SPEECH SYNTHESIS

USING

REFLECTION COEFFICIENTS

by

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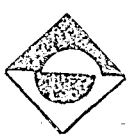
to my mother



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This study outlines a method for transmitting speech using a relatively low bit rate, in comparison to traditional methods. The method is based on the theory of Linear Prediction. In this approach speech is represented by reflection coefficients, energy and pitch parameters. The Reflection Coefficients are calculated using Gueguen - Le Ruex algorithm. Residual energy is encoded as the energy parameter . For pitch detection a modified form of SIFT algorithm is used.

The physical foundations of Reflection Coefficient approach and its theory are explained. The theory given in this study is based on inner product formulation.

The algoritms developed are applied to Turkish words, sounds and sentences. The results and observations are illustrated.

YANSIMA KATSAYILARI

KULLANARAK

SES SENTEZİ

Bu calışmada . eski tekniklere oranla daha düsük ikil aktarımı gerektiren bir yöntem sunulmaktadir. Sunulan yöntem Doğrusal Öngörü kuramına dayanmaktadir. Bu yaklaşimda ses, yansıma katsayilari, enerji ve temel uyari sikliği değerleri ile temsil edilmektedir. Yansıma katsayıları Gueguen-Le Ruex yontemi ile elde edilmektedir . Öngörmedeki hata, enerji katsayısını vermektedir. Temel uyarma sıklığı ise SIFT yöntemine benzeyen bir yaklaşimla hesaplanmaktadır.

Yansıma katsayılarının fiziksel anlamı ve dayandıkları kuram, çalışmada vurgulanmıstır. Kuram verilirken iç çarpım yaklaşımından yararlanılmıstır.

Gelistirilen yöntemler ve izlenceler Türkce sözcük, tümce ve seslere uygulanmış ve elde edilen sonuçlar sunulmustur.

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$A(z)$	Forward predictor
a_i	ith coefficient of forward predictor
$B(z)$	Backward predictor
b_i	ith coefficient of backward predictor
E_t	Total prediction error for one frame
$e(n)$	Prediction error at sample n
e_i	Prediction error for the whole frame at ith recursion (Levinson-Durbin)
$e_{j,i}$	Inner product term described for Guguen-Le Ruex
G	Gain or amplitude of input signal
J	Sum of squares of prediction errors
K_i	Encoded ith reflection coefficient
k_i	ith reflection coefficent
$P_i\ (x,t)$	Pressure in the ith tube at point x and at time t
$P(w)$	Power spectrum of the original signal
p	Predictor order
$R(i)$	ith autocorrelation coefficient
$R_e(i)$	ith autocorrelation coefficient of prediction error
$R_C(t_p)$	Cyclic pitch measure for frequency t_p
r_i	Reflection Coefficients for the lossless tube model
$S(e^{j\omega})$	Spectrum of original signal
$s(i)$	ith speech sample
$\hat{s}(i)$	Predicted value for ith sample

t_p	Pitch estimate
$u_i^+(t)$	positive going travelling volume velocity in the ith tube
$u_i^-(t)$	negative going travelling volume velocity in the ith tube
$w(i)$	Window function
T	Duration between consecutive samples
z^{-1}	Delay element
σ	Mean square error energy
γ_{ij}	Coefficient of $B_j(z)$ when generating $B_i'(z)$ using Gram-Schmidt process
τ_i	Travelling time for volume velocity, until it reaches the junction

CHAPTER 1

I. INTRODUCTION

The purpose of this thesis is to outline a method for obtaining parametric representation of speech , and apply them to some commonly used Turkish words.

In the first chapter voice response systems are introduced. Their application areas and limitations are given. One of the most serious limitations is memory , where speech is stored (or alternatively bit rate at which speech can be transmitted) Therefore a brief summary of voice storage methods is given. Waveform coding , parametric and hybrid coding techniques are introduced. They are compared on the basis of commonly used criteria.

Second chapter is dedicated to natural speech production. Basic sounds and the way they are generated are described. Phonemes constituting Turkish sounds are listed. The lossless tube model for the human vocal tract and the related equations are quoted. The transition from the lossless tube model to the digital lattice filter presentation is emphasized.

In chapter three theory of linear prediction and its application to speech analysis are described. Reflection coefficient approach to Least Squares Estimation is outlined, based on the inner product formulation. Gueguen - Le Ruex algorithm and its advantages are illustrated. Methods for

extracting and encoding of other important features (energy and pitch) are also explained.

The algorithms developed during this work are introduced in chapter four. Each of the hardware and software modules used throughout the analysis are explained stage by stage.

In chapter five the observations and results are listed. Ideas to improve the quality of the output speech are introduced. Also computational aspects that might improve accuracy and speed up the analysis are mentioned.

In Conclusion the results are summarized and some future applications of this study mentioned. The results and tools developed during this study may be helpful for another stage that establishes the rules for creating messages and provides necessary hardware for speech generation.

II. VOICE RESPONSE SYSTEMS

There are generally recognized to be three major areas (modes of communication) within the general area of man-machine communication by voice. These areas include [1] :

1. Voice Response Systems
2. Speaker Recognition Systems
3. Speech Recognition Systems

Voice Response Systems are designed to respond to a request for information , using spoken messages. Thus Voice Ressponse Systems communicate by voice in one direction only, i.e. from the machine to man . On the other hand , areas 2 and 3 deal with systems in which communication is by voice from man to machine. For Speaker Recognition Systems the task of the system is to either verify a speakers identity . i.e. a yes-no decision as to whether the speaker is who he claims to be , or to identify the speaker from some known ensemble. The basic tasks of a speech recognition system is either to recognize the entire spoken utterance exactly (e.g. a phonetic speech to text writer) or else to understand the spoken utterance (i.e. to respond in the correct manner)

The elements of a voice respone system include :

1. Provision for storage of a vocabulary for the voice response system.
2. Rules for forming messages from elements of the vocabulary

3. A program for composing voice response messages

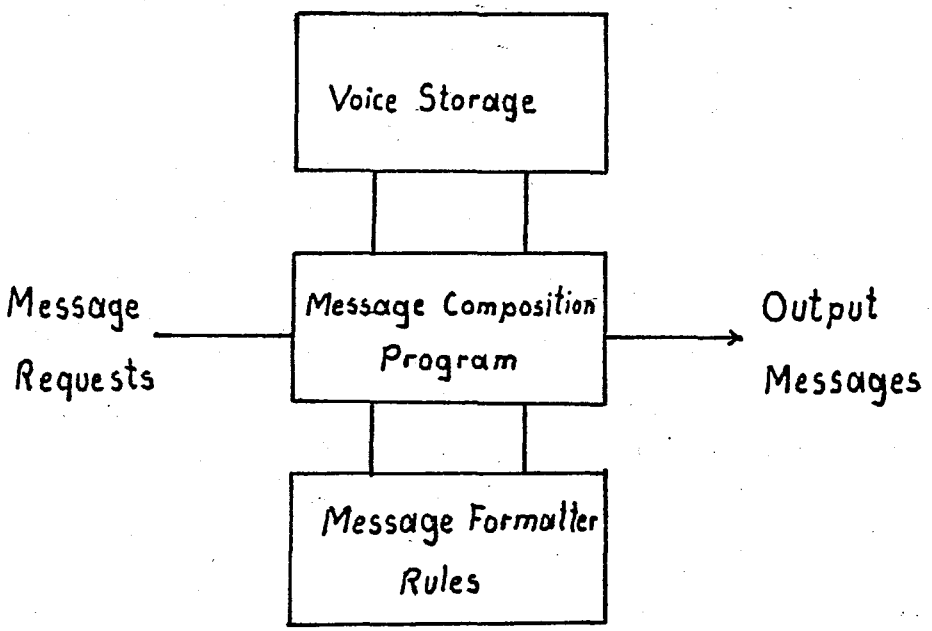


Figure 1.2.1 Block diagram of a voice response system

The input to the voice response system is in the form of a message request , which may be initiated by another information processing system or directly by a human seeking information from the voice response system . The output messages are in the form of speech utterances in response to the message requests.

Typical application areas of computer voice response systems are the following: [2]

1. A system for producing vocal instructions for wiring communications equipment.
2. A directory assistance system
3. Talking toys and computers
4. A data set testing information system

5. A flight information system

6. A speaker verification system

7. Aids to handicapped persons

There are two main approaches to the implementations of a voice response system . One approach is the limited vocabulary system in which the output message is created by concatenating isolated natural speech elements in the vocabulary storage.

The second approach is to attempt to build a machine with powers of speech comparable to human . Such systems (often referred to as speech synthesis by-rule systems) utilize models to simulate human articulatory system. In this case the vocabulary storage is essentially a pronouncing dictionary and the message formation rules must generate the required control signals (e.g. pitch intensity , and vocal tract response parameters) to control a speech synthesizer based on the speech production model. Such systems are of interest when an unlimited vocabulary is required.

III. SPEECH STORAGE METHODS

The representation of speech signals in digital form is of fundamental concern . There are many possibilities for discrete representations of speech signals . These can be classified into three broad grouos :

A. Waveform representations

B. Parametric representation

C. Hybrid representation

A. Waveform Coding

In waveform coding the aim is to convert speech onto a bit stream that determines and preserves the shape of the original signal. In this regard one is guided by the well-known Sampling Theorem which states that a band-limited signal can be represented by samoles taken periodically in time provided that the samples are taken at a high enough rate . The most popular coding methods available under this heading are :

PCM (Pulse Code Modulation)

DPCM (Differential PCM)

DM (Delta Modulation)

In PCM , an analog speech signal , after band-limiting in a low-oass filter , is converted by a sampling circuit into a series of samples s(n) , seperated on the time axis by an interval T . (the sampling rate) The value of

each sample s(n) is then rounded off to s(n) in a quantization circuit and converted into a code word of B bits an encoder.

According to the method used in adjusting the step-size of the quantizer , one distinguishes among linear PCM , log PCM and Adaptive PCM . In linear PCM step-size is fixed , in log PCM a logarithmic compansion is applied to the speech. The two log-quantization characteristics are -law and A-law. The idea in both methods is to quantize small signals more precisely in comparison to signals of large amplitude. They try to establish the maximum dynamic range , and at the same time exceed a given Signal-to-Noise Ratio (SNR). SNR is defined by

$$SNR = 10\log(E_s/E_q) \qquad (1.3.1)$$

where E_s and E_q are signal and quantization error energies respectively. For details about A-law companding refer to Appendix D.

If the step size is adjusted adaptively the coding scheme is called PCM with adaptive quantization.

Speech signals can be represented more efficiently by making use of the close correlation that exists between the value of successive samples s(n) . This is done in all systems based on differential coding. DPCM quantizes the difference between current and previous samples .

When the speech samples s(n) are seperated by a sufficiently small interval T . the quantization circuit need only have two levels . This is DM (Delta Modulation) By using a variable gain whose value is determined from the bit stream representing the difference . one arrives at ADM (Adaptive DM) ADM requires a less bit rate than DM.

Differential coders are actually predictors of the first order. They necessitate the difference signal to generate the current sample. The idea of predictive coding is generalized to predictive coders of orders greater than one. One of the most efficients predictive methods is APC (Adaptive Predictive Coding) . Due to the nonstationary nature of speech signals . a fixed predictor cannot predict the signal values efficiently at all times. Thus the predictor must vary with time to cope with the changing spectral envelope of speech signal as well as with the changing periodicities in voiced speech.

B. Parametric Coding

In the parametric coding approach the aim is to derive a limited number (eg 10 to 20) of relatively slowly varying characteristic parameters of the speech signal and to represent these alone as a bit stream.

A widely used speech production model utilizes two signal sources P and N . The source P delivers a series of quasi-periodic pulses whose repetition frequency 1/t corresponds to the fundamental frequency or pitch of the speech and the source N delivers a noise like signal. The source P generates voiced sounds and N unvoiced sounds. One or the other source is selected on the basis of a voiced/unvoiced decision. The magnitude of the source signal selected can be varied by means of the gain G , and its frequency spectrum can be modified by the filter F. The model described in figure 1.3.2 can also be introreted as the source of the sound and the resonant system that modifiess (or modulates) the sound.

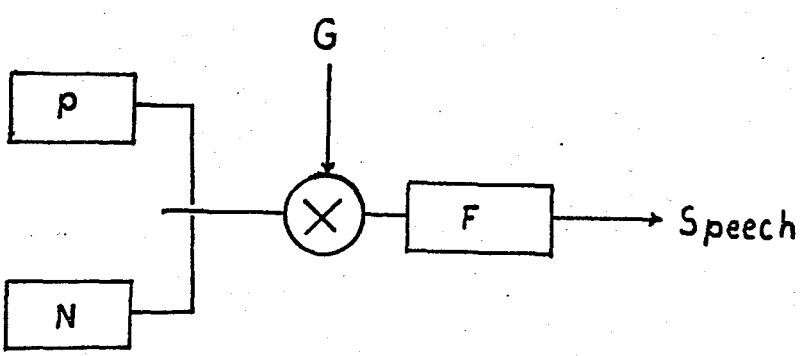


Figure 1.3.1 Speech generation model

In essence the filter performs a function comparable with that of the human vocal tract (Pharynx plus nasal or mouth cavities)

The parameters representing this model are:

-the voiced/unvoiced decision

-for voiced sounds the fundamental frequency $1/t_p$

-the magnitude of the gain G

-some form of description of filter F

This model has been the starting point for the design of many types of speech coding systems (vocoders) . The oldest type of vocoder is the channel vocoder . where the vocal tract is represented by a bank (10 to 20) of band-pass filters . At the transmitting end the average signal amplitude in each small frequency band is determined by means of a rectifier and a low-pass filter. The resultant information is transferred in coded form to the receiver . where it is used to adjust the gain in the branches of an identical bank of filters. The bandwidths of the individual filters in such a filter bank do not have to be equal: with a limited number of filters the best results are obtained when the filters for the lowest frequencies have the smallest bandwidths.

In DFT vocoders the filter bank function is performed by means of a Discrete Fourier Transform (DFT) module.

Another method of characterizing the vocal tract is based on a description of the envelope of the speech spectrum in terms of formants . resulting in a formant vocoder. The

vocal tract is now represented by four or five band-pass filters in which the bandwidths and the centre frequency vary as a function of time. The required values can be derived from speech by means of Linear Predictive Coding (LPC). A formant vocoder of this type is a member of the much larger family of LPC vocoders. The idea behind all these vocoders is again the assumption that any speech sample s(n) can be well approximated by a weighted sum of preceeding speech samples:

$$s(n) = \sum_{i=1}^{p} a_i (s-i) \qquad (3.3.2)$$

For details refer to Chapter 3.

C. Hybrid Coding

Hybrid coding techniques make use of the Waveform and Parametric coding methods at the same time . Among the many different approaches to be found . two techniques have become fairly general : Noise Shaping and Residual Coding

In Noise Shaping . the aim is to make optimum use of the noise-masking effect of human hearing (In human hearing strong sounds tend to mask weaker sounds of the same frequency) An application of this technique is Sub-band coding. where the speech signal is split into 4 to 16 frequency bands and the signals in each sub-band are separately coded .

A method that bears some resemblance to sub-band coding is Adaptive Transform Coding (ATC) in which the speech signal is first subjected to a frequency transformation and

the transformation results are then adaptively coded using optimal bit assignment.

Voice-excitation systems use a 'broad-band' excitation signal instead of the pitch and voiced/unvoiced decision information.

Two more complex forms of hybrid coding are based on Residual Coding. In the feed-forward configuration, the residual signal is encoded and transmitted. In the feed-back system the excitation signal that minimizes error is obtained and transmitted. This approach is often referred to as "Analysis by Synthesis".

IV. DECISION CRITERIA

In considering the choice of digital coding schemes for Voice Response Application . it is helpful to consider three factors:

1. The information rate (bit rate) required for acceptable speech quality
2. The complexity of the coding and decoding schemes
3. The flexibility of the representation . i.e. the potential for modification of the vocabulary elements

1. The complexity is commonly given by the count of logic gates . Relative complexities of various techniques can be approximated as in table 1.1 :

Relative complexity	Coder
1	ADM
1	ADPCM
5	Sub-band coding
50	ATC
50	VEV (Voice Excited Vocoder)
100	LPC
500	Formant vocoder
1000	Articulatory (Vocal Tract synthesizer)

Table 1.4.1 Relative complexities

2. Any assesment of signal quality implies a fidelity measure . For most communication systems this measure is difficult to specify quantitatively because it involves human perception . Speech quality is traditionally assessed by the criterion that a listener understands i) What is being said

ii) Who said it

Objective measures that accurately reflect these factors are intensively sought . but are difficult to establish with generality.

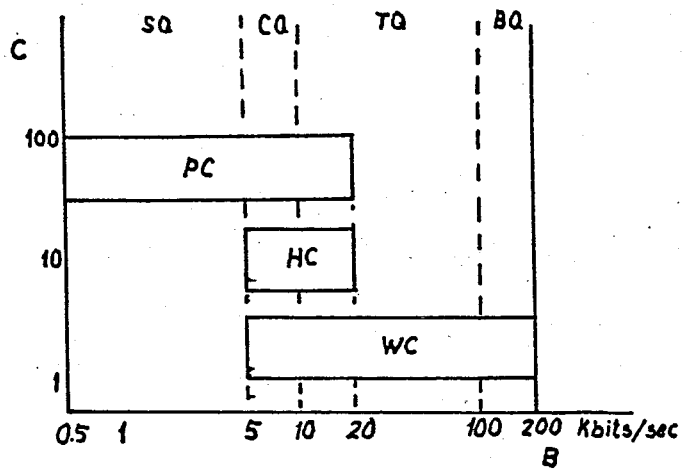


Figure 1.4.1 Complexity versus bit rate with quality as parameter.

Figure 1.4.1 indicates the quality of speech reproduction that can presently be attained at a prescribed **bit rate** . The quality characterizations are denoted as commentary . toll . communications and synthetic.

Toll quality . loosely corresponds to the following properties:

frequency range	:	200 - 3200Hz
SNR	>	30dB
harmonic distortion	<	2-3%

Tables 1.4.2 to 1.4.4 illustrate the performance of several coders at given bit rates.

Coder	Bit rate (Kbits)
log PCM	56
ADM	40
ADPCM	32
Sub-band	24
ATC	16
Voice-excited vocoder	16

Table 1.4.2 Bit rate for some coders that can achive toll quality

Coder	Bit rate (Kbits)
log PCM	36
ADM	24
ADPCM	16
Sub-band	9.6
ATC	7.2
Voice-excited vocoder	7.2

Table 1.4.3 Bit rate for some coders that can achive communications quality

Coder	Bit rate (Kbits)
Channel vocoder	2.4
LPC	2.4
Formant vocoder	0.5

Table 1.4.4 Bit rate for some coders that can establish synthetic-quality transmission

Objective measures such as SNR , not always coincide with subjective measures . Table 1.4.5 compares SNR ratings with subjective preference . Although 6-bit PCM is expected to produce better results than 4-bit ADPCM , listeners preferred 4-bit ADPCM.

Objective rating (SNR)	Subjective rating (preference)
7-bit PCM	7-bit PCM
6-bit PCM	4-bit ADPCM
4-bit ADPCM	6-bit PCM
5-bit PCM	3-bit ADPCM
3-bit ADPCM	5-bit PCM
4-bit PCM	4-bit PCM

Table 1.4.5 Objective versus subjective ratings

CHAPTER 2

I. NATURAL SPEECH PRODUCTION

The acoustical speech waveform is an acoustic pressure wave which originates from voluntary physiological movements of the structure shown in figure 2.1.1:

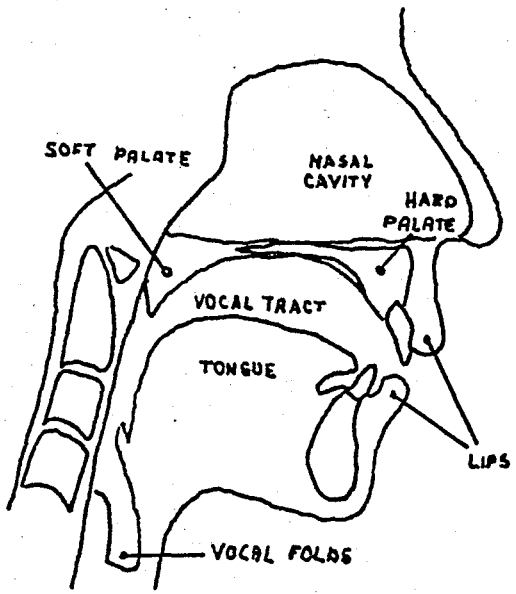


Figure 2.1.1 Human speech system

In the pulmonic air stream mechanism , which is the main mechanism to produce Turkish sounds , air is expelled from the lungs into the trachea and then forced between the vocal folds . During the generation of voiced sounds such as /ı/ , /e/ the air pushed towards the lips from the lungs causes the vocal folds to open and close at a rate dependent upon the air pressure in the trachea and the physiological adjustment of the vocal folds. This adjustment includes changes in the length , thickness and tension of the vocal

folds . The greater the tension the higher the perceived pitch or acoustically measured fundamental frequency of the voice . The opening between the vocal folds is defined as the glottis . The subglottic pressure and the time variations in glottal area determine the volume velocity of glottal air flow (glottal volume velocity waveform) expelled into the vocal tract . The rate at which the glottis opens and closes can be approximately measured acoustically as the inverse of the time interval between observed periods of the acoustic pressure wave . It is the glottal volume velocity waveform that defines the acoustic energy input or driving function to the vocal tract.

Speech signals are composed of a sequence of sounds. These sounds and the transitions between them serve as a symbolic representation of information. The arrangement of these sounds (symbols) is governed by the rules of language. The study of these rules and their implication in human communication is the domain of linguistics and the study and classification of the sounds of speech is called phonetics.

The phonological system of languages is described in terms of a set of distinctive sounds or phonemes. Phonemes can be classified in the following manner:

Vowels

1) Simple Vowels are produced by exciting a fixed vocal tract with quasi-periodic pulses of air caused by vibration of the vocal cords. The period of this excitation is called pitch period. The range of this frequency amounts

from 33Hz for a low pitch male to 1500Hz for a high-pitch singer. (Usually sopranos should be able to produce sounds excited by a 1400Hz pitch, so they have to be able to generate higher pitch frequencies up to 1800Hz). For an average male speaker this frequency lies in the range of 100-110Hz.

As described in Section II the vocal tract is modeled as a concatenation of lossless tubes of various cross-sections. This structure determines the resonant frequencies of the tract. These are called the Formants.

ii) Diphthongs are gliding mono-syllabic speech items that start at or near the articulatory position for one vowel and moves to or towards the position for another. e.g. / ay /

Consonants

i) Stops are transient non-continuant sounds which are produced by building up pressure behind a total constriction somewhere in the oral tract and suddenly releasing the pressure. /p/, /t/, /k/ are voiceless stops. If during the sound production also the vocal cords vibrate a voiced stop is produced. Voiced stops are /b/, /d/ and /g/.

ii) Fricatives are produced by exciting the vocal tract by a steady air flow which becomes turbulent in the region of a constriction in the vocal tract. Voicelesss fricatives are /f/, /s/ and /s/. If additionally vocal cords vibrate during the air flow , the sound generated is a voiced fricative. /v/, /z/, /ʒ/ are such sounds.

iii) Affricatives are produced by first totally constricting air passage and then releasing it with friction.

/c/ is a voiceless affricative and /ɟ/ is a voiced one.

iv) Nasals are produced with glottal excitation and the vocal tract totally constricted at some point along the oral passage way. /m/, /n/ are nasal sounds.

v) Lateral is produced by flow of air an both sides of the tongue. /l/ is an example for lateral sounds.

vi) Sounds that are voiced in initial and intervocalic positions and voiceless in final position are retroflex. /r/ is such a sound.

Semivowels are the group of sounds that cannot easily be distinguished from vowels. /y/ is such a sound.

An allophone is defined as a speech sound which is modified by the enviroment in which it occurs. The results of this study may be used to investigate the features of allophones, and speech synthesis rules using allophones can be developed.

VOWELS

i	ü	ı	u
e	ö	a	o

CONSONANTS

stops	p		t		k	
	b		d		g	
fricatives		f		s	ş	h
		v		z		
affricatives					c	
					ɟ	
nasals	m		n			
lateral				l		
retroflex				r		
semivowel					y	

Table 2.1.1 Phonemes Constituting Turkish Sounds

II. LOSSLESS TUBE MODEL

A widely used model for speech production is based upon the assumption that the vocal tract can be represented as a concatenation of lossless acoustic tubes [1] as shown in Figure 2.2.1

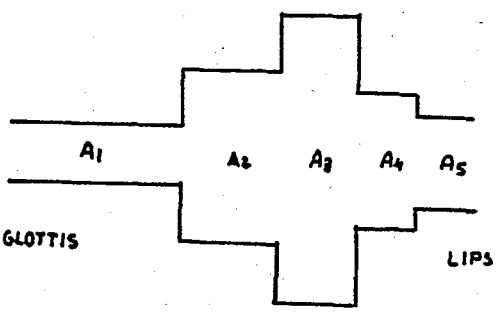


Figure 2.2.1 Lossless tube model

The propagation of waves in concatenated lossless tubes is governed by the following equations :

$$P_i(x,t) = (\rho_c / A_k)\ (\ u_i^+(t-x/c) + u_i^-(t+x/c))\quad (\ 2.2.1\ )$$

$$u_i(x,t) = u_i^+(t-x/c) - u_i^-(t-x/c)\quad (\ 2.2.2\ )$$

where x is distance measured from left end of the ith tube and $u_i^+(\cdot)$ and $u_i^-(\cdot)$ are positive going and negative going travelling volume velocities in the ith tube . A_i gives cross-section of the ith tube and P_i gives pressure in ith tube . Solving these equations and using boundary conditions at the junctions results in:

$$u^{+}_{k+1}(t) = \left(2A_{k+1}/(A_{k+1}+A_k) \right) u^{+}_{k}(t-\tau_k) + r_k\, u^{-}_{k+1}(t) \qquad (2.2.3)$$

$$u^{-}_{k}(t+\tau_k) = -r_k\, u^{+}_{k}(t-\tau_k) + \left(2A_k/(A_{k+1}+A_k) \right) u^{-}_{k+1}(t) \qquad (2.2.4)$$

The quantity $r_i = (A_{i+1} - A_i) / (A_{i+1} + A_i)$ is the amount of $u^{-}_{i+1}(t)$ that is reflected at the junction . Thus the quantity r_i is called the reflection coefficient for the itn junction . Since all cross-section values are positive the value of r s are between −1 and +1.

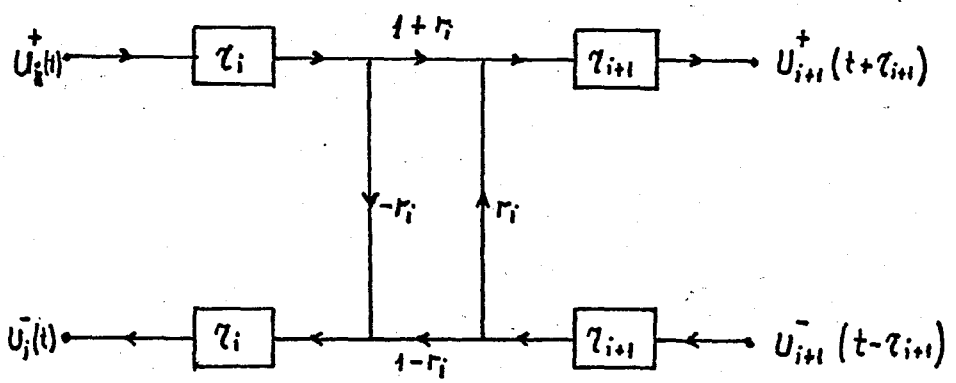


Figure 2.2.2 Signal flow representation of the junction between two lossless tubes

One can easily observe the isomorohism between the signal flow representation of the junction between two lossless tubes and the corresponding digital filter: r_i of figure 2.2.2 corresponds to k_i of figure 2.2.3 , similarly, delays of figure 2.2.2 represented by the z -term of figure 2.2.3.

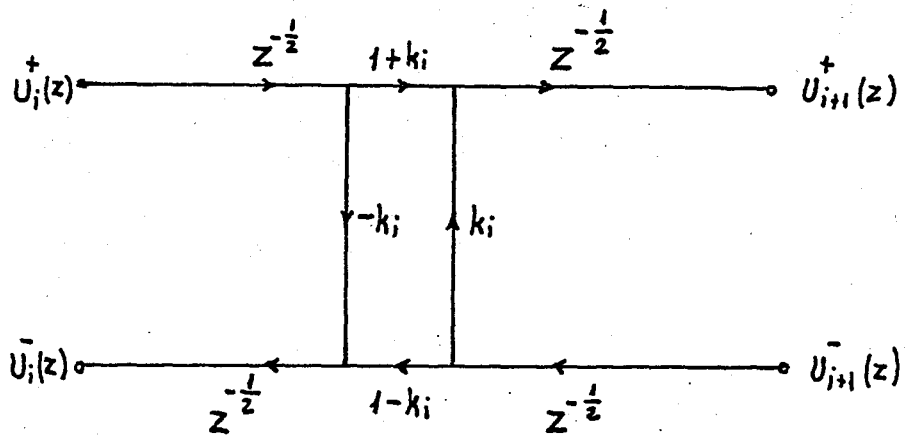


Figure 2.2.3 Flow graph representing relationship among z-transforms at a junction

When passing to the digital filter representation of the vocal tract , one considers a system composed of p losless tubes of length 1/p . In this modeling p gives the order of the filter . Length of various sections are selected to be equal in order to provide the same amount of delay between sections . This makes the usage of z as a common delay operator possible.

CHAPTER 3

I. LINEAR PREDICTION MODEL

Although linear least squares estimation (or prediction) dates from Gauss in 1795 , it appears that the first specific use of the term 'Linear Prediction' was in Wiener's 1949 book in chapter 2. 'The Linear Predictor for a Single Time Series'.

The first application of linear prediction to speech from a Maximum Likelihood formulation was in the work of Saito and Itakura in 1966. In 1967 and 1968 , Atal and Schroder published results on Predictive Coding of speech signals. Since then , several other equivalent Linear Prediction formulations have been developed . The most popular ones are the following:

A. Least Square

B. Maximum Likelihood

C. Prony's Method

D. Correlation Matching

E. Spectral Estimation

Actually all of the mentioned techniques correspond to different perspectives of the model , but they all end up in the same or similar equations.

A. Least Squares

Least Squares approach [8] is useful in the identification of the finite order Auto-regressive (AR) model for scalar observations s(0), s(1).....s(N-1) The linear model is represented by :

$$\hat{s}(n) = -\sum_{i=1}^{p} a_i s(n-i) + Gu(n) \qquad (3.1.1)$$

Where a_i are the coefficients to be identified : s(k-i) corresponds to previous observations and u(k) is a bounded variance , zero-mean and ergodic white noise sequence with

$$E\{u(k)\} = 0 \quad \text{for all } k \qquad (3.1.2.a)$$

$$E\{u(k)u(l)\} = R \quad \text{for all } k,l \qquad (3.1.2.b)$$

for some finite $R > 0$

The error between s(k) and its predicted value $\hat{s}(k)$ is given by :

$$e(k) = s(k) - \hat{s}(k) = \sum_{i=0}^{p} a_i s(k-i) \qquad (3.3)$$

where $a_0 = 1$

Least Squares method minimizes the sum of the squares of the prediction errors:

(3.1.4)

The 'normal equations' are obtained by setting the partial derivatives of J with respect to each a equal to zero:

$$\sum_{i=1}^{p} a_i c(i,j) = -c(0,j) \quad \text{for } j = 1,2,\ldots,p \qquad (3.1.5)$$

where

$$c(i,j) = \sum_{k} s(k-i)s(k-j) \qquad (3.1.6)$$

The Direct Least Squares (LS) method can be derived from the normal equations in matrix form as:

$$\hat{\underline{a}} = -(\underline{\underline{S}}^T\underline{\underline{S}})^{-1}\underline{\underline{S}}^T\underline{s} \qquad (3.1.7)$$

where

$$\underline{\underline{S}} = \begin{bmatrix} s(p-1) & s(p-2) & \cdots & s(0) \\ s(p) & \cdot & \cdots & s(1) \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ s(N-2) & s(N-3) & \cdots & s(N-p-1) \end{bmatrix} \qquad (3.1.8)$$

and

$$\underline{s} = \begin{bmatrix} s(p) \\ s(p+1) \\ \cdot \\ \cdot \\ s(N-1) \end{bmatrix} \qquad (3.2.9)$$

The Covariance method for a given zero mean data sequence can be stated as in equation 3.1.10 to 3.1.12. The matrix product $\underline{\underline{S}}^T\underline{\underline{S}}$ is indicated as $\underline{\underline{W}}$ and $\underline{\underline{S}}^T\underline{s}$ is called $\underline{R}(0)$.

$$\underline{\hat{a}} = -\underline{\underline{W}}^{-1}\underline{R(0)} \qquad (3.1.10)$$

$$\underline{\underline{W}} = \begin{bmatrix} c(1,1) & c(2,1) & \cdots & c(n,1) \\ c(1,2) & \cdots & \cdots & c(n,2) \\ \vdots & & & \vdots \\ c(1,n) & \cdots & \cdots & c(n,n) \end{bmatrix} \qquad (3.1.11)$$

and

$$\underline{R(0)} = \begin{bmatrix} c(0,1) \\ c(0,2) \\ \vdots \\ c(0,p) \end{bmatrix} \qquad (3.1.12)$$

If the signal s(k) is wide-sense stationary for large number of observations N. $R(i,j)$ is equivalent to the sample autocorrelation $R(|i-j|)$ of s(k) i.e.

$$R(|i-j|) = \sum_{k=0}^{N-1} s(k)s(k-|i-j|) \quad \text{for } i,j=1,2,\ldots n \qquad (3.1.13)$$

The following matrix equation represents the approach:

$$\underline{a} = \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_p \end{bmatrix} = \begin{bmatrix} R(0) & \cdots & R(n-1) \\ R(1) & & R(n-2) \\ \vdots & & \vdots \\ R(p-1) & \cdots & R(0) \end{bmatrix}^{-1} \begin{bmatrix} R(1) \\ R(2) \\ \vdots \\ R(p) \end{bmatrix} \qquad (3.1.14)$$

The fact that Autocorrelation matrix is Toeplitz (all elements along each diagonal are equal) enables that various approaches have been developed for solving these equations.

B. Maximum Likelihood

This approach is based on the question what choice of parameter values makes the probability of occurance of the actual observations (the speech samples) most likely . i.e. maximizes the probability density of parameters ?

Speech samples are modeled as elements of a Gaussian. stationary. random process generated by passing uncorrelated noise through an all-pole filter of the form:

$$1 / A(z) = 1 / \sum_{i=0} a_i z^{-i} \qquad \text{where } a_0 = 1 \qquad (3.1.15)$$

Knowing that the sequence {s(n)} is Gaussian with zero mean one can define the joint probabilty density of the variables s(0). s(1). s(2). ....s(N-1) It is simply the standard multivariate probability density :

$$p(n) = f(a_1, a_2, a_3 \ldots\ldots , n) \qquad (3.1.16)$$

The optimum values for a are to be found by differentiating p(n) with respect to a . and setting them equal to zero. But for M greater than 2 the problem becomes extremely non-linear.

Two different approximations have been implemented: Itakura and Saito utilized approximations based upon the assumption N)>M (the number of data points greatly exceeds the filter order) to show that the joint probability

density for the sequence s(0), s(1), ...,s(N-1) can be approximated by:

$$p(n) = (2\pi\sigma)^{-N/2} \cdot e^{-\alpha \frac{1}{2\sigma^2}} \qquad (3.1.17)$$

where

$$\alpha = \sum_{n=-\infty}^{\infty} [\sum_{i=0}^{p} a_i s(n-i)] \qquad (3.1.18)$$

Alpha is precisely the error energy in the Autocorrelation approach to LS Linear Prediction.

This approximation results in the same equation as in the Autocorrelation method . with the additional property that a gain term $\sigma^2 = \alpha/N$ is obtained for matching the energy of the model to that of the inout signal.

The second approximation involves a conditional Maximum Likelihood approach . where the conditional probability density p is given by

$$p = (2\pi\sigma^2)^{-(N-M)/2} e^{-\alpha/2\sigma^2} \qquad (3.1.19)$$

and

$$\alpha = \sum_{n=M}^{N-1} [\sum_{i=0}^{M} a_i s(n-1)]^2 \qquad (3.1.20)$$

and results in the equations obtained in the Covariance method. with the additional prooerty that

$$\sigma_e^2 = \alpha/(N-M)$$

C. Prony's Method

[4]

This approach models voiced speech during a pitch period as a sum of complex exponentials which add uo to a real term. If speech is considered to be consisting of M such terms 2M speech samples are enough to correctly model the system.

A more general model taking care of transients from previous pitch period and zeroes due to nasal tract can be described as in equation (3.1.21)

$$X(z) = P(z) / A(z) = \sum_{i=0}^{M-1} a_i z^{-i} / \sum_{i=0}^{M} a_i z^{-i} \qquad (3.1.21)$$

D. Correlation Matching

Let H(z) = 1/A(z) be the speech synthesizer model and denote its impulse response by the sequence $\hat{h}(n)$

$$\hat{h}(n) = \sum_{i=1}^{p} a_i \hat{h}(n-1) + G\,\delta(n) \qquad (3.1.22)$$

By multiplying both sides with h(n-k) and summing over n, one obtains the expression for autocorrelation coefficients of impulse response:

$$\hat{R}_n(k) = \sum_{i=1}^{p} a_i \hat{R}_n(k-i) + G^2\delta(k) \qquad (3.1.23)$$

The energies of s(n) and h(n) have to be equal :

$$R_n(0) = \hat{R}_n(0) \qquad (3.1.24)$$

and similarly for other coefficients:

$$R_n(i) = \hat{R}_n(i) \qquad (3.1.25)$$

These equalities follow from the similarity of equations (3.1.14) and (3.1.23) for k>0.

This way the problem is reduced to obtaining the filter whose first 1+p values of autocorrelation of its impulse response are equal to the first o+1 values of the speech signal autocorrelation.

Similarly if the input u(n) to the model of a sequence of uncorrelated samples (white noise) with zero mean and unit variance , the output s(n) of the filter is given by:

$$\hat{s}(n) = -\sum_{i=1}^{p} a_i s(n-i) + Gu(n) \qquad (3.1.26)$$

By multiplying both sides with s(n-1) and taking expected values, one obtains autocorrelation of the output s(n) :

$$\hat{R}(i) = -\sum_{k=1}^{p} a_i R(i-k) + G\delta(i) \qquad (3.1.27)$$

Last term exists due to the fact that u(n) and s(n-i) are uncorrelated for i>0. It is the dualism between the deterministic impulse and statistical white noise , that enables their usage in speech synthesis models.

D. Spectral Matching

In the frequency domain formulation of LPC the error e(n) between the actual and predicted signal has a z-transform of the form:

$$E(z) = [1 + \sum_{i=1}^{p} a_i z^{-i}] S(z) = A(z)S(z) \qquad (3.1.28)$$

The total error energy is given by (Parseval's theorem)

$$E_t = \sum_{n=-\infty}^{\infty} e(n) = 1/2\pi \int_{-\pi}^{\pi} |E(e^{-j\omega})| \, dw \qquad (3.1.29)$$

where $E(e^{-j\omega})$ is obtained by evaluating E(z) on the unit circle $z=e^{j\omega}$. Equivalently:

$$E = 1/2\pi \int_{-\pi}^{\pi} P(w)A(e^{jw})A(e^{-jw})dw \qquad (3.1.30)$$

where $P(w) = |S(e^{jw})|$

The power spectrum P(w) of the all-pole model is given by:

$$P(w) = |H(e^{j\omega})| = G^2 / |A(e^{j\omega})|^2 \qquad (3.1.31)$$

and power spectrum P(w) of the original signal is given by :

$$P(w) = |E(e^{j\omega})|^2 / |A(e^{j\omega})|^2 \qquad (3.1.32)$$

By comparing these two equations , one can see that if P(w) is being modeled by P(w) , then the error power spectrum $|E(e^{j\omega})|$ is being modeled by a flat spectrum equal to G . This means that the actual error signal e(n) is being approximated by another signal that has a flat spectrum .

such as a unit impulse, white noise or any other signal with a flat spectrum. Therefore filter A(z) is sometimes known as a 'whitening filter'.

II REFLECTION COEFFICIENT APPROACH TO LEAST SQUARES

As outlined in section I Least Squares method tries to minimize the sum of the squares of prediction error.

If one assumes that the filter A(z) establishes this minimum [4], the following progress is possible :

Definition : Inner product of two filters F(z) and G(z) is defined as follows:

$$\langle F(z), G(z) \rangle = \sum_{n=n_0}^{n_1} u(n)\, v(n) \qquad (3.2.1)$$

where u(n) and v(n) are the outputs of respective filters when a common input x(n) is applied to them.

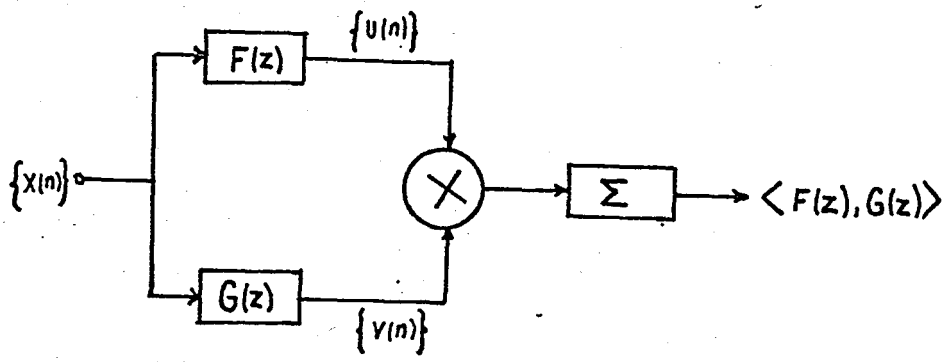


Figure 3.2.1 Inner product formulation

$$\text{If } F(z) = \sum_{i=0}^{\infty} f_i z^{-i} \quad \text{and} \quad G(z) = \sum_{i=0}^{\infty} g_i z^{-i}$$

then

$$\langle F(z), G(z) \rangle = \sum_{i=0}^{\infty} \sum_{j=0}^{\infty} \left[f_i \left[\sum_{n=n_0}^{n_1} x(n-i)\, x(n-j) \right] g_j \right] \qquad (3.2.2)$$

and

$$\langle z^{-i}, z^{-j} \rangle = \sum_{n=n_0}^{n_1} x(n-i)\ x(n-j) \qquad (3.2.3)$$

It is easy to show that the filters together with this definition of inner product define a vector space.

With this definition of inner product, prediction error to be minimized is the norm squared of filter A(z)

$$e(n) = \langle A(z), A(z) \rangle \qquad (3.2.4)$$

$$\text{where } A(z) = \sum_{i=0}^{p} a_i z^{-i}$$

If norm of A(z) is minimum, then norm of $A(z) + cz^{-j}$ $j=1,2,\ldots,p$ has to be greater than A(z)

$$\langle A(z)+cz^{-j}, A(z)+cz^{-j} \rangle \ \rangle \ \langle A(z), A(z) \rangle$$

$$\langle A(z), A(z) \rangle + 2c\langle A(z), z^{-j} \rangle + c\ \langle z^{-j}, z^{-j} \rangle \ \rangle \ \langle A(z), A(z) \rangle$$

$$2c\langle A(z), z \rangle + c\ \langle z^{-j}, z^{-j} \rangle \ \rangle \ 0$$

since c is nonzero and arbitrary one can select

$$c = -\langle A(z), z^{-j} \rangle \ / \ \langle z^{-j}, z^{-j} \rangle$$

and the following inequality follows :

$$-\langle A(z), z^{-j} \rangle \ / \ \langle z^{-j}, z^{-j} \rangle \ \rangle \ 0 \qquad (3.2.5)$$

since $\langle z^{-j}, z^{-j} \rangle$ is always positive, the only condition is :

$$\langle A(z), z^{-j} \rangle = 0 \qquad (3.6)$$

i.e. filter A(z) is orthogonal to z^{-j} $j=1,2,\ldots,p$

This condition is actually identical to equation (3.1.14) The structure of the filter can be modeled as described by figure 3.2.2.

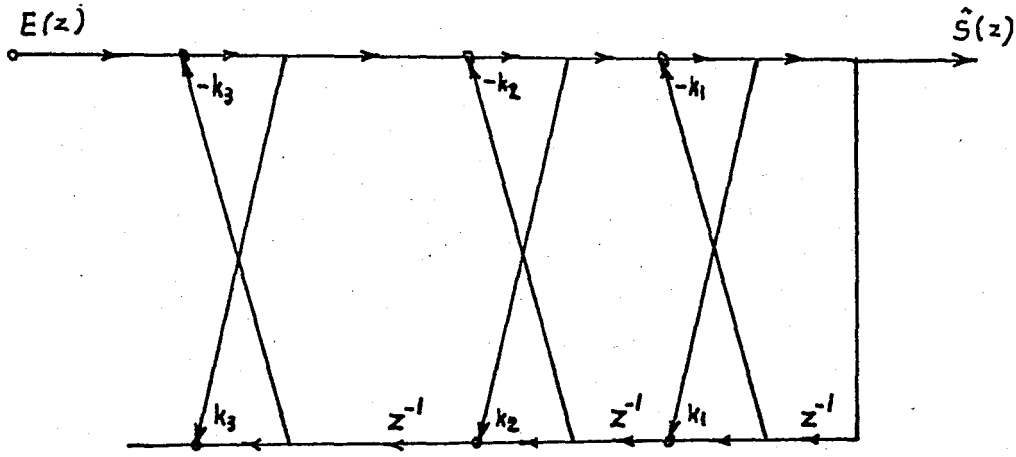


Figure 3.2.2. Lattice filter

As observed in the model there is another filter utilized in the model $B(z) = \sum_{i=1}^{p} b_i z^{-i}$. This filter tries to predict past samples utilizing following ones . It can be interpreted as a backward predictor. The purpose of the Least Squares approach is also to minimize the error due to this backward prediction.

Since in the forward predictor the coefficients corresponding to the last sample (sample to be predicted) is one. the backward predictor has one as the coefficient of its (p+1)th term . (It tries to predict s(n-p-1) as a linear combination of s(n-1),...s(n-p))

The same procedure can be applied to show that B(z) is orthogonal to all powers of z^{-j} $j=1,2,\ldots n+1$

A. Recursive Solution

The advantage of this approach is that one obtains the optimum prediction filters of smaller orders until one ends up in the final nth order prediction filter. There is one more important point in this procedure :
$B_i(z)$ and $B_j(z)$ are orthogonal to each other , unless $i=j$.

$$\langle B_i(z), B_j(z) \rangle = 0 \qquad i \neq j \qquad (3.2.7)$$

This condition follows from the fact that B (z) does not have a z term. Same condition does not apply to A (z) , because A (z) has a zeroth power term.

One starts with

$$A_0(z) = 1 \quad \text{and} \quad B_0(z) = z^{-1} \qquad (3.2.8.a)$$

$$|A_0(z)| = R(0) \quad \text{and} \quad |B_0(z)| = R(0) \qquad (3.2.8.b)$$

$$\langle A_0(z), B_0(z) \rangle = R(1) \qquad (3.2.8.c)$$

where R(i) are the autocorrelation coefficients.
$A_i(z)$ has to be orthogonal to z^{-1} ; so in the general form:

$$A_i(z) = A_0(z) + k_i B_0(z) \qquad (3.2.9)$$

by taking inner product with z^{-1} one gets:

$$k_i = -\langle A_0(z), z^{-1} \rangle / \langle B_0(z), z^{-1} \rangle = -R(1)/R(0) \qquad (3.2.10)$$

$B_1(z)$ has to be orthogonal to $B_0(z)$

$$B_1(z) = z^{-2} + \gamma_{10} B_0(z) \qquad (3.2.11)$$

taking inner product with $B_0(z)$ results in

$$\gamma_{10} = -\langle B_0(z), z^{-2} \rangle \; / \; \langle B_0(z), B_0(z) \rangle \qquad (3.2.12)$$

The procedure carries on until $A_p(z)$ and $B_p(z)$ are reached . Each time the following equations are utilized

$$A_{i+1}(z) = A_i(z) + \kappa_i B_i(z) \qquad (3.2.13.a)$$

$$B_{i+1}(z) = z^{-(i+1)} + \sum_{k=0}^{i} \gamma_{i+1\,k} B_k(z) \qquad (3.2.13.b)$$

Equation (3.2.13.b) is actually the implementation of Gram-Schmidt orthogonalization process to filters $B_i(z)$.

The autocorrelation method has the property that $R(i) = R(-i)$. This enables one to obtain $B_{i+1}(z)$ in a much easier way:

$$B_{i+1}(z) = z^{-1} [\kappa_{i+1} A_i(z) + B_i(z)] \qquad (3.2.14)$$

$B_i(z)$ is related to $A_i(z)$ in the following manner:

$$B_i(z) = z^{-(i+1)} A_i(z^{-1}) \qquad (3.2.15.a)$$

or similarly

$$a_{i,k} = b_{i,i+1-k} \qquad (3.2.15.b)$$

The algorithm can be summarized as follows:

$$a_{0,0} = 1 \qquad b_{00} = 1 \qquad e_0 = R(0) \qquad (3.2.16.a)$$

$$k_1 = -R(1)/R(0) \qquad (3.2.16.b)$$

$$a_{1,0} = 1 \qquad b_{1,0} = 1 \qquad e_1 = e_0 (1-k_1^2) \qquad (3.2.16.c)$$

$$a_{1,1} = k_1 \qquad b_{1,1} = k_1 \qquad (3.2.16.d)$$

$$k_2 = [a_{1,0} R(2) + a_{1,1} R(1)] / e_1 \qquad (3.2.16.e)$$

$$a_{i,0} = 1 \qquad b_{i,0} = 1 \qquad e_i = e_{i-1}(1-k_i^2) \qquad (3.2.16.f)$$

$$a_{i,j} = a_{i-1,j} + k_i a_{i-1,i-j} \qquad (3.2.16.g)$$

$$b_{i,j} = a_{j,i+1-j} \qquad (3.2.16.h)$$

$$k_i = - \sum_{j=0}^{i-1} a_{i-1,j} R(i-j)] / e(i-1) \qquad (3.2.16.i)$$

$$a_{j,j} = k_j \qquad (3.2.16.j)$$

In literature this algorithm is known as the Levinson Durbin algorithm.

B. Gueguen – Le Ruex Algorithm

Equation (3.2.16) describes how reflection coefficients can be evaluated recursively using the autocorrelation coefficients. Levinson-Durbin algoritm also produces and uses predictor coefficients of lower order predictors. But throughout the calculation a_i's have no other usage except the evaluation of numerator term for the expression of k in equation (3.2.16.e)Numerator term can be interpreted as the projection of recently obtained predictor an the new added delay element: $\langle A_i(z) \, . \, z^{-(i+1)} \rangle$

Gueguen – Le Ruex algorithm makes use of this inner product as an intermediate variable but bypasses the calculation of lower order predictors and expression of this inner product in terms of lower order predictor coefficients. It can be summarized as in equations (3.2.17)

$$e_{0,i} = R(i) \qquad i = 1,\ldots,p \qquad (3.2.17.a)$$

$$e_{0,i-i} = R(i-1) \qquad i = 1,\ldots,p \qquad (3.2.17.b)$$

$$k_1 = -e_{0,1} / e_{0,0} \qquad (3.2.17.c)$$

$$e_{1,0} = e_{0,0} + k_1 e_{0,1} \qquad (3.2.17.d)$$

$$e_{1,p} = e_{0,p} + k_1 e_{0,1-p} \qquad (3.2.17.e)$$

$$e_{1,i} = e_{0,i} + k_1 e_{0,1-i} \qquad (3.2.18.f)$$

$$e_{1,1-i} = e_{0,1-i} + k_1 e_{0,i} \qquad (3.2.18.g)$$

generally

$$k_j = -e_{j-1,j} / e_{j-1,0} \qquad (3.2.18.h)$$

$$e_{j,0} = e_{j-1,0} + k_j e_{j-1,j} \qquad (3.2.18.i)$$

$$e_{j,p} = e_{j-1,p} + k_j e_{j-1,i-p} \qquad (3.2.18.j)$$

$$e_{j,i} = e_{j-1,i} + k_j e_{j-1,i-i} \qquad (3.2.18.k)$$

$$e_{j,i-i} = e_{j-1,i-i} + k_j e_{j-1,i} \qquad (3.2.18.l)$$

Instead of predictor coefficients, the projection of inverse filter on various delay elements ($\langle A_i(z) \, , \, z^{-j} \rangle$: $i=1,2,\ldots,m$) are calculated.

Also the update described in equation (3.2.16.i) is implemented in another way. Theoretically for infinite number accuracy the results should be the same.

Update described in equation (3.2.18.f) requires two multiplications and one division. While Gueguen-Le Ruex only requires one division and one multiplication for the corresponding update described by (3.2.18.i) Inner product terms are denoted by:

$$e_{j,i} = \langle A_j(z) \, , \, z^{-i} \rangle = \sum_{m=0}^{j} a_{jm} R(i-m) \qquad (3.2.19.a)$$

$$e_{j,j+1-i} = \langle B_j(z) \, , \, z^{-i} \rangle = \langle A_j(z) \, , \, z^{i-j-1} \rangle \qquad (3.2.19.b)$$

The flow of algorithm is described in figure 3.2.3.

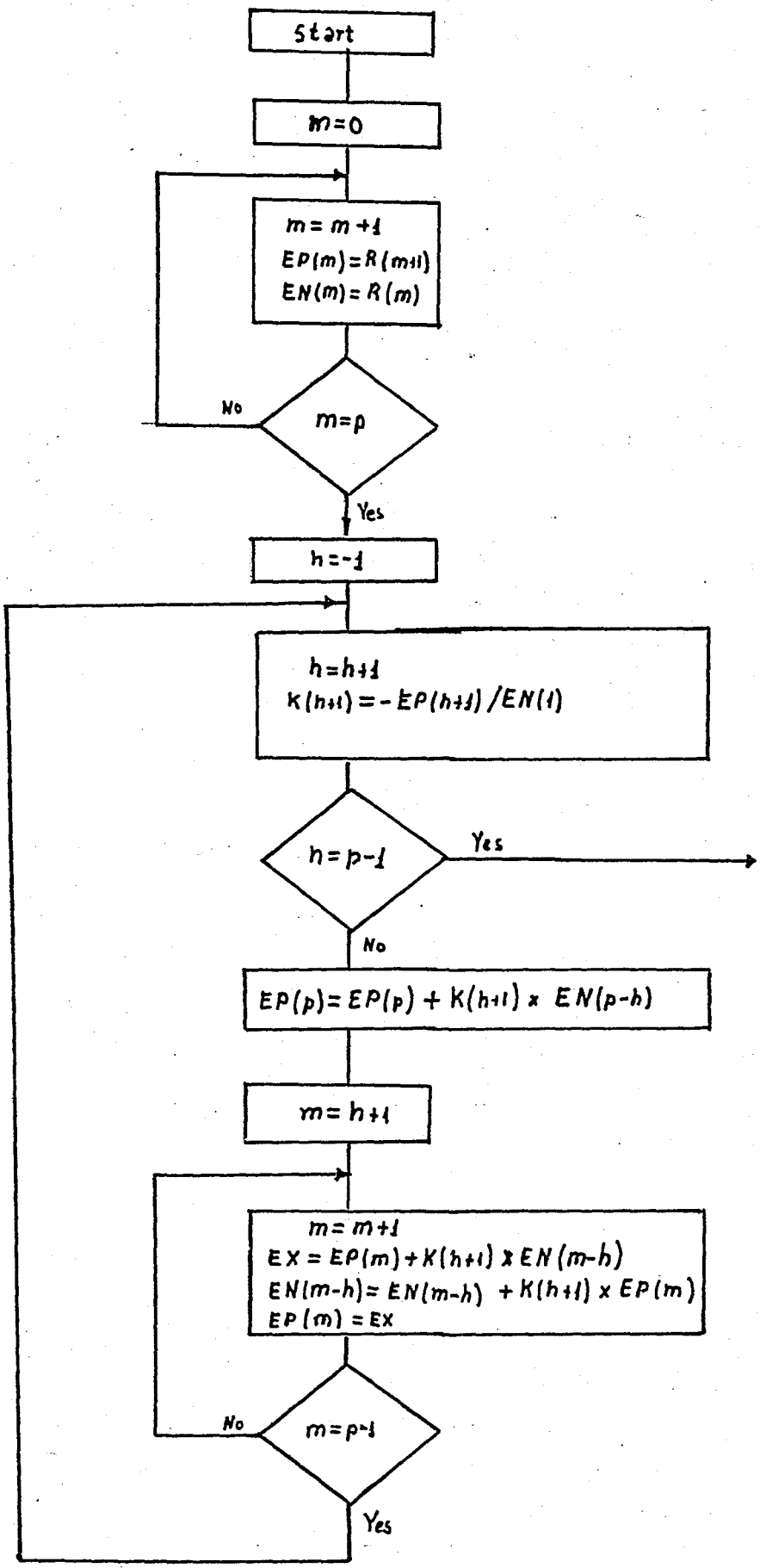


Figure 3.2.3 Flowchart of Gueguen-Le Ruex Algorithm

III. FUNDAMENTAL FREQUENCY ESTIMATION

The model of figure 1.3.1 includes a periodic impulse generator to simulate generation of voiced sounds. The repetition rate of these pulse is actually the fundamental frequency (or pitch frequency). Although pitch period is a personal characteristics, it may change throughout a sentence or even a long sound.

It ranges from 50 to 500 Hz for regular soeech. [10] For an average male voice it is about 100 Hz. This wide range makes it difficult to establish a general algorithm for pitch period estimation. But general rules may be stated as follows:

i) A framelength that includes at least one full pitch period should be selected

ii) In order to minimize interaction between pitch and lowest formant frequencies, preemphasis should be applied

iii) An efficient measure of repetitivity should be established

iv) Thresholds should be adjusted to distinguish between silence, voiced and unvoiced sound.

Four methods are reviewed in this section. The one used in this study is modifed SIFT algorithm.

A. Parallel Processing Approach

This pitch detection algorithm is based on purely time domain processing and is therefore popular for real time aplications. [11], [12] Figure 3.3.1 describes its operation.

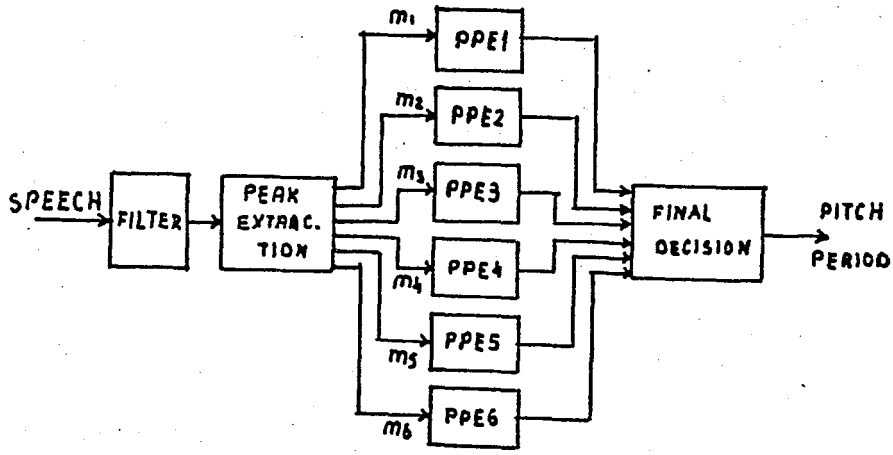


Figure 3.3.1 Parallel Process Pitch Estimation

m_1.....Impulse of peak amplitude at each peak

m_2 .....Impulse of difference amplitude between temporary peak and preceeding valley at each pek

m_3 .....Impulse of difference amplitude between temporary peak and preceeding peak at each pak

m_4 .....Impulse of negative amplitude at each valley

m_5 .....Impulse of negative amplitude of temporary valley plus the preceeding peak value at each valley

m_6 .....Impulse of negative amplitude of temporary valley plus the preceeding amplitude of valley at each valley.

If any difference comes out as negative then the result is accepted as zero.

Each impulse train is processed by a time varying nonlinear system [10]. When an impulse of sufficient amplitude is detected in the input, the output is reset to the value of that impulse and then held for a blanking interval, t(n) during which no pulse can be detected. At the end of t(n), the output begins to decay exponentially. When an impulse exceeds the level of the exponential decaying output, the process is repeated. This procedure results in six estimates of the pitch period (six quasi-periodic sequences of pulses are obtained) These six estimates are combined with two of the most recent estimates for each of the six pitch detectors. These estimates are then compared and the most frequently occurring is declared as the pitch period at that time. For unvoiced speech there is a distinct lack of consistency among estimates.

B. Short Time Average Magnitude Difference Function

This approach makes use of the fact that for periodic signals $d(n) = x(n) - x(n-k)$ approaches zero as k approaches the period t [11]. AMDF is defined as:

$$AMDF(k) = \sum_{m=0}^{N-1} |x(n+m)w(m) - x(n+m-k)w(m-k)| \qquad (3.3.1)$$

With floating point arithmetic, where multiplies and adds take approximately the same time, about the same time is required for other methods. However, for special purpose hardware, or with fixed point arithmetic, AMDF appears to

have the advantage. In this case multiplies usually are more time consuming and furthermore either scaling or a double precision accumulator is required to hold the sum of lagged products.

C. Autocorrelation Function

The short-time autocorrelation function is defined as

$$R(k) = \sum_{m=-\infty}^{\infty} x(m)\,w(n-m)\,x(m+k)\,w(n-k-m) \qquad (3.3.2)$$

The autocorrelation of voiced speech shows periodicities. One problem encountered is : If N (number of samples in a frame) is not chosen sufficiently large (less than or equal to pitch period) pitches cannot be detected.

The modified short-time autocorrelation function is defined as :

$$R_n(k) = \sum_{m=0}^{N-1} x(n+m)\,x(n+m+k) \qquad (3.3.3)$$

To avoid the difficulty , due to the fact that autocorrelation function has many peaks: (because of damped oscillations of the vocal tract response) "Spectrum Flatteners" are used. Their function is to process the speech signal such that the periodicity is made more prominent by distracting features of the signal.

D. SIFT Algorithm

SIFT (Simolified Inverse Filter Tracking) is an implementation of the autocorrelation approach. The block diagram in figure 3.3.2 decribes this model:

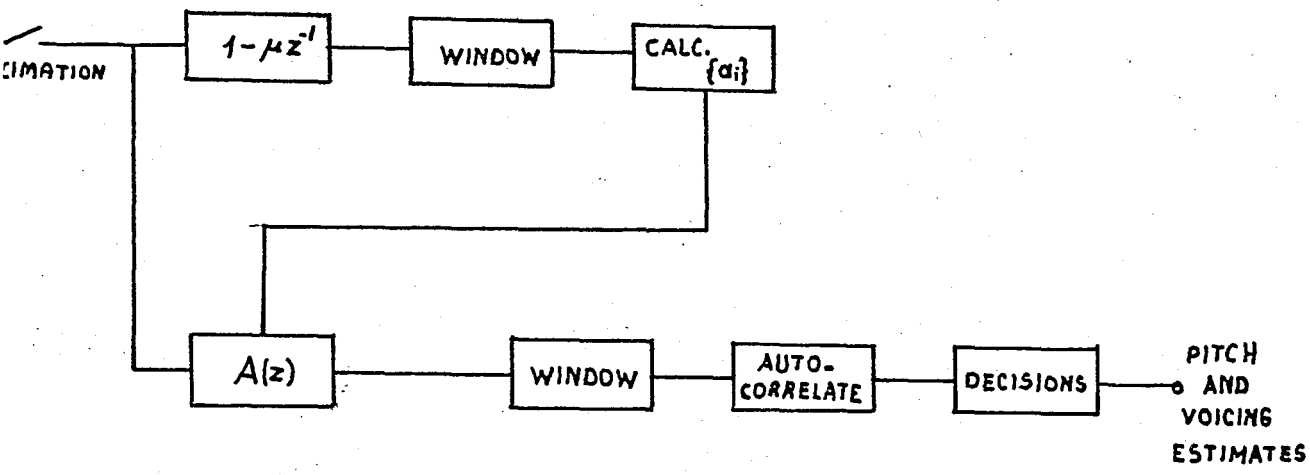


Figure 3.3.2 SIFT Algorithm

At the input the speech signal is decimated by taking one out of four samples. This does not cause any problems because frequencies of interest lie within 0-1kHz range.

$\{ 1-mz^{-1} \}$ is a pre-emphasizer module that differentiates the input signal to accentuate the region of the second formant.

Spectrum flattening is implemented by calculating the predictor coefficients and passing the decimated speech samples through the whitening filter. The whitening filter is a fourth order predictor whose output is a sequence of prediction errors e(n). These samples are passed through a window. This is necessary to deemphasize peaks at both ends

of a given frame. Peaks at the ends occur, because at the beginning one tries to predict nonzero samples from zeroed ones and at the end zeroed samples from nonzero ones.

After the autocorrelation functions have been calculated, the peaks are selected and normalized by R (0). If this ratio exceeds a threshold, this value is declared as a candidate for the searched pitch period. For low pitch periods this threshold is large, for high pitch values low.

After the first pitch prediction rough errors are smoothed and parabolic interpolation is applied to the pitch estimates.

The method used in this work is essentially a modified form of SIFT algorithm. Instead of the autocorrelation function a new function is calculated. This is a cyclic autocorrelation function and is defined as:

$$R_C(t_p) = \sum_{n=0}^{N-1-t_p} x(n)x(n+t_p) + \sum_{N-t_p}^{N-1} x(n)x(n-t_p M) \qquad (3.3.4)$$

M is restricted to be an integer greater than 2 and N is the number of samples in a frame. This definition is based on the assumption that the signal repeats itself with the fundamental frequency $1/t_p$. In this case, one cannot calculate autocorrelation coefficients for $N-p < n < N$. But with this definition the same number of terms are added together for any value of the pitch estimates. This also eliminates the need of defining different thresholds for

different pitch estimates while SIFT algorithm requires this. For a pitch range of 2.5 msec to 12.5 msec , a frame length of at least 37.5 msec is required. At 8 KHz sampling rate this corresponds to 300 samples. A typical threshold for voiced desicion is 0.4 (i.e. ratio of the introduced pitch measure and total prediction error energy should exceed 0.4 for voiced signal frames)

IV. GAIN MATCHING

Following the reasoning of sections I.B and I.D , one can arrive at the conclusion that the excitation to the model has to be proportional to the prediction error . Actually the prediction error is proportional to the energy of input signal: (This equality follows from the recursion described by equation (3.2.16.f))

$$E_t^2 = R(0) \prod_{i=1}^{p} (1-k_i^2) \qquad (3.4.1)$$

The excitation should be modeled by a function which has a flat spectrum. Two candidates for the excitation signal are unit impulse (deterministic input) and white noise (random signal) for voiced and unvoiced speech respectively.

If during analysis pre-emphasis has been applied, at the output of the prediction filter post emphasis is necessary. This integration together with non-zero-mean excitation sequences can cause a low frequency thumping sound as the fundamental frequency increases (because of accumulation of input at the integrator section) The solution to this problem is an input of the form :

$$u(n) = \begin{cases} E_t & n=0, t_p, 2t_p, \ldots \\ -E_t / (t_p-1) & \text{else} \end{cases} \qquad (3.4.2)$$

such that a zero-mean excitation is obtained.

Another approach that experimentally proved to be better is "the Chiro Function". It does not have a flat spectrum . but components at all frequencies. The one used by TMS 5220 has a 5Khz tone at the beginning and then a growing 770Hz. together with accompanying components . It continues about 4 miliseconds.

V. ENCODING

The basic parameters representing speech are energy, pitch and reflection coefficients (or another set of coefficients derivable from them). In vocoder (voice coder) applications the main consideration is to reduce bit rate when transmitting speech.

It is a common approach to encode energy and pitch period on a logarithmic basis. Typical approach is using 4-6 bits for each of them.

An experimentally observed property of k_i's is their skew distribution. i.e. if non-pre-emphasized speech is analyzed, k_1 lies very near to -1 and k_2 very near to +1. Higher order coefficients lie within -0.7 and +0.7. This is one of the reasons why reflection coefficients are not encoded linearly. Some of the proposed methods are the following:

$$K_i = \ln((F-k_i) / (F+k_i)) \qquad (3.5.1.a)$$

$$K_i = \sin^{-1} (k_i) \qquad (3.5.1.b)$$

Another approach is to encode last few coefficients with few bits. The encoding scheme utilized by TMS 5100A is the following:

pitch....5 bits
energy...4 bits
k1-k2....5 bits
k3-k7....4 bits
k8-k10...3 bits

Bit reduction is obtained by not using last six reflection coefficients for unvoiced sounds. (For unvoiced sounds. last six reflection coefficient are usually near to zero . i.e. they do not decrease the prediction error as heavily . as the first four coefficients do.) A further bit reduction means is the repetity factor , which indicates that only pitch and energy values can be changing , but reflection coefficients of the previous frame may be used.

Silence is coded with energy = 0 (four bits), and no further information.

This way bit rates of 1200 bits/second can be achieved. For details refer to Appendix E.

CHAPTER 4

I. SPEECH ANALYSIS SYTEM DESCRIPTION

The block diagram in figure 3.1 describes the flow of operations during analysis of speech.

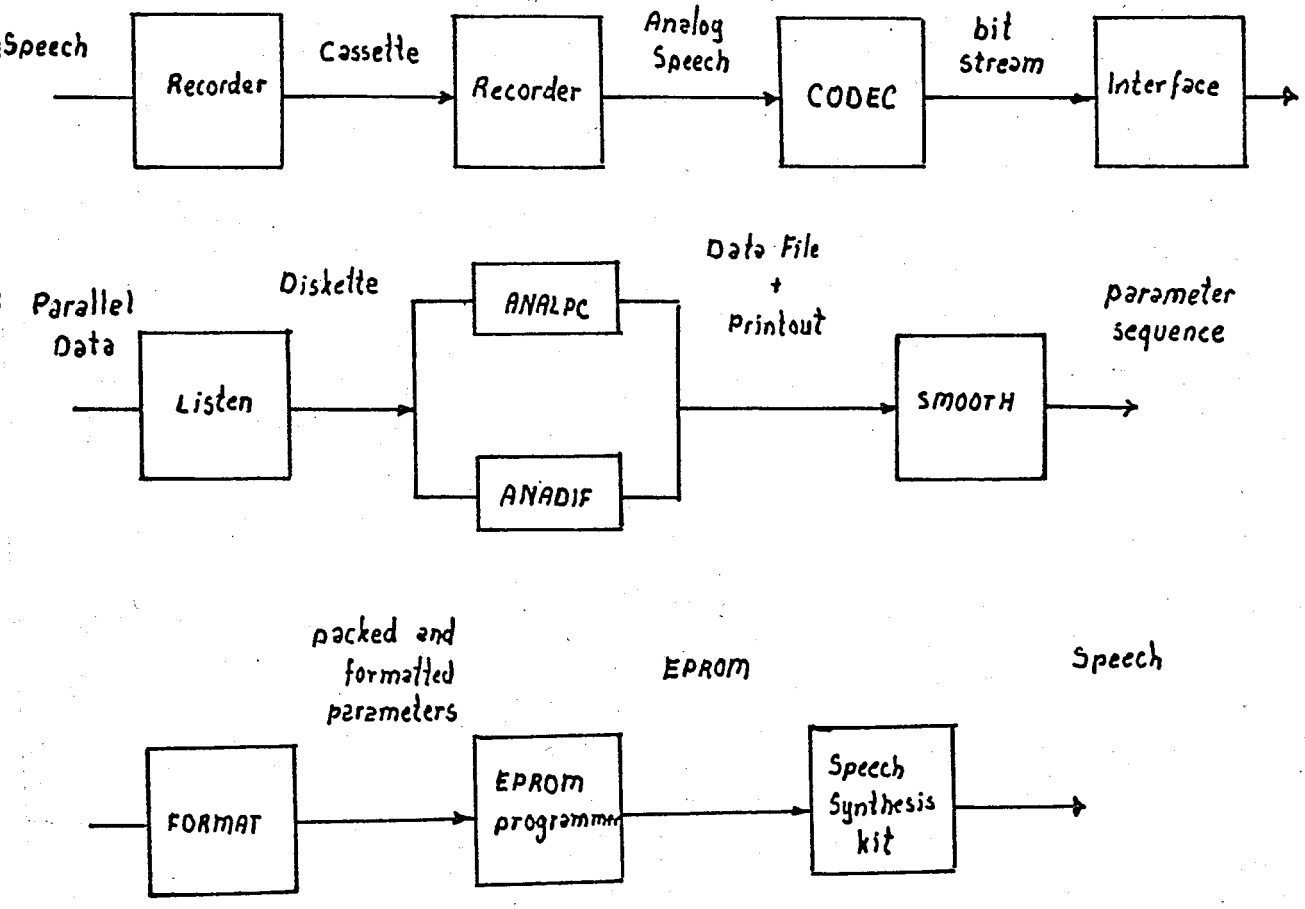


Figure 4.1.1 Analyzing System Description

For purposes of analysis , sentences consisting of various sounds are recorded to a cassette in a noiseless enviroment. In laboratory , analog output of cassette recorder is fed into a CODEC circuit whose output is an 8-bit serial A-law companded bit stream , representing the low-pass filtered speech samples.

The system used for analysing purposes is an INTELLEC 800 MDS (Micro Development System) based on a 8080-microprocessor. Since the serial bit stream is too fast for MDS to receive, it is converted to parallel and sent to a parallel port of MDS.

A software module entitled LISTEN provides for reception of parallel speech data in synchronism with CODEC , enters received data to RAM and after collecting enough data (adjustable in multiples of 1 seconds up to 5 seconds) writes sampled data to diskette.

Another software module entitled ANALPC provides for silence/speech discrimination, pitch analysis and reflection coefficient estimation. This module reads sampled speech from the diskette to RAM , analyses it frame by frame , uses 32-bit arithmetic for coefficient estimation and writes the results to diskette. Also an optional printout is possible.

The output of this module is a a data block consisting of 12 parameters (energy, pitch, 10 reflection coefficients) in encoded form. Residual energy (16bits) and R(0) (in 24 bits) for each frame. If printout option is selected , a hardcopy , giving relative magnitudes of cyclic pitch measures

corresponding to pitch estimates is obtained. A similar output is obtained , when speech samples are processed by ANADIF. The only difference is, that, in the latter analysis reflection coefficients are obtained from pre-emphasized samples, when the frame is estimated as voiced.

The outputs of the mentioned modules are smoothed and scaled by SMOOTH module. a bytewise sequence of representing parameters is obtained.

FORMAT module provides for packing and formatting of the byte sequence into a compact data block, ready for transferring to EPROM.

After subjective judgement of the speech generated, the raw output of ANALPC or ANADIF modules is further smoothed and the procedure repeated.

A. External Hardware

The circuit developed for analog to digital conversion of natural speech and the interface to the minicomputer system consists of four parts:

1. Timing circuitry
2. CODEC
3. serial to parallel converter
4. parallel to serial converter

The diagram of this circuit is given in figure 4.1.2. Figure 4.1.3 summarizes timing requirements of the circuit.

1. Timing Circuitry

The oscillator circuit consisting of inverters provices a square wave at 6.144 MHz. U1 establishes a frequency division by 3. The 2.048 MHz output is fed into U2 which divides the frequency by 16. 128 kHz generated this way is divided in U3 by 16 and finally 8 kHz is obtained. One of the D-type flip-flops in 7474 is clocked by 128 kHz and generates an 16T shifted version of 8 kHz input (T=1/2.048 microseconds). The delayed and nondelayed versions of 8 kHz frequency are NORed to generate a pulse of 8T duration and 8 kHz frequency. This signal is inverted and applied to CE input of CODEC. The other timing input to CODEC is its Clk input. 2.048 MHz generated by U1.

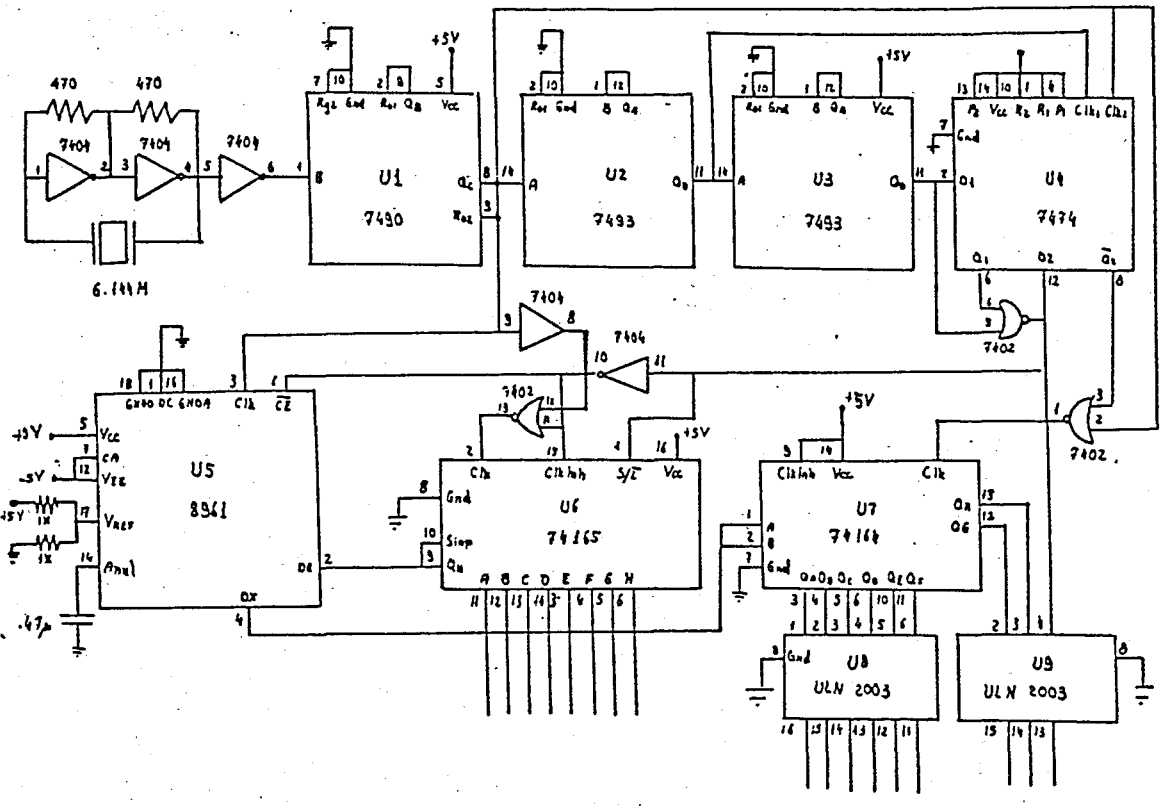


Figure 4.1.2 External Conversion Circuitry

2. 8961 CODEC

The Codec circuitry provides for low-pass filtering of sampled data (3.4 kHz bandwidth when clocked with 2.048 MHz), and also a notch filter for rejecting 50/60 Hz. A-law companding is applied to the filtered data. Starting with the sign bit an 8-bit serial bit stream is generated at every 125 microseconds, representing the analog input sampled at 8 kHz. Also the receive path includes a lowpass filter, and additionally a sinx/x correction. At the output there is a buffer amplifier capable of driving 5V peak to peak into a 10 kOhm load.

3. Serial to Parallel Conversion Circuit

This operation is accomplished by 74164. Serial bit stream is fed into 74164 inputs (both A and B inputs are ANDed in the chip). At each rising edge of its clock input received bit is shifted. After 8 clock periods 8-bit data is ready at the outputs QA-QH. Since 74164 cannot provide current necessary for input port of MDS, a driver circuit is used. ULN2003 provides for this action. In order to synchronize MDS with Codec operation a further signal is sent to MDS: a delayed version of $\overline{CE}$ of CODEC.

4. Parallel to Serial Conversion Circuit

A 74165 provides for conversion of parallel data received from output port of MDS to a serial form suitable for 8961 CODEC. Most significant bit is connected to H. The first clock pulse shifts the bits in a circular fashion: H gives MSB and A gives LSB. This shift occurs before CODEC starts reading serial data. The same connection (delayed version of CE) provides for synchronization of CODEC and MDS.

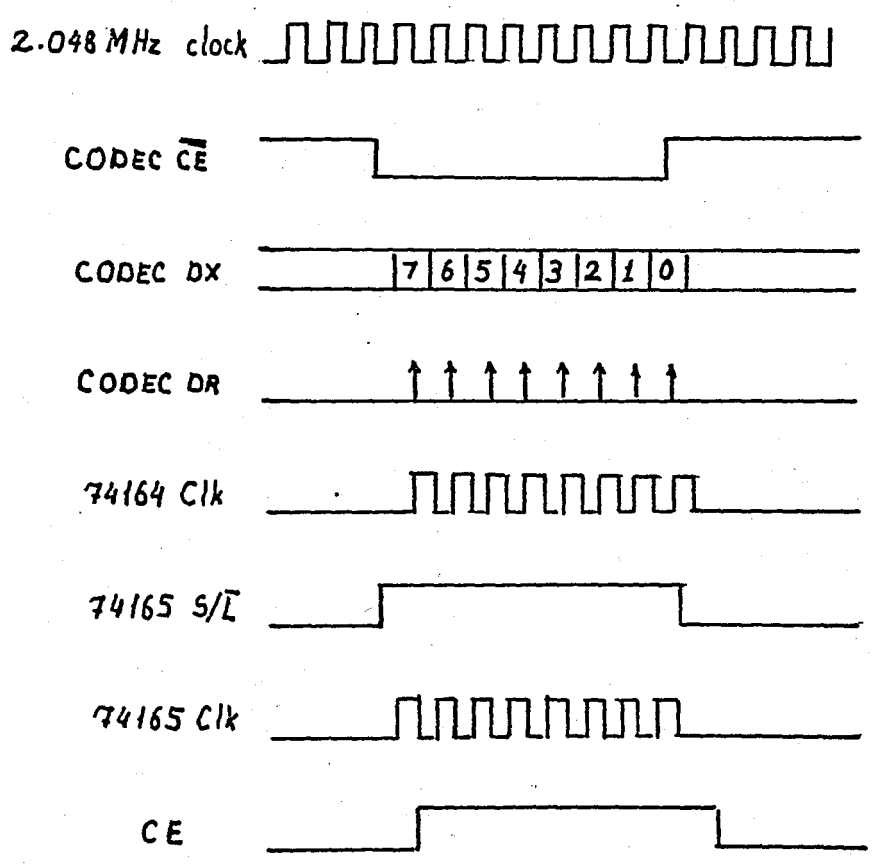


Figure 4.1.3 Timing requirements

B. INTELLEC 800 MDS I/O Ports

Monitor module of MDS provides several I/O interfaces: Those used during the work are the following:

-High speed paper tape reader/punch interface:
This port is utilized for receiption of parallel data samples.

-The line printer interface
Codec-MDS synchronization is established by means of the interrupt pin of this port. For details refer to Appendix B.

C. Software Modules

1. LISTEN

This is an interactive utility program that establisnes transfer of received digital data on the diskette under the file heading given by the user. A typical session is as follows:

```
>LISTEN
How many seconds ? 5
```

Numbers 1-5 are legal inputs at this stage. Immediately after pressing 5 on the keyboard program starts receiving and placing data to RAM. When data corresponding to the duration required has been stored, receiption stops and the following prompt appears:

Enter name of output file!

If the user wants to store received data on a diskette, the following is to be entered:

:FX:filename

X gives the drive number of the diskette; filename consists of 6 main-characters and 3 extension-characters part (this is a restriction of ISIS-II operating System) For example:

SPEECH.LPC

If no record is required, one has to enter :BB: in both cases carriage return should follow. After the diskette write operation is finished the following prompt appears:

Do You want to continue ?

If the user wants to continue Y should be pressed. Any other key exits the recording session.

This module consists of object files of LISTEN, SAMPLR and USRITF files. Also PLM80, SYSTEM and 32BITS libraries should be linked together.

PLM80.LIB contains implicit functions of PLM80 language. SYSTEM.LIB contains I/O routines for the system in use and file management utilities. USRITF contains utilities that interface the user. LISTEN is the main part of the module; and SAMPLR provides for the interrupt driven, speech data reception and placement to RAM area process.

2. SHOW

This module enables the user to see the waveform of speech recorded on the diskette. Display is available as a 17x80 dot matrix. Since different monitors require different control characters to move the cursor. The user has to indicate which system he or she is using . A typical session is as follows:

Enter Filename to be displayed:

Speech.001

Is this new MDS ? Y

The graph is displayed starting from the beginning of data. At the beginning each horizontal dot corresponds to 125 microseconds. and each vertical dot to 16 vertical units (vertical unit descriptive, but since data to be displayed is logarithmically companded one cannot talk about volts or millivolts). The conversion table is available in Appendix D. Acceptable commands for this module are listed below:

T ..... is used to change time base

A ..... is used to shift graph one time base to left (default value of timebase is 1 miliseconds and for amplitude base 20 units)

O ..... is used to change the origin

(..... is used to shift graph one time base to left

) ..... is used to shift graph one time base to right

E ..... to exit the display session

Object files of SHOW, GUTILY, USRITF, SYSTEM.LIB and PLM80.LIB constitute this module. SHOW is the main part and GUTILY is the file containing display utilities.

3. ANALPC

This is the main module that is responsible for

i) Conversion of 8-bit A-law companded data to 12-bit linear data

ii) Silence-speech discrimination

iii) Voiced-unvoiced decision and pitch period calculation

iv) Calculation of reflection coefficients

v) Scaling pitch, energy and reflection coefficients

The flow of this module is summarized in figure 4.3.1.

i) A-law expansion: Since all algorithms implemented require linear data companded, speech is converted to linear data. A-law companion has precisely the following form:

$$F(x) = \begin{cases} \mathrm{sgn}(x)\ (\ A|x| \ /\ (1+\ln(A))\ ) \\ \quad \text{for} \quad 0 \ (\ |x| \ (\ 1/A \\ \mathrm{sgn}(x)\ (\ 1+\ln(|Ax|)\ )\ /\ (\ 1+\ln(A)\ ) \\ \quad \text{for} \quad 1/A \ (\ |x| \ (\ 1 \end{cases} \qquad (\ 4.3.1\ )$$

In order to facilitate conversion, a table can be used. The table for conversion between 8-bit to 12-bit samples is given in Appendix D.

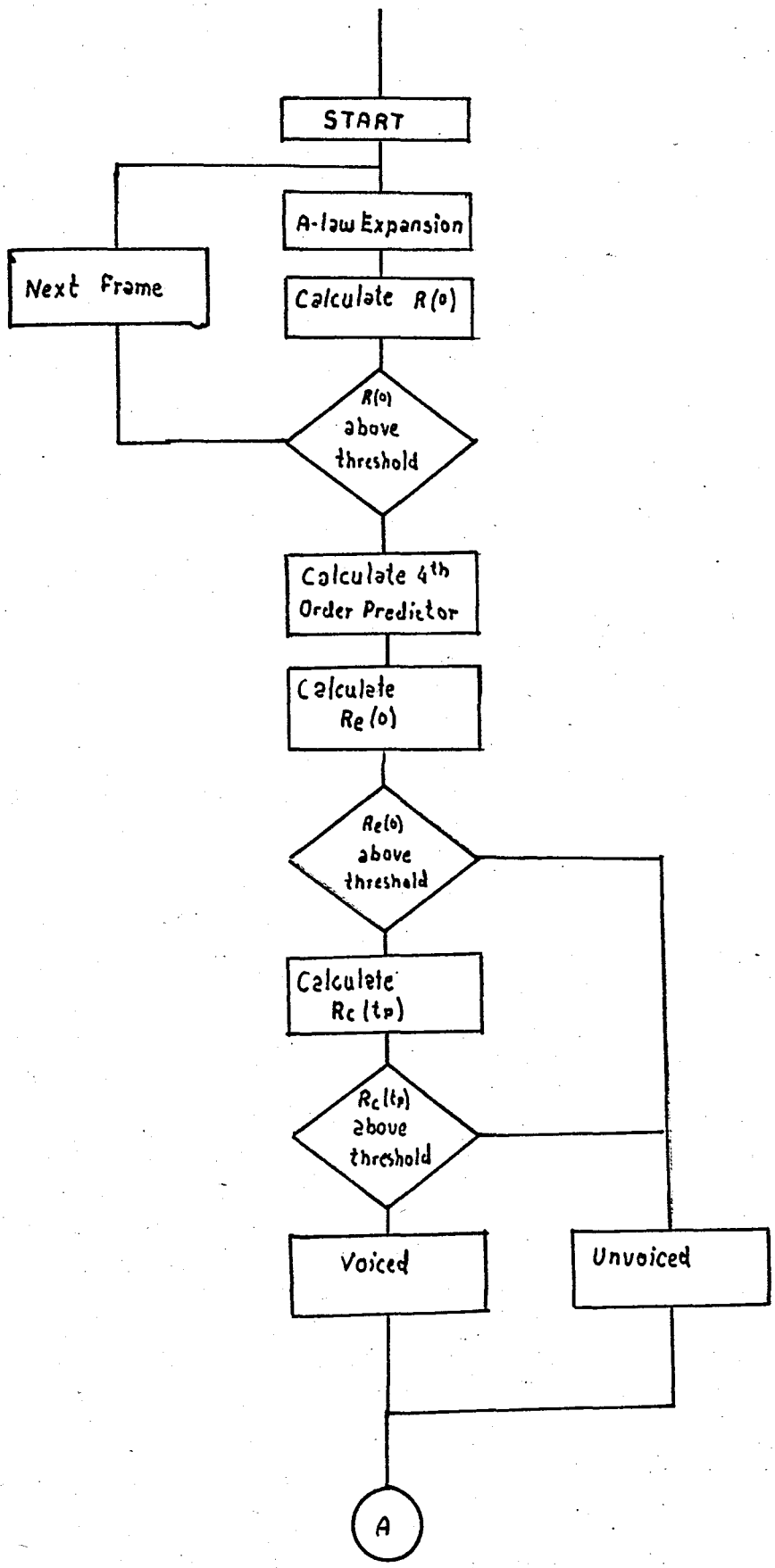
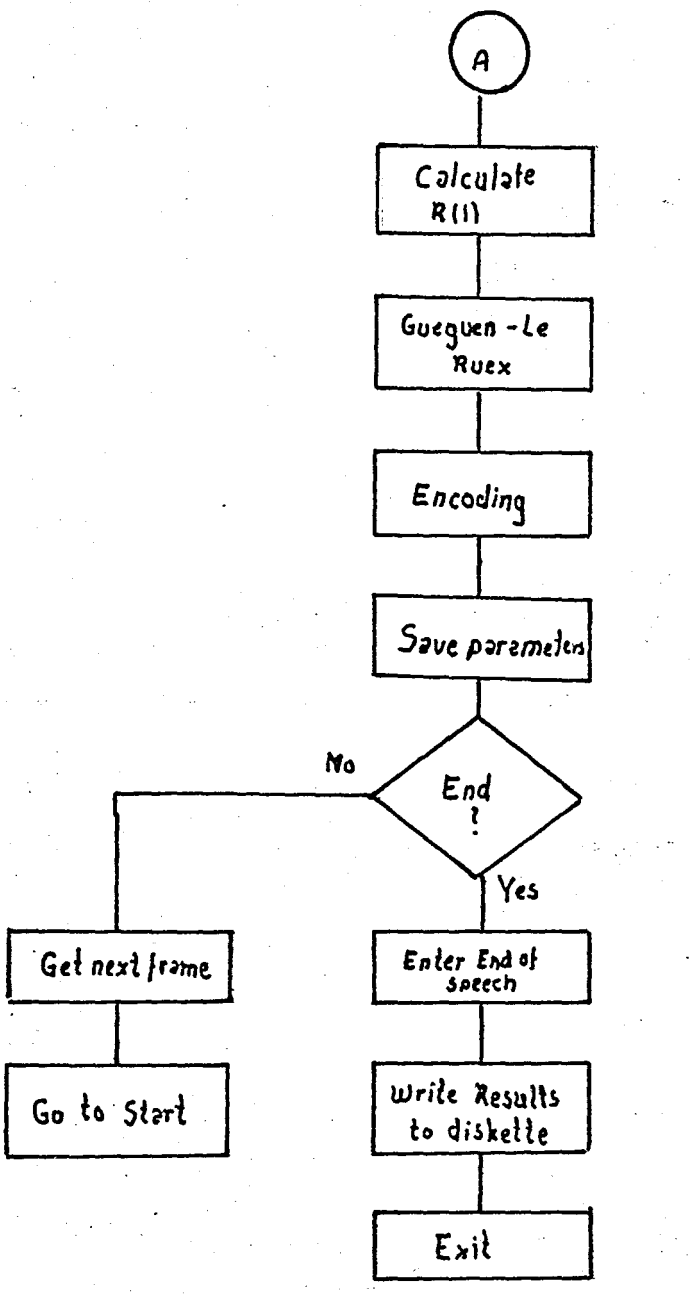


Figure 4.1.4 Flowchart of ANALPC


A
Calculate R(i)
Gueguen - Le Ruex
Encoding
Save paremeters
End ?
No
Yes
Get next frame
Go to Start
Enter End of speech
Write Results to diskette
Exit

Maximum voltage used amounts to 2.5 Volts. An acceptible conversion table for voltage to 7-bit magnitude representation is given in table 4.3.1. During companding data is scaled such that 2.5V corresponds to 0FH=15 and 156 mV corresponds to 1. Although conversion to only 12-bits is required, the output of A-law expansion is a sequence of 32-bit samples .

1.25 - 2.50 V	70H-7FH
0.625- 1.25 V	60H-6FH
312 - 625 mV	50H-5FH
156 - 312 mV	40H-4FH
78 - 156 mV	30H-3FH
39 - 78 mV	20H-2FH
19.5 - 39 mV	10H-1FH
10 -19.5 mV	0H-0FH

Table 4.1 Voltage versus 8-bit A-law companded data

ii) Silence Speech discrimination:

This decision is not made explicitely. For the ongoing analysis calculationsof R(0) is required. This is done as follows:

A frame consists of 200 samples and corresponds to 25 milliseconds. But for pitch analysis 400 samples (200 samples belong to next frame) are utilized. One out of four samples are taken for the pitch analysis (speech signal is decimated). After passsing decimated data through a Hamming window. sum of squares of samples is calculated (R(0)). If this value does not exceed 0.43 , this frame is justified as silence. This ratio has been found empirically and is depencent on the enviroment where speech has been recorded

and where it is played back.

iii) Voiced-Unvoiced decision and pitch period calculation:

The linearized speech samples are decimated by taking one out of four samples and preemphasized. Preemphasis is implemented by taking difference of consecutive data (s(n) = s(n+1) - s(n)). Preemphasized data is passed through a window and first five autocorrelation coefficients are calculated. These coefficients are passed to the Gueguen - Le Ruex algorithm and first four reflection coefficients are obtained. The predictor coefficients are calculated by the STEPUP procedure. The spectrum flattener obtained this way is actually a fourth order predictor and a sequence of prediction errors comes out. This sequence is passed through a Hamming window and cyclic pitch measures corresponding to pitch frequencies in the range of 6 miliseconds to 11.5 miliseconds are calculated. For normalization purposes also $R_e(0)$ is calculated and $R_c(t_p)$s are normalized. Negative values are truncated to zero. If more than 10 of 13 measure coefficients are nonzero, the frame is declared as unvoiced. Similarly, if the maximum normalized $R_c(t_p)$ is below 0.375, the frame is accepted as unvoiced. (Also this value is obtained by trial and error .) Otherwise t_p value corresponding to max{$R(t_p)$} determines the pitch period.

iv) Calculation of reflection coefficients:

For each frame first 11 autocorrelation coefficients are calculated using 200, windowed, linearized samples. These coefficients are passed to Gueguen Le Ruex algorithm . where 10 reflection coefficients calculated. Throughout the process sum of prediction errors is comouted recursively. At the end also sum of squares of prediction error is implicitely obtained. If throughout the analysis the recently calculated reflection coefficient exceeds one in magnitude, no further values are calculated and those from the previous frame are used. This situation is marked by a * in the printout.

v) Energy Calculation and Encoding

Residual energy (sum of squares of prediction error) is used to calculate energy. It is normalized by 125 and encoded according to the conversion table in Appendix E. Similarly , pitch and reflection coefficient values are encoded using the same conversion table.

ANALPC module consists of ANALPC, ANALGR, USRITF, ENCODE, CONVAK, DCDTBL, WINDOW and ALAW object files. Additionally SYSTEM PLM80 and 32BITS libraries are linked together. ANALPC is the main module, ANAPTC provides for pitch and ANALGR for Gueguen Le Ruex algorithm. ALAW file establisens A-law expansion of recorded speech samples. DCDTBL contains conversion tables for reflection coefficients. ENCODE file uses this table and provides for encoding.

ANADIF

This module differs from ANALPC only in the calculation of reflection coefficients. If frame has been judged as voiced during the pitch analysis, speech samples are preempnasized before calculating first 11 autocorrelation coefficients.

Instead of object file of ANALPC , object file of ANADIF is linked with those file mentioned for ANALPC.

5. SMOOTH

This module is used to correct errors made in predicting the parameters, such as energy, pitch or reflection coefficients. During a smoothing session the user can do the following :

FxxEy	Change energy coefficient of frame xx to y
FxxPyy	Change pitch value of frame xx to yy
FxxKyzz	Change K of frame xx to zz
FxxRy	Change repeat bit of frame xx to y
Dxx	Display frame xx .The following information is displayed:

frame number

energy

pitch

reflection coefficients

sum of squared prediction errors (2 bytes)

R(0) (3 bytes)

Sxxyy Scale energy , by dividing sum of squared error entry by the given number yy.xx (yy gives integer part and xx the fractional part)

Rxxyy Remove frames xx to yy (yy included)

Ixx Insert a new sound , starting after frame xx. After having received this instruction , name of the file containing sound to be inserted is requested by the system:

File to be inserted:

The user has to enter the file name and press carriage return.

C Create a file , containing only a sequence of parameters (four reflection coefficients for unvoiced frames, only energy parameter for silence and only energy, repeat bit and pitch for repeated frames) The system first asks , whether a printout is required:

Do You want to take printout?

Y is pressed for positive answer. If any other key is pressed no printout is created , but the frames are displayed on the screen.

Then the system requests for for the output file name:

File name of smoothed data:

After the user has entered file name and pressed carriage return , the new file is created. For no file output :BB: should be entered as file name.

EQ Exit smoothing session, without saving recently made modifications

EX Save last modifications and exit to ISIS-II operating system. The system requests for the name of file , where modified data block has to be written into:

File name of smoothed data:

After the name is entered and carriage return is pressed, save operation follows and control returns to ISIS-II.

6. FORMAT

The output of SMMOTH module is a sequence of bytes each representing one of the parameters necessary. But TMS-5100 speech synthesiser chip , that has been utilized for subjective juggement , requires this information in a packed form. e.g.

```
Energy    4H =  0100B
Repeat    0H =     0B
Pitch     0H = 00000B
K1       13H = 10011B
K2        EH = 01110B
K3        9H =  1001B
K4        7H =  0111B

Should be combined to

00000010
01100100
10010111
    1110
```

i.e. the bits are interchanged such that MSB becomes LSB and vice versa and then packed, such that first byte fills the

least significant bits.

FORMAT module also formats packed LPC data suitable for transferring to EPROM programmer. The resultant data packet consists of lines each starting with the line indicator character " : " , number of bytes in the frame, frame number in multiples of 10H , bytes to be transmitted in this frame and finally the checksum. A sample output is given in figure 4.1.5. Since 0FH for energy means end of phrase program searches until a 0FH is encountered when reading energy. Up to end of phrase all data is packed .

```
:10000000000000644421551 9A9D6EC9C32469D9EFF
:10001000D1046714273 9A309AE6C4E7266935CDE77
:10002000DAF4ACAAB8A22DD901CAD50410A9770177
:10003000 8D68259048B4039372 3A3039A7014388FC
:1000400 2B30990403 8D7000003CFFFFFFFFFFF82
:00000001FF
```

Figure 4.1.5 Hex file generated by the FORMAT program for the word "Bir".

A typical session is as follows. Program requests for input filename:

Filename for LPC data:

BIR.LPC

Then asks name of output file containing formatted data

Filename for formatted data:

BIR.HEX

Immediately after pressing carriage return . program starts to packing and formatting the data and returns to ISIS-II when finished.

This module consists of object files of FORMAT, PACK, USRITF and SYSTEM.LIB. FORMAT is the main file and PACK an ASM80 file establishing the required packing operation.

CHAPTER 5

I. RESULTS

The tools developed during this study have been applied to Turkish sounds. Phonemes alone cannot be generated during regular speech , so syllables have to be chosen. The syllables chosen are the ones constituting the alphabet (i.e. A, BE, CE.....) and numbers from one to ten. Also a sentence has been analysed. The results of the analysis are available in Appendix G.

Throughout this study different algorithms have been tested. In the following sections they are compared with each other and suggestions for further algorithms are developed.

After each analysis I had the opportunity to judge subjectively the results (speech output) . These observations are summarized in part B.

A. Comoutational Asoects

Throughout the whole analysis all of the results are kept as 32 bit twos complement binary and fixed point arithmatic is used. During the analysis of a frame the following operations are performed:

- Four hundred samples are expanded to 32-bits according to A law.

- decimated by taking one out of four samples and
- reduced to 100 samples.
- windowed (100 multiplications) .
- preemphasized (100 multiplication and additions) .
- first five autocorrelation coefficients calculated (500 multiplication and 500 additions) .
- fourth order predictor's coefficients computed (80 additions and 40 multiplications) .
- prediction error sequence computed (400 addition and multiplications) .
- R_e (0) calculated (100 multiplications and 100 additions).
- cyclic pitch measures for 13 different period estimates computed and compared (1300 multiplication and 1300 additions).
- 200 samples are expanded according to A law .
- preemphasized (optional) (200 additions) .
- windowed (200 multiplications) .
- first 11 autocorrelation coefficients computed (1100 multiplications and 1100 additions) .
- tenth order filter reflection coefficients computed (210 multiplications and 400 additions)

The operations add up to about 5000 multiplication and additions there are also other instructions such as decisions , search loops, move operations that occur during the analysis of a frame. The analysis of a sentence of about 2.5 seconds takes about half an hour (18 seconds for a frame) But this is an average value because analysis of silent

frames and unvoiced frames may take considerably less time.

During this work no effort has been spent to speed up the computation. But the following changes would reduce the required time by a considerable amount:

Application of efficient autocorrelation calculation methods that reduce the number of multiplications.

Use of more memory such that results, once calculated, and later to be used again, can be saved and not calculated twice.

Use of 32-bit operations only during computation of autocorrelation coefficients. For other computations such as windowing, preemphasize and recursive solution 24-bit or less would suffice.

A further reduction of operation count (or increase in accuracy, while the number of operations remain the same) can be established by using a sequential lattice method. Sequential methods do not require windowing, and they generate prediction error sequence at the same time. So production of this sequence as a byproduct, eliminates the necessity of extra calculation required for pitch analysis. This way the number of multiplications would be highly reduced. Using a digital signal processor with a very low cycle time (e.g. 200 nanoseconds for 32-bit multiplication) real time applications can be developed. Such a device can manipulate 125 000 multiplications during a 25 miliseconds frame.

B. Subjective Aspects

Before Gueguen-Le Ruex , Levinson-Durbin algorithm has been used to extract reflection coefficients from input speech. Although the precision of operations are the same , Levinson - Durbin algorithm resulted in reflection coefficients, that are greater than one in magnitude. For voiced speech this occurred at predictors of order eight to ten , for unvoiced speech for orders four to five. But Gueguen - Le Ruex always ended up in stable outputs.

It is interesting to note that , even when the first reflection coefficient was calculated correctly , persons, who knew , what the coming utterance should be , have been able to recognize it. This case clearly outlines the importance of the first reflection parameter.

Excitation with a constant pitch value of 100Hz does not result in a monotone sound. Apparently it is the energy parameter, that provides for the intonation in a sentence . Pitch period variations add only naturalness to speech.

Preemphasis , that has been applied to speech samples is actually a form of differentiation. This enhances upper portion of spectrum. It is an accepted idea in literature , that upper part of spectrum contains the main intelligibility.

During pitch analysis several thrsholds have been arranged by trial and error. A set of thresholds , that can produce very good results in pitch detection and voicing

decision for one case , can result in erroraneous voiced/unvoiced decisions for another. But since the autocorrelation function used in SIFT, requires various thresholds for pitch candidates, the pitch measure, introduced in this work , results in less erroraneous outputs. If voiced frames are judged as unvoiced and such frames alternate among voiced frames the sound is like a burbling.

Another problem that has been encountered during the work is the energy parameter. First R(0) (sum of squares of speech samples) is scaled and applied as energy. This does not produce intelligible voice. Then residual energy (sum of squares of prediction errors) is scaled and applied as energy parameter. This resulted in a good speech for a set of records. But for a second set of records the scaling factor has been too small. The result was , that a large number of frames had the maximum allowable energy. The speech output in this case is a distorted one.

The solution to the energy scaling problem is the interactive SMOOTH module. The user can process the raw output data block of ANALPC and ANADIF modules. The outputs of these modules include the residual , that has been scaled by the default value.

Both analysis modules ANADIF and ANALPC are essentially similar. They only differ in the preprocessing before reflection coefficient computation. ANADIF module differentiates input speech, before windowing. This also is based on the idea to enhance the information hidden in the

high frequency part of speech.

Without preemphasis (differentiation) vowels such as /i/ , /o/, /o/ , /u/ , /u/ resulted in very distorted and unrecognizable sounds when analyzed alone. Also /a/ sounded like an /e/. But when accompanied by consonant , in a word, they resulted in recognizable sounds. But even if followed by consonants , /a/ at the beginning of an utterance sounds like an /e/.

ANADIF module applies preemphasis to all samples in the frame , if the frame has been judged as voiced by the pitch estimation program. The speech parameters generated by this module resulted in a higher quality speech. The results outlined in Appendix F are the outputs evaluated by this module. But they are not raw data , but smoothed data.

The output of this module can be improved by first smoothing voicing decisions and then evaluating reflection coefficients. This requires, that, first a pitch detection algorithm process all frames , then voicing decisions are smoothed and later all frames are processed again to extract reflection coefficients.

An important property of reflection coefficients observed during this work is the following: Although there may be large variations between two sets of reflection parameters , the prediction coefficients corresponding to them differ very little. This effect has been seen, by once generating synthetic speech , and then analysing it using ANALPC.

An experimentally observed property of reflection coefficients is their skew distribution for the first two coefficients. First one lies very near to minus one, while the second one lies very near to one. This distribution is true for non-preemphasized speech. Preemphasis has the effect to remove them from one and minus one respectively. This result can be interpreted in the following way: Without preemphasize the prediction error is decreased quickly by the first two coefficients, but since in preemphasized signal higher frequencies are enhanced, the prediction at the second stage does not decrease prediction error by the same amount.

It has been expected that differentiating the signal would result in different signal and error energies. But the outcome of both ANALPC and ANADIF modules have very similar energy levels.

An interesting observation is that, vowels alone cannot be recognized by everyone when produced using the results of analysis. But in a single word they are recognized. Listeners mostly recognized single word utterances. The same utterance in a sentence is only seldom recognized.

CHAPTER 6

I. CONCLUSION

This work establishes a guideline for analysing connected or isolated speech. The algorithms developed can be improved by implementing one or more of the suggested techniques in Chapter 5. The listings of modules are given Appendix F and the analysis results in Appendix G.

With this study it has been shown that reflection coefficient representation is an efficient way of representing speech. But throughout this study success has been limited to single words. Connected speech , generated using this approach is not always intelligible. Further improvement of the algorithms , such that interactions between sounds are take into consideration, can lead to better results.

A. Future Applications

A straightforward application of this study is to analyse messages and store them in memory for using them in future. One of the possible implementations is , to use messages instead of overflow tones in common communication equipment such as an EPABX (Electronic Private Automatic Branch Exchange) It is not easy for every subscriber to understand why his or her call did not terminate

successfully. just by listening to the tone sent.

This work can also be used to generate the allophones of Turkish language. The interactions between consecutive sounds can be deeply explored (some outputs outlining this interaction are given in Appendix F) and a text-to-speech algorithm can be developed.

Text-to-speech synthesis can also be implemented using syllables that constitute Turkish words, by first analyzing and storing them on a disc. Speech can be generated by either concatenating syllables or allophones.

APPENDIX A

32-BIT ARITHMETIC

Since Intel 8080A microprocessor can only perform 16-bit addition and no multiplication and division , these should be produced separately. Therefore a 32-bit fixed point arithmetic library is created.

32-bit data is stored in memory in the following way:

```
base address + 0 :   B0
base address + 1 :   B1
base address + 2 :   B2
base address + 3 :   B3
```

B0 is the least significant byte and B3 is the most significant byte. Most significant bit of B3 determines sign (0 means positive). Negative numbers are stored in 2's complement form. B0 and B1 correspond to the fractional part and B2 and B3 to integer part. For example 352.4 is represented as:

```
B0 = 66H
B1 = 66H
B2 = 60H
B3 = 01H
```

similarly -352.4 is represented as:

```
B0 = 9AH
B1 = 99H
B2 = 9FH
B3 = FEH
```

The operations are performed by the following subroutines:

```
For addition       : FBADD     (C = A + B)
For subtraction    : FBSUB     (C = B - A)
For division       : FBDIV     (C = A / B)
For multiplication: FBMUL      (C = A * B)
```

They have the following general format of usage:

CALL FBxxx(address of A, address of B, address of C)

The listings of these modules are given in Appendix F .

APPENDIX B

INTELLEC 800 MDS HARDWARE

The INTELLEC MDS is a complete microcomputer design center based on Intel's 8080 Microprocessor. It has a 2-microseconds instruction cycle time. The basic hardware configuration includes 16K bytes of Random Access Memory and six fully implemented I/O interfaces to :

- a Teletype (including its paper tape reader)
- a CRT terminal (or other compatible device)
- a high-speed paper tape reader
- a high-speed paper tape punch
- a line printer , and
- Intel's Universal PROM Programmer

Figure B.1 describes the block diagram of the basic configuration used for this work.

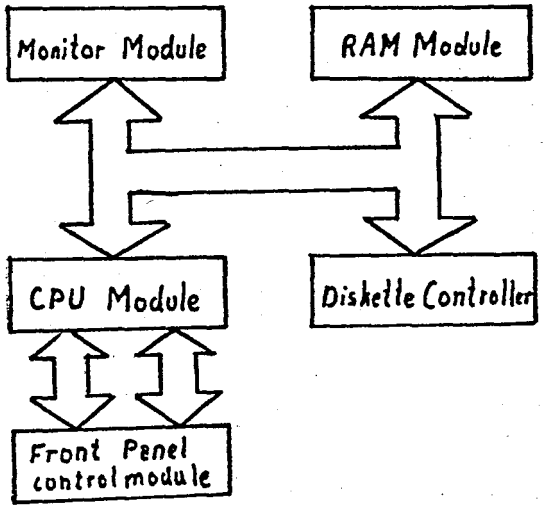


Figure B.1 Block diagram of INTELLEC 800

Monitor module provides for the communication of Intellec 800 MDS system with the external world. Speech storage is established using the interface circuits of this modules. Some of the interfaces are the following:

The high-speed paper tape reader/punch interface provides an 8-bit data input path, two command bit outputs and a single ready status input for a 200 cps paper tape reader. and an 8-bit data output path, two command bit outputs and a single ready status input for a 75 cps paper tape punch.

The PROM programmer interfaceprovides an 8-bit path to PROM programmer perioheral for the transfer of data, address, control and status information. It also presents the necessart commands to the PROM programming perioheral specifying the direction and the type of transfer.

The line printer interface has been designed to operate with printers which are capable of receiving input commanos as coded ASCII characters in the same manner as data

The monitor interrupt logic provides a hardware scheme that can be utilized by a user-generated operating system or specialized application routine to service I/O oevices.

Each time a device indicates that it is ready , the appropriate service request signal is generated. The service request lines form a 7-bit interruot status word which can be read by CPU. In addition if Monitor module interrupts aer enabled. an active service request results in an interrupt

request to CPU on level 3.

Monitor Module Interrupts can be enabled or disabled, and device service requests can be reset individually or as a group by executing a single output instruction.

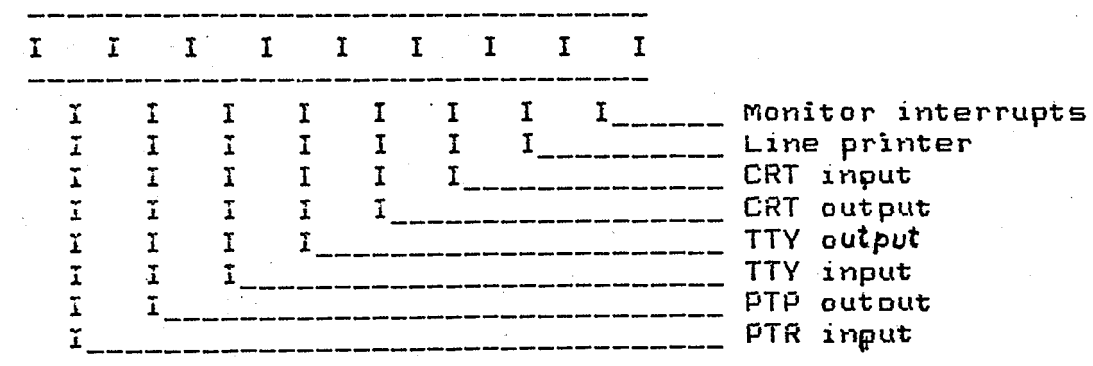
Addresses of I/O ports are 0F0H - 0FBH :

PTP DAT	0F8H
PT CTL	0F9H
PTR DAT	0F8H
PT STAT	0F9H

A low to high transition on the LPT ACK pin causes an interrupt of level 3. This corresponds to Line Printer Acknowledge information (used to establish synchronization between MDS and CODEC during speech storage)

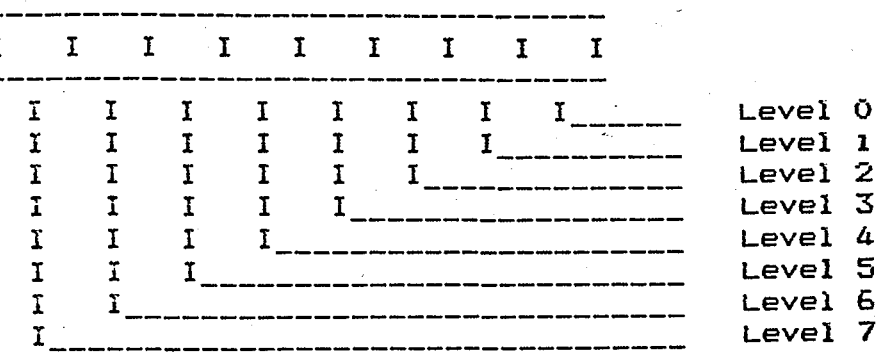
Some of the important addresses related to the monitor module are the following:

0F3H.....Monitor Interrupt Mask
1 corresponds to enabled



0FAH.....Interrupt Status Word
entries correspond to peripherals is explained above. 1 in an entry means : respective interrupt has occurred.

OFCH..... Interrupt Mask
1 corresponds to disabled



I/O Device Driver/Receiver Requirements

Paper Tape Reader : 7437 TTL drivers capable of sinking 48mA
8097 TTL receivers without pull-up

Paper Tape Punch : 8097 TTL drivers capable of sinking 32mA
8097 TTL receivers with 470 Ohm pull-up resistors

PTR edge connector

Data 1	Pin 1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
Gnd	11, 12, 13, 24, 25

PTP edge connector

Data 1	Pin 1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
Gnd	18, 23, 25

LPT

Ack	16
Gnd	15, 25

APPENDIX C

ISIS-II DISKETTE OPERATING SYSTEM

ISIS-II is an operating system for the Intellec develoomment systems:

Intellec Series II Microcomputer Development Systems

Intellec Microcomputer Develoomment System

It supports all models of Intellec systems wth one or more single- or double density disk drives and at least 32K of RAM.

An operating System is a group of programs that manages the resources of a system and frees the user to concentrate on other tasks. It provides a simole command language that allows the user to state what he or she wants done and what device or file is expected to do it.

The computer has to execute thousands of instructions to carry out each command, but the user has not to worry about the details.

A brief list of commands available in ISIS-II is given below:

IDISK format a new disk to a basic system or non-system disk

DEBUG load a program and give control to monitor

SUBMIT enter the file that contains commands to be executed

DIR output the names of and information about the files listed within the disk directory

DELETE remove references to a file from the directory and free disk storage space associated with that file

RENAME change the name of a disk file

OBJHEX convert a program from object module to hexadecimal format

CREDIT create and edit ISIS-II files

COPY copy a file from one device to another

LINK combine program files and resolve external addressing

LOCATE convert relocatable object to absolute addresses for execution

Several compilers and assemblers are also available:

ASM80	8080/85 Assembler
ASM86	8086/88 Assembler
PLM80	8080/85 PLM compiler
PLM86	8086/88 PLM compiler

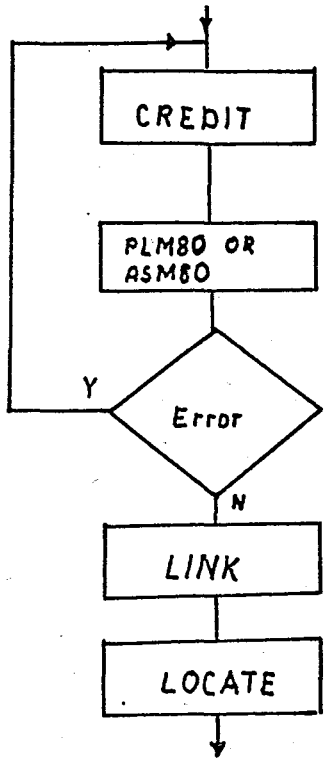


Figure C.1 Command generation

User Generated Commands

Actually commands of any operating system are linked and located object codes , that are suitable for the execution of the main processor, the system is based on. For Intellec 800 MDS, object codes of ASM80 and PLM80 compilers are suitable for execution. The Process can be summarized as in figure C.1.

Some of ISIS-II utilities necessary for file management and interactive command execution are given below. They reside in SYSTEM.LIB . During LINK operation only those, that are used are linked together.

OPEN(AFTNPTR,FILEPTR,ACCESS,ECHOAFTN,STATUS)

OPEN call initializes ISIS tables and allocates buffers that are prepared for input/output processing of the specified file.

AFTNPTR : Active File Table Number Pointer
FILEPTR : Address of the ASCII string that specifies the name of the file to be opened
ACCESS :indicates how the file is to be accessed when open.
1...open for input(READ) Marker=0 , Length not changed
2...open for output(WRITE) Marker=0 , Length=0
3...open for update
ECHOAFTN: contains AFTN of the echo-file , if line editing is desired , otherwise contains zero
STATUS : memory location for the return of non-fatal error number

READ(AFTN,BUFFER,COUNT,ACTUAL,STATUS)

The READ call transfers data from an open file to a specified memory location specified by the calling program.

AFTN : number assigned to the file
BUFFER : address of memory location to which data is to be transferred
COUNT : number of bytes to be transferred
ACTUAL : number of bytes actually transferred
STATUS : memory location for the return of non-fatal error number

WRITE(AFTN,BUFFER,COUNT,STATUS)

The WRITE call transfers data from a specified location in memory called a buffer to an open file.

AFTN : number asssigned to the file
BUFFER : address of memory location to which data is to be transferred
COUNT : number of bytes to be transferred
STATUS : memory location for the return of non-fatal error number

CLOSE(AFTN,STATUS)

The CLOSE call removes a file from the system input/output tables and releases the buffers allocated for it by OPEN.

AFTN : number assigned to the file
STATUS : memory location for the return of non-fatal error number

EXIT

The EXIT call can be used by user programs in order to terminate their excution and return to ISIS-II

CO(CHARACTER)

Console Output Routine takes a single character and transmits it to the system console output device

CHARACTER: ASCII character to be displayed on the CRT

LO(CHARACTER)

List Output Routine takes a single character and transmits it to the system list device

CHARACTER: ASCII character to be printed

CI

The Console Input Routine reads a character entered at the Intellec Console input device and returns it as a byte variable (in A-register)

Memory Allocation of ISIS-II

Total RAM requirement of the system is 32 Kbytes. The first 12Kbytes (starting at location 0) are reserved for use by that portion of ISIS-II , that must remain in memory during operation of disk-based functions of the system. An additional 318 bytes of higher order memory is reserved for monitor workspace. The reameining memory is shared by the program being developed, by programs called by ISIS-II functions from diskette, and by the data used or generated during user program development.

Locations 0-23 : ISIS-II Interrupts 0,1,2

Locations 24-63 : User interrupts

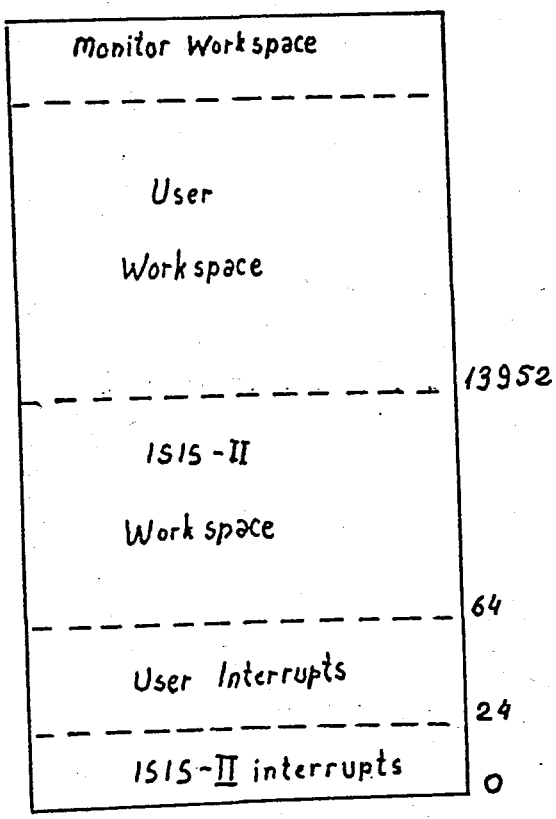


Figure C.2 Memory Map for ISIS-II

APPENDIX D

A-LAW EXPANSION

In order to provide for a wide dynamic range by using few bits to represent the signal companding is applied. The approach advised by CCITT is A law companding. The equations describing companion and expansion of the signal are the following:

$$F(x) = \begin{cases} \operatorname{sgn}(x)\ (A|x| / (1+\ln(A)) & \text{for } 0 < |x| < 1/A \\ \operatorname{sgn}(x)\ (1+\ln(|Ax|)) / (1+\ln(A)) & \text{for } 1/A < |x| < 1 \end{cases} \qquad (D.1)$$

$$F(y) = \begin{cases} \operatorname{sgn}(y)\ (|y| (1+\ln(A))) / A & \text{for } 0 < |y| < 1/(1+\ln(A)) \\ \operatorname{sgn}(y)\ (e^{|y|(1+\ln(A)) - 1}) / A & \text{for } 1/(1+\ln(A)) < |y| < 1 \end{cases} \qquad (D.2)$$

The segmented A law code is usually referred to as a 13 segments code owing to the existence of seven positive and seven negative segments with the two segments near the origin being colinear. In the given tables the first segment is divided into two parts to produce eight positive and eight negative segment. Thus a compressed code word consists of a sign bit P followed by 3 bits of a segment identifier S and 4 bits of quantizer level Q.

linear data	expanded data
0 0 0 w x y z	0 0 0 0 0 0 0 w x y z 1
0 0 1 w x y z	0 0 0 0 0 0 1 w x y z 1
0 0 0 w x y z	0 0 0 0 0 1 w x y z 1 0
0 0 1 w x y z	0 0 0 0 1 w x y z 1 0 0
0 0 0 w x y z	0 0 0 1 w x y z 1 0 0 0
0 0 1 w x y z	0 0 1 w x y z 1 0 0 0 0
0 0 0 w x y z	0 1 w x y z 1 0 0 0 0 0
0 0 1 w x y z	1 w x y z 1 0 0 0 0 0 0

Table D.1 A law expansion

APPENDIX E

CONVERSION TABLE

RMS	Pitch	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	Cod
0	0	-501	-328	-441	-328	-328	-256	-308	-256	-256	-205	0
52	25	-498	-303	-387	-273	-282	-212	-260	-161	-176	-132	1
87	27	-497	-274	-333	-217	-235	-168	-212	-66	-96	-59	2
123	28	-495	-244	-279	-161	-189	-123	-164	29	-15	14	3
174	30	-493	-211	-225	-106	-142	-79	-117	124	65	87	4
246	31	-491	-175	-171	-50	-96	-35	-69	219	146	160	5
348	32	-488	-138	-117	5	-50	10	-21	314	226	234	6
491	34	-482	-99	-63	61	-3	54	27	409	307	307	7
694	35	-478	-59	-9	116	43	98	75				8
981	36	-474	-18	45	172	90	143	122				9
1385	37	-469	24	98	228	136	187	170				10
1957	38	-464	64	152	283	182	232	218				11
2764	39	-459	105	206	339	229	276	266				12
3904	40	-452	143	260	394	275	320	314				13
5514	42	-445	180	314	450	322	365	361				14
7789	44	-437	215	368	506	368	408	409				15
	46	-412	248									16
	48	-380	278									17
	50	-339	306									18
	52	-288	331									19
	54	-227	354									20
	56	-158	374									21
	58	-81	392									22
	61	-1	408									23
	63	80	422									24
	66	157	435									25
	70	226	445									26
	75	287	455									27
	80	337	463									28
	85	379	470									29
	90	411	476									30
	95	436	506									31

Each table entry of K1 to K10 is expressed as a quotient of integers with the denominator value fixed at 512.

Pitch period table entry is the pitch period for voiced excitation expressed as number of samples. For 8KHz sampling rate and a pitch period of 100Hz pitch period corresponds to 80 samples i.e coded value is 128.

APPENDIX F

PROGRAM LISTINGS

The following files are included:

```
IS-II PL/M-80 V3.0 COMPILATION OF MODULE MAIN
JECT MODULE PLACED IN :F1:ANALPC.OBJ
MPILER INVOKED BY:  PLM80 :F1:ANALPC.SRC WORKFILES(:F0:_:F0:)


            $PAGEWIDTH(80)
            /*************************************************************
            **                                                          **
            **                  SPEECH SYNTHESIS SYSTEM                 **
            **                       MAIN MODULE                        **
            **                                                          **
            **  FILE NAME    : ANALPC.SRC              DATE             **
            **  MODULE DEF   : Calls LPC Analysis ---------             **
            **  AUTHOR       : Onder Bicioglu      22 06 85             **
            **                                                          **
            *************************************************************/
 1          MAIN: DO;

 2   1      DISPLAY$MESSAGE: PROCEDURE(POINTER) EXTERNAL;
 3   2        DECLARE POINTER ADDRESS;
 4   2        END DISPLAY$MESSAGE;
 5   1      PRINT$MESSAGE: PROCEDURE(POINTER) EXTERNAL;
 6   2        DECLARE POINTER ADDRESS;
 7   2        END PRINT$MESSAGE;
 8   1      PRINT$NUMBER: PROCEDURE(NO) EXTERNAL;
 9   2        DECLARE NO BYTE;
10   2        END PRINT$NUMBER;
11   1      PRINT$BLOCK: PROCEDURE(POINTER,MCOUNT) EXTERNAL;
12   2        DECLARE (POINTER,MCOUNT) ADDRESS;
13   2        END PRINT$BLOCK;
14   1      PRINT: PROCEDURE(POINTER) EXTERNAL;
15   2        DECLARE POINTER ADDRESS;
16   2        END PRINT;
17   1      GET$CHARACTERS: PROCEDURE EXTERNAL;
18   2        END GET$CHARACTERS;
19   1      FBDIV: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
20   2        DECLARE (OP1,OP2,OP3) ADDRESS;
21   2        END FBDIV;
22   1      ANALYSER: PROCEDURE EXTERNAL;
23   2        END ANALYSER;
24   1      INVERT: PROCEDURE EXTERNAL;
25   2        END INVERT;
26   1      SIFT: PROCEDURE EXTERNAL;
27   2        END SIFT;
28   1      CI: PROCEDURE BYTE EXTERNAL;
29   2        END CI;
30   1      LO: PROCEDURE(MES) EXTERNAL;
31   2        DECLARE MES BYTE;
32   2        END LO;
33   1      EXIT: PROCEDURE EXTERNAL;
34   2        END EXIT;
35   1      IOSET: PROCEDURE(MASK) EXTERNAL;
36   2        DECLARE MASK BYTE;
37   2        END IOSET;
38   1      OPEN:
            PROCEDURE(AFT,FILE,ACCESS,MODE,STATUS) EXTERNAL;
```

```
   2          DECLARE (AFT,FILE,ACCESS,MODE,STATUS) ADDRESS;
   2        END OPEN;
   1        READ:
              PROCEDURE(AFT,BUF,CNT,ACT,STATUS) EXTERNAL;
   2          DECLARE(AFT,BUF,CNT,ACT,STATUS) ADDRESS;
   2        END READ;
   1        WRITE:
              PROCEDURE(AFT,BUF,CNT,STATUS) EXTERNAL;
   2          DECLARE(AFT,BUF,CNT,STATUS) ADDRESS;
   2        END WRITE;
   1        CLOSE:
              PROCEDURE(AFT,STATUS) EXTERNAL;
   2          DECLARE (AFT,STATUS) ADDRESS;
   2        END CLOSE;
   1        DECLARE FILE(20) BYTE PUBLIC;
   1        DECLARE FPOINTER ADDRESS PUBLIC;
   1        DECLARE BUFFER(1) BYTE EXTERNAL;
   1        DECLARE R(1) STRUCTURE(
                    RDIGIT(4) BYTE) EXTERNAL;
   1        DECLARE EN(1) STRUCTURE(
                    NDIGIT(4) BYTE) EXTERNAL;
   1        DECLARE K(1) STRUCTURE(
                    KDIGIT(4) BYTE) EXTERNAL;

   1        DECLARE NSAMPLE ADDRESS EXTERNAL;
   1        DECLARE SAMPLE(1) BYTE EXTERNAL;
   1        DECLARE (ORDER,PITCH,OVER$FLOW$FLAG,ENERGY)
                    BYTE EXTERNAL;

   1        DECLARE (I,J,L) ADDRESS;
   1        DECLARE (M,N,STATUS,NFRAME,COUNT) ADDRESS;
   1        DECLARE (LPC$POINTER,RAM$POINTER) ADDRESS;
   1        DECLARE RAM BASED RAM$POINTER BYTE;
   1        DECLARE LPC BASED LPC$POINTER BYTE;
   1        DECLARE C(2) ADDRESS;

   1        DECLARE F(*) BYTE DATA(
              0,0,200,0);

   1        DECLARE ASK$SPEECH$FILE(*) BYTE DATA(0AH,0DH,
              'File name of speech data :',0AH,0DH,00);
   1        DECLARE ERROR(*) BYTE DATA(
              'Error',0AH,0DH,00);
   1        DECLARE ASK$PRINTER(*) BYTE DATA(
              'Do You want to take print-out?',0AH,0DH,00);
   1        DECLARE ASK$LPC$FILE(*) BYTE DATA(0AH,0DH,
              'File name for LPC coefficients :',0AH,0DH,00);

   1        DECLARE HEADING(*) BYTE DATA(0AH,0DH,
              'Frame ------------Auto-corr',
              'elations--------------- ',
              'RMS   R   P    k1   k2   k3   k4   k5   k6',
              '   k7   k8   k9   k10 Error  Energy',0AH,0DH,00);

            /*****************************************************
            *  PROCEDURE : PLACE
            *  FUNCTION  : Places data to LPC data buffer
```

```
                *  PLM CALL   : CALL PLACE(.POINTER);
                *  INPUT      : POINTER = Address of first entry
                *  OUTPUT     : transfer operation
                *  GLOBALS    : LPC$POINTER
                *  CALLS      : none
                */
1   1           PLACE: PROCEDURE(LPC$DATA) PUBLIC;
2   2             DECLARE LPC$DATA BYTE;

3   2             LPC = LPC$DATA;
4   2             LPC$POINTER = LPC$POINTER + 1;
5   2             COUNT = COUNT + 1;

6   2           END PLACE;
                /*********************************************************/

7   1           DECLARE BEGIN LABEL PUBLIC;
8   1           BEGIN:
                NSAMPLE = 200;
9   1           CALL DISPLAY$MESSAGE(.ASK$PRINTER(0));
10  1           IF (CI AND 7FH) = 'Y' THEN
11  1             CALL IOSET(81H);
                ELSE
12  1             CALL IOSET(41H);

13  1           CALL DISPLAY$MESSAGE(.ASK$SPEECH$FILE(0));
14  1           CALL GETCHARACTERS;
15  1           CALL OPEN(.M,.BUFFER(0),1,0,.STATUS);
16  1           IF STATUS <> 0 THEN
17  1           DO;
18  2             CALL DISPLAY$MESSAGE(.ERROR(0));
19  2             GO TO BEGIN;
20  2           END;
21  1           ELSE DO;
22  2             CALL READ(M,6000H,6000H,.C(1),.STATUS);
23  2             CALL CLOSE(M,.STATUS);
24  2           END;
25  1           CALL FBDIV(.C(0),.F(0),.C(0));
26  1           NFRAME = C(1);

27  1           RAM$POINTER=6000H;
28  1           LPC$POINTER=6000H;

29  1           CALL DISPLAY$MESSAGE(.ASK$LPC$FILE(0));
30  1           CALL GET$CHARACTERS;
31  1           CALL OPEN(.M,.BUFFER(0),2,0,.STATUS);

32  1           COUNT = 0;
33  1           C(1) = 0;

34  1           DO N = 1 TO 10;
35  2             DO I = 0 TO 3;
36  3               K(N).KDIGIT(I) = 0;
37  3             END;
38  2           END;

39  1           DO N=1 TO NFRAME-2;
```

```
0   2         IF C(1) = 0 THEN
1   2         DO;
2   3           CALL LO(0CH); /*--Form Feed--*/
3   3           CALL PRINT$MESSAGE(.HEADING(0));
4   3         END;
5   2         DO I=0 TO 399;
6   3           SAMPLE(I)=RAM;
7   3           RAM$POINTER = RAM$POINTER+1;
8   3         END;
9   2         RAM$POINTER = RAM$POINTER - 200;

:0  2         CALL LO(' ');
:1  2         CALL PRINT$NUMBER(N);
:2  2         CALL LO(' ');

:3  2         CALL SIFT;
:4  2         CALL LO(' ');
:5  2         IF ENERGY = 0 THEN
:6  2           FILE(0) = 0;
:7  2         ELSE DO;
:8  3           CALL ANALYSER;
:9  3           CALL INVERT;
30  3         END;

31  2         DO I = 0 TO 12;
32  3           CALL PRINT$NUMBER(FILE(I));
33  3           CALL PLACE(FILE(I));
34  3           CALL LO(' ');
35  3         END;

36  2         DO I = 0 TO 1;
37  3           CALL PLACE(EN(1).NDIGIT(I));
38  3           CALL PRINT$NUMBER(EN(1).NDIGIT(I));
39  3         END;
40  2         CALL LO(' ');
41  2         DO I = 0 TO 2;
42  3           CALL PLACE(R(0).RDIGIT(I));
43  3           CALL PRINT$NUMBER(R(0).RDIGIT(I));
44  3         END;
45  2         IF OVER$FLOW$FLAG = OFFH THEN
46  2           CALL LO('*');
47  2         CALL LO(0AH);
48  2         CALL LO(0DH);
49  2         C(1) = C(1) + 1;
50  2         IF C(1) = 60 THEN C(1) = 0;
52  2       END;
53  1       CALL WRITE(M,6000H,COUNT,.STATUS);
54  1       CALL CLOSE(M,.STATUS);

55  1       CALL EXIT;

56  1       END MAIN;


ULE INFORMATION:
```

```
CODE AREA SIZE      = 03AFH     943D
VARIABLE AREA SIZE  = 002FH      47D
MAXIMUM STACK SIZE  = 0008H       8D
217 LINES READ
0 PROGRAM ERROR(S)

OF PL/M-80 COMPILATION
```

```
S-II PL/M-80 V3.0 COMPILATION OF MODULE ALAW
ECT MODULE PLACED IN :F1:ALAW.OBJ
PILER INVOKED BY:  PLM80 :F1:ALAW.SRC WORKFILES(:F0:, :F0:)


          $PAGEWIDTH(80)
          /*************************************************************
          **                                                          **
          **                SPEECH SYNTHESIS SYSTEM                   **
          **                   A LAW CONVERSION                       **
          **                                                          **
          **  FILE NAME    : ALAW.SRC                 DATE           **
          **  MODULE DEF   : Decode Tables          ---------        **
          **  AUTHOR       : Onder Bicioglu         22 06 85         **
          **                                                          **
          *************************************************************/
1         ALAW: DO;

2   1     DECLARE SIGNAL(1) STRUCTURE(
                  SBYTE1    BYTE,
                  SADDRESS  ADDRESS,
                  SBYTE2    BYTE) EXTERNAL;

3   1     DECLARE SAMPLE(400) BYTE PUBLIC;
4   1     DECLARE NSAMPLE ADDRESS EXTERNAL;
5   1     DECLARE I ADDRESS;
6   1     DECLARE J BYTE;

          /*************************************************************
          *  PROCEDURE : A$LAW$EXPANSION
          *  FUNCTION  : Establishes conversion of A-law
          *              companded data to linear data:
          *  PLM CALL  : CALL ALAW;
          *  INPUT     : SAMPLE = Companded data
          *  OUTPUT    : SIGNAL.SDIGIT = Expanded data
          *  GLOBALS   : SIGNAL, SAMPLE
          *  CALLS     : none
          *
          I-------------------------------------------------I
          I encoded data      I         decoded data          I
          I-------------------I-------------------------------I
          I   0 0 0 w x y z   I   0 0 0 0 0 0 0 w x y z 1    I
          I-------------------I-------------------------------I
          I   0 0 1 w x y z   I   0 0 0 0 0 0 1 w x y z 1    I
          I-------------------I-------------------------------I
          I   0 1 0 w x y z   I   0 0 0 0 0 1 w x y z 1 0    I
          I-------------------I-------------------------------I
          I   0 1 1 w x y z   I   0 0 0 0 1 w x y z 1 0 0    I
          I-------------------I-------------------------------I
          I   1 0 0 w x y z   I   0 0 0 1 w x y z 1 0 0 0    I
          I-------------------I-------------------------------I
          I   1 0 1 w x y z   I   0 0 1 w x y z 1 0 0 0 0    I
          I-------------------I-------------------------------I
          I   1 1 0 w x y z   I   0 1 w x y z 1 0 0 0 0 0    I
          I-------------------I-------------------------------I
          I   1 1 1 w x y z   I   1 w x y z 1 0 0 0 0 0 0    I
```

```
                I-------------------I-------------------------------I
                */
7    1          A$LAW$EXPANSION: PROCEDURE PUBLIC;

8    2          DO I=0 TO 399;
9    3            J = SHR(SAMPLE(I),4) AND 7;
0    3            SIGNAL(I).SBYTE1 = 0;
1    3            SIGNAL(I).SBYTE2 = 0;
2    3            SIGNAL(I).SADDRESS = SAMPLE(I) AND 0FH;
3    3            SIGNAL(I).SADDRESS = SHL(SIGNAL(I).SADDRESS,1) OR 1;
4    3            IF J <> 0 THEN
5    3              SIGNAL(I).SADDRESS = SIGNAL(I).SADDRESS OR 20H;
6    3            IF J > 1 THEN
7    3              SIGNAL(I).SADDRESS = SHL(SIGNAL(I).SADDRESS,J-1);
8    3            IF (SAMPLE(I) AND 80H) <> 0 THEN DO;
0    4              SIGNAL(I).SADDRESS = NOT SIGNAL(I).SADDRESS;
1    4              SIGNAL(I).SBYTE2 = 0FFH;
2    4            END;
3    3          END;

4    2          END A$LAW$EXPANSION;

                /*************************************************
                *  PROCEDURE : A$LAW$COMPANSION
                *  FUNCTION  : Converts calculated 32-bit linear data
                *              to A-law companded form
                *  PLM CALL  : CALL A$LAW$COMPANSION;
                *  INPUT     : SIGNAL.SDIGIT = 32 bit data
                *  OUTPUT    : SAMPLE = 8 bit companded data
                *  GLOBALS   : SIGNAL,SAMPLE
                *  CALLS     : none
                I-------------------------------------------------I
                I encoded data     I        decoded data          I
                I------------------I------------------------------I
                I   0 0 0 w x y z  I  0 0 0 0 0 0 0 w x y z a    I
                I------------------I------------------------------I
                I   0 0 1 w x y z  I  0 0 0 0 0 0 1 w x y z a    I
                I------------------I------------------------------I
                I   0 1 0 w x y z  I  0 0 0 0 0 1 w x y z a b    I
                I------------------I------------------------------I
                I   0 1 1 w x y z  I  0 0 0 0 1 w x y z a b c    I
                I------------------I------------------------------I
                I   1 0 0 w x y z  I  0 0 0 1 w x y z a b c d    I
                I------------------I------------------------------I
                I   1 0 1 w x y z  I  0 0 1 w x y z a b c d e    I
                I------------------I------------------------------I
                I   1 1 0 w x y z  I  0 1 w x y z a b c d e f    I
                I------------------I------------------------------I
                I   1 1 1 w x y z  I  1 w x y z a b c d e f g    I
                I------------------I------------------------------I
                */
25   1          A$LAW$COMPANSION: PROCEDURE PUBLIC;

26   2          DECLARE (DUMMY,MASK) ADDRESS;
27   2          DO I = 0 TO NSAMPLE - 1;
28   3            DUMMY = SIGNAL(I).SADDRESS;
29   3            IF (SIGNAL(I).SBYTE2 AND 80H) = 0 THEN
```

```
3             SAMPLE(I) = 0;
3           ELSE DO ;
4             SAMPLE(I) = 80H;
4             DUMMY = NOT DUMMY;
4           END;
3           MASK = 800H;
3           DO J = 0 TO 6;
4             IF (MASK AND DUMMY) <> 0 THEN GO TO OKEY;
4             MASK = SHR(MASK,1);
4           END;
3           DUMMY = SHR(DUMMY,1);
3         OKEY:
            J = NOT(J) AND 7;
3           IF J <> 0 THEN
3             DUMMY = SHR(DUMMY,J) AND OFH;
3           SAMPLE(I) = SAMPLE(I) OR SHL(J,4) OR LOW(DUMMY);
3         END;

2         END A$LAW$COMPANSION;

1         END ALAW;
```

```
ULE INFORMATION:

 CODE AREA SIZE      = 01E2H    482D
 VARIABLE AREA SIZE  = 0197H    407D
 MAXIMUM STACK SIZE  = 0004H      4D
 130 LINES READ
 0 PROGRAM ERROR(S)

OF PL/M-80 COMPILATION
```

```
-II PL/M-80 V3.0 COMPILATION OF MODULE ANALYSIS
CT MODULE PLACED IN :F1:ANALGR.OBJ
ILER INVOKED BY:  PLM80 :F1:ANALGR.SRC WORKFILES(:F0:, :F0:)


            $PAGEWIDTH(80)
            /*************************************************************
            **                                                          **
            **         SPEECH SYNTHESIS SYSTEM                          **
            **        REFLECTION COEFFICIENT ANALYSIS                   **
            **        USING GUEGUEN LE-RUEX ALGORITHM                   **
            **                                                          **
            **  FILE NAME    : ANALGR.SRC            DATE              **
            **  MODULE DEF   : Analysees speech     ----------         **
            **  AUTHOR       : Onder Bicioglu      22 06 85            **
            **                                                          **
            *************************************************************/
1           ANALYSIS: DO;

2   1       DECLARE EP(17) STRUCTURE(
                    PWORD(2) ADDRESS) PUBLIC;
3   1       DECLARE R(25) STRUCTURE(
                    RWORD(2) ADDRESS) PUBLIC;
4   1       DECLARE EN(17) STRUCTURE(
                    NWORD(2) ADDRESS) PUBLIC;
5   1       DECLARE K(17) STRUCTURE(
                    KDIGIT(4) BYTE) PUBLIC;
6   1       DECLARE SIGNAL(400) STRUCTURE(
                    SDIGIT(4) BYTE) PUBLIC;
7   1       DECLARE W(1) STRUCTURE(
                    WDIGIT(4) BYTE) EXTERNAL;
8   1       DECLARE SAMPLE(1) BYTE EXTERNAL;

9   1       DECLARE (PITCH,ORDER) BYTE EXTERNAL;
0   1       DECLARE NSAMPLE ADDRESS PUBLIC;
1   1       DECLARE E(4) BYTE PUBLIC;
2   1       DECLARE EDUMMY(4) BYTE PUBLIC;
3   1       DECLARE BDUMMY(4) BYTE PUBLIC;
4   1       DECLARE TEMP(2) ADDRESS PUBLIC;
5   1       DECLARE OVER$FLOW$FLAG BYTE PUBLIC;

6   1       DECLARE (M,N,I,J) ADDRESS;
7   1       DECLARE ZERO(*) BYTE DATA(0,0,0,0);

8   1       FBADD: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
9   2         DECLARE (OP1,OP2,OP3) ADDRESS;
0   2         END FBADD;
1   1       FBSUB: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
2   2         DECLARE (OP1,OP2,OP3) ADDRESS;
3   2         END FBSUB;
4   1       FBDIV: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
5   2         DECLARE (OP1,OP2,OP3) ADDRESS;
6   2         END FBDIV;
7   1       FBMUL: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
8   2         DECLARE (OP1,OP2,OP3) ADDRESS;
9   2         END FBMUL;
```

```
0   1       A$LAW$EXPANSION: PROCEDURE EXTERNAL;
1   2         END A$LAW$EXPANSION;

          /*******************************************************
          *   PROCEDURE : GUEGUEN$LE$RUEX
          *   FUNCTION  : Analysis using Gueguen Le-Ruex
          *               algorithm
          *   PLM CALL  : CALL GUEGUEN$LE$RUEX;
          *   INPUT     : PITCH =pitch period
          *               SAMPLE = 8-bit samples
          *   OUTPUT    : K=reflection coefficients
          *   GLOBALS   : K, R, ORDER, NSAMPLE, SIGNAL
          *   CALLS     : FBMUL, FBDIV, FBADD, A$LAW$EXPANSION
          */
2   1     GUEGUEN$LE$RUEX: PROCEDURE PUBLIC;

          /*------------INITIALIZATION---------------------- */

3   2       DO M = 1 TO 10;
4   3         DO J = 0 TO 1;
5   4           EP(M).PWORD(J) = R(M).RWORD(J);
6   4           EN(M).NWORD(J) = R(M-1).RWORD(J);
7   4         END;
8   3       END;
9   2       OVERFLOW$FLAG = 0;

          /*------- G U E G U E N  L E - R U E X -------------*/

0   2       DO I = 0 TO 9;

          /*-- K(I) = - (EP(I+1) / EN(1))----------------- */

1   3         CALL FBDIV(.EP(I+1).PWORD(0),.EN(1).NWORD(0),
                       .EDUMMY(0));

          /*-------------RANGE CHECK-------------------------------*/

2   3         IF (EDUMMY(2) ) 0) AND (EDUMMY(2) ( OFFH)
            THEN DO;
4   4           OVER$FLOW$FLAG = OFFH;
5   4           RETURN;
6   4         END;

          /*-----------------------------------------------------*/

7   3         CALL FBSUB(.EDUMMY(0),.ZERO(0),
                       .K(I+1).KDIGIT(0));
8   3         CALL FBMUL(.K(I+1).KDIGIT(0),.EP(I+1).PWORD(0),
                       .EDUMMY(0));
9   3         CALL FBADD(.EN(1).NWORD(0),.EDUMMY(0),
                       .EN(1).NWORD(0));
0   3         CALL FBMUL(.EN(10-I).NWORD(0),.K(I+1).KDIGIT(0),
                       .EDUMMY(0));
1   3         CALL FBADD(.EP(10).PWORD(0),.EDUMMY(0),
                       .EP(10).PWORD(0));

2   3         IF I = 9 THEN
```

```
3   3             RETURN;

4   3           DO M = I+2 TO 9;
5   4             CALL FBMUL(.K(I+1).KDIGIT(0),.EN(M-I).NWORD(0),
                          .EDUMMY(0));
6   4             CALL FBADD(.EDUMMY(0),.EP(M).PWORD(0),
                          .E(0));
7   4             CALL FBMUL(.EP(M).PWORD(0),.K(I+1).KDIGIT(0),
                          .EDUMMY(0));
8   4             CALL FBADD(.EDUMMY(0),.EN(M-I).NWORD(0),
                          .EN(M-I).NWORD(0));
9   4             CALL FBADD(.E(0),.ZERO(0),.EP(M).PWORD(0));
0   4           END;
1   3         END;

2   2       END GUEGUEN$LE$RUEX;
        /*******************************************************
        *   PROCEDURE : ANALYSER
        *   FUNCTION  : Analyses the signal and creates
        *               reflection coefficients using auto-
        *               correlation method and
        *               GUEGUEN LE-RUEX algorithm
        *   PLM CALL  : CALL ANALYSER;
        *   INPUT     : ORDER = order of the prediction
        *               NSAMPLE = number of samples to be used
        *   OUTPUT    : K(I).KDIGIT(J) = reflection coefficients
        *               OVERFLOW$FLAG = OFFH if any of the k's
        *                               exceeds 1 in magnitude
        *   GLOBALS   : SIGNAL structure
        *   CALLS     : FBMUL,FBDIV,FBADD,FBSUB,GUEGUEN$LE$RUEX
        */
3   1       ANALYSER: PROCEDURE PUBLIC;

4   2       CALL A$LAW$EXPANSION;

        /*------------------W I N D O W I N G -----------------*/

5   2         DO I = 0 TO SHR(NSAMPLE,1)-1;
6   3           CALL FBMUL(.SIGNAL(I).SDIGIT(0),.W(I).WDIGIT(0),
                          .SIGNAL(I).SDIGIT(0));
7   3           CALL FBMUL(.SIGNAL(NSAMPLE-1-I).SDIGIT(0),.W(I).WDIGIT(0),
                          .SIGNAL(NSAMPLE-1-I).SDIGIT(0));
8   3         END;

        /*------C A L C U L A T I O N  O F  R ( I )-----------*/

9   2         DO I = 0 TO 10;
0   3           DO J = 0 TO 1;
1   4             R(I).RWORD(J) = 0;
2   4           END;
3   3           DO M = 0 TO NSAMPLE-1-I;
4   4             CALL FBMUL(.SIGNAL(M).SDIGIT(0),
                          .SIGNAL(M+I).SDIGIT(0),.TEMP(0));
5   4             CALL FBADD(.TEMP(0),.R(I).RWORD(0),
                          .R(I).RWORD(0));
6   4           END;
7   3         END;
```

```
   2          CALL GUEGUEN$LE$RUEX;

   2        END ANALYSER;

   1        END ANALYSIS;
```

LE INFORMATION:

```
 CODE AREA SIZE      = 0335H    821D
 VARIABLE AREA SIZE = 078BH   1931D
 MAXIMUM STACK SIZE = 0008H      8D
 171 LINES READ
 0 PROGRAM ERROR(S)
```

OF PL/M-80 COMPILATION

```
S-II PL/M-80 V3.0 COMPILATION OF MODULE ENCODE
ECT MODULE PLACED IN :F1:ENCODE.OBJ
PILER INVOKED BY:  PLM80 :F1:ENCODE.SRC WORKFILES(:F0:, :F0:)

        $PAGEWIDTH(80)
        /*********************************************************
        **                                                      **
        **              SPEECH SYNTHESIS SYSTEM                 **
        **                  ENCODING MODULE                     **
        **                                                      **
        **  FILE NAME   : ENCODE.SRC            DATE            **
        **  MODULE DEF  : Encode Tables       ---------         **
        **  AUTHOR      : Onder Bicioglu      22 06 85          **
        **                                                      **
        *********************************************************/
1       ENCODE: DO;

2   1   DECLARE P(*) BYTE DATA(0,
          25,27,28,30,31,32,34,35,
          36,37,38,40,42,44,46,48,
          50,52,54,56,58,61,63,66,
          70,75,80,85,90,95,100);

3   1   DECLARE RMS(*) ADDRESS DATA(0,52,87,123,
        174,246,348,491,694,981,1385,1957,
        2764,3904,5514,7789);

4   1   DECLARE T1(32) ADDRESS EXTERNAL ;
5   1   DECLARE T2(32) ADDRESS EXTERNAL ;
6   1   DECLARE T3(16) ADDRESS EXTERNAL ;
7   1   DECLARE T4(16) ADDRESS EXTERNAL ;
8   1   DECLARE T5(16) ADDRESS EXTERNAL ;
9   1   DECLARE T6(16) ADDRESS EXTERNAL ;
10  1   DECLARE T7(16) ADDRESS EXTERNAL ;
11  1   DECLARE T8(8) ADDRESS EXTERNAL ;
12  1   DECLARE T9(8) ADDRESS EXTERNAL ;
13  1   DECLARE T10(8) ADDRESS EXTERNAL ;

14  1   DECLARE SIZE(*) BYTE DATA(0,31,31,15,15,
        15,15,15,7,7,7);

15  1   DECLARE BEGIN(*) ADDRESS DATA(0,0,64,128,160,192,
        224,256,288,304,320,336);

16  1   DECLARE FACTOR(*) ADDRESS DATA(0,512);
17  1   DECLARE ENERGY$FACTOR(*) ADDRESS DATA(0,128);

18  1   DECLARE K(1) STRUCTURE(
                 KWORD(2) ADDRESS) EXTERNAL;
19  1   DECLARE R(1) STRUCTURE(
                 R1     BYTE,
                 R23    ADDRESS,
                 R4     BYTE) EXTERNAL;

20  1   DECLARE EN(1) STRUCTURE(
```

```
                NWORD(2)  ADDRESS) EXTERNAL;

  1       DECLARE (I,J) BYTE;
  1       DECLARE ORDER BYTE EXTERNAL;
  1       DECLARE PITCH BYTE EXTERNAL;
  1       DECLARE FILE(1) BYTE EXTERNAL;
  1       DECLARE FPOINTER ADDRESS EXTERNAL;
  1       DECLARE NORM(2) ADDRESS;

  1       FBDIV: PROCEDURE(01,02,03) EXTERNAL;
  2         DECLARE (01,02,03) ADDRESS;
  2         END FBDIV;

  1       FBMUL: PROCEDURE(01,02,03) EXTERNAL;
  2         DECLARE (01,02,03) ADDRESS;
  2         END FBMUL;

          /*******************************************************
          *  PROCEDURE : INVERT
          *  FUNCTION  : Inverts 32-bit reflection coefficients
          *              to encoded format for TMS
          *  PLM CALL  : CALL INVERT;
          *  INPUT     : K = 32-bit reflection coefficients
          *              PITCH = pitch period
          *              U = Energy
          *  OUTPUT    : FILE = Inverted parameters
          *  GLOBALS   : E,K,FILE,PITCH
          *  CALLS     : FBMUL,FBDIV
          */

  1       INVERT: PROCEDURE PUBLIC;

  2       DECLARE POINTER ADDRESS;
  2       DECLARE TABLE BASED POINTER ADDRESS;

  2       CALL FBDIV(.EN(1).NWORD(0),.ENERGY$FACTOR(0),
                     .EN(1).NWORD(0));
  2       DO I = 0 TO 14;
  3         IF EN(1).NWORD(0) < RMS(I) THEN GO TO RMS$FOUND;
  3       END;
  2       I = 14;
  2       RMS$FOUND:
          FILE(0) = I;
  2       FILE(1) = 0;

  2       DO I = 0 TO 31;
  3         IF PITCH < P(I) THEN
  3           GO TO PITCH$FOUND;
  3       END;
  2       PITCH$FOUND:
            FILE(2) = I - 1;

  2       DO I = 1 TO 10;
  3         POINTER = .T1(0) + BEGIN(I);
  3         CALL FBMUL(.K(I).KWORD(0),.FACTOR(0),.NORM(0));
  3         J = 0;
  3         DO WHILE 1;
```

```
4            IF NORM(1) ) 8000H THEN
             /*------k(i) is negative------*/
4            DO:
5              IF TABLE ( 8000H THEN GO TO FOUND;
               /*--------table is positive------*/
5              IF NORM(i) ( TABLE THEN GO TO FOUND;
               /*--------table is negative ------------*/
               /*--------and greater than k(i)----------*/
5            END;
4            ELSE DO;
               /*---------k(i) is positive-------------*/
5              IF TABLE ( 8000H THEN
               /*---------table is positive-------------*/
5              DO:
6                IF TABLE ) NORM(i) THEN
                 /*-------table is greater than k(i)----*/
6                  GO TO FOUND;
6              END;
5            END;
4            IF J = SIZE(I) THEN GO TO FOUND;
4            J = J +1;
4            POINTER = POINTER + 2;
4          END;
3          FOUND:
             FILE(I+2) = J;
3        END;

2        END INVERT;

1        END ENCODE;
```

ULE INFORMATION:

```
  CODE AREA SIZE      = 019DH    413D
  VARIABLE AREA SIZE  = 0008H      8D
  MAXIMUM STACK SIZE  = 0004H      4D
  138 LINES READ
  0 PROGRAM ERROR(S)
```

OF PL/M-80 COMPILATION

```
OBJ             LINE        SOURCE STATEMENT

                    1 $PAGEWIDTH(80)
                    2 ;*****************************************************
                    3 ;*                                                   **
                    4 ;*                SPEECH SYNTHESIS SYSTEM            **
                    5 ;*                 TMS CONVERSION TABLES             **
                    6 ;*                                                   **
                    7 ;*  FILE NAME    : DCDTBL.SRC           DATE         **
                    8 ;*  MODULE DEF   : K-conversion table ----------     **
                    9 ;*  AUTHOR       : Onder Bicioglu      22 06 85     **
                   10 ;*                                                   **
                   11 ;*****************************************************/
                   12 ;
                   13          NAME    DCDTBL
                   14 ;
                   15          PUBLIC  T1,T2,T3,T4
                   16          PUBLIC  T5,T6,T7,T8
                   17          PUBLIC  T9,T10
                   18 ;
                   19          CSEG
                   20 ;
0BFE               21 T1:      DW      -501,-498,-497,-495
0EFF
0FFE
11FE
13FE               22          DW      -493,-491,-488,-482,-478,-474,-469,-464
15FE
18FE
1EFE
22FF
26FE
28FE
30FE
35FE               23          DW      -459,-452,-445,-437,-412,-380,-339,-288
3CFE
43FE
4BFE
64FE
84FE
ADFE
E0FE
1DFF               24          DW      -227,-158,-81,-1,80,157,226,287
62FF
9FFF
FFFF
5000
9D00
E200
1F01
5101               25          DW      337,379,411,436
7B01
9501
B401
                   26 ;
B8FE               27 T2:      DW      -328,-303,-274,-244
```

```
)C  OBJ          LINE      SOURCE STATEMENT

)42 D1FE
)44 EEFE
)46 0CFF
)48 2DFF           28        DW      -211,-175,-138,-99,-59,-18,24,64
)4A 51FF
)4C 76FF
)4E 9DFF
)50 C5FF
)52 EEFF
)54 1800
)56 4000
)58 6900           29        DW      105,143,180,215,248,278,306,331
)5A 8F00
)5C B400
)5E D700
)60 F800
)62 1601
)64 3201
)66 4B01
)68 6201           30        DW      354,374,392,408,422,435,445,455
)6A 7601
)6C 8801
)6E 9801
)70 A601
)72 B301
)74 BD01
)76 C701
)78 CF01           31        DW      463,470,476,506
)7A D601
)7C DC01
)7E FA01
                   32 ;
)80 47FE           33 T3:    DW      -441,-387,-333,-279
)82 7DFE
)84 B3FE
)86 E9FE
)88 1FFF           34        DW      -225,-171,-117,-63,-9,45,98,152
)8A 55FF
)8C 8BFF
)8E C1FF
)90 F7FF
)92 2D00
)94 6200
)96 9800
)98 CE00           35        DW      206,260,314,368
)9A 0401
)9C 3A01
)9E 7001
                   36 ;
)A0 B8FE           37 T4:    DW      -328,-273,-217,-161
)A2 EFFE
)A4 27FF
)A6 5FFF
)A8 96FF           38        DW      -106,-50,5,61,116,172,228,283
)AA CEFF
```

```
C  OBJ          LINE        SOURCE STATEMENT

AC 0500
AE 3D00
B0 7400
B2 AC00
B4 E400
B6 1B01
B8 5301          39          DW      339,394,450,506
BA 8A01
BC C201
BE FA01
                 40 ;
C0 B8FE          41 T5:      DW      -328,-282,-235,-189
C2 E6FF
C4 15FF
C6 43FF
C8 72FF          42          DW      -142,-96,-50,-3,43,90,136,182
CA A0FF
CC CEFF
CE FDFF
D0 2B00
D2 5A00
D4 8800
D6 B600
D8 E500          43          DW      229,275,322,368
DA 1301
DC 4201
DE 7001
                 44 ;
E0 00FF          45 T6:      DW      -256,-212,-168,-123
E2 2CFF
E4 58FF
E6 85FF
E8 B1FF          46          DW      -79,-35,10,54,98,143,187,232
EA DDFF
EC 0A00
EE 3600
F0 6200
F2 8F00
F4 BB00
F6 E800
F8 1401          47          DW      276,320,365,408
FA 4001
FC 6D01
FE 9801
                 48 ;
100 CCFE         49 T7:      DW      -308,-260,-212,-164
102 FCFE
104 2CFF
106 5CFF
108 8BFF         50          DW      -117,-69,-21,27,75,122,170,218
10A BBFF
10C EBFF
10E 1B00
110 4B00
112 7A00
```

```
:  OBJ          LINE        SOURCE STATEMENT

14 AA00
16 DA00
18 0A01            51          DW      266,314,361,40
1A 3A01
1C 6901
1E 2800
                   52 ;
20 00FF            53 T8:      DW      -256,-161,-66,29
22 5FFF
24 BEFF
26 1D00
28 7C00            54          DW      124,219,314,409
2A DB00
2C 3A01
2E 9901
                   55 ;
30 00FF            56 T9:      DW      -256,-176,-96,-15
32 50FF
34 A0FF
36 F1FF
38 4100            57          DW      65,146,226,307
3A 9200
3C E200
3E 3301
                   58 ;
40 33FF            59 T10:     DW      -205,-132,-59,14
42 7CFF
44 C5FF
46 0E00
48 5700            60          DW      87,160,234,307
4A A000
4C EA00
4E 3301
                   61 ;
                   62 ;*******************************************************
                   63 ;
                   64          END

IC SYMBOLS
   C 0000    T10     C 0140    T2      C 0040    T3      C 0080
   C 00A0    T5      C 00C0    T6      C 00E0    T7      C 0100
   C 0120    T9      C 0130

RNAL SYMBOLS


 SYMBOLS
   C 0000    T10     C 0140    T2      C 0040    T3      C 0080
   C 00A0    T5      C 00C0    T6      C 00E0    T7      C 0100
   C 0120    T9      C 0130

MBLY COMPLETE,    NO ERRORS
```

```
C  OBJ          LINE        SOURCE STATEMENT

                    1 $PAGEWIDTH(80)
                    2 ;*****************************************************
                    3 ;*                                                   **
                    4 ;*              SPEECH SYNTHESIS SYSTEM              **
                    5 ;*                SAMPLER MODULE                     **
                    6 ;*                                                   **
                    7 ;*  FILE NAME   : SAMPLER.SRC          DATE          **
                    8 ;*  MODULE DEF  : Sampler              ---------     **
                    9 ;*  AUTHOR      : Onder Bicioglu     22 06 85        **
                   10 ;*                                                   **
                   11 ;*****************************************************/
                   12 ;
                   13          NAME    SAMPLR
                   14 ;
                   15          PUBLIC  RECORD,SAMPLE
                   16 ;
                   17          EXTRN   DATBUF
                   18 ;
                   19          CSEG
                   20 ;
                   21 ;*********************************************
                   22 ;
018                23 INTSER   EQU     18H
0F3                24 INTRST   EQU     0F3H
0FC                25 INTMSK   EQU     0FCH
0FD                26 LSTSTT   EQU     0FDH
0F8                27 PRTPTR   EQU     0F8H
0FA                28 STATUS   EQU     0FAH
                   29 ;
                   30 ;*****************************************************
                   31 ;  PROCEDURE : RECORD
                   32 ;  FUNCTION  : Records sampled data to RAM
                   33 ;  PLM CALL  : CALL RECORD(END);
                   34 ;  INPUT     : (BC) = end address
                   35 ;  OUTPUT    : samples
                   36 ;  GLOBALS   : DATBUF
                   37 ;  CALLS     : none
                   38 ;  DESTROYS  : all
                   39 ;
0000 F3            40 RECORD: DI
                   41 ;
0001 3E12          42          MVI     A,12H   ;Initialize interrupt levels
0003 D3FD          43          OUT     LSTSTT
                   44 ;
0005 3EF6          45          MVI     A,0F6H  ;Enable level 0 and 3
0007 D3FC          46          OUT     INTMSK  ;interrupts
                   47 ;
0009 3EC0          48          MVI     A,0C0H  ;Enable monitor interrupts
000B D3F3          49          OUT     INTRST  ;and reset printer FF
                   50 ;
000D 210000    E   51          LXI     H,DATBUF        ;Load start address
                   52                                  ;data buffer
0010 78            53          MOV     A,B     ;Load high part of end
                   54                          ;address to A register
```

```
C  OBJ          LINE        SOURCE STATEMENT

                  55 ;
11 FB             56 LOOP1:  EI
12 BC             57         CMP     H          ;Remain in loop if
13 FB             58         EI                 ;end of buffer is
14 C21100    C    59         JNZ     LOOP1      ;not reached yet
                  60 ;
17 F3             61         DI
                  62 ;
18 3E12           63         MVI     A,12H      ;initialize interrupt
1A D3FD           64         OUT     LSTSTT     ;levels
                  65 ;
1C 3EFC           66         MVI     A,0FCH     ;enable only level
1E D3FC           67         OUT     INTMSK     ;0,1,2 and 3
                  68 ;
20 3EC0           69         MVI     A,0C0H     ;Enable monitor interrupts
22 D3F3           70         OUT     INTRST
                  71 ;
24 FB             72         EI
                  73 ;
25 C9             74         RET
                  75 ;
                  76 ;*****************************************************
                  77 ;  PROCEDURE : SAMPLE
                  78 ;  FUNCTION  : takes data via paper-tape reader input
                  79 ;  PLM CALL  : none
                  80 ;  INPUT     : (HL) = current destination
                  81 ;  OUTPUT    : increments (HL) and places data to RAM
                  82 ;  GLOBALS   : none
                  83 ;  CALLS     : none
                  84 ;  DESTROYS  : HL
                  85 ;
26 F5             86 SAMPLE: PUSH    PSW        ;Starting point of interrupt
                  87                            ; service routine
27 DBFA           88 WAIT:   IN      STATUS     ;if interrupt is not the
29 E640           89         ANI     40H        ;desired one (Line Printer)
2B CA2700    C    90         JZ      WAIT       ;then wait
                  91 ;
2E 3EC0           92         MVI     A,0C0H     ;else reset printer
30 D3F3           93         OUT     INTRST     ;flip-flop
                  94 ;
32 DBF8           95         IN      PRTPTR     ;read data from
                  96                            ;paper tape reader
34 77             97         MOV     M,A        ;place it to buffer
35 23             98         INX     H          ;point to next location
36 3E20           99         MVI     A,20H      ;restore last status
38 D3F0          100         OUT     LSTSTT
3A F1            101         POP     PSW
3B C9            102         RET
                 103 ;
                 104 ;*****************************************
                 105 ;
                 106         END
```

LIC SYMBOLS

ECORD C 0000 SAMPLE C 0026

XTERNAL SYMBOLS
QTBUF E 0000

ER SYMBOLS

QTBUF	E	0000	INTMSK	A	00FC	INTRST	A	00F3	INTSER	A	0018
COP1	C	0011	LSTSTT	A	00FD	PRTPTR	A	00F8	RECORD	C	0000
MPLE	C	0026	STATUS	A	00FA	WAIT	C	0027			

SSEMBLY COMPLETE, NO ERRORS

```
8-II PL/M-80 V3.0 COMPILATION OF MODULE LISTENER
ECT MODULE PLACED IN :F1:LISTEN.OBJ
PILER INVOKED BY:  PLM80 :F1:LISTEN.SRC WORKFILES(:F0:, :F0:)


            $PAGEWIDTH(80)
            /*************************************************
            **                                              **
            **              SPEECH SYNTHESIS SYSTEM         **
            **               LISTENER MAIN MODULE           **
            **                                              **
            **  FILE NAME   : LISTEN.SRC          DATE      **
            **  MODULE DEF  : Listener            --------  **
            **  AUTHOR      : Onder Bicioglu      22 06 85  **
            **                                              **
            *************************************************/
1           LISTENER: DO;
2     1     DECLARE DATBUF(0B000H) BYTE PUBLIC;
3     1     DECLARE BUFFER(1) BYTE EXTERNAL;
4     1     DECLARE (FILE,STATUS,END$ADDRESS) ADDRESS PUBLIC;
5     1     DECLARE KEY BYTE;
6     1     DECLARE SAMPLE ADDRESS EXTERNAL;
7     1     DECLARE INT$POINTER ADDRESS;
8     1     DECLARE INT$DATA BASED INT$POINTER BYTE;
9     1       GET$CHARACTERS: PROCEDURE EXTERNAL;
10    2       END GET$CHARACTERS;
11    1     DISPLAY$MESSAGE: PROCEDURE(POINTER) EXTERNAL;
12    2       DECLARE POINTER ADDRESS;
13    2       END DISPLAY$MESSAGE;
14    1     RECORD: PROCEDURE(DATA$END) EXTERNAL;
15    2       DECLARE DATA$END ADDRESS;
16    2       END RECORD;
17    1     OPEN: PROCEDURE(OP1,OP2,OP3,OP4,OP5) EXTERNAL;
18    2       DECLARE (OP1,OP2,OP3,OP4,OP5) ADDRESS;
19    2       END OPEN;
20    1     WRITE: PROCEDURE(OP1,OP2,OP3,OP4) EXTERNAL;
21    2       DECLARE (OP1,OP2,OP3,OP4) ADDRESS;
22    2       END WRITE;
23    1     CLOSE: PROCEDURE(OP1,OP2) EXTERNAL;
24    2       DECLARE (OP1,OP2) ADDRESS;
25    2       END CLOSE;
26    1     EXIT: PROCEDURE EXTERNAL;
27    2       END EXIT;
28    1     CI: PROCEDURE BYTE EXTERNAL;
29    2       END CI;
30    1     CO: PROCEDURE(MES) EXTERNAL;
31    2       DECLARE MES BYTE;
32    2       END CO;
33    1       DECLARE ASK$SECONDS(*) BYTE DATA(0AH,0DH,
              'How many seconds?',0AH,0DH,00);
34    1       DECLARE ASK$WHICH$WORD(*) BYTE DATA(0AH,0DH,
              'Enter name of output file!',0AH,0DH,00);
35    1     DECLARE ASK$GOON(*) BYTE DATA(0AH,0DH,
              'Do You want to continue?',0AH,0DH,00);
36    1     DECLARE OFFSET(*) ADDRESS DATA(8000,8000,16000,
              24000,32000,40000,40000,40000);
```

```
1          MAIN:
          DO WHILE 1;
2           CALL DISPLAY$MESSAGE(.ASK$SECONDS(0));
2           KEY = CI AND 7FH;
2           CALL CO(KEY);
2           END$ADDRESS = .DATBUF(0)+OFFSET((KEY AND 7));
2           INT$POINTER = 18H;
2           INT$DATA = 0C3H;
2           INT$POINTER = INT$POINTER + 1;
2           INT$DATA = LOW(.SAMPLE);
2           INT$POINTER = INT$POINTER + 1;
2           INT$DATA = HIGH(.SAMPLE);
2           CALL RECORD(END$ADDRESS);
2           CALL DISPLAY$MESSAGE(.ASK$WHICH$WORD(0));
2           CALL GET$CHARACTERS;
2           CALL OPEN(.FILE,.BUFFER(0),2,0,.STATUS);
2           CALL WRITE(FILE,.DAT$BUF(0),OFFSET(KEY AND 7),
                       .STATUS);
2           CALL CLOSE(FILE,.STATUS);
2           CALL DISPLAY$MESSAGE(.ASK$GOON(0));
2           IF (CI AND 5FH) <> 'Y' THEN
2             CALL EXIT;
2         END;
1         END LISTENER;
```

```
LE INFORMATION:

 CODE AREA SIZE     = 0114H    276D
 VARIABLE AREA SIZE = B009H  45065D
 MAXIMUM STACK SIZE = 0008H      8D
 75 LINES READ
 0 PROGRAM ERROR(S)

OF PL/M-80 COMPILATION
```

```
-II PL/M-80 V3.0 COMPILATION OF MODULE MAIN
CT MODULE PLACED IN :F1:FORMAT.OBJ
ILER INVOKED BY:  PLM80 :F1:FORMAT.SRC WORKFILES(:F0:,:F0:)


        $PAGEWIDTH(80)
        /*************************************************
        **                                              **
        **            SPEECH SYNTHESIS SYSTEM           **
        **               FORMATTER MODULE               **
        **                                              **
        **  FILE NAME    : FORMAT.SRC          DATE     **
        **  MODULE DEF   : Formats LPC       ---------  **
        **                 Coefficients     25 05 1985  **
        **  AUTHOR       : Onder Bicioglu               **
        **                                              **
        *************************************************/
        MAIN: DO;

  1     DISPLAY$MESSAGE: PROCEDURE(POINTER) EXTERNAL;
  2       DECLARE POINTER ADDRESS;
  2       END DISPLAY$MESSAGE;
  1     PRINT$MESSAGE: PROCEDURE(POINTER) EXTERNAL;
  2       DECLARE POINTER ADDRESS;
  2       END PRINT$MESSAGE;
  1     GET$CHARACTERS: PROCEDURE EXTERNAL;
  2       END GET$CHARACTERS;
  1     CI: PROCEDURE BYTE EXTERNAL;
  2       END CI;
  1     LO: PROCEDURE(MES) EXTERNAL;
  2       DECLARE MES BYTE;
  2       END LO;
  1     EXIT: PROCEDURE EXTERNAL;
  2       END EXIT;
  1     IOSET: PROCEDURE(MASK) EXTERNAL;
  2       DECLARE MASK BYTE;
  2       END IOSET;
  1     OPEN:
          PROCEDURE(AFT,FILE,ACCESS,MODE,STATUS) EXTERNAL;
  2       DECLARE (AFT,FILE,ACCESS,MODE,STATUS) ADDRESS;
  2     END OPEN;
  1     READ:
          PROCEDURE(AFT,BUF,CNT,ACT,STATUS) EXTERNAL;
  2       DECLARE(AFT,BUF,CNT,ACT,STATUS) ADDRESS;
  2     END READ;
  1     WRITE:
          PROCEDURE(AFT,BUF,CNT,STATUS) EXTERNAL;
  2       DECLARE(AFT,BUF,CNT,STATUS) ADDRESS;
  2     END WRITE;
  1     CLOSE:
          PROCEDURE(AFT,STATUS) EXTERNAL;
  2       DECLARE (AFT,STATUS) ADDRESS;
  2     END CLOSE;

  1     PACK: PROCEDURE(UNPACK$ADDRESS,PACK$ADDRESS)
              ADDRESS EXTERNAL;
```

```
2          DECLARE (UNPACK$ADDRESS,PACK$ADDRESS) ADDRESS;
2          END PACK;

1        DECLARE LPC$DATA(2000H) BYTE PUBLIC;
1        DECLARE FORMAT(6000H) BYTE PUBLIC;
1        DECLARE BUFFER(1) BYTE EXTERNAL;
1        DECLARE (INDEX,READ$COUNT,COUNT) ADDRESS PUBLIC;
1        DECLARE (I,FILE,STATUS,FORMATPOINTER) ADDRESS;
1        DECLARE CHECK$SUM BYTE;

1        DECLARE ASK$LPC$FILE(*) BYTE DATA(0AH,0DH,
           'File name of LPC data :',0AH,0DH,00);
1        DECLARE ERROR(*) BYTE DATA(
           'Error',0AH,0DH,00);
1        DECLARE ASK$HEX$FILE(*) BYTE DATA(0AH,0DH,
           'File name for HEX file :',0AH,0DH,00);

         /*******************************************************
         *  PROCEDURE : PLACE
         *  FUNCTION  : Places data to LPC data buffer
         *  PLM CALL  : CALL PLACE(.POINTER);
         *  INPUT     : POINTER = Address of first entry
         *  OUTPUT    : transfer operation
         *  GLOBALS   : FORMAT$POINTER
         *  CALLS     : none
         */
1        PLACE: PROCEDURE(PACK$DATA) PUBLIC;
2          DECLARE PACK$DATA BYTE;

2          FORMAT(COUNT) = PACK$DATA;
2          FORMAT$POINTER = FORMAT$POINTER + 1;
2          COUNT = COUNT + 1;

2        END PLACE;
         /*******************************************************
         *  PROCEDURE : ENTER
         *  FUNCTION  : Enters data to FORMATDATA
         *  PLM CALL  : CALL ENTER(DATA);
         *  INPUT     : DATA = number to be entered
         *  OUTPUT    : ASCII code of corresponding to number
         *                is generated and placed to memory
         *  GLOBALS   : CHECKSUM
         *  CALLS     : PLACE
         */
1        ENTER: PROCEDURE(PACK$DATA) PUBLIC;
2          DECLARE PACK$DATA ADDRESS;

2          DECLARE CONVERTTABLE(*) BYTE DATA(
             '0','1','2','3','4','5','6','7','8','9','A',
             'B','C','D','E','F');

2          CALL PLACE(CONVERT$TABLE(SHR(PACK$DATA,4)));
2          CALL PLACE(CONVERT$TABLE(PACK$DATA AND 0FH));
2          CHECKSUM = CHECKSUM + PACK$DATA;

2        END ENTER;
```

```
                /*****************************************************/

67    1         DECLARE BEGIN LABEL PUBLIC;
68    1         BEGIN:
                CALL DISPLAY$MESSAGE(.ASK$LPC$FILE(0));
69    1         CALL GETCHARACTERS;
70    1         CALL OPEN(.FILE,.BUFFER(0),1,0,.STATUS);
71    1         IF STATUS <> 0 THEN
72    1         DO;
73    2           CALL DISPLAY$MESSAGE(.ERROR(0));
74    2           GO TO BEGIN;
75    2         END;
76    1         ELSE DO;
77    2           CALL READ(FILE,.FORMAT(0),3000H,.READ$COUNT,
                          .STATUS);
78    2           CALL CLOSE(FILE,.STATUS);
79    2         END;

70    1         CALL DISPLAY$MESSAGE(.ASK$HEX$FILE(0));
71    1         CALL GET$CHARACTERS;
72    1         CALL OPEN(.FILE,.BUFFER(0),2,0,.STATUS);

73    1         READ$COUNT = PACK(.FORMAT(0),.LPC$DATA(0)) -
                             .LPC$DATA(0);
74    1         COUNT = 0;

75    1         DO INDEX = 0 TO READCOUNT;

76    2           IF (INDEX AND 0FH) = 0 THEN
77    2           DO;
78    3              CALL PLACE (':');
79    3              CHECKSUM = 0;
80    3              CALL ENTER(10H);
81    3              CALL ENTER(HIGH(INDEX));
82    3              CALL ENTER(LOW(INDEX));
83    3              CALL ENTER(00);
84    3            END;

85    2            CALL ENTER(LPCDATA(INDEX));
86    2            IF (INDEX AND 0FH) = 0FH THEN
87    2            DO;
88    3               CALL ENTER(-CHECKSUM);
89    3               CALL PLACE(0DH);
90    3               CALL PLACE(0AH);
91    3            END;
92    2         END;

93    1         IF (READCOUNT AND 0FH) <> 0FH THEN
94    1         DO;
95    2            DO I=READ$COUNT + 1
                     TO (READ$COUNT AND 0FFF0H) +0FH;
96    3              CALL ENTER(0FFH);
97    3            END;
98    2            CALL ENTER(-CHECKSUM);
99    2            CALL PLACE(0DH);
00    2            CALL PLACE(0AH);
01    2         END;
```

```
02    1         CALL PLACE(':');
03    1         CALL ENTER(0);
04    1         CALL ENTER(0);
05    1         CALL ENTER(0);
06    1         CALL ENTER(1);
07    1         CALL ENTER(0FFH);
08    1         CALL PLACE(0DH);
09    1         CALL PLACE(0AH);
10    1         CALL WRITE(FILE,.FORMAT(0),COUNT,.STATUS);
11    1         CALL CLOSE(FILE,.STATUS);

12    1         CALL EXIT;

13    1         END MAIN;
```

ULE INFORMATION:

```
  CODE AREA SIZE     = 0268H    616D
  VARIABLE AREA SIZE = 8012H  32786D
  MAXIMUM STACK SIZE = 0008H      8D
  179 LINES READ
  0 PROGRAM ERROR(S)
```

OF PL/M-80 COMPILATION

```
OBJ             LINE        SOURCE STATEMENT

                    1 $PAGEWIDTH(80)
                    2 ;*****************************************************
                    3 ;*                                                   **
                    4 ;*            SPEECH SYNTHESIS SYSTEM                **
                    5 ;*              COEFFICIENT PACKING                  **
                    6 ;*                                                   **
                    7 ;*  FILE NAME    : PACK.SRC              DATE        **
                    8 ;*  MODULE DEF   : PACKER                ---------   **
                    9 ;*  AUTHOR       : Onder Bicioglu        22 06 85    **
                   10 ;*                                                   **
                   11 ;*****************************************************/
                   12 ;
                   13          NAME    PACKER
                   14 ;
                   15          DSEG
                   16 ;
01                 17 SETBIT:  DB      1
01                 18 VOICED:  DB      1
01                 19 SAVE:    DB      1
                   20 ;
                   21          CSEG
                   22 ;
                   23          PUBLIC  PACK
                   24 ;
                   25 ;*****************************************************
                   26 ;  PROCEDURE : PACK
                   27 ;  FUNCTION  : Packs byte values less than 8-bits
                   28 ;              converts a sequence of 3,4,5,6 bit
                   29 ;              coefficients to full bytes
                   30 ;  PLM CALL  : CALL PACK(UNPACKED$ADDRESS,PACK$ADDRESS);
                   31 ;  INPUT     : UNPACKED$ADDRESS = start address of
                   32 ;                         unpacked coefficients
                   33 ;              PACK$ADDRESS = start address of packed
                   34 ;                         coefficients
                   35 ;  OUTPUT    : packed coefficients
                   36 ;  GLOBALS   : VOICED,SETBIT
                   37 ;  CALLS     : PUT
                   38 ;  DESTROYS  : all
                   39 ;
EB                 40 PACK:    XCHG            ;(HL)=start address of
                   41                          ;packed coefficients
50                 42          MOV     D,B
59                 43          MOV     E,C     ;(DE)=start address of
                   44                          ;unpacked coefficients
3E01               45          MVI     A,01H
320000    D        46          STA     SETBIT  ;start filling bits from LSB
3600               47          MVI     M,0
                   48 ;
1B                 49          DCX     D
13                 50 ENERGY:  INX     D
1A                 51          LDAX    D
0604               52          MVI     B,4
07                 53          RLC
07                 54          RLC
```

```
LOC  OBJ            LINE        SOURCE STATEMENT

011  07              55          RLC
012  07              56          RLC
013  CD9E00    C     57          LOOP1:  CALL    PUT
016  05              58                  DCR     B
017  C21300    C     59                  JNZ     LOOP1
01A  1A              60          LDAX    D
01B  B7              61          ORA     A
01C  CA0B00    C     62          JZ      ENERGY
01F  FE0F            63          CPI     0FH
021  C8              64          RZ
                     65  ;
022  13              66  REPEAT: INX     D
023  1A              67          LDAX    D
024  0F              68          RRC
025  CD9E00    C     69          CALL    PUT
                     70  ;
028  13              71  PITCH:  INX     D
029  1A              72          LDAX    D
02A  07              73          RLC
02B  07              74          RLC
02C  07              75          RLC
02D  320100    D     76          STA     VOICED
030  0605            77          MVI     B,5
032  CD9E00    C     78          LOOP2:  CALL    PUT
035  05              79                  DCR     B
036  C23200    C     80                  JNZ     LOOP2
                     81  ;
039  1B              82          DCX     D
03A  1A              83          LDAX    D
03B  13              84          INX     D
03C  B7              85          ORA     A
03D  C20B00    C     86          JNZ     ENERGY
                     87  ;
040  0E02            88  K1K2:   MVI     C,2
042  13              89          LOOP3:  INX     D
043  1A              90                  LDAX    D
044  07              91                  RLC
045  07              92                  RLC
046  07              93                  RLC
047  0605            94                  MVI     B,5
049  CD9E00    C     95                  LOOP4:  CALL    PUT
04C  05              96                          DCR     B
04D  C24900    C     97                          JNZ     LOOP4
050  0D              98                  DCR     C
051  C24200    C     99                  JNZ     LOOP3
                    100  ;
054  0E02           101  K3K4:   MVI     C,2
056  13             102          LOOP5:  INX     D
057  1A             103                  LDAX    D
058  07             104                  RLC
059  07             105                  RLC
05A  07             106                  RLC
05B  07             107                  RLC
05C  0604           108                  MVI     B,4
05E  CD9E00    C    109                  LOOP6:  CALL    PUT
```

```
;  OBJ           LINE        SOURCE STATEMENT

;1 05            110                          DCR     B
;2 C25E00    C   111                          JNZ     LOOP6
;5 0D            112                  DCR     C
;6 C25600    C   113                  JNZ     LOOP5
                 114 ;
;9 3A0100    D   115          LDA     VOICED
;C B7            116          ORA     A
;D CA0B00    C   117          JZ      ENERGY
                 118 ;
'0 0E03          119 K5K6K7:  MVI     C,3
'2 13            120          LOOP7:  INX     D
'3 1A            121                  LDAX    D
'4 07            122                  RLC
'5 07            123                  RLC
'6 07            124                  RLC
'7 07            125                  RLC
'8 0604          126                  MVI     B,4
'A CD9E00    C   127                  LOOP8:  CALL    PUT
'D 05            128                          DCR     B
'E C27A00    C   129                          JNZ     LOOP8
31 0D            130                  DCR     C
32 C27200    C   131                  JNZ     LOOP7
                 132 ;
35 0E03          133 K8910:   MVI     C,3
37 13            134          LOOP9:  INX     D
38 1A            135                  LDAX    D
39 07            136                  RLC
3A 07            137                  RLC
3B 07            138                  RLC
3C 07            139                  RLC
3D 07            140                  RLC
3E 0603          141                  MVI     B,3
40 CD9E00    C   142                  LOOP10: CALL    PUT
43 05            143                          DCR     B
44 C29000    C   144                          JNZ     LOOP10
47 0D            145                  DCR     C
48 C28700    C   146                  JNZ     LOOP9
                 147 ;
4B C30B00    C   148          JMP     ENERGY
                 149 ;
                 150 ;*****************************************************
                 151 ;  PROCEDURE : PUT
                 152 ;  FUNCTION  : sets current bit of packed coefficient
                 153 ;              byte, or skips it , according to MSB
                 154 ;              of content of (A). If full byte is
                 155 ;              filled next byte is accessed
                 156 ;  PLM CALL  : none
                 157 ;  INPUT     : MSB (A) = 1 or 0
                 158 ;  OUTPUT    : shifts content of SETBIT by 1 to right
                 159 ;              and sets or skips current bit of packed
                 160 ;              byte
                 161 ;  GLOBALS   : SETBIT
                 162 ;  CALLS     : none
                 163 ;  DESTROYS  : (A),
                 164 ;
```

```
0C  OBJ           LINE        SOURCE STATEMENT

09E 17             165 PUT:    RAL
09F 320200    D    166         STA     SAVE
0A2 D2AA00    C    167         JNC     NOSET
                   168 ;
0A5 3A0000    D    169         LDA     SETBIT
0A8 B6             170         ORA     M
0A9 77             171         MOV     M,A
                   172 ;
0AA 3A0000    D    173 NOSET:  LDA     SETBIT
0AD 17             174         RAL
0AE B7             175         ORA     A
0AF C2B700    C    176         JNZ     NOFIN
0B2 3E01           177         MVI     A,01H
0B4 23             178         INX     H
0B5 3600           179         MVI     M,0
                   180 ;
0B7 320000    D    181 NOFIN:  STA     SETBIT
0BA 3A0200    D    182         LDA     SAVE
0BD C9             183         RET
                   184 ;
                   185 ;*******************************************************
                   186 ;
                   187         END


LIC SYMBOLS
K    C 0000

ERNAL SYMBOLS


R SYMBOLS
RBY C 000B     K1K2   C 0040     K3K4   C 0054     K5K6K7 C 0070
10  C 0085     LOOP1  C 0013     LOOP10 C 0090     LOOP2  C 0032
P3  C 0042     LOOP4  C 0049     LOOP5  C 0056     LOOP6  C 005E
P7  C 0072     LOOP8  C 007A     LOOP9  C 0087     NOFIN  C 00B7
ET  C 00AA     PACK   C 0000     PITCH  C 0028     PUT    C 009E
EAT C 0022     SAVE   D 0002     SETBIT D 0000     VOICED D 0001

EMBLY COMPLETE,    NO ERRORS
```

```
S-II PL/M-80 V3.0 COMPILATION OF MODULE GRAPHUTILITIES
ECT MODULE PLACED IN :F1:GUTILY.OBJ
PILER INVOKED BY:  PLM80 :F1:GUTILY.SRC WORKFILES(:F0:,:F0:)


            $PAGEWIDTH(80)
            /*************************************************************
            **                                                          **
            **                SPEECH SYNTHESIS SYSTEM                   **
            **                  DISPLAY UTILITIES                       **
            **                                                          **
            **  FILE NAME    : GUTILY.SRC              DATE             **
            **  MODULE DEF   : Disolay utilities       ---------        **
            **  AUTHOR       : Onder Bicioglu          22 06 85         **
            **                                                          **
            *************************************************************/
1           GRAPH$UTILITIES:
            DO;
2   1         DECLARE (TIMEBASE,AMPLITUDEBASE,START)
                      ADDRESS PUBLIC;
3   1         DECLARE GRAPHDATA(80) BYTE PUBLIC;
4   1         DECLARE (LEFT,RIGHT,UP,DOWN,
                       HOME,CLEAR,LI) BYTE EXTERNAL;
5   1         DECLARE MDS BYTE EXTERNAL;
6   1         DECLARE (I,J) ADDRESS;
7   1         DECLARE DATABUF(4000H) BYTE PUBLIC;
8   1         DECLARE CR                LITERALLY '13',
                      HORIZONTALUNITS LITERALLY '8',
                      VERTICALUNITS   LITERALLY '8';
9   1         DECLARE KEY BYTE EXTERNAL;
0   1         DECLARE TEMP BYTE;
1   1         DECLARE CONVERT(*) BYTE DATA('0','1','2','3',
                  '4','5','6','7','8','9','A','B','C','D','E','F');

2   1       CO: PROCEDURE(CHARACTER) EXTERNAL;
3   2         DECLARE CHARACTER BYTE;
4   2         END CO;
5   1       CI: PROCEDURE BYTE EXTERNAL;
6   2         END CI;
7   1       DISPLAY$MESSAGE: PROCEDURE(MESPOINTER) EXTERNAL;
8   2         DECLARE MESPOINTER ADDRESS;
9   2         END DISPLAY$MESSAGE;

            /*************************************************************
            *   PROCEDURE : MOVE$CURSOR
            *   FUNCTION  : moves cursor in the given direction
            *               in the given amount of characters
            *   PLM CALL  : CALL MOVE$CURSOR(DIRECTION,COUNT);
            *   INPUT     : DIRECTION = direction
            *               COUNT     = count
            *   OUTPUT    : cursor movement
            *   GLOBALS   : none
            *   CALLS     : CO
            */
0   1       MOVECURSOR: PROCEDURE(DIRECTION,COUNT) PUBLIC;
1   2         DECLARE (P,DIRECTION,COUNT) BYTE;
```

```
2   2         DO P=1 TO COUNT;
3   3           IF (DIRECTION=UP) OR (DIRECTION=DOWN) OR
                (MDS=1) THEN
4   3             CALL CO(LI);
5   3           CALL CO (DIRECTION);
6   3         END;

7   2       END MOVECURSOR;

            /*************************************************
            *  PROCEDURE : GETHEXDIGIT
            *  FUNCTION  : Receives a 1-digit hex number from
            *              keyboard
            *  PLM CALL  : J = GETHEXDIGIT
            *  INPUT     : key from console
            *  OUTPUT    : returns hex digit
            *  GLOBALS   : none
            *  CALLS     : CI,CO
            */
8   1       GETHEXDIGIT: PROCEDURE BYTE;

9   2       DO WHILE 1;
0   3         KEY=CI AND 7FH;
1   3         DO J=0 TO 15;
2   4           IF KEY=CONVERT(J) THEN
3   4           DO;
4   5             CALL CO(KEY);
5   5             RETURN J;
6   5           END;
7   4         END;
8   3       END;
9   2       END GETHEXDIGIT;

            /*************************************************
            *  PROCEDURE : GETFULL$NUMBER
            *  FUNCTION  : Receives 2-digit hex digit from
            *              keyboard
            *  PLM CALL  : CALL GET$FULL$NUMBER;
            *  INPUT     : none
            *  OUTPUT    : TEMP = 2-digit hex number
            *  GLOBALS   : TEMP
            *  CALLS     : GET$HEX$DIGIT
            */
0   1       GETFULLNUMBER: PROCEDURE PUBLIC;
1   2         TEMP=GETHEXDIGIT;
2   2         TEMP=SHL(TEMP,4) OR GETHEXDIGIT;
3   2       END GETFULLNUMBER;

            /*************************************************
            *  PROCEDURE : DISPLAY$START
            *  FUNCTION  : Disolays time counterpart of origin
            *  PLM CALL  : CALL DISPLAY$START
            *  INPUT     : START = address of memory where
            *              display opeartion has to start
            *  OUTPUT    : disolays origin
            *  GLOBALS   : START
```

```
                *  CALLS      : CO,MOVECURSOR
                */
44   1          DISPLAYSTART: PROCEDURE PUBLIC;
45   2            DECLARE DUMY ADDRESS ;

46   2            CALL MOVECURSOR(DOWN,2*VERTICALUNITS+5);
47   2            CALL MOVECURSOR(RIGHT,65);
48   2            DUMY=START-.DATABUF(0);
49   2            DUMY=SHR(DUMY,3);
50   2            TEMP = HIGH(DUMY);
51   2            CALL CO(CONVERT(SHR(TEMP,4)));
52   2            CALL CO(CONVERT(TEMP AND 0FH));
53   2            TEMP = LOW(DUMY);
54   2            CALL CO(CONVERT(SHR(TEMP,4)));
55   2            CALL CO(CONVERT(TEMP AND 0FH));
56   2            CALL CO(LI);
57   2            CALL CO(HOME);

58   2          END DISPLAYSTART;

                /*****************************************************
                *  PROCEDURE : DRAW$GRAPH
                *  FUNCTION  : Draws the required graph
                *  PLM CALL  : CALL DRAW$GRAPH;
                *  INPUT     : START = begin address of display buffer
                *              TIME$BASE = time base
                *              AMPLITUDE$BASE = amplitude base
                *  OUTPUT    : graph
                *  GLOBALS   : START,TIMEBASE,AMPLITUDEBASE
                *  CALLS     : MOVE$CURSOR,CO
                */

59   1          DRAWGRAPH: PROCEDURE PUBLIC;

60   2            DECLARE POINTER ADDRESS;
61   2            DECLARE DATABUFFER BASED POINTER BYTE;
62   2            DECLARE (DIRECTION,FACTOR) BYTE;
63   2            DECLARE (SUM,TEMPWORD) ADDRESS;

64   2            POINTER=START;
65   2            CALL MOVE$CURSOR(DOWN,2);
66   2            CALL MOVE$CURSOR(RIGHT,3);
67   2            DO I=1 TO HORIZONTALUNITS*8;
68   3              SUM = 0;
69   3              DO J=1 TO TIMEBASE;
70   4                TEMPWORD = DATABUFFER;
71   4                IF (DATABUFFER AND 80H)=0 THEN
72   4                  SUM = SUM + TEMPWORD;
                      ELSE
73   4                  SUM = SUM - (TEMP$WORD AND 7FH);
74   4                POINTER=POINTER+1;
75   4              END;
76   3              TEMPWORD = SUM / TIME$BASE;
77   3              FACTOR = LOW(TEMP$WORD);
78   3              IF (FACTOR AND 80H)=0 THEN
79   3              DO;
80   4                TEMP = VERTICALUNITS-(FACTOR/AMPLITUDEBASE);
```

```
31  4           END;
32  3           ELSE DO;
33  4             TEMP=0FFH-FACTOR+1;
34  4             TEMP=(TEMP/AMPLITUDEBASE)+VERTICALUNITS;
35  4           END;
36  3           IF (I AND 1)=1 THEN DIRECTION=DOWN;
38  3           ELSE DO;
39  4             DIRECTION=UP;
40  4             TEMP=(2*VERTICAL$UNITS)-TEMP;
41  4           END;
42  3           DO J=0 TO VERTICALUNITS*2;
43  4             IF J<> (VERTICALUNITS) THEN
44  4             DO;
45  5               IF TEMP=J THEN
46  5               DO;
47  6                 CALL CO('*');
48  6                 CALL MOVE$CURSOR(LEFT,1);
49  6               END;
50  5               ELSE DO;
51  6                 IF GRAPHDATA(I)=J THEN
52  6                 DO;
53  7                   CALL CO(' ');
54  7                   CALL MOVE$CURSOR(LEFT,1);
55  7                 END;
56  6               END;
57  5             END;

58  4           IF J=VERTICALUNITS*2 THEN
59  4             CALL MOVE$CURSOR(RIGHT,1);
60  4           ELSE DO;
61  5             CALL CO(LI);
62  5             CALL CO(DIRECTION);
63  5           END;
64  4         END;
65  3         GRAPHDATA(I)=TEMP;
66  3       END;

67  2       CALL CO(LI);
68  2       CALL CO(HOME);

69  2       END DRAWGRAPH;

         /*************************************************
         *  PROCEDURE : CHANGE$ORIGIN
         *  FUNCTION  : Changes origin
         *  PLM CALL  : CALL CHANGE$ORIGIN;
         *  INPUT     : new start address from the keyboard
         *  OUTPUT    : START = new begin address
         *  GLOBALS   : START
         *  CALLS     : CO, DRAW$GRAPH
         */
70  1       CHANGE$ORIGIN: PROCEDURE PUBLIC;

71  2         DECLARE DUMY ADDRESS;

72  2         CALL MOVE$CURSOR(DOWN,2*VERTICALUNITS+5);
73  2         CALL MOVE$CURSOR(RIGHT,65);
```

```
4   2           DUMY = GET$HEX$DIGIT;
5   2           DUMY = SHL(DUMY,4) OR GET$HEX$DIGIT;
6   2           DUMY = SHL(DUMY,4) OR GETHEX$DIGIT;
7   2           DUMY = SHL(DUMY,4) OR GET$HEX$DIGIT;
8   2           START = .DATA$BUF(0) + SHL(DUMY,3);
9   2           CALL CO(LI);
0   2           CALL CO(HOME);
1   2           CALL DRAW$GRAPH;

2   2       END CHANGE$ORIGIN;

            /*************************************************
            *   PROCEDURE : CHANGE$TIME$BASE
            *   FUNCTION  : Changes time base
            *   PLM CALL  : CALL CHANGE$TIME$BASE;
            *   INPUT     : New time base from keyboard
            *   OUTPUT    : TIME$BASE = new time base
            *   GLOBALS   : TIME$BASE,TEMP
            *   CALLS     : GET$FULL$NUMBER,CO,MOVE$CURSOR,
            *               DRAW$GRAPH
            */

3   1       CHANGETIMEBASE: PROCEDURE PUBLIC;

4   2           CALL MOVECURSOR(DOWN,2*VERTICALUNITS+5);
5   2           CALL MOVECURSOR(RIGHT,17);
6   2           CALL GETFULLNUMBER;
7   2           TIMEBASE=TEMP;
8   2           CALL CO(LI);
9   2           CALL CO(HOME);
0   2           CALL DRAWGRAPH;

1   2       END CHANGETIMEBASE;

            /*************************************************
            *   PROCEDURE : CHANGE$AMPLITUDE$BASE
            *   FUNCTION  : Changes amplitude base
            *   PLM CALL  : CALL CHANGE$AMPLITUDE$BASE;
            *   INPUT     : new amolitude base from keyboard
            *   OUTPUT    : AMPLITUDE$BASE = new base
            *   GLOBALS   : AMPLITUDE$BASE ,TEMP
            *   CALLS     : MOVE$CURSOR,CO,DRAW$GRAPH,
            *               GET$FULL$NUMBER
            */

2   1       CHANGEAMPLITUDEBASE: PROCEDURE PUBLIC;

3   2           CALL MOVECURSOR(DOWN,2*VERTICALUNITS+5);
4   2           CALL MOVECURSOR(RIGHT,44);
5   2           CALL GETFULLNUMBER;
6   2           AMPLITUDEBASE=TEMP;
7   2           CALL CO(LI);
8   2           CALL CO(HOME);
9   2           CALL DRAWGRAPH;

0   2       END CHANGEAMPLITUDEBASE;
```

```
        /*****************************************************
        *  PROCEDURE : SHIFT$RIGHT
        *  FUNCTION  : Shifts graph one time unit to right
        *  PLM CALL  : CALL SHIFT$RIGHT;
        *  INPUT     : START = begin of display buffer
        *  OUTPUT    : START is updated
        *  GLOBALS   : START
        *  CALLS     : DISPLAYSTART,DRAWGRAPH
        */

  1     SHIFTRIGHT: PROCEDURE PUBLIC;

  2       IF START >= (.DATA$BUF(0) + SHL(TIMEBASE,3))
          THEN DO;
  3         START=START-8*TIMEBASE;
  3         CALL DISPLAYSTART;
  3         CALL DRAWGRAPH;
  3       END;

  2     END SHIFTRIGHT;

        /*****************************************************
        *  PROCEDURE : SHIFT$LEFTT
        *  FUNCTION  : Shifts graph one time unit to leftt
        *  PLM CALL  : CALL SHIFT$RIGHT;
        *  INPUT     : START = begin of display buffer
        *  OUTPUT    : START is updated
        *  GLOBALS   : START
        *  CALLS     : DISPLAYSTART,DRAWGRAPH
        */

  1     SHIFTLEFT: PROCEDURE PUBLIC;

  2       START=START+8*TIMEBASE;
  2       CALL DISPLAYSTART;
  2       CALL DRAWGRAPH;

  2     END SHIFTLEFT;

        /*********************************************/

  1     END GRAPHUTILITIES;


LE INFORMATION:

 CODE AREA SIZE     = 0414H    1044D
 VARIABLE AREA SIZE = 406AH   16490D
 MAXIMUM STACK SIZE = 0008H       8D
 321 LINES READ
 0 PROGRAM ERROR(S)

OF PL/M-80 COMPILATION
```

```
8-II PL/M-80 V3.0 COMPILATION OF MODULE CONVERTATOK
ECT MODULE PLACED IN :F1:CONVAK.OBJ
PILER INVOKED BY:  PLM80 :F1:CONVAK.SRC WORKFILES(:F0:,:F0:)


            $PAGEWIDTH(80)
            /*************************************************
            **                                              **
            **              SPEECH ANALYSIS SYSTEM          **
            **              CONVERSION OF Ks TO As          **
            **                                              **
            **  FILE NAME   : CONVAK.SRC          DATE      **
            **  MODULE DEF  : Conversion K to A   ---------  **
            **  AUTHOR      : Onder Bicioglu      22 06 85    **
            **                                              **
            *************************************************/
1           CONVERT$A$TO$K: DO;

2   1       DECLARE A(1) STRUCTURE(
                    ADIGIT(4) BYTE) EXTERNAL;
3   1       DECLARE K(1) STRUCTURE(
                    KDIGIT(4) BYTE) EXTERNAL;
4   1       DECLARE MIGNAL(150) STRUCTURE(
                    MDIGIT(4) BYTE) PUBLIC;
5   1       DECLARE E(4) BYTE EXTERNAL;
6   1       DECLARE BDUMMY(4) BYTE EXTERNAL;
7   1       DECLARE (M,I,J,L) BYTE;

8   1       FBMUL: PROCEDURE(O1,O2,O3) EXTERNAL;
9   2         DECLARE (O1,O2,O3) ADDRESS;
0   2         END FBMUL;
1   1       FBSUB: PROCEDURE(O1,O2,O3) EXTERNAL;
2   2         DECLARE (O1,O2,O3) ADDRESS;
3   2         END FBSUB;
4   1       FBADD: PROCEDURE(O1,O2,O3) EXTERNAL;
5   2         DECLARE (O1,O2,O3) ADDRESS;
6   2         END FBADD;

7   1       DECLARE ZERO(*) ADDRESS DATA(0,0);
8   1       DECLARE ACCESS$TABLE(*) BYTE DATA(
              0,1,3,6,10,15,21,28,
              36,45,55,66,78,91,105,120,
              136);

            /*************************************************
            *  PROCEDURE : GET
            *  FUNCTION  : Accesses to the matrix element and
            *              returns it in BDUMMY
            *  PLM CALL  : CALL GET(P1,P2);
            *  INPUT     : Index values
            *  OUTPUT    : BDUMMY = element required
            *  GLOBALS   : SIGNAL,M
            *  CALLS     : none
            */
9   1       GET: PROCEDURE(P1,P2) PUBLIC;
0   2         DECLARE (P1,P2) BYTE;
```

```
   2          M = ACCESS$TABLE(P1) + P2;
   2          DO J=0 TO 3;
   3            BDUMMY(J) = MIGNAL(M).MDIGIT(J);
   3          END;
   2        END GET;

            /*************************************************
            *  PROCEDURE : PUT
            *  FUNCTION  : Puts content of E to the cesired entry
            *  PLM CALL  : CALL PUT(P1,P2);
            *  INPUT     : indexes
            *  OUTPUT    : none
            *  GLOBALS   : SIGNAL,M
            *  CALLS     : none
            */
   1        PUT: PROCEDURE(P1,P2) PUBLIC;
   2          DECLARE (P1,P2) BYTE;
   2          M = ACCESS$TABLE(P1) + P2;
   2          DO J=0 TO 3;
   3            MIGNAL(M).MDIGIT(J)=E(J);
   3          END;
   2        END PUT;

            /*************************************************
            *  PROCEDURE : STEPUP
            *  FUNCTION  : Converts K coefficients to  A
            *              coefficient
            *  PLM CALL  : CALL STEPUP(ORDER);
            *  INPUT     : K(I).KDIGIT=K coefficients
            *              ORDER = order of filter
            *  OUTPUT    : A(I).ADIGIT = A coefficients
            *  GLOBALS   : A,K,E,BDUMMY
            *  CALLS     : GET,PUT,FBMUL,FBADD,PRINT$MESSAGE
            */
   1        STEPUP: PROCEDURE(ORD) PUBLIC;

   2          DECLARE ORD BYTE;
   2          DO J=0 TO 3;
   3            K(0).KDIGIT(J)=0;
   3          END;
   2          K(0).KDIGIT(2)=1;

   2          DO L=0 TO ORD;
   3            DO J = 0 TO 3;
   4              E(J)=0;
   4            END;
   3            E(2)=1;
   3            CALL PUT(L,0);

   3            IF L <> 0 THEN DO;
   4              DO I=1 TO L-1;
   5                CALL GET(L-1,L-I);
   5                CALL FBMUL(.BDUMMY(0),.K(L).KDIGIT(0),.E(0));
   5                CALL GET(L-1,I);
   5                CALL FBADD(.E(0),.BDUMMY(0),.E(0));
   5                CALL PUT(L,I);
   5              END;
```

```
4   4           END;

5   3           DO J=0 TO 3;
6   4             E(J) = K(L).KDIGIT(J);
7   4           END;
8   3           CALL PUT(L,L);
9   3         END;

0   2         DO L = 1 TO ORD;
1   3           CALL GET(ORD,L);
2   3           CALL FBSUB(.BDUMMY(0),.ZERO(0),.A(L).ADIGIT(0));
3   3         END;

4   2       END STEPUP;

5   1       END CONVERT$A$TO$K;
```

ULE INFORMATION:

```
  CODE AREA SIZE      = 01FDH    509D
  VARIABLE AREA SIZE = 0261H    609D
  MAXIMUM STACK SIZE = 0006H      6D
  124 LINES READ
  0 PROGRAM ERROR(S)

 OF PL/M-80 COMPILATION
```

```
-II PL/M-80 V3.0 COMPILATION OF MODULE USERINTERFACE
CT MODULE PLACED IN :F1:USRITF.OBJ
LER INVOKED BY:  PLM80 :F1:USRITF.SRC WORKFILES(:F0:, :F0:)


        $PAGEWIDTH(80)
        /*********************************************************
        **                                                      **
        **              SPEECH SYNTHESIS SYSTEM                 **
        **                USER INTERFACE                        **
        **                                                      **
        **  FILE NAME    : USRITF.SRC            DATE          **
        **  MODULE DEF   : User interface       --------       **
        **  AUTHOR       : Onder Bicioglu       22 06 85       **
        **                                                      **
        *********************************************************/
        USER$INTER$FACE: DO;

  1     LO: PROCEDURE(MES) EXTERNAL;
  2       DECLARE MES BYTE;
  2       END LO;

  1     CO: PROCEDURE(MES) EXTERNAL;
  2       DECLARE MES BYTE;
  2       END CO;
  1     CI: PROCEDURE BYTE EXTERNAL;
  2       END CI;

  1     DECLARE BUFFER(40) BYTE PUBLIC;
  1     DECLARE EOm     LITERALLY   '0',
              BACK    LITERALLY   '8',
              BLANK   LITERALLY   '20H',
              RUBOUT  LITERALLY   '7FH',
              CR      LITERALLY   '0DH',
              LF      LITERALLY   '0AH';
        /*********************************************************
        *   PROCEDURE : PRINT$NUMBER
        *   FUNCTION  : Prints out the given number
        *   PLM CALL  : CALL PRINT$NUMBER(NO);
        *   INPUT     : NO = number to be printed
        *   OUTPUT    : printout
        *   GLOBALS   : none
        *   CALLS     : LO
        */
  1     PRINT$NUMBER: PROCEDURE(NO) PUBLIC;
  2       DECLARE NO BYTE;
  2       DECLARE L BYTE;
  2       DECLARE ASCII$TABLE(*) BYTE DATA(
          '0','1','2','3','4','5','6','7','8','9','A',
          'B','C','D','E','F');

  2       CALL LO(' ');
  2       L = SHR(NO,4);
  2       CALL LO(ASCII$TABLE(L));
  2       L = NO AND 0FH;
  2       CALL LO(ASCII$TABLE(L));
```

```
1   2       END PRINT$NUMBER;

            /*************************************************
            *  PROCEDURE : PRINT
            *  FUNCTION  : Prints out the 4 byte entries
            *  PLM CALL  : CALL PRINT(.BASEADDRESS);
            *  INPUT     : BASEADDRESS= points to first of the 4
            *              byte structure
            *  OUTPUT    : printout
            *  GLOBALS   : none
            *  CALLS     : LO
            */
2   1       PRINT: PROCEDURE(BASE$ADDRESS) PUBLIC;
3   2         DECLARE BASE$ADDRESS ADDRESS;
4   2         DECLARE BUF BASED BASE$ADDRESS BYTE;
5   2         DECLARE N BYTE;
6   2         DO N=0 TO 3;
7   3           CALL PRINT$NUMBER(BUF);
8   3           BASE$ADDRESS = BASE$ADDRESS + 1;
9   3         END;
10  2         CALL LO(' ');
11  2         CALL LO(' ');

12  2       END PRINT;

            /*************************************************
            *  PROCEDURE : PRINT$MESSAGE
            *  FUNCTION  : Prints indicated message
            *  PLM CALL  : CALL PRINT$MESSAGE(.MESSAGE);
            *  INPUT     : address of message
            *  OUTPUT    : printout of message
            *  GLOBALS   : none
            *  CALLS     : LO
            */
13  1       PRINT$MESSAGE: PROCEDURE(POINTER) PUBLIC;

14  2         DECLARE POINTER ADDRESS;
15  2         DECLARE OUTBUFFER BASED POINTER BYTE;

16  2         DO WHILE 1;
17  3           IF OUTBUFFER = EOM THEN RETURN;
19  3           CALL LO(OUTBUFFER);
20  3           POINTER = POINTER+1;
21  3         END;

22  2       END PRINT$MESSAGE;
            /*************************************************
            *  PROCEDURE : PRINT$BLOCK
            *  FUNCTION  : Prints indicated amount of numbers
            *              from the given address on
            *  PLM CALL  : CALL PRINT$BLOCK(.START,COUNT);
            *  INPUT     : START = start address
            *              COUNT = number of numbers to be printed
            *  OUTPUT    : printout of message
            *  GLOBALS   : none
            *  CALLS     : LO
```

```
        */
1       PRINT$BLOCK: PROCEDURE(START$ADDRESS,COUNT) PUBLIC;
2         DECLARE (N,START$ADDRESS,COUNT) ADDRESS;

2         DO N = 0 TO COUNT-1;
3           IF (N AND 3) = 0 THEN
3           DO;
4             CALL LO(0AH);
4             CALL LO(0DH);
4           END;
3           CALL PRINT(START$ADDRESS);
3           START$ADDRESS=START$ADDRESS + 4;
3         END;
2         CALL LO(0AH);
2         CALL LO(0DH);

2       END PRINT$BLOCK;
        /*************************************************
        *  PROCEDURE : DISPLAY$MESSAGE
        *  FUNCTION  : Disolays indicated message
        *  PLM CALL  : CALL DISPLAY$MESSAGE(.MESSAGE);
        *  INPUT     : address of message
        *  OUTPUT    : display of message
        *  GLOBALS   : none
        *  CALLS     : CO
        */
1       DISPLAY$MESSAGE: PROCEDURE(POINTER) PUBLIC;

2         DECLARE POINTER ADDRESS;
2         DECLARE OUTBUFFER BASED POINTER BYTE;

2         DO WHILE 1;
3           IF OUTBUFFER = EOM THEN RETURN;
3           CALL CO(OUTBUFFER);
3           POINTER = POINTER+1;
3         END;

2       END DISPLAY$MESSAGE;

        /*************************************************
        *  PROCEDURE : GETCHARACTERS
        *  FUNCTION  : Receives characters from terminal
        *  PLM CALL  : CALL GETFILENAME;
        *  INPUT     : none
        *  OUTPUT    : returns received character string in
        *              BUFFER
        *  GLOBALS   : BUFFER
        *  CALLS     : CI,CO
        */
1       GET$CHARACTERS: PROCEDURE PUBLIC;

2         DECLARE (KEY,J) BYTE;

2         J=0;
2         DO WHILE 1;
3           KEY = (CI AND 7FH);
3           IF KEY = RUBOUT THEN DO;
```

```
4                IF J <> 0 THEN DO;
5                  CALL CO(BACK);
5                  CALL CO(BLANK);
5                  CALL CO(BACK);
5                  J=J-1;
5                END;
4              END;
3              ELSE DO;
4                BUFFER(J)=KEY;
4                CALL CO(KEY);
4                IF KEY=CR THEN DO;
5                  CALL CO(LF);
5                  RETURN;
5                END;
4                J= J+1;
4              END;
3            END;

2          END GET$CHARACTERS;


1          END USER$INTERFACE;
```

```
LE INFORMATION:

 CODE AREA SIZE      = 0180H    384D
 VARIABLE AREA SIZE  = 0039H     57D
 MAXIMUM STACK SIZE  = 0006H      6D
 187 LINES READ
 0 PROGRAM ERROR(S)

OF PL/M-80 COMPILATION
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```
-II PL/M-80 V3.0 COMPILATION OF MODULE PITCHANALYSIS
;T MODULE PLACED IN :F1:ANAPTC.OBJ
ILER INVOKED BY:  PLM80 :F1:ANAPTC.SRC WORKFILES(:F0:,:F0:)


        $PAGEWIDTH(80)
        /*****************************************************
        **                                                  **
        **             SPEECH SYNTHESIS SYSTEM              **
        **                PITCH ANALYSIS                    **
        **                                                  **
        **  FILE NAME   : ANAPTC.SRC          DATE          **
        **  MODULE DEF  : Analyses speech     --------      **
        **  AUTHOR      : Onder Bicioglu      22 06 85      **
        **                                                  **
        *****************************************************/
        PITCH$ANALYSIS: DO;

  1     DECLARE R(20) STRUCTURE(
              RWORD(2) ADDRESS) EXTERNAL;
  1     DECLARE K(1) STRUCTURE(
              KDIGIT(4) BYTE) EXTERNAL;
  1     DECLARE SIGNAL(1) STRUCTURE(
              SDIGIT(4) BYTE) EXTERNAL;
  1     DECLARE W(1) STRUCTURE(
              WDIGIT(4) BYTE) EXTERNAL;
  1     DECLARE SAMPLE(1) BYTE EXTERNAL;

  1     DECLARE (ORDER,PITCH) BYTE PUBLIC;
  1     DECLARE A(5) STRUCTURE(
              ADIGIT(4) BYTE) PUBLIC;

  1     DECLARE OVER$FLOW$FLAG BYTE EXTERNAL;
  1     DECLARE E(1) BYTE EXTERNAL;
  1     DECLARE EDUMMY(1) BYTE EXTERNAL;
  1     DECLARE BDUMMY(1) BYTE EXTERNAL;
  1     DECLARE TEMP(1) ADDRESS EXTERNAL;

  1     DECLARE ENERGY BYTE PUBLIC;

  1     DECLARE RATIO STRUCTURE(
              R1    BYTE,
              R23   ADDRESS,
              R4    BYTE);

  1     DECLARE NON$ZERO$COUNT BYTE;
  1     DECLARE MAXIMUM$RATIO ADDRESS;
  1     DECLARE (M,N,I,J) ADDRESS;
  1     DECLARE L BYTE;

  1     DECLARE VOICED$ENERGY LITERALLY '2';
  1     DECLARE VOICING$RATIO     LITERALLY '6000H';
  1     DECLARE LOWEST$PITCH   LITERALLY '48';
  1     DECLARE PLOSIVE$LIMIT    LITERALLY '11';

  1     FBADD: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
```

```
2          DECLARE (OP1,OP2,OP3) ADDRESS;
2          END FBADD;
1        FBSUB: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
2          DECLARE (OP1,OP2,OP3) ADDRESS;
2          END FBSUB;
1        FBDIV: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
2          DECLARE (OP1,OP2,OP3) ADDRESS;
2          END FBDIV;
1        FBMUL: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
2          DECLARE (OP1,OP2,OP3) ADDRESS;
2          END FBMUL;
1        STEPUP: PROCEDURE(ORD) EXTERNAL;
2          DECLARE ORD BYTE;
2          END STEPUP;
1        GUEGUEN$LE$RUEX: PROCEDURE EXTERNAL;
2          END GUEGUEN$LE$RUEX;
1        A$LAW$EXPANSION: PROCEDURE EXTERNAL;
2          END A$LAW$EXPANSION;
1        PRINT: PROCEDURE(POINTER) EXTERNAL;
2          DECLARE POINTER ADDRESS;
2          END PRINT;
1        PRINTNUMBER: PROCEDURE(NUMBER) EXTERNAL;
2          DECLARE NUMBER BYTE;
2          END PRINTNUMBER;

         /*********************************************************
         *  PROCEDURE  : SIFT
         *  FUNCTION   : Pitch analysis
         *  PLM CALL   : CALL SIFT
         *  INPUT      : SIGNAL.SDIGIT = 32-bit speech samples
         *  OUTPUT     : ENERGY = R(0)
         *  GLOBALS    : R, PITCH, ENERGY
         *  CALLS      : FBMUL, FBADD
         */
1        SIFT: PROCEDURE PUBLIC;

2          CALL A$LAW$EXPANSION;

         /*------------------PRE-EMPHASIS----------------------*/

2          DO M = 1 TO 99;
3            I = SHL(M,2);
3            CALL FBSUB(.SIGNAL(I-4).SDIGIT(0),.SIGNAL(I).SDIGIT(0),
                        .SIGNAL(I-4).SDIGIT(0));
3          END;

         /*------------------WINDOWING-------------------------*/

2          DO M = 0 TO 49;
3            N = SHL(M,1);
3            I = SHL(M,2);
3            CALL FBMUL(.SIGNAL(I).SDIGIT(0),.W(N).WDIGIT(0),
                        .SIGNAL(I).SDIGIT(0));
3            CALL FBMUL(.SIGNAL(399-I).SDIGIT(0),.W(N).WDIGIT(0),
                        .SIGNAL(399-I).SDIGIT(0));
3          END;
```

```
/*-------------------------------------------------------------*/

2          DO I = 0 TO 4;
3            DO J = 0 TO 1;
4              R(I).RWORD(J) = 0;
4            END;
3            J = SHL(I,2);
3            DO M = 0 TO 99-I;
4              N = SHL(M,2);
4              CALL FBMUL(.SIGNAL(N).SDIGIT(0),
                          .SIGNAL(J+N).SDIGIT(0),.E(0));
4              CALL FBADD(.E(0),.R(I).RWORD(0),.R(I).RWORD(0));
4            END;
3          END;

2          ORDER = 4;
2          IF R(0).RWORD(1) = 0 THEN
2          DO;
3            IF R(0).RWORD(0) < 7000H THEN
3            DO;
4              ENERGY = 0;
4              RETURN;
4            END;
3          END;
2          ENERGY = 0FFH;

2          CALL GUEGUEN$LE$RUEX;
2          CALL STEPUP(4);
2          CALL A$LAW$EXPANSION;

/*-------------------CALCULATION OF e(n)-----------*/

2          DO I = 1 TO 3;
3            J = SHL(I,2);
3            DO L = 0 TO 3;
4              SIGNAL(J+1).SDIGIT(L) = SIGNAL(J).SDIGIT(L);
4            END;
3            DO M = 1 TO I;
4              N = SHL(M,2);
4              CALL FBMUL(.A(M).ADIGIT(0),.SIGNAL(J-N).SDIGIT(0),
                          .TEMP(0));
4              CALL FBSUB(.TEMP(0),.SIGNAL(J+1).SDIGIT(0),
                          .SIGNAL(J+1).SDIGIT(0));
4            END;
3          END;

2          DO I = 4 TO 99;
3            J = SHL(I,2);
3            DO L = 0 TO 3;
4              SIGNAL(J+1).SDIGIT(L) = SIGNAL(J).SDIGIT(L);
4            END;
3            DO M = 1 TO 4;
4              N = SHL(M,2);
4              CALL FBMUL(.A(M).ADIGIT(0),.SIGNAL(J-N).SDIGIT(0),
                          .TEMP(0));
4              CALL FBSUB(.TEMP(0),.SIGNAL(J+1).SDIGIT(0),
                          .SIGNAL(J+1).SDIGIT(0));
```

```
4           END;
3         END;

        /*----------------------WINDOW-------------------*/

2         DO M = 0 TO 49;
3           N = SHL(M,1);
3           I = SHL(M,2);
3           CALL FBMUL(.SIGNAL(I+1).SDIGIT(0),.W(N).WDIGIT(0),
                       .SIGNAL(I).SDIGIT(0));
3           CALL FBMUL(.SIGNAL(397-I).SDIGIT(0),.W(N).WDIGIT(0),
                       .SIGNAL(396-I).SDIGIT(0));
3         END;

        /*--------------------CALCULATION OF R(N)--------------*/

2         TEMP(0) = 0;
2         TEMP(1) = 0;
2         DO M = 0 TO 99;
3           N = SHL(M,2);
3           CALL FBMUL(.SIGNAL(N).SDIGIT(0),.SIGNAL(N).SDIGIT(0),
                       .E(0));
3           CALL FBADD(.TEMP(0),.E(0),.TEMP(0));
3         END;
2         CALL PRINT$NUMBER(LOW(TEMP(1)));

2         NON$ZERO$COUNT = 0;

2         DO I = 0 TO 13;
3           DO J = 0 TO 1;
4             R(I).RWORD(J) = 0;
4           END;
3           J = SHL(I,2) + LOWEST$PITCH;
3           DO M = 0 TO 87-I;
4             N = SHL(M,2);
4             CALL FBMUL(.SIGNAL(N).SDIGIT(0),
                         .SIGNAL(J+N).SDIGIT(0),.E(0));
4             CALL FBADD(.E(0),.R(I).RWORD(0),.R(I).RWORD(0));
4           END;
3           J = SHL(J,1);
3           DO M = (88-I) TO 99;
4             N = SHL(M,2);
4             CALL FBMUL(.SIGNAL(N).SDIGIT(0),
                         .SIGNAL(N-J).SDIGIT(0),.E(0));
4             CALL FBADD(.E(0),.R(I).RWORD(0),.R(I).RWORD(0));
4           END;
3           IF (R(I).RWORD(1) AND 8000H) = 0 THEN
3           DO;
4             NON$ZERO$COUNT = NON$ZERO$COUNT + 1;
4             CALL FBDIV(.R(I).RWORD(0),.TEMP(0),.R(I).RWORD(0));
4           END;
            ELSE
3             R(I).RWORD(0) = 0;
3           CALL PRINT$NUMBER(HIGH(R(I).RWORD(0)));
3         END;

2         PITCH = 0;
```

```
2          IF NON$ZERO$COUNT ) PLOSIVE$LIMIT THEN
2            RETURN;
2          IF (TEMP(1) < VOICED$ENERGY)  THEN RETURN;
2          MAXIMUM$RATIO = VOICING$RATIO;
2          DO I = 0 TO 13;
3            IF R(I).RWORD(0) ) MAXIMUM$RATIO THEN
3            DO;
4              MAXIMUM$RATIO = R(I).RWORD(0);
4              PITCH =  SHL(I,2) + LOWEST$PITCH;
4              END;
3          END;

2        END SIFT;

1        END PITCH$ANALYSIS;
```

LE INFORMATION:

```
 CODE AREA SIZE      = 05FCH   1532D
 VARIABLE AREA SIZE  = 0027H     39D
 MAXIMUM STACK SIZE  = 0006H      6D
 237 LINES READ
 0 PROGRAM ERROR(S)
```

OF PL/M-80 COMPILATION

```
IS-II PL/M-80 V3.0 COMPILATION OF MODULE ANALYSIS
JECT MODULE PLACED IN :F1:ANADIF.OBJ
MPILER INVOKED BY:  PLM80 :F1:ANADIF.SRC WORKFILES(:F0:,:F0:)


                $PAGEWIDTH(80)
                /*************************************************************
                **                                                           **
                **              SPEECH SYNTHESIS SYSTEM                      **
                **          REFLECTION COEFFICIENT ANALYSIS                  **
                **          USING GUEGUEN LE-RUEX ALGORITHM                  **
                **               (WITH PRE-EMPHASIZE)                        **
                **                                                           **
                **  FILE NAME    : ANADIF.SRC              DATE              **
                **  MODULE DEF   : Analyses speech         ---------         **
                **  AUTHOR       : Onder Bicioglu          22 06 85          **
                **                                                           **
                *************************************************************/
  1             ANALYSIS: DO;

  2     1       DECLARE EP(17) STRUCTURE(
                        PWORD(2) ADDRESS) PUBLIC;
  3     1       DECLARE R(25) STRUCTURE(
                        RWORD(2) ADDRESS) PUBLIC;
  4     1       DECLARE EN(17) STRUCTURE(
                        NWORD(2) ADDRESS) PUBLIC;
  5     1       DECLARE K(17) STRUCTURE(
                        KDIGIT(4) BYTE) PUBLIC;
  6     1       DECLARE SIGNAL(400) STRUCTURE(
                        SDIGIT(4) BYTE) PUBLIC;
  7     1       DECLARE W(1) STRUCTURE(
                        WDIGIT(4) BYTE) EXTERNAL;
  8     1       DECLARE SAMPLE(1) BYTE EXTERNAL;

  9     1       DECLARE (PITCH,ORDER) BYTE EXTERNAL;
 10     1       DECLARE NSAMPLE ADDRESS PUBLIC;
 11     1       DECLARE E(4) BYTE PUBLIC;
 12     1       DECLARE EDUMMY(4) BYTE PUBLIC;
 13     1       DECLARE BDUMMY(4) BYTE PUBLIC;
 14     1       DECLARE TEMP(2) ADDRESS PUBLIC;
 15     1       DECLARE OVER$FLOW$FLAG BYTE PUBLIC;

 16     1       DECLARE (M,N,I,J) ADDRESS;
 17     1       DECLARE ZERO(*) BYTE DATA(0,0,0,0);

 18     1       FBADD: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
 19     2         DECLARE (OP1,OP2,OP3) ADDRESS;
 20     2         END FBADD;
 21     1       FBSUB: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
 22     2         DECLARE (OP1,OP2,OP3) ADDRESS;
 23     2         END FBSUB;
 24     1       FBDIV: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
 25     2         DECLARE (OP1,OP2,OP3) ADDRESS;
 26     2         END FBDIV;
 27     1       FBMUL: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
 28     2         DECLARE (OP1,OP2,OP3) ADDRESS;
```

```
29   2          END FBMUL;
30   1        A$LAW$EXPANSION: PROCEDURE EXTERNAL;
31   2          END A$LAW$EXPANSION;

                /*********************************************************
                *   PROCEDURE  : GUEGUEN$LE$RUEX
                *   FUNCTION   : Analysis using Gueguen Le-Ruex
                *                algorithm
                *   PLM CALL   : CALL GUEGUEN$LE$RUEX;
                *   INPUT      : PITCH =pitch period
                *                SAMPLE = 8-bit samples
                *   OUTPUT     : K=reflection coefficients
                *   GLOBALS    : K, R, ORDER, NSAMPLE, SIGNAL
                *   CALLS      : FBMUL, FBDIV, FBADD, A$LAW$EXPANSION
                */
32   1        GUEGUEN$LE$RUEX: PROCEDURE PUBLIC;

                /*------------INITIALIZATION---------------------- */

33   2          DO M = 1 TO 10;
34   3            DO J = 0 TO 1;
35   4              EP(M).PWORD(J) = R(M).RWORD(J);
36   4              EN(M).NWORD(J) = R(M-1).RWORD(J);
37   4            END;
38   3          END;
39   2          OVERFLOW$FLAG = 0;

                /*------- G U E G U E N  L E - R U E X ------------*/

40   2          DO I = 0 TO 9;

                /*-- K(I) = - (EP(I+1) / EN(1))----------------- */

41   3            CALL FBDIV(.EP(I+1).PWORD(0),.EN(1).NWORD(0),
                          .EDUMMY(0));

                /*------------RANGE CHECK-----------------------------*/

42   3            IF (EDUMMY(2) > 0) AND (EDUMMY(2) < 0FFH)
                  THEN DO;
44   4              OVER$FLOW$FLAG = 0FFH;
45   4              RETURN;
46   4            END;

                /*-------------------------------------------------------*/

47   3            CALL FBSUB(.EDUMMY(0),.ZERO(0),
                          .K(I+1).KDIGIT(0));
48   3            CALL FBMUL(.K(I+1).KDIGIT(0),.EP(I+1).PWORD(0),
                          .EDUMMY(0));
49   3            CALL FBADD(.EN(1).NWORD(0),.EDUMMY(0),
                          .EN(1).NWORD(0));
50   3            CALL FBMUL(.EN(10-I).NWORD(0),.K(I+1).KDIGIT(0),
                          .EDUMMY(0));
51   3            CALL FBADD(.EP(10).PWORD(0),.EDUMMY(0),
                          .EP(10).PWORD(0));
```

```
62  3           IF I = 9 THEN
63  3             RETURN;

64  3           DO M = I+2 TO 9;
65  4             CALL FBMUL(.K(I+1).KDIGIT(0),.EN(M-I).NWORD(0),
                           .EDUMMY(0));
66  4             CALL FBADD(.EDUMMY(0),.EP(M).PWORD(0),
                           .E(0));
67  4             CALL FBMUL(.EP(M).PWORD(0),.K(I+1).KDIGIT(0),
                           .EDUMMY(0));
68  4             CALL FBADD(.EDUMMY(0),.EN(M-I).NWORD(0),
                           .EN(M-I).NWORD(0));
69  4             CALL FBADD(.E(0),.ZERO(0),.EP(M).PWORD(0));
70  4           END;
71  3         END;

72  2       END GUEGUEN$LE$RUEX;
         /*******************************************************
         *  PROCEDURE : ANALYSER
         *  FUNCTION  : Analyses the signal and creates
         *              reflection coefficients using auto-
         *              correlation method and
         *              GUEGUEN LE-RUEX algorithm
         *  PLM CALL  : CALL ANALYSER;
         *  INPUT     : ORDER = order of the prediction
         *              NSAMPLE = number of samples to be used
         *  OUTPUT    : K(I).KDIGIT(J) = reflection coefficients
         *              OVERFLOW$FLAG = OFFH if any of the k's
         *                              exceeds 1 in magnitude
         *  GLOBALS   : SIGNAL structure
         *  CALLS     : FBMUL,FBDIV,FBADD,FBSUB,GUEGUEN$LE$RUEX
         */
73  1       ANALYSER: PROCEDURE PUBLIC;

74  2       CALL A$LAW$EXPANSION;

75  2         IF PITCH <> 0 THEN
76  2         DO;
77  3           DO I = 1 TO NSAMPLE;
78  4             CALL FBSUB(.SIGNAL(I-1).SDIGIT(0),.SIGNAL(I).SDIGIT(0)
                           .SIGNAL(I-1).SDIGIT(0));
79  4           END;
80  3         END;

         /*------------------W I N D O W I N G -----------------*/

81  2         DO I = 0 TO SHR(NSAMPLE,1)-1;
82  3           CALL FBMUL(.SIGNAL(I).SDIGIT(0),.W(I).WDIGIT(0),
                         .SIGNAL(I).SDIGIT(0));
83  3           CALL FBMUL(.SIGNAL(NSAMPLE-1-I).SDIGIT(0),.W(I).WDIGIT(0
                         .SIGNAL(NSAMPLE-1-I).SDIGIT(0));
84  3         END;

         /*------C A L C U L A T I O N  O F  R ( I )------------*/

85  2         DO I = 0 TO 10;
86  3           DO J = 0 TO 1;
```

```
77    4             R(I).RWORD(J) = 0;
78    4           END;
79    3           DO M = 0 TO NSAMPLE-1-I;
80    4             CALL FBMUL(.SIGNAL(M).SDIGIT(0),
                                .SIGNAL(M+I).SDIGIT(0),.TEMP(0));
81    4             CALL FBADD(.TEMP(0),.R(I).RWORD(0),
                                .R(I).RWORD(0));
82    4           END;
83    3         END;

84    2         CALL GUEGUEN$LE$RUEX;

85    2       END ANALYSER;

86    1       END ANALYSIS;


DULE INFORMATION:

   CODE AREA SIZE     = 037AH    890D
   VARIABLE AREA SIZE = 078BH   1931D
   MAXIMUM STACK SIZE = 0008H      8D
   180 LINES READ
   0 PROGRAM ERROR(S)

D OF PL/M-80 COMPILATION
```

S-II PL/M-80 V3.0 COMPILATION OF MODULE MAIN
JECT MODULE PLACED IN :F1:SMOOTH.OBJ
PILER INVOKED BY: PLM80 :F1:SMOOTH.SRC

```
                $PAGEWIDTH(80)
                /*********************************************************
                **                                                      **
                **              SPEECH SYNTHESIS SYSTEM                 **
                **                 SMOOTHER MODULE                      **
                **                                                      **
                **  FILE NAME    : SMOOTH.SRC            DATE          **
                **  MODULE DEF   : Enables user to    ---------        **
                **                 smooth results     16 06 1985       **
                **  AUTHOR       : Onder Bicioglu                      **
                **                                                      **
                *********************************************************/
 1              MAIN: DO;

 2    1         DISPLAY$MESSAGE: PROCEDURE(POINTER) EXTERNAL;
 3    2           DECLARE POINTER ADDRESS;
 4    2           END DISPLAY$MESSAGE;
 5    1         PRINT$MESSAGE: PROCEDURE(POINTER) EXTERNAL;
 6    2           DECLARE POINTER ADDRESS;
 7    2           END PRINT$MESSAGE;
 8    1         PRINT$NUMBER: PROCEDURE(NO) EXTERNAL;
 9    2           DECLARE NO BYTE;
10    2           END PRINT$NUMBER;
11    1         GET$CHARACTERS: PROCEDURE EXTERNAL;
12    2           END GET$CHARACTERS;
13    1         CI: PROCEDURE BYTE EXTERNAL;
14    2           END CI;
15    1         LO: PROCEDURE(MES) EXTERNAL;
16    2           DECLARE MES BYTE;
17    2           END LO;
18    1         EXIT: PROCEDURE EXTERNAL;
19    2           END EXIT;
20    1         IOSET: PROCEDURE(MASK) EXTERNAL;
21    2           DECLARE MASK BYTE;
22    2           END IOSET;
23    1         OPEN:
                    PROCEDURE(AFT,FILE,ACCESS,MODE,STATUS) EXTERNAL;
24    2           DECLARE (AFT,FILE,ACCESS,MODE,STATUS) ADDRESS;
25    2         END OPEN;
26    1         READ:
                    PROCEDURE(AFT,BUF,CNT,ACT,STATUS) EXTERNAL;
27    2           DECLARE(AFT,BUF,CNT,ACT,STATUS) ADDRESS;
28    2         END READ;
29    1         WRITE:
                    PROCEDURE(AFT,BUF,CNT,STATUS) EXTERNAL;
30    2           DECLARE(AFT,BUF,CNT,STATUS) ADDRESS;
31    2         END WRITE;
32    1         CLOSE:
                    PROCEDURE(AFT,STATUS) EXTERNAL;
33    2           DECLARE (AFT,STATUS) ADDRESS;
34    2         END CLOSE;
```

```
5   1       FBDIV: PROCEDURE(OP1,OP2,OP3) EXTERNAL;
6   2         DECLARE (OP1,OP2,OP3) ADDRESS;
7   2         END FBDIV;

8   1       DECLARE BUFFER(1) BYTE EXTERNAL;
9   1       DECLARE (I,J,L,M,N) ADDRESS;
0   1       DECLARE (FILE,STATUS,NFRAME,COUNT) ADDRESS;
1   1       DECLARE (LPC$POINTER,RAM$POINTER) ADDRESS;
2   1       DECLARE END$OF$BUFFER ADDRESS;
3   1       DECLARE RAM BASED RAM$POINTER BYTE;
4   1       DECLARE LPC BASED LPC$POINTER (20) BYTE;

5   1       DECLARE ASK$SMOOTH$FILE(*) BYTE DATA(0AH,0DH,
            'File name of smoothed data :',0AH,0DH,00);
6   1       DECLARE ERROR(*) BYTE DATA(
            'Error',0AH,0DH,00);
7   1       DECLARE ASK$PRINTER(*) BYTE DATA(
            'Do You want to take print-out?',0AH,0DH,00);
8   1       DECLARE ASK$LPC$FILE(*) BYTE DATA(0AH,0DH,
            'File name for LPC coefficients :',00);
9   1       DECLARE ASK$INSERT$FILE(*) BYTE DATA(
            'File to be inserted : ',00);
0   1       DECLARE PROMPT(*) BYTE DATA(0AH,0DH,')',00);
1   1       DECLARE HEADING(*) BYTE DATA(0AH,0DH,
            'Frame RMS  R  P   k1  k2  k3  k4  k5  k6',
            '   k7  k8  k9  k10 ',0AH,0DH,00);

            /*****************************************************
            *  PROCEDURE : CONVERT
            *  FUNCTION  : converts ASCII string to number
            *  PLM CALL  : I = CONVERT(ASCII);
            *  INPUT     : ASCII = ASCII character
            *  OUTPUT    : returns number
            *  GLOBALS   : none
            *  CALLS     : none
            */
2   1       CONVERT: PROCEDURE(ASCII) BYTE  PUBLIC;

3   2         DECLARE ASCII BYTE;
4   2         DECLARE CONVERT$TABLE(*) BYTE DATA(
            '0','1','2','3','4','5','6','7',
            '8','9','A','B','C','D','E','F');

5   2         DO I = 0 TO 0FH;
6   3           IF ASCII = CONVERT$TABLE(I)
              THEN RETURN I;
8   3         END;

9   2       END CONVERT;

            /*****************************************************
            *  PROCEDURE : CHANGE$FRAME
            *  FUNCTION  : changes pointed entry of selected
            *              frame to the given value
            *  PLM CALL  : CALL CHANGE$FRAME;
            *  INPUT     : BUFFER = ABCDEFG
            *              A = 'F'
            *
```

```
                *                   B = number
                *                   C = number
                *                   D = 'P','E','R' or 'K'
                *                   E = number
                *                   F = number
                *                   G = number
                *   OUTPUT      : changed frame
                *   GLOBALS     : LPC$POINTER,LPC,BUFFER
                *   CALLS       : none
                */
50    1         CHANGE$FRAME: PROCEDURE PUBLIC;

51    2           N = CONVERT(BUFFER(1));
52    2           N = SHL(N,4) OR CONVERT(BUFFER(2));

53    2           DO I = 0 TO N-1;
54    3             LPC$POINTER = LPC$POINTER + 18;
55    3           END;
56    2           LPC$POINTER = LPC$POINTER - 18;
57    2           IF BUFFER(3) = 'P' THEN
58    2           DO;
59    3             LPC(2) = CONVERT(BUFFER(4));
70    3             LPC(2) = SHL(LPC(2),4) OR CONVERT(BUFFER(5));
71    3             RETURN;
72    3           END;

73    2           IF BUFFER(3) = 'E' THEN
74    2           DO;
75    3             LPC(0) = CONVERT(BUFFER(4));
76    3             RETURN;
77    3           END;

78    2           IF BUFFER(3) = 'R' THEN
79    2           DO;
80    3             LPC(1) = CONVERT(BUFFER(4));
81    3             RETURN;
82    3           END;

83    2           IF BUFFER(3) = 'K' THEN
84    2           DO;
85    3             N = 2 + CONVERT(BUFFER(4));
86    3             LPC(N) = CONVERT(BUFFER(5));
87    3             LPC(N) = SHL(LPC(N),4) OR CONVERT(BUFFER(6));
88    3             RETURN;
89    3           END;

90    2           CALL DISPLAY$MESSAGE(.ERROR(0));

91    2         END CHANGE$FRAME;

                /*************************************************
                *   PROCEDURE : CREATE$FILE
                *   FUNCTION  : Creates a file containing smoothed LPC
                *               data
                *   PLM CALL  : CALL CREATE$FILE;
                *   INPUT     : 6000H-7FFFH .....LPC data
                *   OUTPUT    : A new file
```

```
                *  GLOBALS    : LPC$POINTER, RAM$POINTER
                *  CALLS      : OPEN, WRITE, CLOSE
                */
12    1         CREATE$FILE: PROCEDURE PUBLIC;

13    2           CALL DISPLAY$MESSAGE(.ASK$PRINTER(0));
14    2           IF (CI AND 7FH) = 'Y' THEN
15    2             CALL IOSET(81H);
                  ELSE
16    2             CALL IOSET(41H);

17    2           CALL DISPLAY$MESSAGE(.ASK$SMOOTH$FILE(0));
18    2           CALL GET$CHARACTERS;
19    2           CALL OPEN(.M,.BUFFER(0),2,0,.STATUS);
20    2           RAM$POINTER = 8000H;
21    2           J = 1;
22    2           L = 0;
23    2           DO WHILE LPC$POINTER < END$OF$BUFFER;

24    3             IF L = 0 THEN
25    3             DO;
26    4               CALL LO(0CH);
27    4               CALL PRINT$MESSAGE(.HEADING(0));
28    4             END;
29    3             CALL LO(' ');
30    3             CALL PRINT$NUMBER(J);
31    3             CALL LO(' ');
32    3             J = J + 1;
33    3             IF LPC(0) = 0 THEN
34    3               N = 0;
35    3             ELSE DO;
36    4               IF LPC(1) = 1 THEN
37    4                 N = 2;
38    4               ELSE DO;
39    5                 IF LPC(2) = 0 THEN
40    5                   N = 6;
                        ELSE
41    5                   N = 12;
42    5               END;
43    4             END;
44    3             DO I = 0 TO N;
45    4               RAM = LPC(I);
46    4               CALL PRINT$NUMBER(RAM);
47    4               CALL LO(' ');
48    4               RAM$POINTER = RAM$POINTER + 1;
49    4             END;
50    3             LPC$POINTER = LPC$POINTER + 18;
51    3             CALL LO(0AH);
52    3             CALL LO(0DH);
53    3             L = L + 1;
54    3             IF L = 60 THEN L = 0;
56    3           END;

57    2           RAM = 0FH;

58    2           COUNT = RAM$POINTER -7FFFH;
59    2           CALL WRITE(M,8000H,COUNT,.STATUS);
```

```
2          CALL CLOSE(M,.STATUS);

2          CALL IOSET(41H);

2        END CREATE$FILE;
         /*******************************************************
         *  PROCEDURE : SAVE
         *  FUNCTION  : Creates a file containing smoothed row
         *              LPC data
         *  PLM CALL  : CALL SAVE;
         *  INPUT     : 6000H-7FFFH .....LPC data
         *  OUTPUT    : A new file
         *  GLOBALS   : LPC$POINTER, RAM$POINTER
         *  CALLS     : OPEN, WRITE, CLOSE
         */
1        SAVE: PROCEDURE PUBLIC;

2          IF BUFFER(1) = 'X' THEN
2          DO;
3            CALL DISPLAY$MESSAGE(.ASK$SMOOTH$FILE(0));
3            CALL GET$CHARACTERS;
3            CALL OPEN(.FILE,.BUFFER(0),2,0,.STATUS);
3            COUNT = END$OF$BUFFER - 6000H;
3            CALL WRITE(FILE,6000H,COUNT,.STATUS);
3            CALL CLOSE(FILE,.STATUS);
3          END;
2          CALL EXIT;

2        END SAVE;

         /*******************************************************
         *  PROCEDURE : DISPLAY$FRAME
         *  FUNCTION  : Disolays frame data
         *  PLM CALL  : CALL DISPLAY$FRAME
         *  INPUT     : BUFFER = ABC
         *                A = 'D'
         *                B = number
         *                C = number
         *  OUTPUT    : Disolays frame data
         *  GLOBALS   : LPC$POINTER
         *  CALLS     : DISPLAY$MESSAGE, PRINT$NUMBER
         */
1        DISPLAY$FRAME: PROCEDURE PUBLIC;

2          N = CONVERT(BUFFER(1));
2          N = SHL(N,4) OR CONVERT(BUFFER(2));

2          DO I = 0 TO N-1;
3            LPC$POINTER = LPC$POINTER + 18;
3          END;
2          LPC$POINTER = LPC$POINTER - 18;
2          CALL PRINT$MESSAGE(.HEADING(0));
2          CALL LO(' ');
2          CALL PRINT$NUMBER(N);
2          CALL LO(' ');
2          DO I = 0 TO 17;
3            CALL PRINT$NUMBER(LPC(I));
```

```
3   3           CALL LO(' ');
3   3         END;

0   2       END DISPLAY$FRAME;
        /*************************************************
        *  PROCEDURE : CHANGE$ENERGY
        *  FUNCTION  : Changes energy levels
        *  PLM CALL  : CALL CHANGE$ENERGY;
        *  INPUT     : LPC$POINTER points to data block
        *  OUTPUT    : Changed energy levels
        *  GLOBALS   : LPC$POINTER,BUFFER
        *  CALLS     : CONVERT
        */
1   1       CHANGE$ENERGY: PROCEDURE PUBLIC;

2   2         DECLARE RMS(*) ADDRESS DATA(
              0,52,87,123,174,246,348,491,
              694,981,1385,1957,2764,3904,5514,7789);
3   2         DECLARE E(4) BYTE;
4   2         DECLARE DUMMY ADDRESS;
5   2         DECLARE TEMP(2) ADDRESS;

6   2         E(1) = CONVERT(BUFFER(1));
7   2         E(1) = SHL(E(1),4) OR CONVERT(BUFFER(2));
8   2         E(2) = CONVERT(BUFFER(3));
9   2         E(2) = SHL(E(2),4) OR CONVERT(BUFFER(4));
0   2         E(3) = 0;

1   2         DO WHILE LPC$POINTER < END$OF$BUFFER;

2   3           DUMMY = LPC(14);
3   3           TEMP(0) = LPC(13);
4   3           TEMP(0) = TEMP(0) OR SHL(DUMMY,8);
5   3           TEMP(1) = 0;

6   3           CALL FBDIV(.TEMP(0),.E(0),.TEMP(0));
7   3           DO I = 0 TO 14;
8   4             IF TEMP(0) < RMS(I) THEN GO TO RMS$FOUND;
0   4           END;
1   3           I = 15;
2   3         RMS$FOUND:
              IF (LPC(0) = 0) AND (I = 15) THEN;
4   3           ELSE LPC(0) = I-1;
5   3           LPC$POINTER = LPC$POINTER + 18;

6   3         END;

7   2       END CHANGE$ENERGY;

        /*************************************************
        *  PROCEDURE : REMOVE
        *  FUNCTION  : Removes indicated frames from block
        *  PLM CALL  : CALL REMOVE;
        *  INPUT     : LPC$POINTER points to data block
        *              BUFFER(1),BUFFER(2) = Starting frame
        *              BUFFER(3),BUFFER(4) = End frame
        *  OUTPUT    : New block does not contain removed
```

```
                *                   frames
                *   GLOBALS     : LPC$POINTER, BUFFER, RAMPOINTER
                *   CALLS       : CONVERT
                */
3   1           REMOVE: PROCEDURE PUBLIC;

9   2             N = CONVERT(BUFFER(1));
0   2             N = SHL(N,4) OR CONVERT(BUFFER(2));
1   2             I = CONVERT(BUFFER(3));
2   2             I = SHL(I,4) OR CONVERT(BUFFER(4));

3   2             DO J = 1 TO N;
4   3               LPC$POINTER = LPC$POINTER + 18;
5   3             END;
6   2             RAM$POINTER = LPC$POINTER;
7   2             DO J = N+1 TO I;
8   3               RAM$POINTER = RAM$POINTER + 18;
9   3             END;

0   2             DO WHILE RAM$POINTER < END$OF$BUFFER;
1   3               DO J = 0 TO 17;
2   4                 LPC(J) = RAM;
3   4                 RAM$POINTER = RAM$POINTER + 1;
4   4               END;
5   3               LPC$POINTER = LPC$POINTER + 18;
6   3             END;
7   2             END$OF$BUFFER = LPC$POINTER;

8   2           END REMOVE;

                /*************************************************
                *   PROCEDURE : INSERT
                *   FUNCTION  : Inserts selected file after the
                *               indicated frame
                *   PLM CALL  : CALL INSERT;
                *   INPUT     : LPC$POINTER points to data block
                *               BUFFER(1), BUFFER(2) = Starting frame
                *   OUTPUT    : New block contains inserted frames
                *   GLOBALS   : LPC$POINTER, BUFFER, RAMPOINTER
                *   CALLS     : CONVERT
                */
9   1           INSERT: PROCEDURE PUBLIC;

0   2             N = CONVERT(BUFFER(1));
1   2             N = SHL(N,4) OR CONVERT(BUFFER(2));

2   2             RAM$POINTER = 8000H;
3   2             DO J = 1 TO N;
4   3               DO I = 0 TO 17;
5   4                 RAM = LPC(I);
6   4                 RAM$POINTER = RAM$POINTER + 1;
7   4               END;
8   3               LPC$POINTER = LPC$POINTER + 18;
9   3             END;
0   2           ASK$AGAIN:
                  CALL DISPLAY$MESSAGE(.ASK$INSERT$FILE(0));
1   2             CALL GET$CHARACTERS;
```

```
    2          CALL OPEN(.FILE,.BUFFER(0),1,0,.STATUS);
    2          IF STATUS <> 0 THEN
    2          DO;
    3            CALL DISPLAY$MESSAGE(.ERROR(0));
    3            GO TO ASK$AGAIN;
    3          END;
    2          CALL READ(FILE,RAM$POINTER,2000H,.COUNT,.STATUS);
    2          CALL CLOSE(FILE,.STATUS);
    2          END$OF$BUFFER = END$OF$BUFFER + COUNT;
    2          IF END$OF$BUFFER > 7FFFH THEN
    2          DO;
    3            CALL DISPLAYMESSAGE(.ERROR(0));
    3            END$OF$BUFFER = END$OF$BUFFER - COUNT;
    3            RETURN;
    3          END;

    2          RAM$POINTER = RAM$POINTER + COUNT;
    2          DO WHILE LPC$POINTER < (END$OF$BUFFER-COUNT);
    3            DO J = 0 TO 17;
    4              RAM = LPC(J);
    4              RAM$POINTER = RAM$POINTER + 1;
    4            END;
    3            LPC$POINTER = LPC$POINTER + 18;
    3          END;
    2          RAM$POINTER = 8000H;
    2          LPC$POINTER = 6000H;

    2          DO WHILE LPC$POINTER < END$OF$BUFFER;
    3            DO J = 0 TO 17;
    4              LPC(J) = RAM;
    4              RAM$POINTER = RAM$POINTER + 1;
    4            END;
    3            LPC$POINTER = LPC$POINTER + 18;
    3          END;

    2        END INSERT;

             /*******************************************************/

    1        DECLARE BEGIN LABEL PUBLIC;
    1        BEGIN:
             CALL IOSET(41H);
    1        CALL DISPLAY$MESSAGE(.ASK$LPC$FILE(0));
    1        CALL GETCHARACTERS;
    1        CALL OPEN(.FILE,.BUFFER(0),1,0,.STATUS);
    1        IF STATUS <> 0 THEN
    1        DO;
    2          CALL DISPLAY$MESSAGE(.ERROR(0));
    2          GO TO BEGIN;
    2        END;
    1        ELSE DO;
    2          CALL READ(FILE,6000H,2000H,.COUNT,.STATUS);
    2          END$OF$BUFFER = 6000H + COUNT;
    2          CALL CLOSE(FILE,.STATUS);
    2        END;
    1        DO WHILE 1;
    2        LOOP:
```

```
   2          CALL DISPLAY$MESSAGE(.PROMPT(0));
   2          CALL GET$CHARACTERS;
   2          LPC$POINTER = 6000H;
   2          IF BUFFER(0) = 'S' THEN
   2          DO;
   3            CALL CHANGE$ENERGY;
   3            GO TO LOOP;
   3          END;
   2          IF BUFFER(0) = 'F' THEN
   2          DO;
   3            CALL CHANGE$FRAME;
   3            GO TO LOOP;
   3          END;
   2          IF BUFFER(0) = 'D' THEN
   2          DO;
   3            CALL DISPLAY$FRAME;
   3            GO TO LOOP;
   3          END;
   2          IF BUFFER(0) = 'E' THEN
   2          DO;
   3            CALL SAVE;
   3            GO TO LOOP;
   3          END;
   2          IF BUFFER(0) = 'C' THEN
   2          DO;
   3            CALL CREATE$FILE;
   3            GO TO LOOP;
   3          END;
   2          IF BUFFER(0) = 'R' THEN
   2          DO;
   3            CALL REMOVE;
   3            GO TO LOOP;
   3          END;
   2          IF BUFFER(0) = 'I' THEN
   2          DO;
   3            CALL INSERT;
   3            GO TO LOOP;
   3          END;
   2        END;

   1        END MAIN;



LE INFORMATION:

 CODE AREA SIZE     = 0916H   2326D
 VARIABLE AREA SIZE = 0023H     35D
 MAXIMUM STACK SIZE = 000AH     10D
 491 LINES READ
 0 PROGRAM ERROR(S)

OF PL/M-80 COMPILATION
```

-II PL/M-80 V3.0 COMPILATION OF MODULE GRAPHMODULE
T MODULE PLACED IN :F1:SHOW.OBJ
LER INVOKED BY: PLM80 :F1:SHOW.SRC WORKFILES(:F0:,:F0:)

```
$PAGEWIDTH(80)
/*************************************************************
**                                                          **
**              SPEECH SYNTHESIS SYSTEM                     **
**                GRAPH DISPLAY MODULE                      **
**                                                          **
**  FILE NAME    : SHOW.SRC                 DATE            **
**  MODULE DEF   : Main Display             ----------      **
**  AUTHOR       : Onder Bicioglu           22 06 85        **
**                                                          **
*************************************************************/
GRAPH$MODULE:
DO;
1       DECLARE I BYTE;
1       DECLARE (FILE,COUNT,STATUS) ADDRESS;

1       DECLARE KEY BYTE PUBLIC;
1       DECLARE (LEFT,RIGHT,UP,DOWN,
                 HOME,CLEAR,LI) BYTE PUBLIC;
1       DECLARE (TIME$BASE,AMPLITUDE$BASE,START)
                ADDRESS EXTERNAL;
1       DECLARE DATABUF(1) BYTE EXTERNAL;
1       DECLARE BUFFER(1) BYTE EXTERNAL;
1       DECLARE MDS BYTE PUBLIC;

1       DECLARE CR              LITERALLY '13',
                HORIZONTALUNITS LITERALLY '8',
                VERTICALUNITS   LITERALLY '8',
                VCLEFT          LITERALLY '8',
                VCRIGHT         LITERALLY '10H',
                VCUP            LITERALLY '0CH',
                VCDOWN          LITERALLY '0BH',
                VCHOME          LITERALLY '12H',
                VCCLEAR         LITERALLY '1CH',
                VCLI            LITERALLY '1BH',
                INTELLEFT       LITERALLY '44H',
                INTELRIGHT      LITERALLY '43H',
                INTELUP         LITERALLY '41H',
                INTELDOWN       LITERALLY '42H',
                INTELHOME       LITERALLY '48H',
                INTELCLEAR      LITERALLY '45H',
                INTELLI         LITERALLY '1BH';


1       DECLARE (DESPTR,SRCPTR) ADDRESS;
1       DECLARE DES BASED DESPTR BYTE;
1       DECLARE SRC BASED SRCPTR BYTE;
1       DECLARE UPPER(*) BYTE DATA(VCLI,VCCLEAR,VCLI,
          VCDOWN,VCLI,VCDOWN,CR,' ',' ',0);
1       DECLARE YAXIS(*) BYTE DATA('-',VCLI,VCDOWN,
          VCLEFT,'I',VCLI,VCDOWN,VCLEFT,00,00,00);
```

```
16  1       DECLARE XAXIS(*) BYTE DATA('-------I',00);
17  1       DECLARE BASEDATA(*) BYTE DATA('   Timebase :',
            ' 01 msec    Amplitudebase : 20 Units    ',
            'Origin : 0000 msec',00);

18  1       DECLARE ASK$SYSTEM(*) BYTE DATA(0AH,0DH,
            'Is this new MDS ? ',0AH,0DH,00);
19  1       DECLARE ASK$SHOW$FILE(*) BYTE DATA(0AH,0DH,
            'Enter file name to be displayed',0AH,0DH,00);
20  1       DECLARE ERROR(*) BYTE DATA(0AH,0DH,
            'ERROR',0AH,0DH,00);
21  1       DECLARE VC414DATA(*) BYTE DATA(
            VCLEFT,VCRIGHT,VCUP,VCDOWN,VCHOME,
            VCCLEAR,VCLI);
22  1       DECLARE INTEL$DATA(*) BYTE DATA(
            INTELLEFT,INTELRIGHT,INTELUP,INTELDOWN,
            INTELHOME,INTELCLEAR,INTELLI);
23  1       DECLARE INTELTABLE(*) BYTE DATA(
            INTELLI,INTELCLEAR,INTELLI,INTELDOWN,
            INTELLI,INTELDOWN,CR,' ',' ',0,
            '-',INTELLI,INTELDOWN,INTELLI,INTELLEFT,'I',
             INTELLI,INTELDOWN,INTELLI,INTELLEFT,00);

        /*****************************************************/

24  1       CO: PROCEDURE(CHARACTER) EXTERNAL;
25  2         DECLARE CHARACTER BYTE;
26  2         END CO;
27  1       CI: PROCEDURE BYTE EXTERNAL;
28  2         END CI;
29  1       MOVECURSOR: PROCEDURE(DIRECTION,COUNT) EXTERNAL;
30  2         DECLARE (DIRECTION,COUNT) BYTE;
31  2         END MOVECURSOR;
32  1       CHANGETIMEBASE: PROCEDURE EXTERNAL;
33  2         END CHANGETIMEBASE;
34  1       CHANGEAMPLITUDEBASE: PROCEDURE EXTERNAL;
35  2         END CHANGEAMPLITUDEBASE;
36  1       SHIFTLEFT: PROCEDURE EXTERNAL;
37  2         END SHIFTLEFT;
38  1       SHIFTRIGHT: PROCEDURE EXTERNAL;
39  2         END SHIFTRIGHT;
40  1       CHANGE$ORIGIN: PROCEDURE EXTERNAL;
41  2         END CHANGE$ORIGIN;
42  1       DRAWGRAPH: PROCEDURE EXTERNAL;
43  2         END DRAWGRAPH;
44  1       DISPLAY$MESSAGE: PROCEDURE(POINTER) EXTERNAL;
45  2         DECLARE POINTER ADDRESS;
46  2         END DISPLAY$MESSAGE;
47  1       EXIT: PROCEDURE EXTERNAL;
48  2         END EXIT;
49  1       OPEN: PROCEDURE(P1,P2,P3,P4,P5) EXTERNAL;
50  2         DECLARE (P1,P2,P3,P4,P5) ADDRESS;
51  2         END OPEN;
52  1       READ: PROCEDURE(P1,P2,P3,P4,P5) EXTERNAL;
53  2         DECLARE (P1,P2,P3,P4,P5) ADDRESS;
54  2         END READ;
55  1       CLOSE: PROCEDURE(P1,P2) EXTERNAL;
```

```
2         DECLARE (P1,P2) ADDRESS;
2         END CLOSE;
1       GETCHARACTERS: PROCEDURE EXTERNAL;
2         END GET$CHARACTERS;
        /*********************************************/
1       BEGIN:
        CALL DISPLAY$MESSAGE(.ASK$SHOW$FILE(0));
1       CALL GET$CHARACTERS;
1       CALL OPEN(.FILE,.BUFFER(0),1,0,.STATUS);
1       IF STATUS <> 0 THEN
1       DO;
2         CALL DISPLAY$MESSAGE(.ERROR(0));
2         GO TO BEGIN;
2       END;
1       CALL READ(FILE,.DATABUF(0),4000H,.COUNT,.STATUS);
1       CALL CLOSE(FILE,.STATUS);

1       CALL DISPLAY$MESSAGE(.ASK$SYSTEM(0));
1       IF (CI AND 7FH) = 'Y' THEN
1       DO;
2         SRCPTR = .INTEL$TABLE(0);
2         DESPTR = .UPPER(0);
2         DO I=1 TO 21;
3           DES = SRC;
3           DESPTR = DESPTR + 1;
3           SRCPTR = SRCPTR + 1;
3         END;
2         MDS = 1;
2         SRCPTR = .INTEL$DATA(0);
2       END;
1       ELSE DO;
2         MDS = 0;
2         SRCPTR = .VC414DATA(0);
2       END;
1       DESPTR = .LEFT;
1       DO I = 1 TO 7;
2         DES = SRC;
2         DESPTR = DESPTR + 1;
2         SRCPTR = SRCPTR + 1;
2       END;

1       START=.DATABUF(0);
1       TIMEBASE=1;
1       AMPLITUDEBASE=32;

1       CALL DISPLAY$MESSAGE(.UPPER(00));
1       DO I=1 TO VERTICALUNITS;
2         CALL DISPLAY$MESSAGE(.YAXIS(0));
2       END;
1       CALL CO('-');
1       CALL MOVECURSOR(UP,VERTICALUNITS);
1       DO I=1 TO HORIZONTALUNITS;
2         CALL DISPLAY$MESSAGE(.XAXIS(0));
2       END;

1       CALL MOVECURSOR(LEFT,8*HORIZONTALUNITS);
1       CALL MOVECURSOR(DOWN,VERTICALUNITS+3);
```

```
1       CALL DISPLAY$MESSAGE(.BASEDATA(0));
1       CALL CO(LI);
1       CALL CO(HOME);
1       CALL DRAWGRAPH;

1       DO WHILE 1;
2         KEY=CI AND 7FH;
2         IF KEY='E'    THEN CALL EXIT;
2         IF KEY='T'    THEN CALL CHANGE$TIME$BASE;
2         IF KEY='A'    THEN CALL CHANGE$AMPLITUDE$BASE;
2         IF KEY=RIGHT  THEN CALL SHIFTRIGHT;
2         IF KEY=LEFT   THEN CALL SHIFTLEFT;
2         IF KEY='O'    THEN CALL CHANGE$ORIGIN;
2       END;

1       END GRAPHMODULE;
```

```
LE INFORMATION:

 CODE AREA SIZE      = 0291H    657D
 VARIABLE AREA SIZE  = 0014H     20D
 MAXIMUM STACK SIZE  = 0008H      8D
 181 LINES READ
 0 PROGRAM ERROR(S)

OF PL/M-80 COMPILATION
```

```
) :F1:WINDOW.SRC


-II 8080/8085 MACRO ASSEMBLER, V3.0          WINDOW          166

C  OBJ          LINE        SOURCE STATEMENT

                    1 $PAGEWIDTH(80)
                    2 ;*****************************************************
                    3 ;*
                    4 ;*            SPEECH SYNTHESIS SYSTEM
                    5 ;*                HAMMING WINDOW
                    6 ;*
                    7 ;*  FILE NAME    : WINDOW.SRC              DATE
                    8 ;*  MODULE DEF   : Hamming Window       ----------
                    9 ;*  AUTHOR       : Onder Bicioglu       22 06 85
                   10 ;*
                   11 ;*****************************************************
                   12 ;
                   13          NAME    WINDOW
                   14 ;
                   15          PUBLIC  W
                   16 ;
                   17          CSEG
                   18 ;
00 7B14            19 W:       DW      5243,0,5258,0,5303,0,5377,0
02 0000
04 8A14
06 0000
08 B714
0A 0000
0C 0115
0E 0000
10 6915            20          DW      5481,0,5614,0,5777,0,5969,0
12 0000
14 EE15
16 0000
18 9116
1A 0000
1C 5117
1E 0000
20 2E18            21          DW      6190,0,6440,0,6718,0,7025,0
22 0000
24 2819
26 0000
28 3E1A
2A 0000
2C 711B
2E 0000
30 C01C            22          DW      7360,0,7722,0,8112,0,8529,0
32 0000
34 2A1E
36 0000
38 B01F
3A 0000
3C 5121
3E 0000
40 0C23            23          DW      8972,0,9441,0,9936,0,10456,0
42 0000
44 E124
46 0000
```

```
LOC  OBJ           LINE      SOURCE STATEMENT

0048 D026
004A 0000
004C D828
004E 0000
0050 F82A            24          DW      11000,0,11568,0,12161,0,12776,0
0052 0000
0054 302D
0056 0000
0058 B12F
005A 0000
005C E831
005E 0000
0060 6534            25          DW      13413,0,14073,0,14753,0,15453,0
0062 0000
0064 F936
0066 0000
0068 A139
006A 0000
006C 5D3C
006E 0000
0070 2D3F            26          DW      16173,0,16912,0,16670,0,18444,0
0072 0000
0074 1042
0076 0000
0078 1E41
007A 0000
007C 0C48
007E 0000
0080 244B            27 W8:      DW      19236,0,20043,0,20892,0,21703,0
0082 0000
0084 4B4E
0086 0000
0088 9C51
008A 0000
008C C754
008E 0000
0090 1A58            28          DW      22554,0,23417,0,24291,0,25178,0
0092 0000
0094 795B
0096 0000
0098 E35E
009A 0000
009C 5A62
009E 0000
00A0 D965            29          DW      26073,0,26979,0,27892,0,28813,0
00A2 0000
00A4 6369
00A6 0000
00A8 F46C
00AA 0000
00AC 8D70
00AE 0000
00B0 2F74            30          DW      29740,0,30673,0,31611,0,32552,0
00B2 0000
00B4 D177
```

```
LOC  OBJ            LINE      SOURCE STATEMENT

00B6 0000
00B8 7B7B
00BA 0000
00BC 287F
00BE 0000
00C0 D882             31          DW      33496,0,34442,0,35389,0,36336,0
00C2 0000
00C4 8A86
00C6 0000
00C8 3D8A
00CA 0000
00CC F08D
00CE 0000
00D0 A291             32          DW      37282,0,38226,0,39168,0,40105,0
00D2 0000
00D4 5295
00D6 0000
00D8 0099
00DA 0000
00DC A99C
00DE 0000
00E0 4EA0             33          DW      41038,0,41965,0,42887,0,43800,0
00E2 0000
00E4 EDA3
00E6 0000
00E8 87A7
00EA 0000
00EC 18AB
00EE 0000
00F0 A1AE             34          DW      44705,0,45601,0,46487,0,47362,0
00F2 0000
00F4 21B2
00F6 0000
00F8 97B5
00FA 0000
00FC 02B9
00FE 0000
0100 61BC             35 W16:     DW      48225,0,49076,0,49912,0,50735,0
0102 0000
0104 B4BF
0106 0000
0108 F8C2
010A 0000
010C 2FC6
010E 0000
0110 5AC9             36          DW      51542,0,52334,0,53109,0,53866,0
0112 0000
0114 6ECC
0116 0000
0118 75CF
011A 0000
011C 6AD2
011E 0000
0120 4DD5             37          DW      54605,0,55325,0,56026,0,56706,0
0122 0000
```

```
LOC  OBJ           LINE        SOURCE STATEMENT

0124 1DD8
0126 0000
0128 DADA
012A 0000
012C 82DD
012E 0000
0130 15E0           38          DW      57365,0,58003,0,58617,0,59210,0
0132 0000
0134 93E2
0136 0000
0138 F9E4
013A 0000
013C 4AE7
013E 0000
0140 87F9           39          DW      59779,0,60323,0,60842,0,61338,0
0142 0000
0144 A3EB
0146 0000
0148 AAED
014A 0000
014C 9AEF
014E 0000
0150 6FF1           40          DW      61807,0,62191,0,62669,0,63057,0
0152 0000
0154 EFF2
0156 0000
0158 CDF4
015A 0000
015C 51F6
015E 0000
0160 BBF7           41          DW      63419,0,63753,0,64061,0,64339,0
0162 0000
0164 09F9
0166 0000
0168 3DFA
016A 0000
016C 53FB
016E 0000
0170 4DFC           42          DW      64589,0,64810,0,65001,0,65165,0
0172 0000
0174 2AFD
0176 0000
0178 E9FD
017A 0000
017C 8DFE
017E 0000
0180 12FF           43          DW      65298,0,65402,0,65476,0,65521,0
0182 0000
0184 7AFF
0186 0000
0188 C4FF
018A 0000
018C F1FF
018E 0000

                    44 ;
```

```
LOC  OBJ          LINE        SOURCE STATEMENT

                    45 END


BLIC SYMBOLS
      C 0000

TERNAL SYMBOLS


ER SYMBOLS
      C 0000    W16    C 0100    W8    C 0080

SEMBLY COMPLETE,  NO ERRORS
```

```
80 :F1:ALU001.SRC


S-II 8080/8085 MACRO ASSEMBLER, V3.0          FBDATA          171

OC  OBJ          LINE        SOURCE STATEMENT

                    1 $PAGEWIDTH(80)
                    2 ;*****************************************************
                    3 ;*
                    4 ;*                SPEECH SYNTHESIS SYSTEM
                    5 ;*                 32-BIT LIBRARY DATA
                    6 ;*
                    7 ;*  FILE NAME    : ALU001.SRC              DATE
                    8 ;*  MODULE DEF   : Data definitions      ---------
                    9 ;*  AUTHOR       : Onder Bicioglu        22 06 85
                   10 ;*
                   11 ;*****************************************************
                   12 ;
                   13          NAME    FBDATA
                   14 ;
                   15          PUBLIC  OP1,OP1END,OP2,OP2END
                   16          PUBLIC  OP3,OP3END,OP4,OP4END
                   17          PUBLIC  SIGN,INDEX,I,J
                   18          PUBLIC  ACOUNT,BCOUNT,LINDEX
                   19          PUBLIC  RESULT
                   20 ;
                   21          DSEG
                   22 ;*****************************************************
                   23 ;
0000               24 OP1:     DS      3
0003               25 OP1END:  DS      1
0004               26 OP2:     DS      3
0007               27 OP2END:  DS      1
0008               28 OP3:     DS      3
000B               29 OP3END:  DS      1
000C               30 OP4:     DS      3
000F               31 OP4END:  DS      1
0010               32 SIGN:    DS      1
0011               33 INDEX:   DS      1
0012               34 ACOUNT:  DS      1
0013               35 BCOUNT:  DS      1
0014               36 I:       DS      1
0015               37 J:       DS      1
0016 0100          38 RESULT:  DW      1
0018               39 LINDEX:  DS      1
0019               40 SIGNAL:  DS      1
                   41 ;
                   42 ;*****************************************************
                   43 ;
                   44          END


BLIC SYMBOLS
OUNT  D 0012    BCOUNT D 0013    I       D 0014    INDEX   D 0011
      D 0015    LINDEX D 0018    OP1     D 0000    OP1END  D 0003
2     D 0004    OP2END D 0007    OP3     D 0008    OP3END  D 000B
4     D 000C    OP4END D 000F    RESULT  D 0016    SIGN    D 0010

TERNAL SYMBOLS
```

R SYMBOLS

UNT	D	0012	BCOUNT	D	0013	I	D	0014
INDEX	D	0011		D	0015	LINDEX	D	0018
OP1	D	0000	OP1END	D	0003		D	0004
OP2END	D	0007	OP3	D	0008	OP3END	D	000B
	D	000C	OP4END	D	000F	RESULT	D	0016
SIGN	D	0010	NAL	D	0019			

EMBLY COMPLETE, NO ERRORS

```
OBJ             LINE        SOURCE STATEMENT

                    1 $PAGEWIDTH(80)
                    2 ;*****************************************************
                    3 ;*                                                   **
                    4 ;*              SPEECH SYNTHESIS SYSTEM              **
                    5 ;*         ADDITION,SUBTRACTION,MULTIPLICATION       **
                    6 ;*                                                   **
                    7 ;*  FILE NAME    : ALU002 .SRC          DATE         **
                    8 ;*  MODULE DEF   : Four byte arith.     ---------    **
                    9 ;*  AUTHOR       : Onder Bicioglu       22 06 85     **
                   10 ;*                                                   **
                   11 ;*****************************************************/
                   12 ;
                   13          NAME    FBARIT
                   14 ;
                   15          EXTRN   OP1,OP1END,OP2,OP2END
                   16          EXTRN   OP3,OP3END,OP4,OP4END
                   17          EXTRN   SIGN,INDEX,I,J
                   18          EXTRN   LINDEX,RESULT
                   19 ;
                   20          EXTRN   BY2,TIMES2
                   21 ;
                   22          PUBLIC  FBADD,FBSUB,FBMUL
                   23 ;
                   24          CSEG
                   25 ;
                   26 ;*****************************************************
                   27 ;  PROCEDURE : FBADD
                   28 ;  FUNCTION  : Adds two four byte operands pointed by
                   29 ;              the first two parameters and placed t
                   30 ;              result to the memory pointed by the l
                   31 ;              operand
                   32 ;  PLM CALL  : CALL FBADD(OPERAND1,OPERAND2,RESULT
                   33 ;  INPUT     : OPERAND1....address of the first byte
                   34 ;              of first operand
                   35 ;              OPERAND2....address of the first byte
                   36 ;              of the second operand
                   37 ;              RESULT......address of the first byte
                   38 ;              of memory to store the result
                   39 ;  OUTPUT    : RESULT=result
                   40 ;  GLOBALS   : none
                   41 ;  CALLS     : none
                   42 ;  DESTROYS  : all
                   43 ;
00 E1              44 FBADD:  POP     H
01 E3              45         XTHL
                   46 ;
02 0A              47         LDAX    B
03 86              48         ADD     M
04 12              49         STAX    D
                   50 ;
05 23              51         INX     H
06 13              52         INX     D
07 03              53         INX     B
08 0A              54         LDAX    B
```

```
 OBJ          LINE        SOURCE STATEMENT

9 8E            55          ADC     M
A 12            56          STAX    D
                57 ;
B 23            58          INX     H
C 13            59          INX     D
D 03            60          INX     B
E 0A            61          LDAX    B
F 8E            62          ADC     M
0 12            63          STAX    D
                64 ;
1 23            65          INX     H
2 13            66          INX     D
3 03            67          INX     B
4 0A            68          LDAX    B
5 8E            69          ADC     M
6 12            70          STAX    D
                71 ;
7 C9            72          RET
                73 ;
                74 ;*****************************************************
                75 ;   PROCEDURE : FBSUB
                76 ;   FUNCTION  : Subtracts the four byte operand pointe
                77 ;               by the first parameter from the second
                78 ;               four byte parameter and puts the resul
                79 ;               to the memory location pointed by thir
                80 ;               parameter
                81 ;   PLM CALL  : CALL FBSUB(OPERAND1,OPERAND2,RESULT
                82 ;   INPUT     : OPERAND1....address of the first byte
                83 ;               of first operand
                84 ;               OPERAND2....address of the first byte
                85 ;               of the second operand
                86 ;               RESULT......address of the first byte
                87 ;               of memory to store the result
                88 ;   OUTPUT    : RESULT=result
                89 ;   GLOBALS   : none
                90 ;   CALLS     : none
                91 ;   DESTROYS  : all
                92 ;
8 E1            93 FBSUB:   POP     H
9 E3            94          XTHL
                95 ;
A 0A            96          LDAX    B
B 96            97          SUB     M
C 12            98          STAX    D
                99 ;
D 23           100          INX     H
E 13           101          INX     D
F 03           102          INX     B
0 0A           103          LDAX    B
1 9E           104          SBB     M
2 12           105          STAX    D
               106 ;
3 23           107          INX     H
4 13           108          INX     D
5 03           109          INX     B
```

```
 OBJ          LINE        SOURCE STATEMENT

 0A            110          LDAX    B
 9E            111          SBB     M
 12            112          STAX    D
               113 ;
 23            114          INX     H
 13            115          INX     D
 03            116          INX     B
 0A            117          LDAX    B
 9E            118          SBB     M
 12            119          STAX    D
               120 ;
 C9            121          RET
               122 ;
               123 ;*****************************************************
               124 ;  PROCEDURE : FBMUL
               125 ;  FUNCTION  : Multiplies two four byte operands and
               126 ;              places the result to the memory
               127 ;              location pointed by the third paramete
               128 ;  PLM CALL  : CALL SBMUL(OPERAND1,OPERAND2,RESULT);
               129 ;  INPUT     : OPERAND1.......First multiplier
               130 ;              OPERAND2.......Second multiplier
               131 ;              RESULT.........points to the memory to
               132 ;              store the result
               133 ;  OUTPUT    : RESULT=result
               134 ;  GLOBALS   : OP1,OP2,OP1END,OP2END,INDEX,SIGN
               135 ;  CALLS     : FBADD,BY2
               136 ;  DESTROYS  : all
               137 ;
0 210000    E  138 FBMUL:  LXI     H,OP1
3 0A           139          LDAX    B
4 77           140          MOV     M,A
5 23           141          INX     H
5 03           142          INX     B
7 0A           143          LDAX    B
8 77           144          MOV     M,A
9 23           145          INX     H
A 03           146          INX     B
B 0A           147          LDAX    B
C 77           148          MOV     M,A
D 23           149          INX     H
E 03           150          INX     B
F 0A           151          LDAX    B
0 77           152          MOV     M,A      ;OP1 loaded
               153                           ;
1 E1           154          POP     H
2 E3           155          XTHL
3 010000    E  156          LXI     B,OP2
6 7E           157          MOV     A,M
7 02           158          STAX    B
8 23           159          INX     H
9 03           160          INX     B
A 7E           161          MOV     A,M
B 02           162          STAX    B
C 23           163          INX     H
D 03           164          INX     B
```

```
C  OBJ            LINE        SOURCE STATEMENT

 4E 7E              165          MOV     A,M
 4F 02              166          STAX    B
 50 23              167          INX     H
 51 03              168          INX     B
 52 7E              169          MOV     A,M
 53 02              170          STAX    B
                    171                                  ;OP2 loaded
 54 EB              172          XCHG
 55 220000    E     173          SHLD    RESULT
 58 AF              174          XRA     A
 59 77              175          MOV     M,A
 5A 23              176          INX     H
 5B 77              177          MOV     M,A
 5C 23              178          INX     H
 5D 77              179          MOV     M,A
 5E 23              180          INX     H
 5F 77              181          MOV     M,A
                    182                                  ;RESULT zeroed
 60 320000    E     183          STA     SIGN
                    184                                  ;SIGN = +
 63 3E1F            185          MVI     A,31
 65 320000    E     186          STA     LINDEX
                    187                                  ;LINDEX = 31
 68 3E11            188          MVI     A,17
 6A 320000    E     189          STA     INDEX
                    190                                  ;INDEX = 17
 6D 210000    E     191          LXI     H,OP1END
 70 CDEB00    C     192          CALL    SGNCHK
                    193                                  ;conversion if necessary
 73 3A0000    E     194 GOON:    LDA     OP1
 76 E601            195          ANI     1
 78 C28C00    C     196          JNZ     GOON1
                    197                                  ;
 7B 210000    E     198          LXI     H,OP1END
 7E CD0000    E     199          CALL    BY2
                    200                                  ;OP1 = OP1 / 2
 81 210000    E     201          LXI     H,LINDEX
 84 35              202          DCR     M
 85 210000    E     203          LXI     H,INDEX
 88 35              204          DCR     M
 89 C27300    C     205          JNZ     GOON
                    206                                  ;
 8C 210000    E     207 GOON1:   LXI     H,OP2END
 8F CDEB00    C     208          CALL    SGNCHK
                    209                                  ;conversion if necessary
                    210 ;
 92 3A0000    E     211 DOMULT:  LDA     INDEX
 95 B7              212          ORA     A
 96 CAA900    C     213          JZ      SIFT02
 99 3D              214          DCR     A
 9A 320000    E     215          STA     INDEX
                    216                                  ;If INDEX<>0 then
                    217                                  ;decrement INDEX
 9D 2A0000    E     218          LHLD    RESULT
 A0 23              219          INX     H
```

```
 OC  OBJ            LINE        SOURCE STATEMENT

 0A1 23              220          INX     H
 0A2 23              221          INX     H
 0A3 CD0000    E     222          CALL    BY2
                     223                                  ;RESULT = RESULT / 2
 0A6 C3AF00    C     224          JMP     SIFTO1
                     225                                  ;
 0A9 210000    E     226 SIFTO2:  LXI     H,OP2
 0AC CD0000    E     227          CALL    TIMES2
                     228                                  ;OP2 = 2 * OP2
 0AF 210000    E     229 SIFTO1:  LXI     H,OP1END
 0B2 CD0000    E     230          CALL    BY2
                     231                                  ;OP1 = OP1 / 2
 0B5 D2C300    C     232          JNC     NOADD
 0B8 2A0000    E     233          LHLD    RESULT
 0BB E5              234          PUSH    H
 0BC EB              235          XCHG
 0BD 010000    E     236          LXI     B,OP2
 0C0 CD0000    C     237          CALL    FBADD
                     238                                  ;RESULT = RESULT + OP2
 0C3 210000    E     239 NOADD:   LXI     H,LINDEX
 0C6 35              240          DCR     M
 0C7 C29200    C     241          JNZ     DOMULT
                     242                                  ;If LINDEX <> 0 then loop
 0CA 3A0000    E     243          LDA     SIGN
 0CD B7              244          ORA     A
 0CE C8              245          RZ
                     246
 0CF 2A0000    E     247          LHLD    RESULT
 0D2 AF              248          XRA     A
 0D3 7E              249          MOV     A,M
 0D4 D601            250          SUI     1
 0D6 2F              251          CMA
 0D7 77              252          MOV     M,A     ;
 0D8 23              253          INX     H
 0D9 7E              254          MOV     A,M
 0DA DE00            255          SBI     0
 0DC 2F              256          CMA
 0DD 77              257          MOV     M,A     ;
 0DE 23              258          INX     H
 0DF 7E              259          MOV     A,M
 0E0 DE00            260          SBI     0
 0E2 2F              261          CMA
 0E3 77              262          MOV     M,A     ;
 0E4 23              263          INX     H
 0E5 7E              264          MOV     A,M
 0E6 DE00            265          SBI     0
 0E8 2F              266          CMA
 0E9 77              267          MOV     M,A
 0EA C9              268 EXIT:    RET
                     269 ;
                     270 ;*****************************************************
                     271 ;
 0EB 7E              272 SGNCHK:  MOV     A,M
 0EC B7              273          ORA     A
 0ED F0              274          RP
```

```
LOC  OBJ            LINE        SOURCE STATEMENT

                     275 ;
00EE 2B              276         DCX     H
00EF 2B              277         DCX     H
00F0 2B              278         DCX     H
                     279 ;
00F1 7E              280         MOV     A,M
00F2 2F              281         CMA
00F3 C601            282         ADI     1
00F5 77              283         MOV     M,A
                     284 ;
00F6 23              285         INX     H
00F7 7E              286         MOV     A,M
00F8 2F              287         CMA
00F9 CE00            288         ACI     0
00FB 77              289         MOV     M,A
                     290 ;
00FC 23              291         INX     H
00FD 7E              292         MOV     A,M
00FE 2F              293         CMA
00FF CE00            294         ACI     0
0101 77              295         MOV     M,A
                     296 ;
0102 23              297         INX     H
0103 7E              298         MOV     A,M
0104 2F              299         CMA
0105 CE00            300         ACI     0
0107 77              301         MOV     M,A
                     302 ;
0108 3A0000    E     303         LDA     SIGN
010B 2F              304         CMA
010C 320000    E     305         STA     SIGN
010F C9              306         RET
                     307 ;
                     308 ;*****************************************************
                     309 ;
                     310         END


PUBLIC SYMBOLS
FBADD  C 0000    FBMUL  C 0030    FBSUB  C 0018

EXTERNAL SYMBOLS
I2     E 0000    I      E 0000    INDEX  E 0000    J      E 0000
INDEX  E 0000    OP1    E 0000    OP1END E 0000    OP2    E 0000
OP2END E 0000    OP3    E 0000    OP3END E 0000    OP4    E 0000
OP4END E 0000    RESULT E 0000    SIGN   E 0000    TIMES2 E 0000

USER SYMBOLS
I2     E 0000    DOMULT C 0092    EXIT   C 00EA    FBADD  C 0000
FMUL   C 0030    FBSUB  C 0018    GOON   C 0073    GOON1  C 008C
J      E 0000    INDEX  E 0000    J      E 0000    LINDEX E 0000
FBADD  C 00C3    OP1    E 0000    OP1END E 0000    OP2    E 0000
OP2END E 0000    OP3    E 0000    OP3END E 0000    OP4    E 0000
OP4END E 0000    RESULT E 0000    SGNCHK C 00EB    SIFT01 C 00AF
SIFT02 C 00A9    SIGN   E 0000    TIMES2 E 0000
```

```
OBJ             LINE        SOURCE STATEMENT

                  1 $PAGEWIDTH(80)
                  2 ;*******************************************************
                  3 ;*                                                     **
                  4 ;*                SPEECH SYNTHESIS SYSTEM              **
                  5 ;*                      DIVISION                       **
                  6 ;*                                                     **
                  7 ;*  FILE NAME    : ALU003.SRC            DATE         **
                  8 ;*  MODULE DEF   : Four byte arith.      ---------    **
                  9 ;*  AUTHOR       : Onder Bicioglu        22 06 85     **
                 10 ;*                                                     **
                 11 ;*******************************************************
                 12 ;
                 13          NAME    DIVIDE
                 14 ;
                 15          PUBLIC  FBDIV,BY2,TIMES2
                 16          PUBLIC  LOOP1,LOOP,CHKSGN
                 17 ;
                 18          EXTRN   ACOUNT,BCOUNT,INDEX,SIGN
                 19          EXTRN   I,J,RESULT
                 20          EXTRN   OP1,OP1END,OP2,OP2END
                 21          EXTRN   OP3,OP3END,OP4,OP4END
                 22          EXTRN   FBSUB
                 23 ;
                 24          CSEG
                 25 ;
                 26 ;*******************************************************
                 27 ;  PROCEDURE : FBDIV
                 28 ;  FUNCTION  : Divides first operand by the second one
                 29 ;              places the result to the memory
                 30 ;              location pointed by the third parameter
                 31 ;  PLM CALL  : CALL FBDIV(OPERAND1,OPERAND2,RESULT);
                 32 ;  INPUT     : OPERAND1.......dividend
                 33 ;              OPERAND2.......divisor
                 34 ;              RESULT.........result
                 35 ;  OUTPUT    : RESULT=result
                 36 ;  GLOBALS   : OP1,OP2,OP1END,OP2END,INDEX,SIGN
                 37 ;  CALLS     : FBADD
                 38 ;  DESTROYS  : all
                 39 ;
EB               40 FBDIV:   XCHG
220000     E     41          SHLD    RESULT
                 42 ;
AF               43          XRA     A
320000     E     44          STA     SIGN    ;sign=+
320000     E     45          STA     BCOUNT  ;BCOUNT=0
320000     E     46          STA     I       ;I=0
320000     E     47          STA     ACOUNT  ;ACOUNT=0
                 48 ;
210000     E     49          LXI     H,OP2
AF               50          XRA     A
0A               51          LDAX    B
2F               52          CMA
C601             53          ADI     1
77               54          MOV     M,A
```

```
LOC  OBJ            LINE        SOURCE STATEMENT

                      55 ;
001A 03               56          INX     B
001B 23               57          INX     H
001C 0A               58          LDAX    B
001D 2F               59          CMA
001E CE00             60          ACI     0
0020 77               61          MOV     M,A
                      62 ;
0021 03               63          INX     B
0022 23               64          INX     H
0023 0A               65          LDAX    B
0024 2F               66          CMA
0025 CE00             67          ACI     0
0027 77               68          MOV     M,A
                      69 ;
0028 03               70          INX     B
0029 23               71          INX     H
002A 0A               72          LDAX    B
002B B7               73          ORA     A
002C F23B00      C    74          JP      PLUS
                      75 ;
002F 2F               76          CMA
0030 CE00             77          ACI     0
0032 77               78          MOV     M,A
0033 3EFF             79          MVI     A,0FFH
0035 320000      E    80          STA     SIGN
0038 C34A00      C    81          JMP     GOON
                      82 ;
003B 77               83 PLUS:    MOV     M,A
                      84 ;
003C 2B               85          DCX     H
003D 0B               86          DCX     B
003E 0A               87          LDAX    B
003F 77               88          MOV     M,A
                      89 ;
0040 2B               90          DCX     H
0041 0B               91          DCX     B
0042 0A               92          LDAX    B
0043 77               93          MOV     M,A
                      94 ;
0044 2B               95          DCX     H
0045 0B               96          DCX     B
0046 0A               97          LDAX    B
0047 77               98          MOV     M,A
                      99 ;
0048 E1              100 GOON:    POP     H
0049 E3              101          XTHL
                     102 ;                        ;get first parameter
004A 010000      E   103          LXI     B,OP1
004D AF              104          XRA     A
                     105 ;
004E 7E              106          MOV     A,M
004F 2F              107          CMA
0050 C601            108          ADI     1
0052 02              109          STAX    B
```

```
LOC  OBJ            LINE      SOURCE STATEMENT

                     110 ;
0053 03              111       INX     B
0054 23              112       INX     H
0055 7E              113       MOV     A,M
0056 2F              114       CMA
0057 CE00            115       ACI     0
0059 02              116       STAX    B
                     117 ;
005A 03              118       INX     B
005B 23              119       INX     H
005C 7E              120       MOV     A,M
005D 2F              121       CMA
005E CE00            122       ACI     0
0060 02              123       STAX    B
                     124 ;
0061 03              125       INX     B
0062 23              126       INX     H
0063 7E              127       MOV     A,M
0064 B7              128       ORA     A
0065 F27600      C   129       JP      PLUS1
                     130 ;
0068 2F              131       CMA
0069 CE00            132       ACI     0
006B 02              133       STAX    B
006C 3A0000      E   134       LDA     SIGN
006F 2F              135       CMA
0070 320000      E   136       STA     SIGN
0073 C38300      C   137       JMP     DODIV
                     138 ;
0076 02              139 PLUS1:  STAX    B       ;
0077 2B              140       DCX     H
0078 0B              141       DCX     B
0079 7E              142       MOV     A,M
007A 02              143       STAX    B       ;
007B 2B              144       DCX     H
007C 0B              145       DCX     B
007D 7E              146       MOV     A,M
007E 02              147       STAX    B       ;
007F 2B              148       DCX     H
0080 0B              149       DCX     B
0081 7E              150       MOV     A,M
0082 02              151       STAX    B       ;
                     152 ;
0083 2A0000      E   153 DODIV:  LHLD    RESULT
0086 AF              154       XRA     A
0087 77              155       MOV     M,A
0088 23              156       INX     H
0089 77              157       MOV     M,A
008A 23              158       INX     H
008B 77              159       MOV     M,A
008C 23              160       INX     H
008D 77              161       MOV     M,A
                     162                       ;RESULT is made zero
008E 3A0000      E   163       LDA     OPIEND
0091 E640            164       ANI     40H
```

```
LOC  OBJ          LINE        SOURCE STATEMENT

093  C2A900   C    165             JNZ     OP1OK
                  166 ;
096  210000   E    167             LXI     H,OP1
099  CDA901   C    168             CALL    TIMES2
09C  210000   E    169             LXI     H,ACOUNT
09F  34            170             INR     M
0A0  3E1F          171             MVI     A,31
0A2  BE            172             CMP     M
0A3  CA9701   C    173             JZ      EXIT
                  174 ;
0A6  C38300   C    175             JMP     DODIV
                  176 ;
0A9  3A0000   E    177 OP1OK:      LDA     OP2END
0AC  E640          178             ANI     40H
0AE  C2BE00   C    179             JNZ     OP2OK
                  180 ;
0B1  210000   E    181             LXI     H,OP2
0B4  CDA901   C    182             CALL    TIMES2
0B7  210000   E    183             LXI     H,BCOUNT
0BA  34            184             INR     M
0BB  C3A900   C    185             JMP     OP1OK
                  186 ;
0BE  210000   E    187 OP2OK:      LXI     H,BCOUNT
0C1  3E10          188             MVI     A,16
0C3  86            189             ADD     M
0C4  210000   E    190             LXI     H,ACOUNT
0C7  96            191             SUB     M
0C8  FE1F          192             CPI     31
0CA  DADF00   C    193             JC      LDIDX   ;load index
                  194 ;
0CD  2A0000   E    195             LHLD    RESULT
0D0  36FF          196             MVI     M,0FFH
0D2  23            197             INX     H
0D3  36FF          198             MVI     M,0FFH
0D5  23            199             INX     H
0D6  36FF          200             MVI     M,0FFH
0D8  23            201             INX     H
0D9  367F          202             MVI     M,07FH
0DB  C39701   C    203             JMP     EXIT
                  204 ;
0DE  320000   E    205 LDIDX:      STA     INDEX
                  206 ;
0E1  210000   E    207 LOOP:       LXI     H,OP2
0E4  E5            208             PUSH    H
0E5  010000   E    209             LXI     B,OP1
0E8  110000   E    210             LXI     D,OP4
0EB  CD0000   E    211             CALL    FBSUB
                  212 ;
0EE  3A0000   E    213             LDA     OP4END
0F1  E680          214             ANI     80H
0F3  C25B01   C    215             JNZ     ALTB
                  216                             ;A Less Than B
0F6  2A0000   E    217             LHLD    RESULT
0F9  7E            218             MOV     A,M
0FA  F601          219             ORI     1
```

```
LOC  OBJ              LINE      SOURCE STATEMENT

00FC 77                220          MOV     M,A
                       221                                ;RESULT=RESULT+1
00FD 210000      E     222          LXI     H,OP4
0100 CDA901      C     223          CALL    TIMES2
                       224                                ;OP4=(A-B)*2
0103 210000      E     225          LXI     H,OP4
0106 110000      E     226          LXI     D,OP1
0109 7E                227          MOV     A,M
010A 12                228          STAX    D
010B 13                229          INX     D
010C 23                230          INX     H
010D 7E                231          MOV     A,M
010E 12                232          STAX    D
010F 23                233          INX     H
0110 13                234          INX     D
0111 7E                235          MOV     A,M
0112 12                236          STAX    D
0113 13                237          INX     D
0114 23                238          INX     H
0115 7E                239          MOV     A,M
0116 12                240          STAX    D
                       241                                ;A=OP4
                       242 ;
0117 3A0000      E     243          LDA     OP2END
011A E640              244          ANI     40H
011C C22801      C     245          JNZ     RSLTX2
                       246 ;
011F 210000      E     247          LXI     H,OP2
0122 CDA901      C     248          CALL    TIMES2
                       249                                ;B=2*B
0125 C33901      C     250          JMP     LOOP1
                       251 ;
0128 210000      E     252 RSLTX2:  LXI     H,I
012B 3A0000      E     253          LDA     INDEX
012E BE                254          CMP     M
012F CA7501      C     255          JZ      CHKSGN
                       256                                ;if I=INDEX then exit
0132 34                257          INR     M
                       258                                ;I=I+1
0133 2A0000      E     259          LHLD    RESULT
0136 CDA901      C     260          CALL    TIMES2
                       261                                ;RESULT=RESULT*2
0139 3A0000      E     262 LOOP1:   LDA     OP1END
013C E640              263          ANI     40H
013E C2E100      C     264          JNZ     LOOP
                       265 ;
0141 210000      E     266          LXI     H,I
0144 3A0000      E     267          LDA     INDEX
0147 BE                268          CMP     M
0148 CA7501      C     269          JZ      CHKSGN
                       270                                ;if I=INDEX then exit
014B 34                271          INR     M
                       272                                ;I=I+1
014C 210000      E     273          LXI     H,OP1
014F CDA901      C     274          CALL    TIMES2
```

```
LOC  OBJ           LINE        SOURCE STATEMENT

                    275                                 ;A=2*A
0152 2A0000    E    276          LHLD    RESULT
0155 CDA901    C    277          CALL    TIMES2
                    278                                 ;RESULT=RESULT*2
0158 C33901    C    279          JMP     LOOP1
                    280 ;
                    281 ;
015B 210000    E    282 ALTB:    LXI     H,I
015E 3A0000    E    283          LDA     INDEX
0161 BE             284          CMP     M
0162 CA7501    C    285          JZ      CHKSGN
                    286                                 ;if I=INDEX then exit
0165 34             287          INR     M
                    288                                 ;I=I+1
0166 2A0000    E    289          LHLD    RESULT
0169 CDA901    C    290          CALL    TIMES2
                    291                                 ;RESULT=RESULT*2
016C 210000    E    292          LXI     H,OP2END
016F CD9801    C    293          CALL    BY2
                    294                                 ;B=B/2
                    295 ;
0172 C3E100    C    296          JMP     LOOP
                    297 ;
0175 3A0000    E    298 CHKSGN:  LDA     SIGN
0178 B7             299          ORA     A
0179 CA9701    C    300          JZ      EXIT
                    301 ;
017C AF             302          XRA     A
017D 2A0000    E    303          LHLD    RESULT
0180 7E             304          MOV     A,M
0181 D601           305          SUI     1
0183 2F             306          CMA
0184 77             307          MOV     M,A
0185 23             308          INX     H
0186 7E             309          MOV     A,M
0187 DE00           310          SBI     0
0189 2F             311          CMA
018A 77             312          MOV     M,A
018B 23             313          INX     H
018C 7E             314          MOV     A,M
018D DE00           315          SBI     0
018F 2F             316          CMA
0190 77             317          MOV     M,A
0191 23             318          INX     H
0192 7E             319          MOV     A,M
0193 DE00           320          SBI     0
0195 2F             321          CMA
0196 77             322          MOV     M,A
0197 C9             323 EXIT:    RET
                    324 ;
                    325 ;*************************************************
                    326 ;
0198 AF             327 BY2:     XRA     A
0199 7E             328          MOV     A,M
019A 1F             329          RAR
```

```
 LOC  OBJ          LINE      SOURCE STATEMENT

 019B 77            330          MOV     M,A
 019C 2B            331          DCX     H
 019D 7E            332          MOV     A,M
 019E 1F            333          RAR
 019F 77            334          MOV     M,A
 01A0 2B            335          DCX     H
 01A1 7E            336          MOV     A,M
 01A2 1F            337          RAR
 01A3 77            338          MOV     M,A
 01A4 2B            339          DCX     H
 01A5 7E            340          MOV     A,M
 01A6 1F            341          RAR
 01A7 77            342          MOV     M,A
 01A8 C9            343          RET
                    344 ;
                    345 ;*************************************************
                    346 ;
 01A9 AF            347 TIMES2: XRA     A
 01AA 7E            348          MOV     A,M
 01AB 17            349          RAL
 01AC 77            350          MOV     M,A
 01AD 23            351          INX     H
 01AE 7E            352          MOV     A,M
 01AF 17            353          RAL
 01B0 77            354          MOV     M,A
 01B1 23            355          INX     H
 01B2 7E            356          MOV     A,M
 01B3 17            357          RAL
 01B4 77            358          MOV     M,A
 01B5 23            359          INX     H
 01B6 7E            360          MOV     A,M
 01B7 17            361          RAL
 01B8 77            362          MOV     M,A
 01B9 C9            363          RET
                    364 ;
                    365 ;*************************************************
                    366 ;
                    367          END


PUBLIC SYMBOLS
BY2     C 0198    CHKSGN C 0175    FBDIV  C 0000    LOOP   C 00E1
LOOP1   C 0139    TIMES2 C 01A9

EXTERNAL SYMBOLS
ACOUNT  E 0000    BCOUNT E 0000    FBSUB  E 0000    I      E 0000
INDEX   E 0000    J      E 0000    OP1    E 0000    OP1END E 0000
OP2     E 0000    OP2END E 0000    OP3    E 0000    OP3END E 0000
OP4     E 0000    OP4END E 0000    RESULT E 0000    SIGN   E 0000

USER SYMBOLS
ACOUNT  E 0000    ALTB   C 015B    BCOUNT E 0000    BY2    C 0198
CHKSGN  C 0175    DODIV  C 0083    EXIT   C 0197    FBDIV  C 0000
FBSUB   E 0000    GOON   C 0048    I      E 0000    INDEX  E 0000
J       E 0000    LDIDX  C 00DE    LOOP   C 00E1    LOOP1  C 0139
```

```
     E 0000    OP1END E 0000    OP1OK  C 00A9    OP2    E 0000
END  E 0000    OP2OK  C 00BE    OP3    E 0000    OP3END E 0000
     E 0000    OP4END E 0000    PLUS   C 003B    PLUS1  C 0076
ULT  E 0000    RSLTX2 C 0128    SIGN   E 0000    TIMES2 C 01A9

EMBLY COMPLETE,   NO ERRORS
```

APPENDIX G

The results of the analysis carried throughout the study are listed. Only those that produced best results are given. They are smoothed versions of the outouts of ANADIF module.

PARAMETERS FOR SOUND " BE "

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	00												
04	01	00	00	03	0D	0E	0A						
05	07	00	00	04	1D	09	0A						
06	0E	00	1B	10	12	06	0B	09	07	0A	05	05	03
07	0E	00	1C	10	11	08	0C	09	08	08	05	06	04
08	0E	00	1C	10	11	08	0B	07	0A	08	05	06	04
09	0D	00	1C	12	0D	05	0C	08	0A	05	05	04	04
0A	0E	00	1C	12	0D	04	0B	0A	0A	07	04	05	02
0B	0D	00	1C	10	0F	06	0C	08	08	08	05	05	03
0C	0E	00	1C	10	0E	07	0C	09	09	06	05	05	04
0D	0D	00	1B	12	0D	05	0B	0B	0A	06	04	06	03
0E	0C	00	00	06	17	08	0B						
0F	0B	00	00	07	19	09	0B						
10	09	00	18	11	0B	06	0A	0A	0A	05	03	06	03
11	05	00	17	0E	0C	07	0B	0C	0A	04	02	04	04
12	02	00	00	01	1F	0B	08						
13	01	00	00	01	1F	0D	09						
14	01	00	00	01	1F	0E	07						
15	01	00	00	01	1F	0D	08						
16	01	00	00	01	19	0F	08						
17	01	00	00	00	1A	0F	09						
18	01	00	00	00	18	0F	09						
19	01	00	00	00	19	0F	09						
1A	00												
1B	00												
1C	00												
1D	00												

PARAMETERS FOR SOUND " A "

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	0D	00	1B	12	14	08	07	04	0D	08	04	02	02
02	0D	00	1B	12	13	07	07	05	0C	07	04	03	02
03	0D	00	1C	11	11	09	07	03	0C	07	04	04	01
04	0D	00	1C	12	12	08	08	05	0B	05	05	03	02
05	0D	00	1C	12	10	0A	08	02	0D	07	03	05	02
06	0D	00	1C	12	14	07	06	04	0D	07	04	03	03
07	0D	00	1C	12	12	09	07	04	0D	07	04	04	01
08	0C	00	1B	12	0F	0A	09	03	0E	07	04	04	02
09	0B	00	19	11	14	08	05	05	0C	08	03	04	02
0A	08	00	18	11	14	07	04	07	0D	09	01	04	03
0B	03	00	15	11	0F	0B	07	03	0B	09	02	04	03
0C	02	00	00	01	1A	08	05						
0D	01	00	00	04	1A	0C	05						
0E	01	00	00	01	19	0D	08						
0F	01	00	00	01	11	0F	08						
10	00												
11	00												
12	00												
13	00												
14	00												
15	00												

PARAMETERS FOR SOUND " E "

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	0B	00	1B	11	0D	08	0C	0B	0B	06	04	04	04
03	0E	00	1B	12	0D	06	0B	0C	0C	07	05	05	05
04	0E	00	1C	14	0B	05	0A	0B	0D	07	04	04	05
05	0D	00	1C	14	0A	06	0B	0A	0E	06	05	04	05
06	0D	00	1C	14	0A	05	0A	0A	0E	07	04	03	05
07	0D	00	1C	13	0B	06	0A	0B	0D	06	05	05	03
08	0D	00	1C	14	0C	05	0B	0A	0D	07	05	04	05
09	0D	00	1C	14	0C	05	0A	0A	0D	07	05	05	05
0A	0D	00	1C	14	0B	05	0A	0A	0E	06	04	04	04
0B	0B	00	1B	0A	15	09	0C	08	06	02	04	04	04
0C	09	00	19	15	0B	04	07	0A	0E	06	03	02	04
0D	05	00	14	13	09	04	09	0A	0B	08	02	02	04
0E	01	00	00	03	14	0C	0B						
0F	00												
10	00												
11	00												

PARAMETERS FOR SOUND " I "

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	00												
04	00												
05	0D	00	15	10	0C	08	0A	07	07	07	06	04	04
06	0C	00	17	10	0D	07	09	07	06	06	05	05	05
07	0E	00	17	10	10	07	09	07	07	08	04	05	05
08	0E	00	17	10	0E	08	0A	07	09	08	05	04	05
09	0E	00	18	10	0F	08	09	07	09	08	05	04	05
0A	0E	00	18	10	0E	09	0A	07	08	08	05	04	05
0B	0C	00	18	0F	0E	08	0B	06	08	07	05	04	05
0C	0D	00	19	12	0B	04	0B	07	08	08	04	04	03
0D	0C	00	19	11	0B	07	0A	09	08	07	04	04	04
0E	0B	00	18	0E	0C	09	0B	09	07	07	04	05	04
0F	08	00	18	0B	0E	0A	0A	0A	07	06	04	05	05
10	05	00	17	08	13	0D	09	08	0A	09	04	05	04
11	00												
12	00												
13	00												
14	00												

PARAMETERS FOR SOUND " Ö "

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	00												
04	0D	00	17	11	0E	07	09	07	09	09	05	03	06
05	0C	00	17	10	10	07	09	07	08	0B	05	05	06
06	0D	00	18	11	0F	06	09	07	09	0A	05	04	05
07	0D	00	19	11	10	06	09	08	0A	08	04	03	05
08	0E	00	1A	13	0F	05	08	08	0A	09	05	03	04
09	0D	00	1A	12	0E	07	08	09	0A	08	05	03	04
0A	0D	00	1B	11	0D	07	09	09	0B	08	04	04	04
0B	0B	00	1B	11	0E	07	09	08	0B	08	04	04	04
0C	0B	00	1B	10	0E	08	09	09	0A	08	05	02	05
0D	0A	00	1B	0F	10	08	0A	08	09	09	05	04	05
0E	0A	00	1B	10	0F	07	09	08	0A	08	05	03	05
0F	08	00	19	0E	11	08	09	09	0B	09	05	02	04
10	06	00	19	0C	12	0B	08	0A	0A	09	05	02	04
11	01	00	14	0C	0E	0C	0B	0A	09	07	04	02	02
12	00												

PARAMETERS FOR SOUND " U "

ame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	01	00	00	00	14	0E	08						
04	01	00	00	05	18	0D	04						
05	0C	00	15	0A	12	0A	04	07	08	09	03	05	05
06	0C	00	17	0A	14	08	06	06	08	0A	04	05	04
07	0A	00	17	0A	15	0B	05	08	0B	0A	04	03	03
08	0B	00	17	0A	14	0A	05	08	08	0A	04	05	04
09	0B	00	18	0A	16	0B	05	09	07	09	04	04	04
0A	0B	00	18	0A	15	0C	06	07	09	07	04	05	04
0B	0C	00	18	0A	15	0B	06	08	07	08	04	05	04
0C	0B	00	18	09	15	0B	06	08	07	07	04	05	05
0D	0B	00	17	09	14	0C	06	06	08	08	03	05	04
0E	08	00	17	07	15	0E	07	07	05	06	05	05	02
0F	08	00	15	07	11	0D	08	06	07	0A	05	04	03
10	09	00	14	07	10	0D	06	08	07	09	04	06	06
11	06	00	14	05	12	0D	0A	08	07	08	04	05	05
12	02	00	12	06	0D	0E	0B	0A	08	07	03	03	03
13	03	00	00	01	1F	0D	09						
14	01	00	00	01	1F	0E	09						
15	01	00	00	01	1F	0E	08						
16	01	00	00	00	1F	0F	08						

PARAMETERS FOR SOUND " Ü "

rame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	01	00	00	00	11	0E	09						
03	07	00	15	11	0B	03	08	0C	0D	07	05	03	01
04	09	00	14	07	0E	0D	09	0A	08	06	04	05	05
05	0A	00	14	07	11	0C	08	0A	05	08	04	05	06
06	0B	00	14	07	12	0A	08	08	06	08	04	05	05
07	0B	00	14	0A	12	0A	08	05	06	09	05	06	04
08	0C	00	15	09	12	0A	06	07	07	09	05	05	04
09	0C	00	14	08	11	0A	08	0A	07	08	04	04	03
0A	0C	00	14	09	11	09	08	0A	08	07	03	05	04
0B	0C	00	14	0A	13	0A	05	07	07	0A	05	03	04
0C	0C	00	14	09	12	0B	07	07	06	0A	04	05	03
0D	0C	00	14	0A	0F	09	09	0B	08	06	04	04	05
0E	0A	00	12	0E	0E	06	09	0C	0B	08	04	03	02
0F	0A	00	14	0B	0E	09	08	0B	0B	07	04	04	03
10	07	00	12	06	12	0D	07	0B	08	08	03	05	05
11	01	00	00	01	1F	0A	05						
12	01	00	00	01	1F	0D	06						
13	01	00	00	00	1F	0D	07						
14	01	00	00	00	1C	0F	07						
15	01	00	00	00	17	0E	09						
16	01	00	00	00	1B	0F	07						
17	01	00	00	00	17	0E	08						
18	01	00	00	00	12	0F	09						
19	01	00	00	00	18	0F	07						
1A	00												
1B	00												
1C	00												
1D	00												
1E	00												

PARAMETERS FOR SOUND " FE "

ame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	03	00	00	14	0B	03	09						
03	01	00	00	13	09	03	06						
04	03	00	00	13	09	05	08						
05	02	00	00	15	0A	05	07						
06	06	00	00	14	0E	03	07						
07	09	00	1A	12	0E	04	09	0A	0B	0B	03	03	05
08	0C	00	1B	12	0E	05	0A	0A	0D	08	03	03	06
09	0E	00	1B	14	0E	04	0A	09	0D	08	03	03	05
0A	0E	00	1C	13	0D	06	0B	0C	0D	08	04	04	05
0B	0D	00	1C	14	0C	05	08	0A	0D	09	04	03	05
0C	0E	00	1C	0F	11	09	0D	09	0A	03	02	03	04
0D	0D	00	1C	0E	11	09	0D	08	0A	02	03	04	04
0E	0C	00	1C	14	0C	05	09	09	0D	0A	04	02	05
0F	0B	00	00	0D	12	09	0C						
10	06	00	00	06	13	08	0C						
11	04	00	00	07	13	08	0C						
12	01	00	00	05	16	0A	0B						
13	00												
14	00												
15	00												

PARAMETERS FOR SOUND " VE"

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	01	00	00	07	0B	09	0A						
04	02	00	00	01	15	0A	0A						
05	02	00	00	00	19	0B	09						
06	03	00	1B	12	09	06	07	0A	09	07	05	05	02
07	04	00	1B	12	09	05	07	07	0B	08	05	04	02
08	0B	00	1B	15	0E	03	08	05	0A	0B	06	03	04
09	0E	00	1B	10	0E	06	0B	09	0A	0B	04	04	04
0A	0E	00	1C	10	0F	08	0B	09	0B	09	05	04	04
0B	0E	00	1C	10	0F	09	0B	09	0B	09	05	03	03
0C	0E	00	1D	10	0D	08	0C	0A	0A	07	04	05	03
0D	0D	00	1D	12	0C	06	0C	0A	0B	04	04	03	03
0E	0C	00	1C	10	0C	07	0C	0A	0B	04	03	04	03
0F	0C	00	1C	10	0D	06	0C	0C	0A	04	04	04	03
10	0C	00	1C	10	0D	08	0B	0B	0A	06	02	05	03
11	0C	00	1C	10	0D	07	0B	0A	0A	05	04	04	04
12	0C	00	1B	12	0C	05	0C	0B	0B	06	04	04	03
13	0A	01	18										
14	06	00	12	0D	0A	08	0A	0D	0B	05	02	04	04
15	02	00	00	01	1E	0C	0B						
16	01	00	00	01	1F	0D	0A						
17	01	00	00	01	1F	0E	09						
18	01	00	00	01	1F	0F	07						
19	01	00	00	01	1F	0E	08						
1A	01	00	00	00	1E	0E	09						
1B	01	00	00	00	17	0F	08						
1C	01	00	00	00	17	0F	07						
1D	01	00	00	00	16	0F	09						
1E	01	00	00	00	0F	0F	0A						
1F	01	00	00	00	16	0F	08						
20	00												
21	00												
22	00												
23	00												

PARAMETERS FOR SOUND " CE "

rame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	00												
04	00												
05	01	00	00	01	0C	0E	09						
06	05	00	00	13	08	05	08						
07	0A	00	00	13	0B	08	09						
08	0B	00	00	11	0B	05	0C						
09	0E	00	1A	12	0B	05	0B	06	08	06	05	04	06
0A	0E	00	1B	13	0B	05	0B	08	0A	08	05	04	06
0B	0D	00	1C	11	0C	07	0C	09	0B	07	04	04	06
0C	0E	00	1C	11	0E	07	0C	09	0B	08	05	05	04
0D	0D	00	1D	12	0D	05	0D	0B	0B	07	03	04	05
0E	0D	00	1D	13	0D	04	0C	0B	0B	06	03	04	03
0F	0C	00	1D	13	0D	04	0C	0B	0C	07	03	03	04
10	0C	00	1C	11	0E	05	0C	0C	0B	06	03	04	04
11	0B	01	1A										
12	0B	01	1A										
13	06	00	15	11	0D	06	0C	0A	0C	05	02	03	04
14	04	00	15	12	0B	04	09	0C	0A	09	02	03	05
15	02	00	00	01	19	0A	0C						
16	01	00	00	01	1D	0B	09						
17	01	00	00	01	1C	0E	08						
18	01	00	00	01	1C	0E	08						
19	01	00	00	00	1A	0F	08						
1A	01	00	00	00	15	0F	09						
1B	01	00	00	00	17	0F	08						
1C	01	00	00	00	15	0F	09						
1D	00												
1E	00												
1F	00												

PARAMETERS FOR SOUND " CE "

rame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	00												
04	00												
05	06	00	00	18	0A	06	06						
06	0A	00	00	15	09	09	09						
07	0B	00	00	13	0A	07	08						
08	0D	00	00	14	0D	06	07						
09	0D	00	00	15	0E	06	07						
0A	0B	00	00	11	07	05	0A						
0B	0C	00	00	02	13	0B	0A						
0C	0E	00	14	14	0D	04	0A	0A	0A	07	03	03	04
0D	0D	00	18	0E	10	06	0C	07	08	05	03	02	02
0E	0D	00	1A	10	10	06	0D	07	08	06	04	02	03
0F	0D	00	1B	14	0E	04	0B	09	0D	08	05	05	05
10	0E	00	1B	14	0D	04	0A	0B	0C	07	04	04	05
11	0B	00	1B	0F	10	06	0D	08	08	03	04	04	03
12	0A	00	1B	14	0E	04	0A	0A	0C	07	04	04	05
13	0A	00	1A	0C	11	07	0C	07	06	03	04	03	05
14	08	00	18	15	0E	03	07	0A	0C	09	03	02	04
15	04	00	17	15	0D	03	08	0A	0C	08	03	03	03
16	01	00	00	05	0E	08	0B						
17	00												
18	00												
19	00												
1A	00												
1B	00												
1C	00												

PARAMETERS FOR SOUND " ŞE "

rame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	01	00	00	16	0C	01	06						
03	05	00	00	18	17	03	05						
04	09	00	00	19	15	03	06						
05	0B	00	00	17	0E	04	07						
06	0C	00	00	16	0B	05	09						
07	0D	00	00	15	0A	05	0A						
08	0D	00	00	15	0C	06	0A						
09	0C	00	00	16	0C	05	09						
0A	0C	00	00	15	09	05	0A						
0B	09	00	19	1A	12	07	08	02	06	06	06	04	06
0C	0C	00	1A	10	0D	08	0B	09	0C	07	04	04	05
0D	0D	01	1A										
0E	0C	01	1B										
0F	0C	00	00	0C	11	08	0D						
10	0C	00	1B	13	0C	05	0A	0B	0D	07	04	04	05
11	0B	00	1B	14	0D	04	09	0B	0E	07	04	04	05
12	0B	00	1B	13	0C	06	0B	0A	0B	06	04	04	05
13	0A	00	1B	12	0D	06	0B	0C	0C	05	04	03	04
14	07	00	1B	13	0E	04	0B	0C	0C	06	03	02	04
15	04	00	00	07	19	0A	09						
16	01	00	00	06	18	09	0A						
17	00												
18	00												
19	00												
1A	00												
1B	00												

PARAMETERS FOR SOUND " BIR "

rame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	00												
04	00												
05	00												
06	00												
07	02	00	18	11	08	04	0A	0A	09	08	04	05	02
08	0D	00	19	17	07	02	09	08	0C	03	03	04	05
09	0E	00	18	16	08	03	09	08	0A	03	04	04	04
0A	0E	00	18	16	08	03	0A	09	0B	03	04	04	04
0B	0E	00	19	16	09	03	0A	07	0B	05	05	04	05
0C	0E	00	1A	15	0A	03	0A	08	0B	06	04	04	06
0D	0E	00	00	0A	0E	0A	0C						
0E	08	00	00	11	05	07	0B						
0F	0A	00	00	16	04	05	0A						
10	09	00	00	12	04	08	0B						
11	07	00	00	19	05	03	09						
12	07	00	00	19	07	03	09						
13	06	00	00	18	08	04	07						
14	05	00	00	19	06	04	08						
15	03	00	00	16	04	03	08						
16	00												
17	00												
18	00												
19	00												

PARAMETERS FOR SOUND " IKI "

rame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	0E	00	1B	18	08	0B	0D	0A	09	04	06	04	03
04	0E	00	1B	18	09	03	06	08	0B	03	04	03	05
05	09	01	1B										
06	04	01	1A										
07	00												
08	00												
09	00												
0A	0B	00	00	14	07	09	0A						
0B	0E	00	00	18	0B	05	08						
0C	0E	00	00	18	0B	03	09						
0D	0E	00	1A	13	06	06	0C	07	0A	06	04	06	06
0E	0E	00	19	14	09	04	0A	08	0A	06	05	05	06
0F	0E	00	18	17	09	03	09	08	0A	07	04	04	05
10	0E	00	15	17	09	03	09	09	0A	07	05	04	06
11	0E	00	14	15	07	04	0A	0A	0A	05	04	03	05
12	0A	00	12	17	08	03	07	0A	0E	07	02	02	05
13	05	00	12	16	07	02	0A	0B	0E	09	04	02	04
14	02	00	00	05	11	0D	0E						
15	02	00	00	06	14	0D	0C						
16	00												
17	00												
18	00												
19	00												

PARAMETERS FOR SOUND " UC "

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	00												
04	00												
05	01	00	00	01	0F	0F	0A						
06	0B	00	18	0F	09	09	09	08	09	06	04	04	04
07	0E	00	18	10	0A	08	0A	07	07	05	04	04	06
08	0E	00	18	0E	0C	09	09	06	07	06	04	04	04
09	0E	00	17	12	09	07	0A	07	07	03	03	04	04
0A	0E	00	15	13	0B	04	09	07	09	06	04	03	04
0B	0E	00	14	12	0A	06	09	08	09	07	04	03	06
0C	06	00	12	15	06	03	06	08	0F	05	05	03	02
0D	04	00	14	12	02	07	0D	0A	0F	09	05	04	02
0E	03	00	00	01	1A	0F	0C						
0F	04	00	00	02	16	0A	0D						
10	08	00	15	18	13	04	07	05	06	04	04	05	06
11	0D	00	00	15	0A	02	09						
12	0C	00	00	16	0D	02	08						
13	0C	00	00	16	0D	04	07						
14	0B	00	00	17	0F	04	06						
15	0B	00	1C	19	15	09	0A	0A	09	04	03	02	05
16	08	00	00	14	0D	05	06						
17	05	00	00	11	0A	06	07						
18	02	00	00	10	0F	04	05						
19	02	00	15	06	0D	0D	0A	09	06	06	03	04	03
1A	02	00	00	00	1F	0D	05						
1B	01	00	00	00	18	0E	08						
1C	01	00	00	00	16	0F	08						
1D	00												
1E	00												
1F	00												
20	00												

PARAMETERS FOR SOUND " DORT "

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	00												
04	00												
05	00												
06	00												
07	00												
08	00												
09	0D	00	1A	17	0A	06	07	05	09	06	05	03	04
0A	0E	00	1B	11	0F	08	08	07	0A	08	05	04	06
0B	0E	00	1B	12	10	07	08	08	0B	0A	05	04	05
0C	0E	00	1B	13	0D	09	08	07	0A	09	05	04	06
0D	0E	00	1B	13	10	09	07	06	0A	09	06	04	05
0E	0E	00	1B	13	10	09	08	07	0A	09	06	05	05
0F	0E	00	19	14	11	09	09	04	08	09	06	04	05
10	0E	00	18	12	10	08	07	06	0B	07	05	05	06
11	08	01	17										
12	06	01	16										
13	05	00	14	14	07	07	0C	07	0A	07	06	05	04
14	02	00	00	0C	0E	0B	0B						
15	00												
16	00												
17	00												
18	04	00	00	13	08	04	0B						
19	01	00	00	12	07	03	09						
1A	01	00	00	12	07	03	09						
1B	01	00	00	12	07	03	09						
1C	01	00	00	12	07	03	09						
1D	01	00	00	12	07	03	09						

PARAMETERS FOR SOUND " BES "

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	00												
04	00												
05	00												
06	00												
07	00												
08	00												
09	00												
0A	00												
0B	0E	00	1B	13	0C	06	0A	07	0A	09	04	04	06
0C	0E	00	1C	15	0B	05	0A	06	0C	09	04	05	06
0D	0E	00	1D	15	0B	05	0C	07	0B	07	04	05	06
0E	0E	00	1C	17	0B	04	0B	06	0C	07	04	05	05
0F	0E	00	1C	15	0A	05	0B	07	0B	07	04	05	05
10	0E	00	00	0B	14	0B	0C						
11	0E	00	18	15	09	04	09	0A	0B	07	04	03	05
12	08	00	15	16	08	02	0B	0C	0D	07	04	01	04
13	0B	00	00	14	08	03	0B						
14	0D	00	1B	1A	1B	09	08	04	08	06	03	04	06
15	0D	00	00	18	0E	03	06						
16	0B	00	00	18	0D	03	06						
17	0B	00	00	19	13	04	05						
18	0A	00	00	19	15	04	05						
19	0A	00	00	18	12	04	06						
1A	0A	00	00	19	13	03	06						
1B	06	00	00	19	11	02	06						
1C	06	00	00	19	11	02	06						
1D	06	00	00	19	11	02	06						
1E	06	00	00	19	11	02	06						
1F	06	00	00	19	11	02	06						

PARAMETERS FOR SOUND " ALTI "

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	01	00	00	06	0D	0C	07						
03	0E	00	1B	12	15	0B	09	07	09	05	05	03	05
04	0E	00	1B	12	16	0B	0B	05	09	05	05	03	06
05	0E	00	1B	12	13	0C	0A	06	09	05	04	03	06
06	0E	00	1B	13	11	0D	0B	06	09	04	04	04	06
07	0E	00	1B	13	0E	0C	0B	05	09	06	04	04	06
08	0E	00	1B	13	0C	0B	09	05	09	06	05	04	05
09	0E	00	1B	12	09	0B	0A	03	09	08	05	03	05
0A	0B	00	00	0B	0F	0A	0B						
0B	04	00	1B	13	07	0B	0D	04	07	08	06	05	06
0C	02	00	00	07	14	0D	08						
0D	01	00	00	06	13	0D	06						
0E	01	00	00	05	14	0D	09						
0F	01	00	00	04	0F	0C	08						
10	09	00	00	10	0F	07	09						
11	0B	00	00	12	0E	05	06						
12	0E	00	1B	12	11	06	08	06	0B	07	03	05	04
13	0E	00	1B	13	0E	06	09	06	0D	0A	04	03	04
14	0E	00	1B	12	0F	06	09	08	0C	0A	05	04	04
15	0E	00	19	13	0D	07	0A	06	0D	09	04	04	04
16	0E	00	00	0A	19	0A	0A						
17	0E	00	14	14	0C	06	06	02	0E	0A	04	04	04
18	08	00	12	13	09	06	09	05	0C	0B	02	03	03
19	06	00	14	12	0B	07	0A	07	0D	0B	03	03	02
1A	02	00	00	02	15	0A	0A						
1B	01	00	00	04	18	0A	08						
1C	01	00	00	01	14	0D	09						
1D	01	00	00	01	14	0D	07						
1E	00												
1F	00												
20	00												

PARAMETERS FOR SOUND " YEDI "

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	00												
04	00												
05	00												
06	00												
07	01	00	00	01	0D	0D	08						
08	01	00	00	00	1E	0F	05						
09	01	00	00	00	16	0F	09						
0A	01	00	00	00	1E	0E	08						
0B	01	00	1D	0C	08	09	0B	0D	09	04	03	03	03
0C	04	00	1D	0C	08	0A	0A	0C	09	04	03	04	03
0D	04	00	1D	0A	08	0A	0B	0D	08	04	03	04	03
0E	04	00	1D	0B	07	09	0C	0D	08	04	03	03	04
0F	03	00	1D	0D	04	0A	0C	0B	0B	05	03	04	02
10	04	00	1C	10	05	09	0B	0C	0C	05	04	03	03
11	0B	00	1B	13	04	05	08	0B	0E	06	04	03	06
12	0E	00	1B	16	0B	04	07	08	0B	04	05	05	04
13	0E	00	1B	14	0B	04	0A	0A	0B	05	04	06	04
14	0E	00	1B	16	0C	04	0A	08	0B	04	05	05	05
15	0E	00	1B	17	0D	03	08	06	0D	04	04	05	05
16	0C	00	1B	16	09	02	08	08	0E	08	04	03	03
17	08	00	1B	18	0C	02	06	06	0F	08	03	01	03
18	06	00	1B	12	07	04	0B	0B	0C	06	02	02	03
19	04	00	00	00	13	0B	0C						
1A	02	00	10	14	07	02	09	0C	0C	0A	01	03	03
1B	07	00	00	10	0B	05	0A						
1C	0E	00	1B	15	0A	03	08	07	0C	07	04	05	06
1D	0E	00	1A	16	0C	03	07	07	0C	04	05	06	05
1E	0E	00	19	17	0C	02	07	07	0D	04	05	06	05
1F	0E	00	15	12	08	06	0C	08	0A	06	05	04	05
20	0D	00	14	13	08	04	0B	0B	0B	05	03	05	05
21	0A	00	12	16	09	02	0A	0A	0E	04	03	03	02
22	07	00	12	15	09	02	05	07	0E	08	03	04	04
23	04	00	00	03	11	0A	0D						
24	03	00	00	07	0D	07	0E						
25	01	00	00	04	0E	08	0C						
26	01	00	00	00	12	0D	0B						
27	00												
28	00												
29	00												
30	00												

PARAMETERS FOR SOUND " SEKIZ "

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	00												
04	01	00	00	0F	06	08	07						
05	04	00	00	14	08	06	07						
06	08	00	00	14	0C	07	09						
07	09	00	00	13	0B	09	08						
08	09	00	00	13	0B	09	07						
09	0A	00	10	19	0E	0A	09	07	0A	06	04	03	04
0A	0A	00	00	14	0C	07	08						
0B	0E	00	1A	11	0B	07	0B	09	0A	08	04	06	04
0C	0E	00	1B	16	0C	03	09	09	0C	04	05	06	04
0D	0E	00	00	09	0E	09	0D						
0E	07	00	00	0A	09	07	0E						
0F	05	00	00	0F	0A	07	0E						
10	02	00	00	0B	08	07	0E						
11	01	00	00	09	0B	0A	0D						
12	01	00	00	06	0E	0C	0E						
13	01	00	00	06	0D	0C	0D						
14	09	00	00	13	06	09	09						
15	0E	00	19	17	06	03	09	09	09	06	05	05	05
16	0E	00	18	17	08	03	09	07	0C	06	03	05	05
17	0E	00	17	14	09	04	0A	08	0B	05	05	04	05
18	0E	00	15	14	08	03	09	08	0B	07	04	03	06
19	0E	00	15	0F	0A	08	0B	07	09	06	04	04	05
1A	08	00	14	0E	07	08	0C	08	0B	09	04	03	04
1B	09	00	14	14	07	05	07	07	0B	09	04	03	05
1C	08	00	00	04	13	08	0B						
1D	09	00	00	07	10	0A	09						
1E	06	00	00	06	0F	0C	0B						
1F	03	00	00	03	12	0E	0B						
20	01	00	00	01	17	0E	0B						
21	01	00	00	01	14	0D	0A						
22	01	00	00	00	17	0E	08						
23	00												
24	00												
25	00												

PARAMETERS FOR SOUND " DOKUZ "

rame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	01	00	00	01	0C	0E	09						
04	01	00	00	00	1C	0D	05						
05	0E	00	19	14	05	06	0A	06	0B	06	05	04	05
06	0E	00	1B	10	11	07	08	07	0A	0A	05	04	05
07	0E	00	1B	11	13	07	0A	06	07	07	04	05	06
08	0E	00	00	09	1E	05	07						
09	05	00	00	07	1C	09	04						
0A	03	00	00	06	1F	0B	04						
0B	02	00	00	07	1F	0C	03						
0C	01	00	00	03	1F	0B	04						
0D	01	00	00	05	1D	0C	05						
0E	01	00	00	03	18	0F	05						
0F	05	00	00	0B	1F	06	05						
10	08	00	17	12	11	08	08	05	06	07	04	04	05
11	0E	00	17	10	14	05	09	08	08	07	04	04	05
12	0E	00	15	10	12	08	07	07	08	06	04	04	04
13	0E	00	14	0F	13	06	07	08	08	08	04	04	04
14	0E	00	12	0F	0F	0A	08	06	09	08	04	04	04
15	0E	00	1D	12	09	07	0A	07	09	05	05	04	04
16	0C	00	1D	13	08	05	0C	07	08	06	05	04	04
17	0A	00	10	14	07	04	0A	06	08	08	05	05	06
18	08	00	00	08	0D	0B	0D						
19	08	00	00	07	0E	0B	0E						
1A	06	00	00	10	05	06	0E						
1B	06	00	00	10	07	06	0E						
1C	04	00	00	16	07	00	0D						
1D	04	00	00	12	05	03	0D						
1E	03	00	00	15	07	00	0C						
1F	02	00	00	14	06	01	0D						
20	03	00	00	11	0B	07	07						
21	00												
22	00												
23	00												
24	00												

IETERS FOR THE SENTENCE " COK CALISMAK GEREKLI " ALTINDAN KALKABILMEK ICIN

ame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
01	00												
02	00												
03	00												
04	00												
05	01	00	00	09	02	0C	0B						
06	04	00	00	11	14	0A	07						
07	0E	00	1B	14	11	0C	0B	07	06	07	04	04	06
08	0E	00	1C	14	0E	0B	0C	06	09	05	04	04	05
09	0E	00	1C	14	0D	0A	0B	08	0A	04	05	04	04
0A	0C	00	1C	12	10	0A	09	07	0B	07	03	04	04
0B	06	00	1D	0F	0F	0C	08	05	09	09	03	04	04
0C	02	00	00	03	13	0C	06						
0D	02	00	00	07	11	0A	0A						
0E	00												
0F	01	00	00	04	0A	0E	0A						
10	08	00	00	12	0C	07	08						
11	02	00	14	19	0B	0A	08	06	05	06	04	04	06
12	08	00	15	0F	10	07	07	08	08	07	03	04	04
13	08	00	1B	11	0B	07	0C	08	09	06	04	04	04
14	09	00	1B	11	0A	07	0B	08	09	07	05	05	04
15	06	00	1C	0D	0D	09	0C	08	08	08	04	05	03
16	06	00	1C	0E	0C	09	0B	09	08	09	03	05	03
17	05	00	1C	0B	0D	0B	08	09	08	08	05	04	03
18	05	00	1C	0B	0F	0B	09	08	06	09	04	05	03
19	09	00	1B	11	10	09	06	08	08	09	04	04	04
1A	0B	00	1B	12	0F	07	09	06	08	08	04	05	03
1B	0B	00	19	13	11	09	09	04	09	08	04	03	03
1C	0A	00	18	11	10	08	06	08	08	0A	05	03	04
1D	08	00	15	10	0C	07	0A	0B	08	08	04	04	03
1E	08	00	15	10	0B	07	0C	0B	09	07	03	04	05
1F	07	00	15	10	0A	06	0C	0C	09	06	03	03	05
20	06	00	15	0C	0B	09	0B	0E	06	08	03	04	03
21	02	00	00	02	1F	0B	09						
22	01	00	15	0E	07	0C	0A	0D	0A	07	04	04	02
23	08	00	00	12	15	03	06						
24	03	00	00	07	0F	0A	07						
25	06	00	1B	14	09	0B	07	05	05	08	05	02	03
26	08	00	1B	12	0C	0B	0B	06	03	09	04	03	05
27	0A	00	1C	12	12	07	09	07	07	06	05	05	04
28	0A	00	1C	11	12	07	08	08	08	07	04	05	04
29	05	00	1C	0D	13	0B	06	08	08	09	04	05	04
2A	01	00	00	00	11	0F	07						
2B	00												
2C	01	00	00	00	09	0D	09						
2D	05	00	00	10	14	02	08						
2E	09	00	00	0A	16	06	09						
2F	0E	00	1C	14	0E	07	07	06	09	0A	06	03	03
30	0B	00	10	13	08	08	09	07	0A	07	06	04	04
31	03	00	00	02	0E	0C	0A						
32	01	00	00	01	10	0E	0B						
33	0A	00	1C	16	0B	03	05	08	0C	09	05	03	05
34	0A	00	1D	13	08	04	0B	0A	0A	07	03	04	06
35	04	00	1D	12	06	04	0B	0D	0B	07	04	02	02
36	05	00	1E	12	04	07	0C	0C	0A	06	03	02	04
37	04	00	1E	11	08	06	09	0C	0A	08	04	02	03
38	05	00	1D	12	09	05	08	0D	0A	09	03	04	02
39	05	00	1B	12	0A	04	09	0B	0A	06	06	04	02
3A	0E	00	18	15	09	06	08	07	0B	08	06	03	05
3B	0E	00	15	17	0A	05	07	09	0B	0A	06	03	04
3C	0C	00	15	13	07	05	0A	0A	09	05	05	04	04

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
3D	05	00	00	07	0D	0C	0C						
3E	03	00	00	06	0D	0D	0C						
3F	0A	00	00	12	07	06	0C						
40	06	00	00	14	04	02	0B						
41	05	00	00	03	10	0E	0C						
42	04	00	00	06	0A	0E	0C						
43	01	00	00	00	0A	0E	0B						
44	02	00	00	0F	02	08	0C						
45	0A	00	00	1B	0C	04	04						
46	08	00	00	18	08	03	03						
47	05	00	1B	1A	0B	05	06	04	0C	08	06	02	04
48	0E	00	1B	17	0A	04	07	07	0B	09	06	03	05
49	0E	00	1A	16	0A	04	07	08	0A	0B	04	02	04
4A	0A	00	18	14	0A	03	09	0A	0B	09	04	03	04
4B	06	00	15	11	08	06	0A	0C	0B	08	04	03	03
4C	02	00	00	01	19	0D	09						
4D	01	00	00	00	12	0E	0B						
4E	00												
4F	00												
50	00												
51	00												
52	00												
53	00												
54	00												
55	00												
56	00												
57	00												
58	00												
59	09	00	18	1A	12	0A	0A	06	06	04	04	04	06
5A	07	00	00	06	1A	07	07						
5B	0E	00	14	13	0B	09	08	06	0A	06	05	04	04
5C	0C	00	14	12	0C	0A	08	06	09	05	06	04	05
5D	02	00	00	04	16	0D	06						
5E	01	00	00	03	11	0E	09						
5F	00												
60	00												
61	00												
62	01	00	00	0B	07	07	0B						
63	0A	00	00	19	11	06	06						
64	0A	00	00	19	0E	04	05						
65	07	00	00	09	10	0B	08						
66	0A	00	1A	11	11	08	07	06	09	0A	05	05	05
67	09	00	1A	11	0C	0A	09	05	06	0A	06	03	05
68	05	00	19	11	07	0B	0A	05	05	08	06	06	04
69	09	00	18	11	09	0A	0A	06	08	08	05	05	05
6A	0C	00	18	12	08	08	09	08	0A	09	06	03	04
6B	07	00	18	12	06	07	0A	0A	0B	09	06	04	02
6C	0A	00	00	16	0E	05	04						
6D	0C	00	00	18	0E	07	05						
6E	0C	00	00	16	11	08	08						
6F	03	00	00	11	05	06	09						
70	05	00	00	0A	1A	0A	09						
71	01	00	00	06	0C	0C	0A						
72	0A	00	15	11	10	0A	08	07	08	05	05	03	05
73	0C	00	14	13	12	08	08	06	04	08	05	04	04
74	0B	00	14	11	0F	0A	05	07	09	09	04	03	03
75	03	00	14	11	08	09	08	0B	07	05	05	03	02
76	01	00	00	01	18	0D	07						
77	00												
78	00												

Frame	RMS	R	P	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
79	01	00	00	03	08	0E	0B						
7A	01	00	00	04	05	0A	0A						
7B	07	00	1D	17	07	03	09	0A	0B	08	05	03	03
7C	0D	00	1E	13	09	06	09	0B	0B	08	05	03	05
7D	0E	00	10	16	0C	05	07	08	0A	0A	06	03	04
7E	0E	00	00	0D	0F	09	0B						
7F	04	00	00	0A	0C	0B	0C						
80	0C	00	00	0F	0C	07	0B						
81	05	00	00	08	12	0A	0C						
82	02	00	00	07	0A	0A	0B						
83	00												
84	00												
85	00												
86	00												
87	01	00	00	01	05	0B	0C						
88	02	00	00	11	09	02	0A						
89	01	00	00	04	0B	09	0D						
8A	05	00	00	07	13	0A	0C						
8B	07	00	00	0A	0E	09	0D						
8C	00												
8D	00												
8E	00												

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