



TECHNICAL DATA

AN EXCLUSIVE RADIO SHACK SERVICE TO THE EXPERIMENTER

SPO256 NARRATOR™ SPEECH PROCESSOR

Features

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

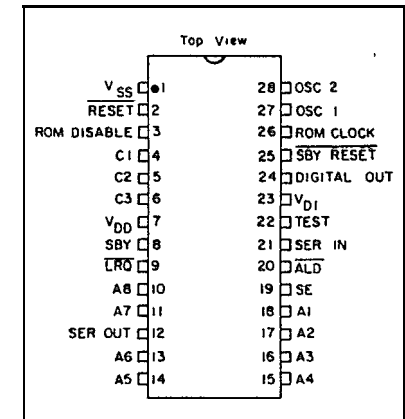
General Description

The SPO256 (Speech Processor) is a single chip N-Channel MOS LSI device that is able, using its stored program, to synthesize speech or complex sounds.

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

The SP0256 incorporates four basic functions:

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



PIN CONFIGURATION

verted to an analog signal when filtered by an external low pass filter.

Allophone Based Speech Processor – SPO256-AL2

One example of a preprogrammed SPO256 is the AL2 pattern.

Allophone Usage with a Microprocessor

The SPO256-AL2 requires the use of a processor to concatenate the speech sounds to form words.

The SPO256 is controlled using the address pins (A1-A8), ALD (Address Load), and SE (Strobe Enable). The object for controlling the chip is to load an address into it which contains the desired allophone. The speech data for the allophone set is contained within the internal 16K ROM of the SPO256-AL2.

CUSTOM PACKAGED IN U.S.A. BY RADIO SHACK A DIVISION OF TANDY CORPORATION

RADIO SHACK, A DIVISION OF TANDY CORPORATION

U.S.A.: FORT WORTH, TEXAS 76102
CANADA: BARRIE, ONTARIO L4M 4W5

TANDY CORPORATION

AUSTRALIA	BELGIUM	UK
91 KURRAJONG ROAD MOUNT DRUITT, N S W 2770	PARC INDUSTRIEL DE NANINNE 5140 NANINNE	BILSTON ROAD WEDNESBURY WEST MIDLANDS WS10 7JN

Printed in USA

This particular application (Allophone Set) requires only six address Pins (A1-A6) to address all the 69 allophones plus five pauses, a total of 64 locations. For simplicity, since only six address pins are needed to address the 64 locations, pins A7 and A8 can be tied low (to ground) and now any further references to the address bus will include A1-A6 and A7=A8=0

There are two modes available for loading an address into the chip. SE (Strobe Enable) controls the mode that will be used.

Mode 0 (SE=0) will latch in an address when any one or more of the address pins makes a low to high transition. For example, to load the address one (1), A2 to A6=0 and A1 is pulsed high. To load the address twelve (12 octal), A1=A3=A5=A6=0, A2 and A4 are pulsed high simultaneously. (Note that an address of zero cannot be loaded using this mode).

Mode 1 (SE=1) will latch in an address using the ALD pin. First, setup the desired address on the address bus (A1-A6) and

low. Any address can be loaded using this mode, but certain setup and hold times are then pulse ALD required (refer to the attached timing diagram for the specific times).

Two microprocessor interface pins are available for quick loading of addresses. They are LRQ and SBY. LRQ (Load Request) tells the processor when the input buffer is full. SBY (Stand By) tells the processor that the chip has stopped talking and no new address has been loaded. Either interface pin can be used when concatenating allophones. LRQ is an active low signal, when LRQ goes low it is time to load a new address to the chip. If LRQ is high, then simply wait for it to go low before loading the address. SBY will stay high until an address is loaded, then it will go low and stay low until all the internal instructions (Speech Code) from that one address are completed. Once this signal goes high, it is time to load a new address. Since speech does not require very fast address loading, it would be acceptable to use SBY to interface to the processor.

To end a word using allophones it is necessary to load a pause to complete the word. For example, the word "TWO"

can be implemented using the following allophones, TT2-VW2-PA1. PA1 is actually not an allophone but a pause which is needed to end the word.

ELECTRICAL CHARACTERISTICS

Maximum Ratings*

All pins with respect to Vss.....-0.3 to 8.0V
Storage Temperature.....-25°C to 125°C

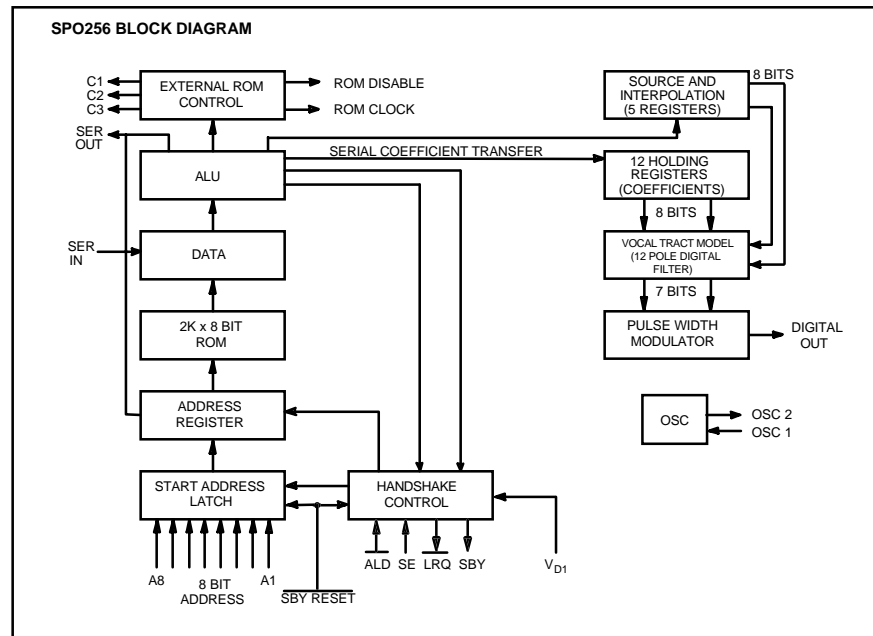
Standard Conditions

Clock - Crystal Frequency3.120 MHz
Operating Temperature (Ta).....0°C to 70°C

DC CHARACTERISTICS/SPO 256

*Exceeding these ratings could cause permanent damage to the device. This is a stress rating only and functional operation of this device at these conditions is not implied. Operating ranges are specified in Standard Conditions. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Data labeled "typical" is presented for design guidance only and is not guaranteed

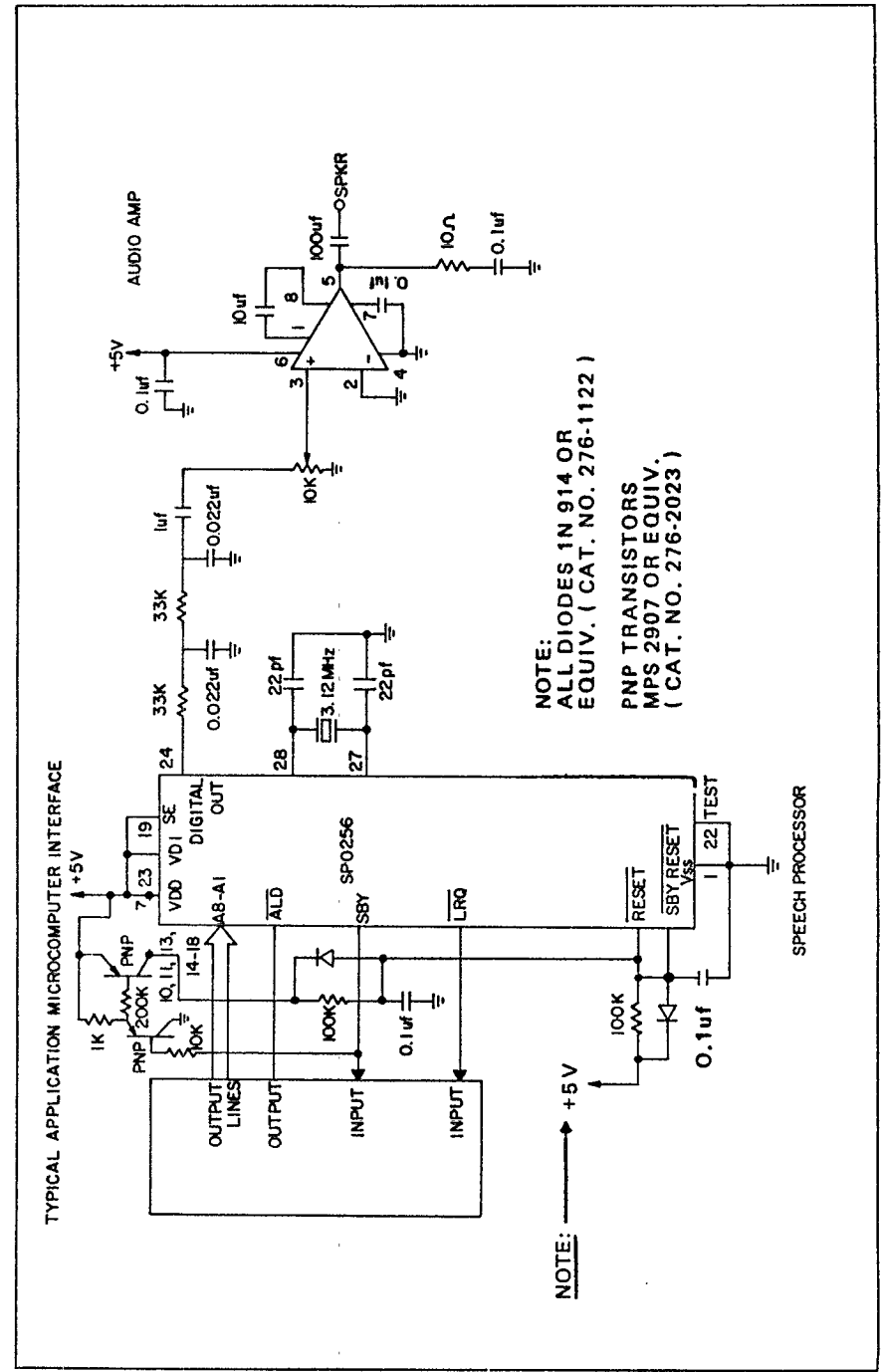


Characteristic	Sym	Min	Typ	Max	Units	Conditions
Supply Voltage	V _{DD}	4.6	—	7.0	V	
	V _{D1}	4.6	—	7.0	V	
Supply Current	I _{DD}	—	—	90	mA	T _A = 25°C, V _{D1} , V _{DD} = 7.0V Reset & SBY Reset high. All outputs floating. Same as above.
	I _{D1}	—	—	21	mA	
INPUTS						
A1-A8, ALD, SERIN, TEST, SE						0 Volts bias, f = 3.12 MHz V _{PIN} = 7.0V Other Pins = 0.0V
LOGIC 0	V _{IL}	0.0	—	0.6	V	
LOGIC 1	V _{IH}	2.4	—	V _{D1}	V	
CAPACITANCE	C _{IN}	—	—	10	pF	
LEAKAGE	I _L	—	—	+10	µa	
RESET, SBY RESET						
LOGIC 0	V _{IL}	0.0	—	0.6	V	
LOGIC 1	V _{IH}	3.6	—	V _{D1}	V	
OUTPUTS						
SBY, Digital Out, C1, C2, C3, LRQ, ROM DIS, ROM CLK, SEROUT						I _{OL} = 0.72ma (2LS TTL Loads) I _{OH} = -50 µa (2LS TTL Loads)
LOGIC 0	V _{OL}	0.0	—	0.6	V	
LOGIC 1	V _{OH}	2.5	—	V _{D1}	V	
OSCILLATOR						
OSC 2 (Output)						When driven from external source. OSC 1 (Input) = 3.90 V MIN OSC 1 (Input) = 0.60 V MAX
LOGIC 0	V _{OL}	0.0	—	0.6	V	
LOGIC 1	V _{OH}	2.5	—	V _{D1}	V	

AC CHARACTERISTICS	SYM	MIN	TYP	MAX	UNITS	CONDITIONS
ALD	tpw1	200	—	1100	ns	$200 \leq \overline{\text{ALD}} \leq 1100$ ns
A1-A8 Set Up	ts1	0	—	—	ns	
Hold	th1	160	—	—	ns	
LRQ	tpd1	—	—	300	ns	
SBY	tpd2	—	—	300	ns	

AC CHARACTERISTICS	SYM	MIN	TYP	MAX	UNITS	CONDITIONS
ALD	tpw2	1100	—	—	ns	$\overline{\text{ALD}} > 1100$ ns
A1-A8 Set Up	ts2	0	—	—	ns	
Hold	th2	1120	—	—	ns	
LRQ	tpd1	—	—	300	ns	
SBY	tpd2	—	—	300	ns	

AC CHARACTERISTICS	SYM	MIN	TYP	MAX	UNITS	CONDITIONS
Clock Frequency	F	—	3.120	—	MHz	Crystal Oscillator driven from external.
Clock Duty Cycle	—	48	—	52	%	
Reset	tpw3	100	—	—	us	
SBY Reset	tpw4	100	—	—	us	



PIN FUNCTIONS

PIN NUMBER	NAME	FUNCTION
1	V _{SS}	Ground
2	RESET	A logic 0 resets that portion of the SP powered by VDD. Must be returned to a logic 1 for normal operation.
3	ROM DISABLE	For use with an external serial speech ROM, a logic 1 disables the external ROM.
4, 5, 6	CI, C2, C3	Output control lines for use with an external serial speech ROM. Refer to the SPR016 Data Sheet for details.
7	V _{DD}	Power supply for all portions of the SP except the microprocessor interface logic.
8	SBY	STANDBY. A logic 1 output indicates that the SP is inactive and VDD can be powered down externally to conserve power. When the SP is reactivated by an address being loaded, SBY will go to a logic 0.
B	LRQ	LOAD REQUEST. LRQ is a logic 1 output whenever the input buffer is full. When LRQ goes to a logic 0, the input port may be loaded by placing the 8 address bits on A1-A8 and pulsing the ALD output.
10,11,13,14 15,16,17,18	A8, A7, A6, A5, A4, A3, A2, A1	8 bit address which defines any one of 256 speech entry points.
12	SER OUT	SERIAL ADDRESS OUT. This output transfers a 16-bit address serially to an external speech ROM.
19	SE	STROBE ENABLE. Normally held in a logic 1 state. When tied to ground, ALD is disabled and the SP will automatically latch in the address on the input bus approximately 1µs after detecting a logic 1 on any address line.
20	ALD	ADDRESS LOAD. A negative pulse on this input loads the 8 address bits into the input port. The negative edge of this pulse causes LRQ to go high.
21	SER IN	SERIAL IN. This is an 8-bit serial data input from an external speech ROM.

Pin Functions Continued

PIN NUMBER	NAME	FUNCTION
22	TEST	This pin should be grounded for normal operation.
23	VD1	Power supply for the microprocessor interface logic and controller.
24	DIGITAL OUT	Pulse width modulated digital speech output which, when filtered by a 5KHz low pass filter and amplified, will drive a loudspeaker.
25	SBY RESET	STANDBY RESET. A logic 0 resets the microprocessor interface logic and the address latches. Must be returned to a logic 1 for normal operation.
26	ROM CLOCK	This is a 1.56MHz clock output used to drive an external serial speech ROM.
27	OSC1	XTAL IN. Input connection for a 3.12MHz crystal.
28	OSC2	XTAL OUT. Output connection for a 3.12MHz crystal.

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) are five pauses are stored at different addresses in the SPO256 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**'s 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 **IH**, **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 mono-syllabic 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". One 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		
one, won		
two, to, too		
three		
four, for, fore		
five		
six		
seven		
eight, ate		
nine		
ten		
eleven		
thirteen		
fourteen		
fifteen		
sixteen		
	eighteen	EY PA2 PA3 TT2 IY NN1
	nineteen	NN1 AY NN1 PA2 PA3 TT2 IY NN1
	twenty	TT2 WH EH EH NN1 PA2 PA3 TT2 IY
	thirty	TH ER2 PA2 PA3 TT2 IY
	forty	FF OR PA3 TT2 IY
	fifty	FF FF IH FF FF PA2 PA3 TT2 IY
	sixty	SS SS IH PA3 KK2 SS PA2 PA3 TT2 IY
	seventy	SS SS EH VV IH NN1 PA2 PA3 TT2 IY
	eighty	EY PA3 TT2 IY
	ninety	NN1 AY NN1 PA3 TT2 IY
	hundred	HH2 AX AX NN1 PA2 DD2 RR2 IH IH PA1 DD1
	thousand	TH AA AW ZZ TH PA1 PA1 NN1 DD1
	million	MM IH IH LL YY1 AX NN1

Table 1 Continued

DAY OF THE WEEK:		K	KK1 EH EY	coop	KK3 UW2 PA3 PP	fir	FF ER2
		L	EH EH EL	correct	KK1 ER2 EH E H	freeze	FF FF RR1 IY ZZ
Sunday	SS SS AX AX NN1	M	EH EH MM	corrected	PA2 KK2 PA2 TT1	freezer	FF FF RR1 IY ZZ
Monday	PA2 DD2 EY	N	EH EH NN1		KK1 ER2 EH EH	freezers	ER1
	MM AX AX NN1	O	ow	correcting	PA2 KK2 PA2 TT2		FF FF RR1 IY ZZ
	PA2 DD2 EY	P	PP IY		IH PA2 DDI	freezing	ER1 ZZ
Tuesday	TT2 UW2 ZZ PA2	Q	KK1 YY1 UW2		KK1 ER2 EH EH		FF FF RR1 IY ZZ
	DD2 EY	R	AR	corrects	PA2 KK2 PA2 TT2	frozen	IH NG
Wednesday	WW EH EH NN1 ZZ	S	EH EH SS SS		IH NG		FF FF RR1 OW ZZ
	PA2 DD2 EY	T	TT2 IY		KK1 ER2 EH E H		EH NN1
Thursday	TH ER2 ZZ PA2	U	YY1 UW2	crown	PA2 KK2 PA2 TT1	gauge	GG1 EY PA2 JH
	DD2 EY	V	VV IY	date	ss	guaged	GG1 EY PA2 JH
Friday	FF RR2 AY PA2	W	DD2 AX PA2 BB2	daughter	KK1 RR2 AW NN1	guager	PA2 DD1
	DD2 EY		EL YY1 UW2	day	DD2 EY PA3 TT2	guaging	GG1 EY PA2 JH
Saturday	SS SS AE PA3	X	EH EH PA3 KK2	divided	DD2 A0 TT2 ER1		IH ZZ
	TT2 PA2 DD2 EY	Y	SS SS		DD2 EH EY		GG1 EY PA2 JH
MONTHS:		Z	WW AY		DD2 IH VV AY	hello	IH NG
			ZZ IY	emational	PA2 DD2 IH PA2	hour	HH EH LL AX OW
January	JH AE AE NN1	DICTIONARY:			DD1		AW ER1
	YY2 XR 1Y	alarm	AX LL AR MM	engage	IY MM OW SH AX	infinitive	HH ER1
February	FF EH EH PA1	bathe	BB2 EY DH2	engagement	NN1 AX EL		AW ER1
	BR RR2 uw2 XR IY	bather	BB2 EY DH2 ER1		EH EH PA1 NN1	intrigue	IH NN1 FF FF IH
March	MM AR PA3 CH	bathing	BB2 EY DH2 IH NG	engages	GG1 EY PA2 JH		IH NN1 IH PA2 PA3
April	EY PA3 PP RR2	beer	BB2 YR		EH EH PA1 NN1	intrigued	TT2 IH VV
	IH IH LL	bread	BB1 RR2 EH EH PA1	engaging	GG1 EY PA2 JH MM		IN NN1 PA3 TT2
May	MM EY	by	DD1		EH EH NN1 PA2		RR2 IY PA1 GG3
June	JH UW2 NN1	calendar	BB2 AA AY		PA3 TT2		IH NN1 PA3 TT2
July	JH UW1 LL AY	clock	KK1 AE AE LL	engages	EH EH PA1 NN1	intrigues	RR2 IY PA1 GG3
August	AO AO PA2 GG2	clown	EH NN1 PA2 DD2		GG1 EY PA2 JH IH		PA2 DD1
	AX SS PA3 TT1	check	ER1	enrage	zz		IH NN1 PA3 T-I-2
September	SS SS EH PA3 PP	checked	KK1 LL AA AA		EH EH PA1 NN1	intriguing	RR2 IY PA1 GG3
	PA3 TT2 EH EH	checker	PA3 KK2	enraged	GG1 EY PA2 JH IH		zz
	PA1 BB2 ER1	checkers	KK1 LL AW NN1		NG		IH NN1 PA3 TT2
October	AA PA2 KK2 PA3	checking	CH EH EH PA3	enrages	EH NN1 RR1 EY	investigate	RR2 IY PA1 GG3
	TT2 OW PA1 BB2	checks	KK2	enraging	PA2 JH		IH NG
	ER1	cognitive	CH EH EH PA3	escape	EH NN1 RR1 EY	Investigated	IH IH NN1 VV EH
November	NN2 OW VV EH EH	collide	KK2 PA2 TT2	escaped	PA2 JH IH ZZ		EH SS PA2 PA3
	MM PA1 BB2 ER1	computer	CH EH EH PA3		EH NN1 RR1 EY		TT2 IH PA1 GG1
December	DD2 IY SS SS EH	cookie	KK1 ER1	escapes	PA2 JH IH NG		EY PA2 TT2
	EH MM PA1 BB2		KK1 ER1 ZZ	escaping	EH SS SS PA3	Investigator	IH IH NN1 VV EH
	ER1		CH EH EH PA3	equal	KK1 PA2 PA3 PP		EH SS PA2 PA3
LETTERS:			KK1 IH NG	equals	EH SS SS PA3 PP	investigates	TT2 IH PA1 GG1
A	EY		CH EH EH PA3	error	EH SS SS PA3 PP SS		DD1
B	BB2 IY		KK1 IH NG	extent	EH SS SS PA3 KK1		IH IH NN1 VV EH
C	SS SS IY		CH EH EH PA3		PA2 PA3 PP SS		EH SS PA2 PA3
D	DD2 IY		KK1 SS		EH SS SS PA3 KK1		TT2 IH PA1 GG1
E	IY		KK3 AA AA GG3		PA2 PA3 PP IH NG		EY PA2 TT2 ER1
F	EH EH FF FF		NN1 IH PA3 TT2		IY PA2 PA3 KK3		EH SS PA2 PA3
G	JH IY		IH VV		WH AX EL		TT2 IH PA1 GG1
H	EY PA2 PA3 CH		KK3 AX LL AY		IY PA2 PA3 KK3		EY PA2 TT2 ER1
I	AA AY		DD1		WH AX EL ZZ		zz
J	JH EH EY		KK1 AX MM PP1		EH XR OR		IH IH NN1 VV EH
			YY1 UW1 TT2 E R		EH KK1 SS TT2 EH		EH SS PA2 PA3
			KK3 UH KK1 IY		EH NN1 TT2		TT2 IH PA1 GG1
							EY PA2 TT1 SS

Table 1 Continued

investigating	IH IH NN1 VV EH EH SS PA2 PA3 TT2 IH PA1 GG1 EY PA2 TT2 IH NG KK1 IY	pledging	PP LL EH EH PA3 JH IH NG
key	LL EH EH PA2	plus	PP LL AX AX SS SS
legislate	JH JH SS SS LL EY PA2 PA3 TT2	ray	RR1 EH EY
legislated	LL EH EH PA2 JH JH SS SS LL EY PA2 PA3 TT2 IH DD1	rays	RR1 EH EY ZZ
legislates	LL EH EH PA2 JH JH SS SS LL EY PA2 PA3 TT1 SS	ready	RR1 EH EH PA1 DD2 IY
legislating	LL EH EH PA2 JH JH SS SS LL EY PA2 PA3 TT2 IH NG	red	RR1 EH FH PA1 DD1
legislature	LL EH EH PA2 JH JH SS SS LL EY PA2 PA3 CH ER1	robot	RR1 OW PA2 BB2 AA PA3 TT2
letter	LL EH EH PA3 TT2 ER1	robots	RR1 OW PA2 BB2 AA PA3 TT1 SS
litter	LL IH IH PA3 TT2 ER1	score	SS SS PA3 KK3 OR
little	LL IH IH PA3 TT2 EL	second	SS SS EH PA3 KK1 IH NN1 PA2 DD1
memory	MM EH EH MM ER2 IY	sensitive	SS SS EH EH NN1 SS SS IH PA2 PA3 TT2 IH VV
memories	MM EH EH MM ER2 IY ZZ	sensitivity	SS SS EH EH NN1 SS SS IH PA2 PA3 TT2 IH VV IH PA2 PA3 TT2 IY
minute	MM 1H NN1 IH PA3 TT2	sincere	SS SS IH IH NN1 SS SS YR
month	MM AX NN1 TH	sincerely	SS SS IH IH NN1 SS SS YR LL IY
nip	NN1 IH IH PA2 PA3 PP	sincerity	SS SS IH IH NN1 SS SS EH EH RR1 IH PA2 PA3 TT2 IY SS SS IH IH SS PA3 TT2 ER1
nipped	NN1 IH IH PA2 PA3 PP PA3 TT2	sister	SS SS IH IH SS PA3 TT2 ER1
nipping	NN1 IH IH PA2 PA3 PP IH NG	speak	SS SS PA3 IY PA3 KK2
nips	NN1 IH IH PA2 PA3 PP SS	spell	SS SS PA3 PP EH EH EL
no	NN2 AX OW	spelled	SS SS PA3 PP EH EH EL PA3 DD1
physical	FF FF IH ZZ IH PA3 KK1 AX EL	speller	SS SS PA3 PP EH EH EL ER2
pin	PP IH IH NN1	spellers	SS SS PA3 PP EH EH EL ER2 ZZ
pinned	PP IH IH NN1 PA2 DD1	spelling	SS SS PA3 PP EH EH EL IH NG
pinning	PP IH IH NN1 IH NG1	spells	SS SS PA3 PP EH EH EL ZZ
pins	PP IH IH NN1 ZZ	start	SS SS PA3 TT2 AR PA3 TT2
pledge	PP LL EH EH PA3 JH	started	SS SS PA3 TT2 AR PA3 TT2 IH PA1 DD2
pledged	PP LL EH EH PA3 JH PA2 DD1	starter	SS SS PA3 TT2 AR PA3 TT2 ER1
pledges	PP LL EH EH PA3 JH IH ZZ		

starting	SS SS PP3 TT2 AR PA3 TT2 IH NC
starts	SS SS PP3 TT2 AR PA3 TT1 SS
stop	SS SS PA3 TT1 AA AA PA3 PP
stopped	SS SS PA3 TT1 AA AA PA3 PP PA3 TT2
stopper	SS SS PA3 TT1 AA AA PA3 PP ER1
stopping	SS SS PA3 TT1 AA AA PA3 PP IH NG
stops	SS SS PA3 TT1 AA AA PA3 PP SS
subject (noun)	SS SS AX AX PA2 BB1 PA2 JH EH PA3 KK2 PA3 TT2
subject (verb)	SS SS AX PA2 BB1 PA2 JH EH EH PA3 KK2 PA3 TT2
sweat	SS SS WW EH EH PA3 TT2
sweated	SS SS WW EH EH PA3 TT2 IH PA3 DD1
sweater	SS SS WW EH EH PA3 TT2 ER1
sweaters	SS SS WW EH EH PA3 TT2 ER1 ZZ
sweating	SS SS WW EH EH PA3 TT2 IH NG
sweats	SS SS WW EH EH PA3 TT2 SS
switch	SS SS WH IH IH PA3 CH
switched	SS SS WH IH IH PA3 CH PA3 TT2
switches	SS SS WH IH IH PA3 CH IH ZZ2
switching	SS SS WH IH IH PA3 CH IH NG2
system	SS SS IH IH SS SS PA3 TT2 EH MM
systems	SS SS IH IH SS SS PA3 TT2 EH MM Z Z
talk	TT2 AO AO PA2 KK2
talked	TT2 AO AO PA3 KK2 PA3 TT2
talker	TT2 AO AO PA3 KK1 ER1
talkers	TT2 AO AO PA3 KK1 ER1 ZZ
talking	TT2 AO AO PA3 KK1 IH NG
talks	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 Z Z
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 LL Z Z
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	vEIn
	fEEt	forElgn
	pEte	dElsm
	pEOple	dElcer
	pennY	gElsha
Consonants	SHIp	althouGH
	tenSlon	GHastly
	preClous	couGH
	naTlon	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

Labio-Dental: Upper Teeth and Lower Lip Touch

Inter-Dental: Tongue Between Teeth

Alveolar: Tip of Tongue Touches or Approximates Alveolar Ridge (just behind upper teeth)

Palatal: Body of Tongue Approxi- mates Palate (roof of mouth)

Velar: Body of Tongue Touches Velum (posterior portion of roof of mouth)

Glottal: Glottis (opening between vocal cords)

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	Resonants	Voiceless Stops	Affricates
PA1 (10 ms) - before BB, DD, GG, and JH	/WW/ - we, warrant, linguist	/PP/ - pleasure, ample, trip	/CH/ - church, feature
PA2 (30 ms) - before BB, DD, GG, and JH	/RR1/ - initial position: read, write, x-ray	/TT1/ - final clusters before SS: tests its	/JH/ - judge, injure
PA3 (50 ms) - before PP, TT, KK, and CH, and between words	/RR2/ - initial clusters: brown, crane, grease	/TT2/ - all other positions: test, street	Nasal
PA4 (100 ms) - between clauses and sentences	/LL/ - like, hello, steel	/KK1/ - before front vowels: YR, IY, IH, EY, EH, XR, AY, AE, ER, AX; initial clusters: cute, clown, scream	/MM/ - milk, alarm, ample
PA5 (200 ms) - between clauses and sentences	/YY1/ - clusters: cute, beauty, computer	/KK2/ - final position: speak; final clusters: task	/NN1/ - before front and central vowels: YR, IY, IH, EY, EH, XR, AE, ER, AX, AW, AY, UW; final clusters: earn
	/YY2/ - initial position: yes, yarn, yo-yo	/KK3/ - before back vowels: UW, UH, OW, OY, OR, AR, AO; initial clusters: crane, quick, clown, scream	/NN2/ - before back vowels: UH, OW, OY, OR, AR, AA
	Voiced Fricatives		/NG/ - string, anger
	/VV/ - vest, prove, even		* These allophones can be doubled.
	/DH1/ - word-initial position: this, then, they		
Short Vowels	/DH2/ - word-final and between vowels: bathe, bathing		
*/IH/ - sitting, stranded	/ZZ/ - zoo, phase		
*/EH/ - extent, gentlemen	/ZH/ - beige, pleasure		
*/AE/ - extract, acting	Voiceless Fricatives		
*/UH/ - cookie, full	*/FF/ -) These may be doubled for initial position and used singly in final position		
*/AO/ - talking, song	*/TH/ -) position		
*/AX/ - lapel, instruct	*/SS/ -)		
*/AA/ - pottery, cotton	/SH/ - shirt, leash, nation		
	/HH1/ - before front vowels: YR, IY, IH, EY, EH, XR, AE		
	/HH2/ - before back vowels: UW, UH, OW, OY, AO, OR, AR		
	/WH/ - white, whim, twenty		
Long Vowels	Voiced Stops		
/IY/ - treat, people, penny	/BB1/ - final position: rib; between vowels: fibber, in clusters: bleed, brown		
/EY/ - great, statement, tray	/BB2/ - initial position before a vowel: beast		
/AY/ - kite, sky, mighty	/DD1/ - final position: played, end		
/OY/ - noise, toy, voice	/DD2/ - initial position: down; clusters: drain		
/UW1/ - after clusters with YY: computer	/GG1/ - before high front vowels: YR, IY, IH, EY, EH, XR		
/UW2/ - in monosyllabic words: two, food	/GG2/ - before high back vowels: UW, UH, OW, OY, AX; and clusters: green, glue		
/OW/ - zone, close, snow	/GG3/ - before low vowels: AE, AW, AY, AR, AA, AO, OR, ER; and medial clusters: anger; and final position: peg		
/AW/ - sound, mouse, down			
/EL/ - little, angle, gentlemen			
R-Colored Vowels			
/ER1/ - letter, furniture, interrupt			
/ER2/ - monosyllables: bird, fern, burn			
/OR/ - fortune, adorn, store			
/AR/ - farm, alarm, garment			
/YR/ - hear, earring, irresponsible			
/XR/ - hair, declare, stare			

TABLE 6 - ALLOPHONE ADDRESS TABLE

HEX ADD	OCTAL ADDRESS	ALLO- PHONE	SAMPLE WORD	DURATION	HEX ADD	OCTAL ADDRESS	ALLO- PHONE	SAMPLE WORD	DURATION
00	000	PA1	PAUSE	10MS	20	040	/AW/	Out	370MS
01	001	PA2	PAUSE	30MS	21	041	/DD2/	Do	160MS
02	002	PA3	PAUSE	50MS	22	042	/GG3/	Wig	140MS
03	003	PA4	PAUSE	100MS	23	043	/VV/	Vest	190MS
04	004	PA5	PAUSE	200MS	24	044	/GG1/	Got	80MS
05	005	/OY/	BOY	420MS	25	045	/SH/	Ship	160MS
06	006	/AY/	Sky	260MS	26	046	/ZH/	Azure	190MS
07	007	/EH/	End	70MS	27	047	/RR2/	Brain	120MS
08	010	/KK3/	Comb	120MS	28	050	/FF/	Food	150MS
09	011	/PP/	Pow	210MS	29	051	/KK2/	Sky	190MS
0A	012	/JH/	Dodge	140MS	2A	052	/KK1/	Can't	160MS
0B	013	/NN1/	Thin	140MS	2B	053	/ZZ/	Zoo	210MS
0C	014	/IH/	Sit	70MS	2C	054	/NG/	Anchor	220MS
0D	015	/TT2/	To	140MS	2D	055	/LL/	Lake	110MS
0E	016	/RR1/	Rural	170MS	2E	056	/WW/	Wool	180MS
0F	017	/AX/	Succeed	70MS	2F	057	/XR/	Repair	360MS
10	020	/MM/	Milk	180MS	30	060	/WH/	Whig	200MS
11	021	/TT1/	Part	100MS	31	061	/YY1/	Yes	130MS
12	022	/DH1/	They	290MS	32	062	/CH/	Church	190MS
13	023	/IY/	See	250MS	33	063	/ER1/	Fir	160MS
14	024	/EY/	Beige	280MS	34	064	/ER2/	Fir	300MS
15	025	/DD1/	Could	70MS	35	065	/OW/	Beau	240MS
16	026	/UW1/	To	100MS	36	066	/DH2/	They	240MS
17	027	/AO/	Aught	100MS	37	067	/SS/	Vest	90MS
18	030	/AA/	Hot	100MS	38	070	/NN2/	No	190MS
19	031	/YY2/	Yes	180MS	39	071	/HH2/	Hoe	180MS
1A	032	/AE/	Hat	120MS	3A	072	/OR/	Store	330MS
1B	033	/HH1/	He	130MS	3B	073	/AR/	Alarm	290MS
1C	034	/BB1/	Business	80MS	3C	074	/YR/	Clear	350MS
1D	035	/TH/	Thin	180MS	3D	075	/GG2/	Guest	40MS
1E	036	/UH/	Book	100MS	3E	076	/EL/	Saddle	190MS
1F	037	/UW2/	Food	260MS	3F	077	/BB2/	Business	50MS