

ADAM Speech Synthesizer

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INSTALLATION

Before connecting the ADAM Speech Synthesizer, you should inspect the ADAM computer expansion port connector. Ensure the contacts are clean and shiny. Any oxidation on the contacts could cause the ADAM Speech Synthesizer to malfunction.

The ADAM Speech Synthesizer connects to the expansion port on the right-hand side of the ADAM computer. See Figure 1. The components on the ADAM Speech Synthesizer should be pointing up when the female edge connector on the card is mated with the male card edge on the ADAM expansion port.

WARNING: Inserting the ADAM Speech Synthesizer upside down could cause damage to the ADAM Speech Synthesizer, your ADAM computer or both.

You should only connect or disconnect the ADAM Speech Synthesizer with the ADAM computer powered off.

There is no external speaker connected to the ADAM Speech Synthesizer. All sound is routed through the ADAM computer.

OPERATION

The operation of the unit is straight forward, but it is important to understand its operation so that you can use it effectively. The SPO256A-AL2 is made to speak by sending it a series of ALLOPHONES. An allophone is the smallest individual sound that the unit can speak. Words and sentences are formed by outputting a series of allophones, one after the other.

Each allophone is assigned a number and this number is loaded onto the ADAM data bus then the ALD line is pulsed low and the value is read in to the SPO256A-AL2. The LRQ line is driven high by this indicating the input buffer is full.

The SPO now commences to speak the allophone and indicates so by pushing the SBY line high. When a received allophone has been spoken the SBY and LRQ lines are pulled low.

Sound is clocked out of the unit at a rate of 3.12 MHZ determined by the onboard crystal.

Sound is filtered by an R-C network, to make the sound more "human like" and amplified by the LM386.

PORTS

There are 3 ports you can use to communicate with the Speech Synthesizer. Those are 43h (67), 44h (68) and 45h (69).

43h (67) COMMAND PORT

This port is used to send a single allophone to the Speech Synthesizer to speak. In machine language this would be:

COMMAND:

```
OUT (43h),A      ;A can be any valid allophone value from 0
                 ;to 63.
RET
```

See Table 6 – Allophone Address Table for the complete allophone list and descriptions.

44h (68) STATUS PORT

This port is used to query the status of the Speech Synthesizer to determine if it is busy or safe to send another allophone for processing. In machine language an example would be:

STATUS:

```
IN A, (44h)      ;get status of SPO256A-AL2
AND 1            ;check is bit 0 is set
CP 1             ;is the SPO256A-AL2 busy?
JR Z,STATUS      ;yes, get status again
RET              ;no, return
```

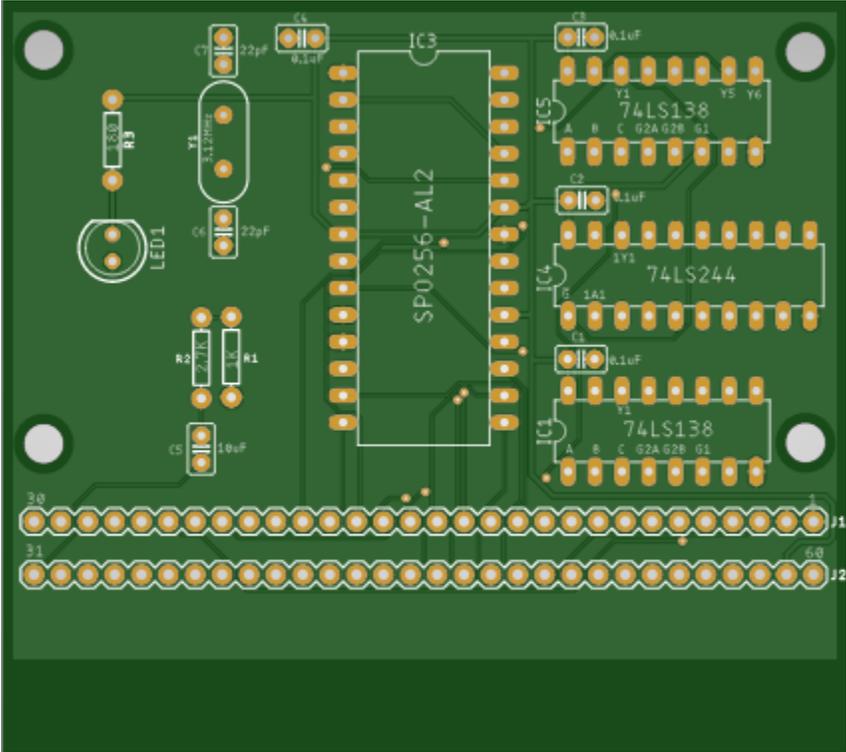
45h (69) RESET

This port is used to reset the SPO256A-AL2. After the ADAM is powered on or reset the SPO256A-AL2 may be in an unknown state. This command ensures the SPO256A-AL2 is reset and ready to accept commands. This is done in machine language as follows:

RESET:

```
OUT (45h),N      ;N can be any value between 0 and 255
RET
```

PCB LAYOUT



BILL OF MATERIALS

QTY	PART	DESCRIPTION
2	IC1	74LS138N
	IC2	
1	IC3	SPO256A-AL2
1	IC4	74LS244
Capacitors		
4	C1	0.1uF ceramic capacitor
	C2	
	C3	
	C4	
1	C5	10uF electrolytic capacitor
2	C6	22pF ceramic capacitor
	C7	
Resistors		
1	R1	1k
1	R2	2.7k
1	R3	180ohm
LED		
1	LED1	Red 5MM
Crystal		
1	Y1	3.12MHz
Edge Connector		
1	J1/J2	60 pin (30x2) female card edge connector

BASIC PROGRAMS

SPOTEST1

This test program instructs the SPO256A-AL2 to say "Greetings Professor Falken".

```
10 PRINT CHR$(12)
20 PRINT "ADAM Speech Synthesizer v1.0"
30 PRINT "2023 RE Pearson": PRINT
90 REM command ml
100 FOR x = 40000 TO 40004
110 READ a: POKE x, a
120 NEXT
125 REM reset ml
130 FOR x = 40005 TO 40009
140 READ a: POKE x, a
150 NEXT
155 REM status ml
160 FOR x = 40010 TO 40017
170 READ a: POKE x, a
180 NEXT
185 CALL 40005: FOR t = 1 TO 10000: NEXT
190 PRINT "Sending Speech Data"
200 READ c
210 IF c = 99 THEN END
220 GOSUB 1000
230 GOTO 200
1000 POKE 40001, c
1010 CALL 40000
2000 CALL 40010
2010 IF PEEK(40100) = 0 THEN 2030
2020 GOTO 2000
2030 RETURN
3000 DATA 62,0,211,67,201
3005 DATA 62,1,211,69,201
3010 DATA 219,68,230,1,50,164,156,201
3040 REM speech data
3050 DATA 36,14,19,2,13,12,44,43,2
3060 DATA 9,14,53,40,40,7,55,55,51,2
3070 DATA 40,40,26,45,41,7,7,0,11,4,99
3080 DATA 26,2,21,15,16,4,4,4,4,4,4
3110 DATA 27,1,26,35,3
3120 DATA 20,3
3130 DATA 56,6,2,55,55,3
3140 DATA 33,7,20,4,99
```

SPOTEST 2

This test program first instructs the SPO256A-AL2 to speak all 58 spoken allophones, second the SPO256A-AL2 will speak the numbers 1 through 10 and finally the days of the week.

```
5 PRINT CHR$(12);
10 PRINT "ADAM Speech Synthesizer 1.0"
20 PRINT "2023 RE Pearson": PRINT
90 REM command ml
100 FOR x = 40000 TO 40004
110 READ a: POKE x, a
120 NEXT
125 REM reset ml
130 FOR x = 40005 TO 40009
140 READ a: POKE x, a
150 NEXT
155 REM status ml
160 FOR x = 40010 TO 40017
170 READ a: POKE x, a
180 NEXT
185 CALL 40005: FOR t = 1 TO 5000: NEXT
190 PRINT "SPO256A-AL2 Test"
200 PRINT "Allophone Test"
230 FOR i = 5 TO 63
240 PRINT "allophone "; i
245 POKE 40001, 4: CALL 40000: GOSUB 600
250 POKE 40001, i: CALL 40000: GOSUB 600
260 FOR t = 1 TO 4
270 POKE 40001, 4: CALL 40000: GOSUB 600
280 NEXT t
290 NEXT i
300 PRINT: PRINT "Numbers"
310 READ c: IF c = 99 THEN 400
320 POKE 40001, c: CALL 40000: GOSUB 600
330 GOTO 310
400 PRINT: PRINT "Days of the Week"
410 READ c: IF c = 99 THEN 480
420 POKE 40001, c: CALL 40000: GOSUB 600
430 GOTO 410
480 FOR t = 1 TO 1000: NEXT
500 PRINT: PRINT "ADAM Speech Synthesizer"
510 PRINT "Tests complete"
520 READ c: IF c = 99 THEN END
530 POKE 40001, c: CALL 40000: GOSUB 600
540 GOTO 520
600 CALL 40010: IF PEEK(40100) = 1 THEN 600
610 RETURN
3000 DATA 62,0,211,67,201
3005 DATA 62,1,211,69,201
3010 DATA 219,68,230,1,50,164,156,201
10000 DATA 4,43,60,53,2
10001 DATA 46,15,15,11,2
```

10002 DATA 13,31,2
10003 DATA 29,14,19,2
10004 DATA 40,40,58,2
10005 DATA 40,40,6,35,2
10006 DATA 55,55,12,12,2,41,55,2
10007 DATA 55,55,7,7,35,12,11,2
10008 DATA 20,2,13,2
10009 DATA 11,24,6,11,2
10010 DATA 13,7,7,11,4,99
10020 DATA 4,55,55,15,15,11,1,33,20,4
10021 DATA 16,15,15,11,1,33,20,4
10022 DATA 13,31,43,1,33,20,4
10023 DATA 46,7,7,11,43,1,33,20,4
10024 DATA 29,52,43,33,20,4
10025 DATA 40,39,6,1,33,20,4
10026 DATA 55,55,26,2,13,1,33,20,4,99
10030 DATA 4,26,33,1,15,16,4
10031 DATA 55,55,2,9,19,2,50,4
10032 DATA 55,55,2,12,11,2,29,29,30,2,55,55,6,43,2,51,4
10033 DATA 17,7,55,15,55,4
10034 DATA 8,30,16,2,9,45,19,19,17,4,99

ALLOPHONE SPEECH SYNTHESIS

Introduction

The allophone speech synthesis technique provides the user with the ability to synthesize an unlimited vocabulary at a very low bit rate. Fifty-nine discrete speech sounds (called allophones) and five pauses are stored at different addresses in the SP0256 internal ROM. Each speech sound was excised from a word and analyzed using linear predictive coding (LPC). Any English word or phrase can be created by addressing the appropriate combination of allophones and pauses. Since there is a total of 64 address locations each requires a 6 bit address. Assuming that speech contains 10 to 12 sounds per second, allophone synthesis requires addressing less than 100 bits per second.

Linguistics

A few basic linguistic concepts will help you start your own library of "allophone words". (See Table 1 for the General Instrument Allophone Dictionary). First, there is no one-to-one correspondence between written letters and speech sounds; secondly, speech sounds are acoustically different depending upon their position within a word; and lastly, the human ear may perceive the same acoustic signal differently in the context of different sounds. The first point compares to the problem that a child encounters when learning to read. Each sound in a language may be represented by more than one letter and, conversely each letter may represent more than one sound. (See the examples in Table 2.) Because of these spelling irregularities, it is necessary to think in terms of sounds, not letters, when using allophones.

The second, and equally important, point to understand, is that the acoustic signal of a speech sound may differ depending upon its position within a word. For example, the initial K sound in *coop* will be acoustically different from the K sound in *keep* and *speak*. The K's in *coop* and *keep* differ due to the influence of the vowels which follow them, and the final K in *speak* is usually not as loud as initial K's.

Finally, a listener may identify the same acoustic signal differently depending on the context in which it is perceived. Don't be surprised, therefore, if an allophone word sounds slightly different when used in various phrases.

Phonemes Of English

The sounds of a language are called phonemes, and each language has a set which is slightly different from that of other languages. Table 3 contains a chart of all the consonant phonemes of English, Table 4 all the vowel phonemes. Consonants are produced by creating an occlusion or constriction in the vocal tract which produces an aperiodic sound source. If the vocal cords are vibrating at the same time, as in the case of the voiced fricatives *VV*, *DH*, *ZZ*, and *ZH*, (See Table 5) there are two sound sources: one which is aperiodic and one which is periodic. Vowels are usually produced with a relatively open vocal tract and a periodic sound source provided by the vibrating vocal cords. They are classified according to whether the front or back of the tongue is high or low (See Table 4 whether they are long or short, and whether the lips are rounded or unrounded. In English all rounded vowels are produced in or near the back of the mouth (*UW*, *UH*, *OW*, *AO*, *OR*, *AW*). Speech sounds which have features in common behave in similar ways. For example, the voiceless stop consonants *PP*, *TT*, and *KK* (See Table 3) should be

preceded by 50-80 msec of silence, and the voiced stop consonants BB, DD, and GG by 10-30 msec of silence.

Allophones

Phoneme is the name given to a group of similar sounds in a language. Recall that a phoneme is acoustically different depending upon its position within a word. Each of these positional variants is an allophone of the same phoneme. An allophone, therefore, is the manifestation of a phoneme in true speech signal. It is for this reason that our inventory of English speech sounds is called an allophone set.

How To Use The Allophone Set

(See Table 1 for instructions on how to create all the sample words mentioned in this section.) The allophone set (Refer to Table 5) contains two or three versions of some phonemes. It may be necessary to use one allophone of a particular phoneme for word-or-syllable-final position. A detailed set of guidelines for using the allophones is given in Table 5. Note that these are suggestions, not rules.

For example, DD2 sounds good in initial position and DD1 sounds good in final position, as in "daughter" and "collide". One of the differences between the initial and final versions of a consonant is that an initial version may be longer than the final version. Therefore, to create an initial SS, you can use two SSs instead of the usual single SS at the end of a word or syllable, as in "sister". Note that this can be done with TH, and FF, and the inherently short vowels (to be discussed below), but with no other consonants. You will want to experiment with some consonants such as str, cl) to discover which version works best in the cluster. For example, KK1 sounds good before LL as in "clown", and KK2 sounds good before WW as in "square". One allophone of a particular phoneme may sound better before or after back vowels and another before or after front vowels. KK3 sounds good before UH and KK1 sounds good before IY, as in "cookie". Some sounds (PP, BB, TT, DD, KK, GG, CH, and JH) require a brief duration of silence before them. For most of these, the silence has already been added but you may decide you want to add more. Therefore there are several pauses included in the allophone set varying from 10-200 msec. To create the final sounds in the words "letter" and "little" use the allophones ER and EL.

Remember that you must always think about how a word sounds, not how it is spelled. For example, the NG sound is represented by the letter N in "uncle". And remember that some sounds may not even be represented in words by any letters, as the YY in "computer".

As mentioned earlier there are some vowels which can be doubled to make longer versions for stressed syllables. These are the inherently short vowels I H, EH, AE, AX, AA, and UH. For example, in the word "extent" use one EH in the first syllable, which is unstressed and two EHs in the second syllable which is stressed. Of the inherently long vowels there is one, UW, which has a long and short version. The short one, UW1, sounds good after YY in computer. The long version, UW2, sounds good in monosyllabic words like "two". Included in the vowel set is a group called R-colored vowels. These are vowel + R combinations. For example, the AR in "alarm" and the OR in "score". Of the R-colored vowels there is one, ER, which has a long and short version. The short version is good for polysyllabic words with final ER sounds like "letter", and the long version is good for monosyllabic words like "fir". Om' final suggestion is that you may want to add a pause of 30-50 msec between words, when creating sentences, and a pause of 100-200 msec between clauses.

Note: Every utterance must be followed by a pause in order to make the chip stop talking the last allophone.

TABLE 1:

NUMBERS		seventeen	SS SS EH VV TH NN1 PA2 PA3 TT2 IY NN1
zero	ZZ YR OW		
one, won	WW AX AX NN1	eighteen	EY PA2 PA3 TT2 IY NN1
two, to, too	TT2 UW2		
three	TH RR1 IY	nineteen	NN1 AY NN1 PA2
four, for, fore	FF FF OR		PA3 TT2 IY NN1
five	FF FF AY VV	twenty	TT2 WH EH EH NN1 PA2 PA3 TT2 IY
six	SS SS IH IH PA3 KK2 SS	thirty	TH ER2 PA2 PA3 TT2 IY
seven	SS SS EH EH VV IH NN1	forty	FF OR PA3 TT2 IY
eight, ate	EY PA3 TT2	fifty	FF FF IH FF FF PA2 PA3 TT2 IY
nine	NN1 AA AY NN1		
ten	TT2 EH EH NN1	sixty	SS SS IH PA3 KK2 SS PA2 PA3 TT2 IY
eleven	IH LL EH EH VV IH NN1	seventy	SS SS EH VV IH NN1 PA2 PA3 TT2 IY
twelve	TT2 WH EH EH LL VV	eighty	EY PA3 TT2 IY
thirteen	TH ER1 PA2 PA3 TT2 IY NN1	ninety	NN1 AY NN1 PA3 TT2 IY
fourteen	FF OR PA2 PA3 TT2 IY NN1	hundred	HH2 AX AX NN1 PA2 DD2 RR2 IH IH PA1 DD1
fifteen	FF IH FF PA2 PA3 TT2 IY NN1	thousand	TH AA AW ZZ TH PA1 PA1 NN1 DD1
sixteen	SS SS IH PA3 KK2 SS PA2 PA3 TT2 IY NN1	million	MM IH IH LL YY1 AX NN1

DAY OF THE WEEK

EH MM PA1 BB2
ER1

Sunday	SS SS AX AX NN1 PA2 DD2 EY	LETTERS	
Monday	MM AX AX NN1 PA2 DD2 EY	A	EY
Tuesday	TT2 UW2 ZZ PA2 DD2 EY	B C	BB2 IY SS SS IY
Wednesday	WW EH EH NN1 ZZ PA2 DD2 EY	D E	002 IY IY
Thursday	TH ER2 ZZ PA2 DD2 EY	F G	EH EH FF FF JH IY
Friday	FF RR2 AY PA2 DD2 EY	H I	EY PA2 PA3 CH AA AY
Saturday	SS SS AE PA3 TT2 PA2 DD2 EY	J K L	JH EH EY KK1 EH EY EH EH EL
<i>MONTHS</i>		M N	EH EH MM EH EH NN1
January	JH AE AE NN1 YY2 XR IY	O P	OW PP IY
February	FF EH EH PA1 BR RR2 UW2 XR IY	Q R	KK1 YY1 UW2 AR
March	MM AR PA3 CH	S	EH EH SS SS
April	EY PA3 PP RR2 IH IH LL	T U	TT2 IY YY1 UW2
May	MM EY	V	VV IY
June	JH UW2 NN1	W	DD2 AX PA2 BB2
July	JH UW1 LL AY		EL YY1 UW2
August	AO AO PA2 GG2 AX SS PA3 TT1	X	EH EH PA3 KK2 SS SS
September	SS SS EH PA3 PP PA3 TT2 EH EH PA1 BB2 ER1	Y Z	WW AY ZZ IY
October	AA PA2 KK2 PA3 TT2 OW PA1 BB2 ER1	<i>DICTIONARY</i>	
November	NN2 OW VV EH EH MM PA1 BB2 ER1	alarm bathe bather	AX LL AR MM BB2 EY DH2 BB2 EY DH2 ER1
December	DD2 IY SS SS EH	bathing	BB2 EY DH2 IH NG

beer	BB2 YR	crown	KK1 RR2 AW NN1
bread	BB1 RR2 EH EH PA1 DD1	date	DD2 EY PA3 TT2
by	BB2 AA AY	daughter	DD2 AO TT2 ERI
calendar	KK1 AE AE LL EH NN1 PA2 DD2 ER1	day	DD2 EH EY
clock	KK1 LL AA AA PA3 KK2	divided	DD2 IH VV AY PA2 DD2 IH PA2 DD1
clown	KK1 LL AW NN1	emotional	IY MM OW SH AX NN1 AX EL
check	CH EH EH PA3 KK2	engage	EH EH PA1 NN1 GGI EY PA2 JH
checked	CH EH EH PA3 KK2 PA2 TT2	engagement	EH EH PA1 NN1 GG1 EY PA2 JH MM EH EH NN1 PA2 PA3 TT2
checker	CH EH EH PA3 KK1 ER1	engages	EH EH PA1 NN1 GG1 EY PA2 JH IH ZZ
checkers	CH EH EH PA3 KK1 ER1 ZZ	engaging	EH EH PA1 NN1 GG1 EY PA2 JH IH NG
checking	CH EH EH PA3 KK1 IH NG	enrage	EH NN1 RR1 EY PA2 JH
checks	CH EH EH PA3 KK1 SS	enraged	EH NN1 RR1 EY PA2 JH PA2 DD1
cognitive	KK3 AA AA GG3 NN1 IH PA3 TT2 IH VV	enrages	EH NN1 RR1 EY PA2 JH IH ZZ
collide	KK3 AX LL AY DD1	enraging	EH NN1 RR1 EY PA2 JH IH NG
computer	KK1 AX MM PP1 YY1 UW1 TT2 ER	escape	EH SS SS PA3 KK1 PA2 PA3 PP
cookie	KK3 UH KK1 IY	escaped	EH SS SS PA3 KK1 PA2 PA3 PP PA2 TT2
coop	KK3 UW2 PA3 PP	escapes	EH SS SS PA3 KK1 PA2 PA3 PP SS
correct	KK1 ER2 EH EH PA2 KK2 PA2 TT1	escaping	EH SS SS PA3 KK1 PA2 PA3 PP IH NG
corrected	KK1 ER2 EH EH PA2 KK2 PA2 TT2 IH PA2 DDI	equal	IY PA2 PA3 KK3 WH AX EL
correcting	KK1 ER2 EH EH PA2 KK2 PA2 TT2 IH NG	equals	IY PA2 PA3 KK3 WH AX EL ZZ
corrects	KK1 ER2 EH EH PA2 KK2 PA2 TT1 SS		

error	EH XR OR	investigate	IH IH NN1 VV EH
extent	EH KK1 SS TT2 EH EH NN1 TT2		EH SS PA2 PA3 TT2 IH PA1 GG1
fir	FF ER2		EY PA2 TT2
freeze	FF FF RR1 IY ZZ	investigated	IH IH NN1 VV EH
freezer	FF FF RR1 IY ZZ ER1		EH SS PA2 PA3 TT2 IH PA1 GG1
freezers	FF FF RR1 IY ZZ ERI ZZ		EY PA2 TT2 IH PA2 DD1
freezing	FF FF RR1 IY ZZ IH NG	investigator	IH IH NN1 VV EH EH SS PA2 PA3
frozen	FF FF RR1 OW ZZ EH NN1		TT2 IH PA1 GG1 EY PA2 TT2 ER1
		investigators	IH IH NN1 VV EH EH SS PA2 PA3
gauge	GG1 EY PA2 JH		TT2 IH PA1 GG1
guaged	GG1 EY PA2 JH PA2 DD1		EY PA2 TT2 ER1 ZZ
guages	GG1 EY PA2 JH IH ZZ	investigates	IH IH NN1 VV EH EH SS PA2 PA3
guaging	GGI EY PA2 JH IH NG		TT2 IH PA1 GG1 EY PA2 TT1 SS
hello	HH EH LL AX OW	investigating	IH IH NN1 VV EH EH SS PA2 PA3
hour	AW ER1		TT2 IH PA1 GG1 EY PA2 TT2 IH NG
infinitive	IH NN1 FF FF IH IH NN1 IH PA2 PA3 TT2 IH VV	key	KK1 IY
intrigue	IH NN1 PA3 TT2 RR2 IY PA1 GG3	legislate	LL EH EH PA2 JH JH SS SS LL EY
intrigued	IH NN1 PA3 TT2 RR2 IY PA1 GG3	legislated	PA2 PA3 TT2 LL EH EH PA2 JH JH SS SS LL EY
	PA2 DD1		PA2 PA3 TT2 IH DD1
intrigues	IH NN1 PA3 TT2 RR2 IY PA1 GG3 ZZ	legislates	LL EH EH PA2 JH JH SS SS LL EY
intriguing	IH NN1 PA3 TT2 RR2 IY PA1 GG3 IH NG	legislating	PA2 PA3 TT1 SS LL EH EH PA2 JH JH SS SS LL EY PA2 PA3 TT2 IH NG

legislature	LL EH EH PA2 JH JH SS SS LL EY PA2 PA3 CH ER1	pledging	PP LL EH EH PA3 JH IH NG
letter	LL EH EH PA3 TT2 ER1	plus	PP LL AX AX SS SS
litter	LL IH IH PA3 TT2 ER1	ray	RR1 EH EY
little	LL IH IH PA3 TT2 EL	rays	RR1 EH EY ZZ
memory	MM EH EH MM ER2 IY	ready	RR1 EH EH PA1 DD2 IY
memories	MM EH EH MM ER2 IY ZZ	red	RR1 EH FH PA1 DD1
minute	MM IH NN1 IH PA3 TT2	robot	RR1 OW PA2 BB2 AA PA3 TT2
month	MM AX NN1 TH	robots	RR1 OW PA2 BB2 AA PA3 TT1 SS
nip	NN1 IH IH PA2 PA3 PP	score	SS SS PA3 KK3 OR
nipped	NN1 IH IH PA2 PA3 PP PA3 TT2	second	SS SS EH PA3 KK1 IH NN1 PA2 DD1
nipping	NN1 IH IH PA2 PA3 PP IH NG	sensitive	SS SS EH EH NN1 SS SS IH PA2 PA3 TT2 IH VV
nips	NN1 IH IH PA2 PA3 PP SS	sensitivity	SS SS EH EH NN1 SS SS IH PA2 PA3 TT2 IH VV IH PA2 PA3 TT2 IY
no	NN2 AX OW	sincere	SS SS IH IH NN1 SS SS YR
physical	FF FF IH ZZ IH PA3 KK1 AX EL	sincerely	SS SS IH IH NN1 SS SS YR LL IY
pin	PP IH IH NN1	sincerity	SS SS IH IH NN1 SS SS EH EH RR1 IH PA2 PA3 TT2 IY
pinned	PP IH IH NN1 PA2 DDI	sister	SS SS IH IH SS PA3 TT2 ER1
pinning	PP IH IH NN1 IH NG1	speak	SS SS PA3 IY PA3 KK2
pins	PP IH IH NN1 ZZ		
pledge	PP LL EH FH PA3 JH		
pledged	PP LL EH EH PA3 JH PA2 DD1		
pledges	PP LL EH EH PA3 JH IH ZZ		

spell	SS SS PA3 PP EH EH EL	subject (verb)	SS SS AX PA2 BB1 PA2 JH EH EH PA3
spelled	SS SS PA3 PP EH EH EL PA3 DD1	sweat	KK2 PA3 TT2 SS SS WW EH EH
speller	SS SS PA3 PP EH EH EL ER2	sweated	PA3 TT2 SS SS WW EH EH
spellers	SS SS PA3 PP EH EH EL ER2 ZZ	sweater	PA3 TT2 IH PA3 DD1
spelling	SS SS PA3 PP EH EH EL IH NG	sweaters	SS SS WW EH EH PA3 TT2 ER1 ZZ
spells	SS SS PA3 PP EH EH EL ZZ	sweating	SS SS WW EH EH PA3 TT2 IH NG
start	SS SS PA3 TT2 AR PA3 TT2	sweats	SS SS WW EH EH PA3 TT2 SS
started	SS SS PA3 TT2 AR PA3 TT2 IH PA1 DD2	switch	SS SS WH IH IH PA3 CH
starter	SS SS PA3 TT2 AR PA3 TT2 ERI	switched	SS SS WH IH IH PA3 CH PA3 TT2
starting	SS SS PP3 TT2 AR PA3 TT2 IH NG	switches	SS SS WH IH IH PA3 CH IH ZZ2
starts	SS SS PP3 TT2 AR PA3 TT1 SS	switching	SS SS WH IH IH PA3 CH IH NG2
stop	SS SS PA3 TT1 AA AA PA3 PP	system	SS SS IH IH SS SS PA3 TT2 EH MM
stopped	SS SS PA3 TT1 AA AA PA3 PP PA3 TT2	systems	SS SS I H I H SS SS PA3 TT2 EH MM ZZ
stopper	SS SS PA3 TT1 AA AA PA3 PP ERI	talk	TT2 AO AO PA2 KK2
stopping	SS SS PA3 TT1 AA AA PA3 PP IH NG	talked	TT2 AO AO PA3 KK2 PA3 TT2
stops	SS SS PA3 TT1 AA AA PA3 PP SS	talker	TT2 AO AO PA3 KK1 ERI
subject (noun)	SS SS AX AX PA2 BB1 PA2 JH EH PA3 KK2 PA3 TT2	talkers	TT2 AO AO PA3 KK1 ERI ZZ

talking	TT2 AO AO PA3 KK1 IH NG
talk	TT2 AO AO PA2 KK2 SS
thread	TH RR1 EH EH PA2 DD1
threaded	TH RR1 EH EH PA2 DD2 IH PA2 DD1
threader	TH RR1 EH EH PA2 DD2 ER1
threaders	TH RR1 EH EH PA2 DD2 ER1 ZZ
threading	TH RR1 EH EH PA2 DD2 IH NG
threads	TH RR1 EH EH PA2 DD2 ZZ
then	DH1 EH EH NN1
time	TT2 AA AY MM
times	TT2 AA AY MM ZZ
uncle	AX NG PA3 KK3 EL
whale	WW EY EL
whaler	WW EY LL ER1
whalers	WW EY LL ER1 ZZ
whales	WW EY EL ZZ
whaling	WW EY LL TH NG
year	YY2 YR
yes	YY2 EH EH SS SS

TABLE 2 - Examples of Spelling Irregularities

	Same sound represented by different letters	Different sounds represented by the same letters
Vowels	mEAt fEEt pEte pEOple pennY	vEIn forElgn dElsm dElcer gElsha
Consonants	SHip tenSIOn preClous naTIon	althouGH GHastly couGH hiccouGH

TABLE 3 - CONSONANT PHONEMES OF ENGLISH

		LABIAL	LABIO-DENTAL	INTER-DENTAL	ALVEOLAR	PALATAL	VELAR	GLOTTAL
Stops	Voiceless	PP			TT		KK	
	Voiced	BB			DD		GG	
Fricatives	Voiceless	WH	FF	TH	SS	SH		HH
	Voiced		VV	DH	ZZ	ZH*		
Affricates	Voiceless					CH		
	Voiced					JH		
Nasals	Voiced	MM			NN		NG*	
Resonants	Voiced	WW			RR,LL	YY		

* These do not occur in word-initial position in English

Labial	Upper and lower lips touch or approximate	Palatal	Body of tongue approximates palate (roof of mouth)
Labio-Dental	Upper teeth and lower lip touch	Velar	Body of tongue touches Velum (posterior portion of roof of mouth)
Inter-Dental	Tongue between teeth	Glottal	Glottis (opening between vocal cords)
Alveolar	Tip of tongue touches or approximates alveolar ridge (just behind upper teeth)		

TABLE 4 - VOWEL PHONEMES OF ENGLISH

	FRONT	CENTRAL	BACK
HIGH	YR IY IH*		UW# UH*#
MID	EY EH* XR	ER AX*	OW# OY#
LOW	AE*	AW# AY AR AA*	AO*# OR#

* Short Vowels

Rounded Vowels

TABLE 5 - GUIDELINES FOR USING THE ALLOPHONES

Silence

PA1	10 mS before BB, DD, GG, and JH
PA2	30 mS before BB, DD, GG, and JH
PA3	50 mS before PP, TT, KK, and CH, and between words
PA4	100 mS between clauses and sentences
PA5	200 mS between clauses and sentences

Resonants

/WW/ /RR1/	we, warrant, linguist initial position: read, write, x-ray
/RR2/	initial clusters: brown, crane, grease
/LL/ /YY1/	like, hello, steel clusters: cute, beauty, computer
/YY2/	initial position: yes, yarn, yo-yo

Short Vowels

*/IH/	sitting, stranded
*/EH/	extent, gentlemen
*/AE/	extract, acting
*/UH/	cookie, full
*/AO/	talking, song
*/AX/	lapel, instruct
*/AA/	pottery, cotton

Voiced Fricatives

/VV/ /DH1/	vest, prove, even word-initial position: this, then, they
/DH2/	word-final and between vowels: bathe, bathing
/ZZ/ /ZH/	zoo, phase beige, pleasure

TABLE 5 - GUIDELINES FOR USING THE ALLOPHONES (continued)

R-Colored Vowels		Voiced Stops	
/ER1/	letter, furniture, interrupt	/BB1/	final position: rib; between vowels: fibber, in clusters: bleed, brown
/ER2/	monosyllables: bird, fern, burn	/BB2/	initial position before a vowel: beast
/OR/	fortune, adorn, store	/DD1/	final position: played, end
/AR/	farm, alarm, garment	/DD2/	initial position: down; clusters drain
/YR/	hear, earring, irresponsible	/GG1/	before high front vowels: YR, IY, IH, EY, EH, XR
/XR/	hair, declare, stare	/GG2/	before high back vowels: UW, UH, OW, OY, AX; and clusters: green, glue
		/GG3/	before low vowels: AE, AW, AY, AR, AA, AO, OR, ER; and medial clusters : anger; and final position: peg
Voiceless Stops		Affricates	
/PP/	pleasure, ample, trip	/CH/	church, feature
/TT1/	final clusters before SS: tests its	/JH/	judge, injure
/TT2/	all other positions: test, street	Nasal	
/KK1/	before front vowels: YR, IY, IH, EV, EH, XR, AV, AE, ER, AX; initial clusters: cute, clown, scream	/MM/	milk, alarm, ample
/KK2/	final position: speak; final clusters: task	/NN1/	before front and central vowels: VR, IV, IH, EV, EH, XR, AE, ER, AX, AW, AV, UW; final clusters: earn
/KK3/	before back vowels: UW, UH, OW, OV, OR, AR, AO; initial clusters: crane, quick, clown, scream	/NN2/	before back vowels: UH, OW, OY, OR, AR, AA
		/NG/	string, anger

* These allophones can be doubled.

TABLE 6 – Allophone Address Table

DECIMAL				DECIMAL			
ADDRESS	ALLOPHONE	WORD	DURATION	ADDRESS	ALLOPHONE	WORD	DURATION
0	PA1	PAUSE	10 mS	32	/AW/	Out	370 mS
1	PA2	PAUSE	30 mS	33	/DD2/	Do	160 mS
2	PA3	PAUSE	50 mS	34	/GG3/	Wig	140 mS
3	PA4	PAUSE	100 mS	35	/VV/	Vest	190 mS
4	PA5	PAUSE	200 mS	36	/GG1/	Got	80 mS
5	/OY/	Boy	420 mS	37	/SH/	Ship	160 mS
6	/AY/	Sky	260 mS	38	/ZH/	Azure	190 mS
7	/EH/	End	70 mS	39	/RR2/	Brain	120 mS
8	/KK3	Comb	120 mS	40	/FF/	Food	150 mS
9	/PP/	Pow	210 mS	41	/KK2/	Sky	190 mS
10	/JH/	Dodge	140 mS	42	/KK1/	Can't	160 mS
11	/NN1/	Thin	140 mS	43	/ZZ/	Zoo	210 mS
12	/IH/	Sit	70 mS	44	/NG/	Anchor	220 mS
13	/TT2/	To	140 mS	45	/LL/	Lake	110 mS
14	/RR1/	Rural	170 mS	46	/WW/	Wool	180 mS
15	/AX/	Succeed	70 mS	47	/XR/	Repair	360 mS
16	/MM/	Milk	180 mS	48	/VH/	Whig	200 mS
17	/TT1/	Part	100 mS	49	/YY1/	Yes	130 mS
18	/DH1/	They	290 mS	50	/CH/	Church	190mS
19	/IY/	See	250 mS	51	/ER1/	Fir	160 mS
20	/EY/	Beige	280 mS	52	/ER2/	Fir	300 mS
21	/DD1/	Could	70 mS	53	/OW/	Beau	240 mS
22	/UW1/	To	100 mS	54	/DH2/	They	240 mS
23	/AO/	Aught	100 mS	55	/SS/	Vest	90 mS
24	/AA/	Hot	100 mS	56	/NN2/	No	190 mS
25	/YY2/	Yes	180 mS	57	/HH2/	Hoe	180 mS
26	/AE/	Hat	120 mS	58	/OR/	Store	330 mS
27	/HH1/	He	130 mS	59	/AR/	Alarm	290 mS
28	/BB1/	Business	80 mS	60	/YR/	Clear	350 mS
29	/TH/	Thin	180 mS	61	/GG2/	Guest	40 mS
30	/UH/	Book	100 mS	62	/EL/	Saddle	190 mS
31	/UW2/	Food	260 mS	63	/BB2/	Business	50 mS