,(IX+0)
071B  57              0983          LD    D,A
071C  CB BA           0984          RES   7,D       ; D=VOCAB WORD LENGTH
071E  A9              0985          XOR   C
071F  CB 7F           0986          BIT   7,A
0721  C4 58 07        0987          CALL  NZ,NULL   ; STOP BIT 7'S UNLIKE
0724  3A B2 08        0988          LD    A,(LEN)   ; LENGTH LIMIT CHECK
0727  5F              0989          LD    E,A
```

```
0728 CB 3B              0990            SRL   E
072A CB 3B              0991            SRL   E           ; E=LEN/4
072C 93                 0992            SUB   E
072D BA                 0993            CP    D           ; D>MIN LENGTH?
072E D4 58 07           0994            CALL  NC,NULL
0731 83                 0995            ADD   E
0732 83                 0996            ADD   E
0733 BA                 0997            CP    D           ; D<MAX LENGTH?
0734 DC 58 07           0998            CALL  C,NULL
0737 3A E7 14           0999            LD    A,(INFOND)
073A FD AE 00           1000            XOR   (IY+0)
073D 16 00              1001            LD    D,0         ; COMPARISONS COUNT
073F C5                 1002            PUSH  BC          ; RETAIN VOCAB COUNT
0740 06 08              1003            LD    B,8         ; B=BIT COUNT
0742 1F                 1004 MA2:       RRA
0743 38 01              1005            JR    C,MA3
0745 14                 1006            INC   D           ; D=MATCHING BITS SUM
0746 10 FA              1007 MA3:       DJNZ  MA2
0748 7A                 1008            LD    A,D
0749 FE 04              1009            CP    4
074B DC 58 07           1010            CALL  C,NULL
074E 23                 1011            INC   HL
074F 23                 1012            INC   HL
0750 DD 23              1013            INC   IX
0752 FD 23              1014            INC   IY
0754 C1                 1015            POP   BC
0755 10 C1              1016            DJNZ  MA1
0757 C9                 1017            RET
0758                    1018 ;
0758                    1019 ; BLANKS A WORD IN SUMS TABLE
0758                    1020 ;
0758 3E FF              1021 NULL:      LD    A,0FFH
075A 77                 1022            LD    (HL),A
075B 23                 1023            INC   HL
075C 77                 1024            LD    (HL),A
075D 2B                 1025            DEC   HL
075E C9                 1026            RET
075F                    1027 ;
075F                    1028 ; PRINTS VALID SUMS AFTER RECOGNITION RESPONSE
075F                    1029 ;
075F 3E 00              1030 SUMOUT:    LD    A,0         ; A=VOCAB COUNTER
0761 DD 21 AC 08        1031            LD    IX,VOCSIZ   ; IX=VOCSIZ ADDRESS
0765 01 FF FF           1032            LD    BC,0FFFFH   ; BC=NULL COMPARATOR
0768 21 56 14           1033            LD    HL,SUMS     ; HL=SUMS ADDRESS
076B CD C5 04           1034            CALL  CRLF
076E 56                 1035 SU1:       LD    D,(HL)
076F 23                 1036            INC   HL
0770 5E                 1037            LD    E,(HL)
0771 EB                 1038            EX    DE,HL       ; HL STORED HI-LO
0772 F5                 1039            PUSH  AF
0773 E5                 1040            PUSH  HL
0774 B7                 1041            OR    A
0775 ED 42              1042            SBC   HL,BC       ; NULL CHECK
0777 E1                 1043            POP   HL
0778 28 08              1044            JR    Z,SU2
```

```
077A  CD F8 04        1045          CALL  OUTWD     ; PRINT WORD
077D  3E 20           1046          LD    A,20H
077F  CD D7 04        1047          CALL  OUTC
0782  CD 41 06        1048          CALL  BCDHL     ; PRINT SUM
0785  EB              1049 SU2:     EX    DE,HL
0786  F1              1050          POP   AF
0787  3C              1051          INC   A
0788  23              1052          INC   HL
0789  DD BE 00        1053          CP    (IX+0)
078C  20 E0           1054          JR    NZ,SU1
078E  C9              1055          RET
078F                  1056 ;
078F                  1057 ; NULL WORD TEST IN SUMS. RETURNS ZERO FLAG
078F                  1058 ;
078F  C5              1059 NULTST:  PUSH  BC
0790  E5              1060          PUSH  HL
0791  06 00           1061          LD    B,0
0793  79              1062          LD    A,C       ; C=WORD COUNT
0794  87              1063          ADD   A
0795  4F              1064          LD    C,A
0796  21 56 14        1065          LD    HL,SUMS
0799  09              1066          ADD   HL,BC
079A  7E              1067          LD    A,(HL)
079B  FE FF           1068          CP    0FFH
079D  20 04           1069          JR    NZ,NU1
079F  23              1070          INC   HL
07A0  7E              1071          LD    A,(HL)
07A1  FE FF           1072          CP    0FFH
07A3  E1              1073 NU1:     POP   HL
07A4  C1              1074          POP   BC
07A5  C9              1075          RET
07A6                  1076 ;
07A6                  1077 ; INITIALIZE STORAGE OF SIZE ELEMENT AND STOPWD
07A6                  1078 ; BEFORE SEARCH FOR A STOP
07A6                  1079 ;
07A6  3E 00           1080 INIT:    LD    A,0       ; ZERO STOPWD
07A8  32 E0 14        1081          LD    (STOPWD),A
07AB  3A AD 08        1082          LD    A,(MODE)
07AE  FE 50           1083          CP    'P'
07B0  C8              1084          RET   Z
07B1  3A 73 15        1085          LD    A,(WORDC)
07B4  FE 00           1086          CP    0
07B6  C0              1087          RET   NZ        ; FOR 1ST T WORD ONLY
07B7  CD 2D 06        1088          CALL  SZADD     ; GET WORD SIZE ADDRESS
07BA  36 00           1089          LD    (HL),0
07BC  C9              1090          RET
07BD                  1091 ;
07BD                  1092 ; PRINTS MESSAGE WHEN ZCD DATA IS FOUND
07BD                  1093 ;
07BD  E5              1094 ZCDMES:  PUSH  HL
07BE  CD 90 06        1095          CALL  PCBCD     ; PRINT C REG
07C1  21 95 15        1096          LD    HL,MESS5
07C4  CD A3 04        1097          CALL  WRITE
07C7  E1              1098          POP   HL
07C8  C9              1099          RET
```

```
07C9                    1100 ;
07C9                    1101 ; CHECKS ZCD DATA V THRESHOLD, RETURNS CARRY
07C9                    1102 ;
07C9  2B                1103 ZCHK:  DEC   HL
07CA  7E                1104        LD    A,(HL)
07CB  23                1105        INC   HL
07CC  FE 02             1106        CP    2           ; ZCD < THRESHOLD?
07CE  D8                1107        RET   C
07CF  CD 8D 07          1108        CALL  ZCDMES      ; PRINT 'ZCD'
07D2  37                1109        SCF               ; RETURN CARRY RESET
07D3  3F                1110        CCF
07D4  C9                1111        RET
07D5                    1112 ;
07D5                    1113 ; INITIALIZE TRAINING SUMS DATA
07D5                    1114 ;
07D5  21 EA 14          1115 ZERO:  LD    HL,BSUM
07D8  06 80             1116        LD    B,128
07DA  11 00 00          1117        LD    DE,0
07DD  72                1118 Z1:    LD    (HL),D
07DE  23                1119        INC   HL
07DF  10 FC             1120        DJNZ  Z1
07E1  ED 53 E8 14       1121        LD    (LSUM),DE
07E5  21 6A 15          1122        LD    HL,ISUM
07E8  06 08             1123        LD    B,8
07EA  72                1124 Z2:    LD    (HL),D
07EB  23                1125        INC   HL
07EC  10 FC             1126        DJNZ  Z2
07EE  7A                1127        LD    A,D
07EF  32 72 15          1128        LD    (SSUM),A
07F2  C9                1129        RET
07F3                    1130 ;
07F3                    1131 ; COLLECTS CUMULATIVE STATISTICS OF 'T' WORD
07F3                    1132 ;
07F3  21 BC 08          1133 STAT:  LD    HL,SAM      ; HL=SAMPLE POINTER
07F6  06 40             1134        LD    B,64        ; B=NO OF SAMPLES
07F8  DD 21 EA 14       1135        LD    IX,BSUM     ; IX=BAND SUM POINTER
07FC  5E                1136 STA1:  LD    E,(HL)      ; E=SAMPLE DATA
07FD  16 00             1137        LD    D,0
07FF  E5                1138        PUSH  HL
0800  DD 6E 00          1139        LD    L,(IX+0)    ; (HL)=CUMUL BAND SUM
0803  DD 66 01          1140        LD    H,(IX+1)
0806  19                1141        ADD   HL,DE
0807  DD 75 00          1142        LD    (IX+0),L    ; UPDATE CUMUL SUM
080A  DD 74 01          1143        LD    (IX+1),H
080D  E1                1144        POP   HL
080E  23                1145        INC   HL
080F  DD 23             1146        INC   IX
0811  DD 23             1147        INC   IX
0813  10 E7             1148        DJNZ  STA1
0815  2A E8 14          1149        LD    HL,(LSUM)   ; UPDATE LENGTH SUM
0818  3A B2 08          1150        LD    A,(LEN)
0818  5F                1151        LD    E,A
081C  16 00             1152        LD    D,0
081E  19                1153        ADD   HL,DE
081F  22 E8 14          1154        LD    (LSUM),HL
```

```
0822  21 72 15          1155          LD    HL,SSUM    ; UPDATE STOP SUM
0825  3A E6 14          1156          LD    A,(STOPWD)
0828  FE 00             1157          CP    0
082A  28 01             1158          JR    Z,STA2
082C  34                1159          INC   (HL)
082D  CD 31 08          1160 STA2:    CALL  ISUMLD     ; UPDATE INFO SUM
0830  C9                1161          RET
0831                    1162 ;
0831                    1163 ; LOADS ISUM VECTOR FROM INFOWD
0831                    1164 ;
0831  21 5A 15          1165 ISUMLD:  LD    HL,ISUM
0834  3A E7 14          1166          LD    A,(INFOWD)
0837  06 08             1167          LD    B,8
0839  CB 07             1168 IS1:     RLC   A
083B  30 01             1169          JR    NC,IS2
083D  34                1170          INC   (HL)
083E  23                1171 IS2:     INC   HL
083F  10 F8             1172          DJNZ  IS1
0841  C9                1173          RET
0842                    1174 ;
0842                    1175 ; CALCULATES AND LOADS MEAN STATS IN T MODE
0842                    1176 ;
0842  ED 4B E8 14       1177 CALC:    LD    BC,(LSUM)  ; MEAN LENGTH
0846  3A 74 15          1178          LD    A,(WORDL)
0849  57                1179          LD    D,A
084A  CD 71 04          1180          CALL  DIV
084D  79                1181          LD    A,C
084E  32 B2 08          1182          LD    (LEN),A
0851  3A 72 15          1183          LD    A,(SSUM)   ; MEAN STOP
0854  4F                1184          LD    C,A
0855  06 00             1185          LD    B,0
0857  3A 74 15          1186          LD    A,(WORDL)
085A  57                1187          LD    D,A
085B  CD 71 04          1188          CALL  DIV
085E  79                1189          LD    A,C
085F  FE 00             1190          CP    0
0861  28 02             1191          JR    Z,CAL1
0863  0E 80             1192          LD    C,80H
0865  3A B2 08          1193 CAL1:    LD    A,(LEN)
0868  B1                1194          OR    C
0869  32 E6 14          1195          LD    (STOPWD),A
086C  11 BC 08          1196          LD    DE,SAM     ; MEAN SAMPLES
086F  21 EA 14          1197          LD    HL,BSUM
0872  06 80             1198          LD    B,128
0874  C5                1199 CAL2:    PUSH  BC
0875  D5                1200          PUSH  DE
0876  4E                1201          LD    C,(HL)
0877  23                1202          INC   HL
0878  46                1203          LD    B,(HL)
0879  3A 74 15          1204          LD    A,(WORDL)
087C  57                1205          LD    D,A
087D  CD 71 04          1206          CALL  DIV
0880  79                1207          LD    A,C
0881  D1                1208          POP   DE
0882  12                1209          LD    (DE),A
```

```
0883  13              1210          INC   DE
0884  23              1211          INC   HL
0885  C1              1212          POP   BC
0886  10 EC           1213          DJNZ  CAL2
0888  21 6A 15        1214          LD    HL,ISUM    ; MEAN INFO
088B  1E 00           1215          LD    E,0
088D  06 08           1216          LD    B,8
088F  C5              1217 CAL3:    PUSH  BC
0890  4E              1218          LD    C,(HL)
0891  06 00           1219          LD    B,0
0893  3A 74 15        1220          LD    A,(WORDL)
0896  57              1221          LD    D,A
0897  CD 71 04        1222          CALL  DIV
089A  79              1223          LD    A,C
089B  FE 00           1224          CP    0
089D  28 02           1225          JR    Z,CAL4
089F  CB FB           1226          SET   7,E
08A1  CB 03           1227 CAL4:    RLC   E
08A3  23              1228          INC   HL
08A4  C1              1229          POP   BC
08A5  10 E8           1230          DJNZ  CAL3
08A7  78              1231          LD    A,E
08A8  32 E7 14        1232          LD    (INFOWD),A
08AB  C9              1233          RET
08AC                  1234 ;
08AC                  1235 ; DATA
08AC                  1236 ;
08AC  24              1237 VOCSIZ:  DB    36         ; MAXIMUM VOCABULARY
08AD  0001            1238 MODE:    DS    1          ; TRAIN/PERF MODE
08AE  0001            1239 AVER:    DS    1          ; AVERAGE AMPLITUDE
08AF  0001            1240 WORD:    DS    1          ; T MODE IDENTIFICATION
0880  0001            1241 BPT:     DS    1          ; BEGINNING POINTER
0881  0001            1242 EPT:     DS    1          ; ENDING POINTER
0882  0001            1243 LEN:     DS    1          ; WORD LENGTH
0883  0001            1244 TMP:     DS    1
0884  0002            1245 SAMPT:   DS    2
0886  0002            1246 FRAC:    DS    2
0888  0002            1247 BUFPT:   DS    2
088A  0002            1248 IND:     DS    2
088C  0040            1249 SAM:     DS    64         ; PROCESSED SAMPLE
08FC  0258            1250 BUF:     DS    600        ; RAW SPEECH BUFFER
0854  0900            1251 TABLE:   DS    2304       ; VOCABULARY STORAGE
1454  0002            1252 MIN:     DS    2
1456  0048            1253 SUMS:    DS    72         ; SUMS VECTOR
149E  0024            1254 SIZE:    DS    36         ; SIZE VECTOR
14C2  0024            1255 INFO:    DS    36         ; INFO VECTOR
14E6  0001            1256 STOPWD:  DS    1          ; STOP WORD
14E7  0001            1257 INFOWD:  DS    1          ; INFO WORD
14E8  0002            1258 LSUM:    DS    2          ; LENGTH SUM
14EA  0080            1259 BSUM:    DS    128        ; BAND SUM
156A  0008            1260 ISUM:    DS    8          ; INFO SUM
1572  0001            1261 SSUM:    DS    1          ; STOP SUM
1573  0001            1262 WORDC:   DS    1          ; TRAINING WORD COUNT
1574  0A              1263 WORDL:   DB    10         ; TRAINING WORD LIMIT
1575  00              1264 DEVICE:  DB    0          ; OUTPUT DEVIVE TYPE
```

```
1576  00                    1265 SWITCH: DB    0          ; PRINTER SWITCH
1577  54 20 4F 52           1266 MESS1:  DB    'T OR P ?',0
      20 50 20 3F
      00
1580  57 4F 52 44          1267 MESS2:  DB    'WORD
      20 24
1586  53 54 4F 50          1268 MESS3:  DB    'STOP',0
      00
1588  4C 45 4E 47          1269 MESS4:  DB    'LENGTH =
      54 48 20 3D
      20 24
1595  5A 43 44 00          1270 MESS5:  DB    'ZCD',0
1599  52 45 4A 45          1271 MESS6:  DB    'REJECT (R)?',0
      43 54 20 28
      52 29 3F 00
15A5  49 4E 46 4F          1272 MESS7:  DB    'INFO =
      20 3D 20 24
15AD  52 45 43 4F          1273 MESS8:  DB    'RECOGNIZED
      47 4E 49 5A
      45 44 20 24
15B9  4E 4F 20 53          1274 E1:     DB    'NO SPEECH',0
      50 45 45 43
      48 00
15C3  4F 55 54 20          1275 E2:     DB    'OUT OF WINDOW',0
      4F 46 20 57
      49 4E 44 4F
      57 00
```

APPENDIX B

- The International Civil Aviation Organization Phonetic Alphabet

A	Alpha
B	Bravo
C	Charlie
D	Delta
E	Echo
F	Foxtrot
G	Golf
H	Hotel
I	India
J	Juliette
K	Kilo
L	Lima
M	Mike
N	November
O	Oscar
P	Papa
Q	Quebec
R	Romeo
S	Sierra
T	Tango
U	Uniform
V	Victor
W	Whisky
X	X-ray
Y	Yankee
Z	Zulu

APPENDIX C

Speech Routines

100. (SPCH collects raw speech) Call BEEP to signal speech window start.
101. Set pointer to raw speech buffer BUF and sample counter to 150.
102. Set band counter to 0. (0=F1, 1=F2, 2=F3, 3=ZCD)
103. If band counter = 4 go to step 106.
104. Call SAMPL to get band data from speech board.
105. Load band data into BUF pointer location. Increment pointer and band counter and go to step 103.
106. Call DELAY for 10ms inter-sample delay and decrement sample counter.
107. If sample counter is not 0 then go to step 102.
108. Call BEEP to signal end of speech window.
109. Return.

110. (SAMPL collects single band) Send bit 5 = 1 to speech board to disable multiplexor M1.
111. Send bit 5 = 0 to start conversion.
112. Input status/data word.
113. If bit 7 = 1 go to step 112.
114. Return.

APPENDIX D

Match Routine

120. (MATCH compares target word with vocabulary storage) Set pointer to SUMS, SIZE and INFO and set vocabulary counter to vocabulary size.
121. Load STOPWD.
122. Get SIZE contents, reset bit 7 to give SIZE length.
123. XOR SIZE contents with STOPWD and test bit 7.
124. If bit 7 = 1 then call NULL to nullify vocabulary entry.
125. Get target word length LEN and divide by 4.
126. If LEN-LEN/4 < SIZE length then call NULL.
127. If LEN+LEN/4 > SIZE length then call NULL.
128. XOR INFOWD and vocabulary INFO data and count 1 bits in result.
129. If count < threshold call NULL.
130. Return