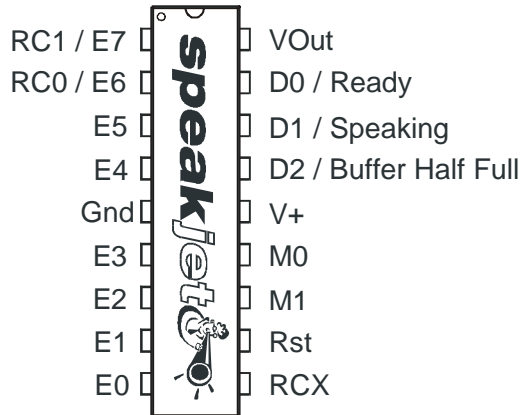




Natural Speech & Complex Sound Synthesizer User's Manual

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General Description

The SpeakJet is a completely self contained, single chip voice and complex sound synthesizer. It uses Mathematical Sound Architecture™ (MSA) technology which controls an internal five channel sound synthesizer to generate on-the-fly, unlimited vocabulary speech synthesis and complex sounds. The SpeakJet is preconfigured with 72 speech elements (allophones), 43 sound effects, and 12 DTMF Touch Tones. Through the selection of these MSA components and in combination with the control of the pitch, rate, bend, and volume parameters, the user has the ability to produce unlimited phrases and sound effects, with thousands of variations, at any time. This is not recorded waveforms or sound fragments but truly synthetic sound.

The SpeakJet can be controlled simultaneously by logic changes on any one of its eight Event Input lines, and/or by a Serial Data line from a CPU (such as the OOPic, Basic Stamp or PC) allowing for both CPU-Controlled and Stand-Alone operations.

Other features include an internal 64 byte input buffer, Internal Programmable EEPROM, three programmable outputs, and direct user access to the internal five channel sound synthesizer.

More information can be found at www.SpeakJet.com

Core Features:

- Programmable, 5 channel synthesizer.
- Natural phonetic speech synthesis.
- DTMF and other sound effects.
- Programmable control of pitch, rate, bend and volume.
- Programmable power – up or reset announcements.
- Multiple modes of operation.
- Simple interface to microcontrollers.
- Simple “Stand Alone” operation.
- Three programmable digital outputs.
- Internal 64 Byte input buffer.
- Internal programmable EEPROM.
- Extremely low power consumption.
- Low pin count.
- Multiple case styles available.

Special Features

- Three multipurpose, programmable digital outputs allow the SpeakJet to control external devices based on timing of the sound output. Control of devices may include lights, motors, or even launch model rocket after a count down sequence.
- An internal clock oscillator provides for a truly “Self Contained sound system. Simply connect the SpeakJet to a power supply and a speaker to hear it speak. *
- An internal user programmable EEPROM allows for programming of up to 16 complex phrases or sound sequences. These may be played back once or looped many times in response to events.
- Phrases may call other phrases, sounds or controls, with nesting up to 3 levels deep.
- No special equipment is required to program the internal EEPROM, only a serial connection is required.

Interface Options

- **CPU Control:** Single Wire Serial Input from microprocessors such as the OOPic, Basic Stamp, or any other computer system equipped with a serial port.
- **Stand Alone:** Eight Event Inputs for execution of up to sixteen phrases, sound effects or control functions with or without a microcontroller.
- **RC Input:** Two Servo Pulse Inputs for execution of up to four phrases, sound effects or control functions via wireless model Airplane or Car Radio Control receivers.

SpeakJet Pin Details

Pin #	Description	Functional Details
1	RC1/E7	Event Input 7
2	RC0/E6	Event Input 6
3	E5	Event Input 5
4	E4	Event Input 4
5	Gnd	Ground
6	E3	Event Input 3
7	E2	Event Input 2
8	E1	Event Input 1
9	E0	Event Input 0
10	RCX	Serial Input
11	Rst	Master Reset
12	M1	Mode Select 1 (Baud Configure)
13	M0	Mode Select 0 (Demo Mode)
14	V+	Power input +2.0 to +5.5 volts DC
15	D2/Buffer Half Full	Data Out 2 (External) / Buffer Half Full (Internal)
16	D1/Speaking	Data Out 1 (External) / Speaking (Internal)
17	D0/Ready	Data Out 0 (External) / Ready (Internal)
18	VOut	Voice Output

Electrical Specifications:

Supply voltage 2.0 to 5.5 VDC

Supply Current:

Idle: <5ma. Plus loads

Speaking: <5ma. Plus loads

Sink/Source Current:

Outputs 25ma.

Inputs levels:

High Supply

Low GND

EEPROM:

Max. Write cycles Typical 1,000,000 times

Mechanical Specification:

Thermal storage: -60 to +140 Degrees C

Thermal operating -18 to +60 Degrees C

The thermal specifications are preliminary and may change as testing is completed.

Table A

SpeakJet Pin Functional Explanation

E0 – E7 : Event Input 0 – 7

Event Inputs provides a way to execute phrases, sound effects or control functions that have been pre-programmed into the EEPROM. Each Event Input can be configured to activate on a Low to High going transition, or a High to Low going transition. This can be combined to allow two Events with one Event Input. This feature is controlled by a configuration setting in the EEPROM. The Event Inputs are logical inputs that require a High or Low logic level and two Event Inputs can be configured as RC inputs. Any Event Input that is not used, must be connected to GND

RC0, RC1 : Event Input 6, 7

RC inputs provide a way to trigger an Event Inputs using a variable width pulse from a model RC receiver. This allows the SpeakJet to be controlled by a remote link to execute up to four phrases, sound effects or control functions. This feature is controlled by a configuration setting in the EEPROM.

RCX : Serial Input

Serial Input provides the means for external devices to communicate with the SpeakJet. This is a logical input that requires a High or Low voltage level. If the Serial Input line is not used, it must be connected to GND.

NOTE: This is not RS-232 signal level voltages. See section on RS-232 for more details.

Rst : Master Reset

The Master Reset provides a way to reset the SpeakJet to power up conditions. This forces the internal control circuit to reset and clear the input buffer. The configuration bits and stored phrases in the EEPROM are not affected. This is a logical input that requires a High or Low logic level and is active low. The use of RESET along with the logic states of the Mode Select inputs M0 and M1, places the SpeakJet into the different modes of operation.

NOTE: For normal operation, reset *must* be connected to V+ through a resistor.

M0, M1 : Mode Select 0, 1

Mode Select inputs are read by the internal control system after a power-up or a reset is forced, and is used to determine which one of two modes to start up in: Normal Operation or Demo / Test mode. When in Demo / Test mode the SpeakJet can be placed in Baud Rate Configure mode. These pins are logical inputs that require a High or Low logic level. For normal operation, connect M0 to GND. and M1 to V+ through a resistor.

D2 / Buffer Half Full : Data Out 2 / Buffer Half Full

Data Out 2 / Buffer Half Full output is used for flow control with a serial port by connecting to the CTS line back to the computer or controller. Or it may be used as a general-purpose output. This line is a logical output with either a High or Low logic level. Which function this output uses is determined by a configuration bit stored in the EEPROM and the factory default configurations is: "Buffer Half Full" and is Active High.

D1 / Speaking : Data Out 1 / Speaking

Data Out 1 / Speaking output is used to indicate when the SpeakJet is "Speaking". Or it may be used as a general-purpose output. This line is a logical output with either a High or Low logic level. Which function this output uses is determined by a configuration bit stored in the EEPROM and the factory default configurations is: "Speaking" and is Active

D0 / Ready : Data Out 0 / Ready

Data Out 0 / Ready output is used to indicate when the SpeakJet is Ready. This indicates that the internal self-test has passed and the Speakjet is ready to accept data through one of its inputs. Or it may be used as a general-purpose output. This line is a logical output with either a High or Low logic level. Which function this output uses is determined by a configuration bit stored in the EEPROM and the factory default configurations is: "Ready" and is Active High.

Vout : Voice Output

Voice Output modulates the SpeakJet's voice on a square wave carrier of 32 khz. The duty cycle of this carrier is varied by the modulation of the sound output. This duty cycles typically varies by 70% and can vary up to 100% depending on the level of output represented by the audio wave. A simple "two pole" low pass filter (see Figure 1) is all that is required before an amplifier to obtain quality sound.

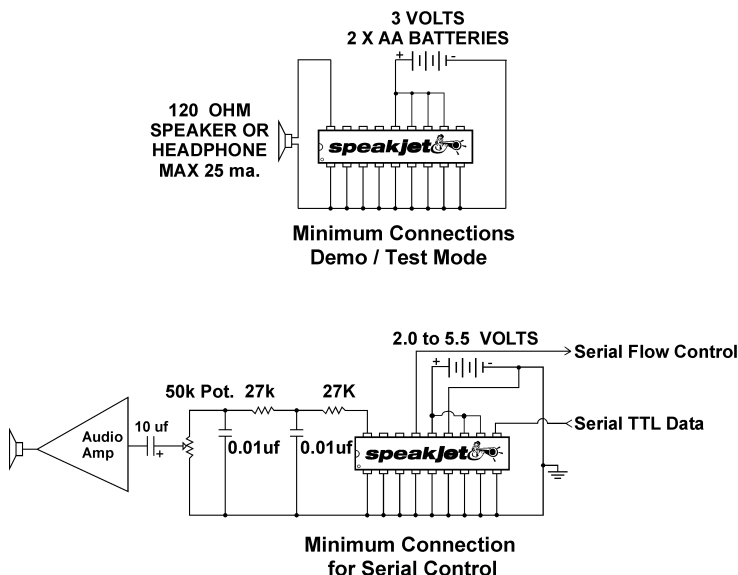


Figure 1. SpeakJet Typical connections

General Operation:

The SpeakJet is an advanced CMOS LSI device that incorporates six basic internal modules: (Figure 2)

- 5-Channel Synthesizer. For generating both voice and sound effects.
- Mathematical Sound Architecture™ (MSA) engine and Sound Component Database that controls the 5-Channel Synthesizer.
- Chip control I/O, which consists of 1Serial Input, 8 Event Inputs, 3 Data Outputs, and 2 Mode Select inputs and Reset.
- 64-Byte Input Buffer.
- User EEPROM.
- A Serial Control Protocol (SCP), which supervises the incoming serial commands.

When powered on, the SpeakJet will first read the Mode Select line M0 to determine if the SpeakJet is to operate in Demonstration Mode. Once the Initial Mode is set, (note that this only occurs at power-up or reset) the input buffer is cleared, the status lines are set, D0 / Ready is brought high and the SpeakJet begins operating.

During operation, the Serial Port waits for incoming command data, which specifies which sounds and effects the MSA is to direct the 5 channel synthesizer to produce.

The commands sent to the SpeakJet can be any of 256 commands (See Table D & E). There are 7 operational groups of commands. SCP, Allophones, Sound Effects, DTMF, Pauses, Levels and Controls. Each operational group will behave in different ways.

With the exception of SCP commands, each command received, is buffered into a 64-Byte input buffer and executed by the MSA in the order that they are received, First In First Out (FIFO). In the case of SCP, these commands are executed immediately as they are received and not stored in the input buffer. See the section on SCP for further details.

As the MSA executes the commands stored in the input buffer, it directs the 5 Channel Synthesizer, which produces the Voice output (See Figure2 and Figure 3) and each command is removed from the input buffer after the command is executed.

Both the Serial Input and the 8 Event Inputs provide methods of placing command data in the Input Buffer.

Serial Input: A single input line is used to receive command data at the preset baud rate. The RCX is the serial input and is expecting a logical level (non-inverted) signal.

Event Inputs: In the case that an Event Input is configured to do so, a single EEPROM Call command is stored into the input buffer whenever one of the Event Input's logic state is changed or in the case of the RC Event Input, when a PWM pulse changes to a predetermined amount.

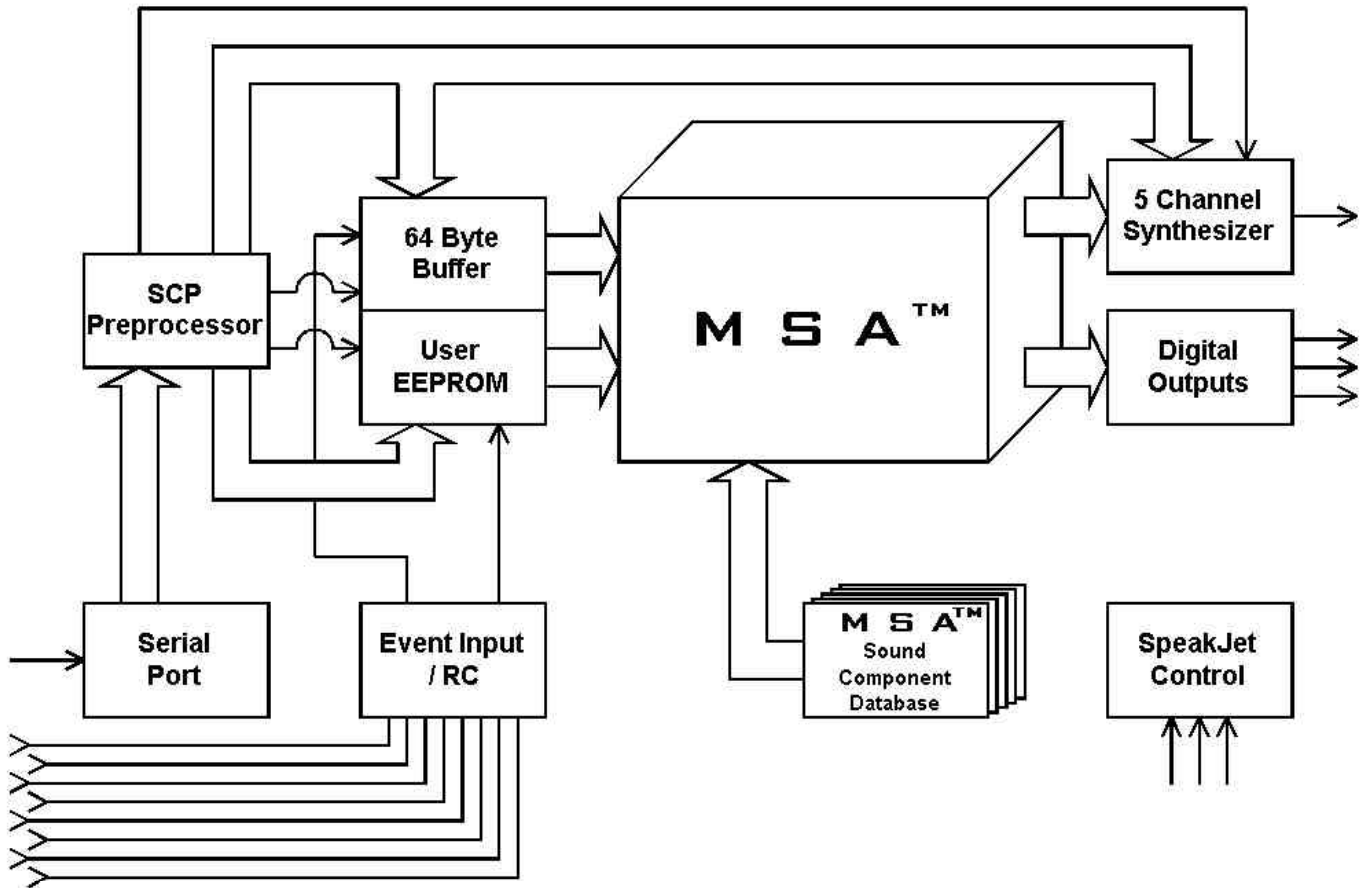


Figure 2. SpeakJet Block Diagram

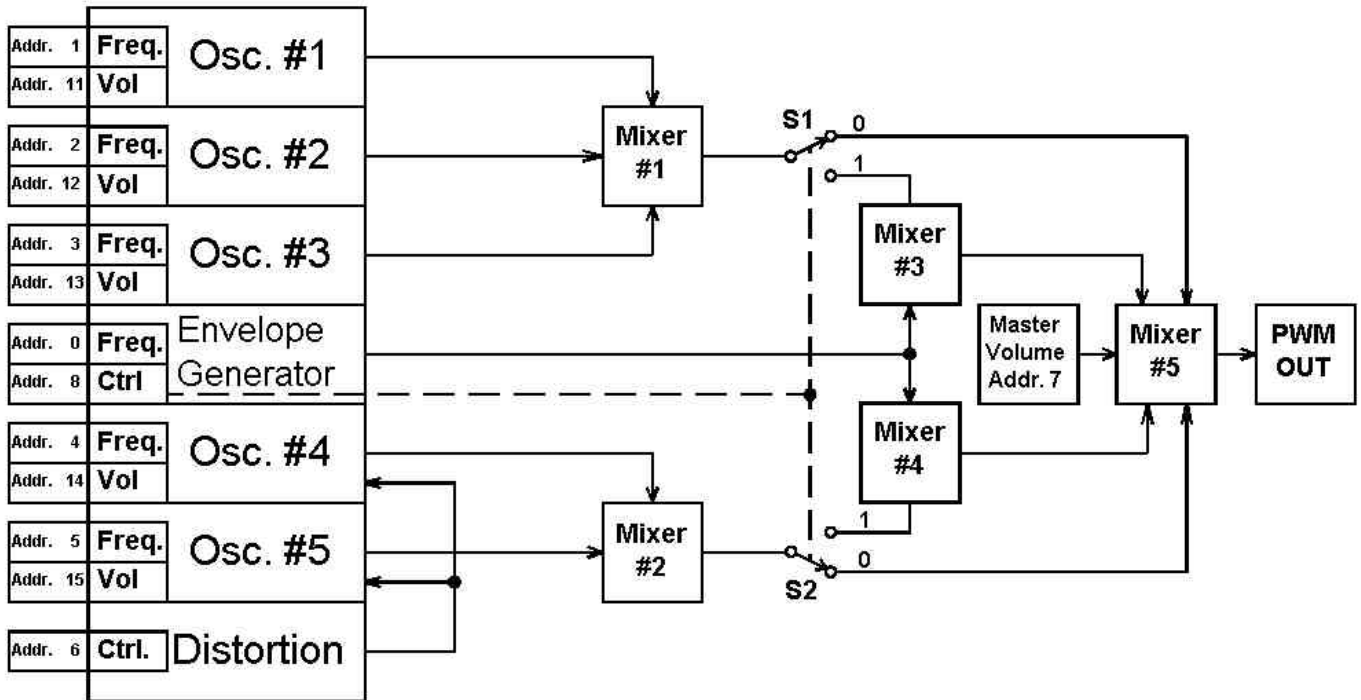


Figure 3. SpeakJet 5 Channel Synthesizer Block Diagram

Status lines provide information on the current operational status of the SpeakJet.

“D0 / Ready” is active high when the SpeakJet is on and ready to accept commands.

“D1 / Speaking” is active high when the SpeakJet is currently generating any sound.

“D2 / Buffer Half Full” is active high when the input buffer is 1/2 full. This indicates when the 64-Byte input buffer has more than 32 bytes in it. As the MSA executes the commands stored in the input buffer, the buffer memory is freed and as 32 bytes of the buffer becomes available, the Buffer Half Full output line will reflect that status. This line can be used in a serial connection as the serial port's CTS line. A logical Low output indicates that the buffer can accept 32 bytes and a logical High output indicates that the buffer cannot.

The status lines can also be user programmed to control external devices. Each Status line can be individually selected to be and internal Status or user selected logic state.

Mode Select:

When a High logic level is placed on Mode Select, M0, and RESET is forced, the SpeakJet starts a Demo mode where all internal allophones and sound effects are played in a loop. This loop plays only when the buffer is empty and will suspend if any data is sent to the buffer. When M0 is brought back to a low state the demo mode is suspended. If M0 is brought back to a high state, the demo mode continues from the point where it was suspended. A RESET with a low logic level on Mode select M0 will discontinue the Demo/Test mode and place the SpeakJet back to normal operation.

Baud Rate Configure:

If the SpeakJet is in the Demo/Test mode and a momentary Low logic level is placed on Mode Select M1, the Speakjet starts a Sonar Ping sound to indicate the Baud Rate Configuration mode is selected. At this time the Speakjet is waiting for a serial sync character (hex 55) to set the internal clock for the baud rate that is to be used. Once the baud rate is captured, the Speakjet automatically stores this value in the EEPROM and returns to the demo mode. The SpeakJet will continue to use this new Baud Rate until configured again.

Normal operation requires that M0 to be Low logic level and M1 to be a High logic level.

Serial Data:

Serial Data is the main method of communicating with the SpeakJet to execute commands or create voices and sounds. The serial data can also be used to program the internal EEPROM. The SpeakJet does not accept actual RS-232A signal levels, and will be damaged if attempted to input these levels. In order to read data from a RS-232A type of serial data stream, a level shifter/line receiver must be used. This can be as simple as a small transistor or more robust device like the MAX232A from Maxim.

The SpeakJet serial configuration is fixed at: 8 bits, No- Parity, and 1 stop bit (8, N, 1) and non-inverted, (RS-232 is inverted logic and higher voltages). The Speakjet can be configured to accept Baud rates from 2400 to 19200. The factory default setting is 9600 baud. This baud rate can be changed any time by placing the SpeakJet into the “Baud Rate Configure Mode.

Serial Control Protocol (SCP)

In addition to using the serial port to communicate with the MSA module, the SpeakJet includes a system called the Serial Control Protocol (SCP), which allows the 5-Channel Synthesizer and the EEPROM in the SpeakJet to be controlled over the serial port. More information can be found at www.openscp.com

Overview:

The function of the SpeakJet's implementation of the Serial Control Protocol (SCP) is to allow a serially attached device to interact with the control portion of the SpeakJet. Note that the entire character set used by SCP is composed of human readable characters so that a serial terminal program can be used to manually control the SpeakJet.

The SCP module will silently monitor all incoming serial data that is received by the SpeakJet's serial port for the Escape Sequence that activates the Serial Control Mode. When activated, all serial data is then exchanged with the SCP module until a future Escape Sequence or End SCP Control changes the serial port's operating mode back to sending data to the MSA module.

Escape Sequence:

The Escape Sequence is modeled after the ANSI 'C' Escape Sequence where the Escape character is represented by the Backwards Slash character (\) and the character immediately following the Escape character is used as a control value. When the SCP module detects the Escape character (\), the next character received (the control value) is used to set the serial port's operating mode.

Serial Control Mode:

The SCP Escape Sequence [Escape] [Node] is used to place the SpeakJet into Serial Control Mode where the control value of the Escape sequence, [Node], is a 1 digit number 0-7 which represents the SpeakJet's SCP Node Number. When this Escape Sequence is encountered, the [Device-Number] is checked against the SpeakJet's SCP Node number and if they match, or [Device-Number] is 0, then the SpeakJet will be placed into Serial Control Mode. Upon being placed in Serial Control Mode, the serial port's input buffer and the 3 control registers; Memory Address, Memory Type and Sub Address are cleared. Once in Serial Control Mode, the SpeakJet's SCP Module will respond to any commands that are issued. Either issuing the Exit command "X" or an Escape Sequence exits the Serial Control Mode, where the control character is a non-numeric character. After exiting Serial Control Mode, the SpeakJet's serial port's operating mode is set so that all incoming data is sent to the MSA and the SCP module will return to silently monitor the incoming serial data.

Example: To place the SpeakJet in and out of serial control mode,

Send "\0". (The SpeakJet is now in Serial Control Mode)
Send "\A". (The SpeakJet is now out of serial control mode)

Example: To place the SpeakJet in and out of serial control mode,

Send "\0". (The SpeakJet is now in Serial Control Mode)
Send "X". (The SpeakJet is now out of serial control mode)

The SpeakJet's SCP Node Number is set in EEPROM. It can be any number from 0 to 7. When set to any number other than 0, the SCP Module can be activated by either of the two Escape Sequences; [Escape] [0] or [Escape] [Node]. Note that the SCP Module will always respond to "\0" regardless of what the serial network Node has been set to. This allows up to 7 SpeakJet's to share a connection to a single serial port. When multiple SpeakJets are sharing a single serial port, the Escape Sequence: [Escape] [0] will activate all of them while [Escape] [Node] will only activate the ones that are set for that Node.

When a SpeakJet's SCP Module has been activated, access to its Registers and program EEPROM are achieved via a set of commands, which are used to specify the address and type of the memory to read and write. A single uppercase ALPHA character is used to initiate each of the commands and each command returns a lower case character to indicate when it has completed its function. Most of the commands can be issued in any order. For example the Acknowledge command "V" can be issued at any time to verify a valid connection with SCP and the Exit command "X" can be issued at any time to exit SCP.

Example: To place the SpeakJet in serial control mode, issue some commands, and exit serial control mode,

Send "\0".
Send "V" - SpeakJet enunciates "Ready"
Send "X". (The SpeakJet is now out of serial control mode)

To verify that the SpeakJet was placed in serial control mode, the Acknowledge Commands Command "V" can be issued which causes the SpeakJet to enunciate the word "Ready"

Example: To place the SpeakJet in serial control mode and verify a valid connection with SCP and then exit,

Send "\0".
Send "V" (SpeakJet enunciates "Ready")
Send "\A" (The SpeakJet is now out of serial control mode)

Sending Values:

While in Serial Control Mode, Decimal and Hexadecimal Characters are used for transferring data. Decimal Characters are used when a single value is being sent, and Hexadecimal Characters are used when multiple values are being sent. When sending values to the SpeakJet, each character of incoming serial data is stored in the SCP's 16-character input buffer. Any data that is in the input buffer when a store command is executed will be evaluated for its numeric value. Even non-numeric characters will be evaluated based on their ASCII values.

Example: To put Hex ("1D3F") into the buffer,

Send "\0"
Send "1D3F" ("1D3F" is now in the buffer)

The Clear Buffer command "R" is used to clear the buffer.

Example: To put "1234" into the buffer.

Send "\0"
Send "1234" ("1234" is now in the buffer)
Send "R" (the buffer is now clear)

Note that if the buffer is empty when a command that reads its value is used, then the buffer's value will be read as 0.

Also note that ALL incoming characters are stored to the input buffer. This includes the backspace character. Therefore, if the buffer winds up with erroneous data in it, the backspace character will not erase the data.

Accessing Memory:

The SpeakJet's memory is arranged into 16 registers plus a 256-Byte bank of EEPROM. Memory is set by using the - Set Memory "N" command.

Before any memory can be set, a few specifications must be set. The Store Memory Command relies on 2 control registers that specify how to perform the write function. These control registers are; Memory Type and Memory Address.

Memory Type:

Each time memory is set, the Memory Type control register is examined to determine how to handle the memory write. The Memory Type is an 8-Bit value that is used to specify the attributes about the memory. To set the Memory Type, the Set Type command "H" is used.

Example: To set the Memory Type to "32".

Send "\0"

Send "32H" (The memory type is now 32)

In the SpeakJet, there are 2 different types of memory that can be accessed with SCP. Register Values and Internal EEPROM.

The two types of SpeakJet memory can be set with the following memory types:

0: Write a register's value.

32 Write to the Internal EEPROM

Examples of these Memory Types are shown in latter sections.

Memory Address

Each time memory is accessed; the Memory Address control register is used to determine where the accessed memory is. The Memory Address is an 8-Bit value that is used to specify the memory's address. To set the memory address, the Set Address command "J" is used.

Example: To set the memory address to "126".

Send "\0"

Send "126J" (The memory address is now 126)

Accessing a Register's Value.

Accessing a register's Value is the simplest form of the SCP protocol. To write a register's Value, the Memory Type control register should be set to 0, the Memory Address control register needs to be set to the address of the Register to access, and the value to write needs to be specified. Once the conditions are met to access the Register's Value, the Set Memory command "N" is used to set the Register's value. If accessing the Register's Value is done immediately after entering into SCP mode, then setting the Memory Type control register to 0 can be skipped because is set to 0 by the SCP initialization routines.

Example: To write a value of 500 to the first oscillator and set its volume to 16,

Send "\0"

Send "8J" (Set address for Envelope Control)

Send "0N" (Set Envelope Control to 0)

Send "1J" (Set address for Oscillator 1 Frequency)

Send "500N" (Set Frequency of Oscillator 1)

Send "11J" (Set address for Oscillator 1 Volume)

Send "16N" (Set Oscillator 1 Volume to 16)

If the SCP Mode is not exited and the Memory Address and Memory Type values are not changed after being set, the default Object property may be written repeatedly.

Example: To set the frequency of the first oscillator to 500 Hz, 1500 Hz and 2500 Hz consecutively,

Send "\0"

Send "8J" (Set address for Envelope Control)

Send "0N" (Set Envelope Control to 0)

Send "11J" (Set address for Oscillator 1 Volume)

Send "16N" (Set Oscillator 1 Volume to 16)

Send "1J" (Set address for Oscillator 1 Frequency)

Send "500N" (Set Frequency of Oscillator 1 to 500 Hz)

Send "1500N" (Set Frequency of Oscillator 1 to 1500 Hz)

Send "2500N" (Set Frequency of Oscillator 1 to 2500 Hz)

A full list of Item Addresses can be found in the 5-Channel Oscillator Diagram, see Figure 3.

Accessing Internal EEPROM Memory

The SpeakJet has a 256 byte Internal EEPROM that is used for Phrase storage and configuration. To write to the Internal EEPROM, the Memory Type 32 and the desired Memory Address is specified followed by the values of the memory to write which are specified in 2-character per digit Hexadecimal followed by the Store Memory command "N".

Example: To write the hex (01) to the first location of the Internal EEPROM.

Send "\0"

Send "0J"

Send "32H"

Send "01N"

Note: It is critical that the values to be written are properly formatted in 2-character per digit Hexadecimal. Not doing so will cause erroneous data to be written.

A full memory map of the SpeakJet's Internal EEPROM can be found in the SpeakJet's Internal EEPROM Diagram see Figure 4.

Resetting the SpeakJet:

The Hard Reset Command "W" drops out of SCP Mode, and then resets the SpeakJet as if the reset line was cycled.

Example: To reset the SpeakJet,

Send "\0"

Send "W"

Exiting the SCP

The Exit Command "X" drops out of SCP Mode.

Example: To Exit SCP,

Send "X"

SpeakJet's Subset of the SCP Commands

The following table lists the SCP commands.

Command	Function	Description
\	Begin Escape Sequence	The Escape character is the first character of a two character Escape Sequence. The Escape character is followed with a single digit, which represents the Serial Node of the SpeakJet to communicate with. SCP Mode is entered when the received Serial Node is either 0, or matches the SpeakJet's Node value. If the received Serial Node is not 0 and does not match the SpeakJet's Node value then SCP Mode is turned off.
0 to 9 A to F	Numbers.	As digits are received, they are stored into the SCP's input buffer.
H	Store Memory Type	Stores a value into the 8-Bit Memory Type control register.
J	Store Memory Address	Stores a value into the 8-Bit Memory Address control register.
N	Store Memory	Stores value into the Memory specifies by the control registers.
R	Clear Buffer	Clears the contents of the SpeakJet's 64 byte Input Buffer and the SCP's 16 byte Input Buffer.
S	Stop Enunciating	Sets the SpeakJet's Wait flag to "1" which will cause the MSA module to ignore any data currently in the SpeakJet's 64 byte input buffer.
T	Start Enunciating	Sets the SpeakJet's Wait flag to "0" which will cause the MSA module to enunciate any data currently in the SpeakJet's 64 byte input buffer.
V	Acknowledge	Causes the SpeakJet to enunciate the word "Ready"
W	Hard Reset	Resets the SpeakJet in the same way that cycling the Reset Line does.
X	Exit	Exits SCP Mode.

The 5-Channel Synthesizer

The SpeakJet's 5-Channel Synthesizer, as shown in figure 3, is the module responsible for production the SpeakJet's voice. It is comprised of 6 Oscillators, 5 mixers and a Pulse Width Modulated (PWM) digital output.

Oscillators

Each oscillator can be set to any frequency from 0 to 3999Hz. The frequency is produced at a rate of 8192 samples per second. (8 kHz)

Two oscillators have a distortion control which affects a white noise bandwidth centered on the oscillator's current frequency.

Five of the oscillators have volume controls, while the sixth is used exclusively for enveloping the other 5 oscillators.

Mixers

The 5 mixers are used to combine the outputs of all oscillators to produce a final output.

Mixer 1 takes the outputs from oscillators 1, 2 and 3 and combines them. Note that the maximum combined volume that this mixer can handle is 63. For example, setting the volumes of oscillators 1, 2 and 3 to 31, 31, 0 respectively is acceptable, while setting the volumes to 22, 22 & 22 respectively is not.

Mixer 2 takes the outputs from oscillators 4 and 5 and combines them.

Mixers 3 and 4 are selectable mixers that are used to apply the envelope to the outputs of mixers 1 and 2. Register 8 controls the selection of these mixers.

Mixer 5 is the final summation mixer, which combines the outputs from all other mixers and applies the master volume level.

PWM output

The final output of mixer 5 is sent to the PWM module, which outputs the sound signal as a pulse width modulated digital signal on a square wave carrier of 32 kHz.

Controlling the Synthesizer

The SpeakJet provides two distinct ways to control the 5-Channel Synthesizer.

1. Sending commands to the MSA Engine.
2. Sending SCP commands to directly manipulating the 5-Channel Synthesizer's registers.

Sending commands to the MSA Engine is covered in the General Operations section of this manual. When the MSA Engine executes the commands stored in the 64-byte input buffer, it directs the 5 Channel Synthesizer, to produce the voice and sound effects output.

All MSA sound components will manipulate the synthesizer's registers according to its own needs. After the MSA Engine is finished executing the commands in the input buffer, the values of the synthesizer's registers are left in their last used state. The Auto-Silence option determines whether or not a Pause 0, (/P0) is played after the input buffer is empty. The pause commands will only ramp the Oscillator volume level registers to 0 and will not affect any of the other registers.

NOTE: Since the MSA Engine will leave the synthesizer's registers in a configuration suited for its own needs, it is important to understand how this affects any future SCP commands. For example, if the MSA Engine is instructed to vocalize the word "ready" at power up, then the Envelope Control register will be set up for voice output and will need to be changed appropriately for any direct synthesizer control.

Direct synthesizer control via SCP.

The SCP commands covered in the Serial Control Protocol (SCP) section of this manual outline a method of directly setting the values of the SpeakJet's internal registers over the serial port. These register values are used to control the 5-Channel Synthesizer.

The following is a list of the register addresses:

Register 0.	Envelope Frequency.
Register 1.	Oscillator 1 Frequency
Register 2.	Oscillator 2 Frequency
Register 3.	Oscillator 3 Frequency
Register 4.	Oscillator 4 Frequency
Register 5.	Oscillator 5 Frequency
Register 6.	Distortion – Affects Oscillator 4 & 5
Register 7.	Master Volume.
Register 8.	Envelope Control.
Register 9.	Not used
Register 10.	Not used
Register 11.	Oscillator 1 Volume
Register 12.	Oscillator 2 Volume
Register 13.	Oscillator 3 Volume
Register 14.	Oscillator 4 Volume
Register 15.	Oscillator 5 - Volume

Registers 0 through 5 are frequency registers. These registers can accept a value from 0 to 3999 and will cause the corresponding oscillator's frequency to oscillate at the specified frequency.

Example: To set the frequency of Oscillator 1 to 500Hz :
"1J500N"

Register 6 is a distortion control value, which affects oscillators 4 and 5. This register can accept a value from 0 to 255. When set to 0, the oscillator's frequencies are pure and as the value increases to 255 the frequency becomes more disordered with white noise.

Register 7 is the master volume. This register can accept a value from 0 to 127. When set to 0, the output volume is off and as the value increases to 127, the volume is increased.

Register 8 is the Envelope Control. This register can accept a value from 0 to 255. The individual bits of this register are used to control different aspects of the Envelope.

The first two bits are used to select the type of Envelope

- 00 = Saw Wave
- 01 = Sine Wave
- 10 = Triangle Wave
- 11 = Square Wave

The 3rd, 4th, 5th and 6th bits are not used.

The 7th bit is used to select if Oscillators 1, 2 and 3 are enveloped.

- 0 = Not Enveloped.
- 1 = Enveloped.

The 8th bit is used to select if Oscillators 4 & 5 are half enveloped.

- 0 = Not Enveloped.
- 1 = ½ Enveloped + ½ Not Enveloped.

All bits are sent in a single value.

Example: To turn off the envelopes: "8J0N"

Registers 9 and 10 are not used.

Registers 11 through 15 are volume registers. These registers can accept a value from 0 to 31 and will cause the corresponding oscillator to produce its current frequency at the specified volume.

See Table B for details:

	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value Range
SCP Address 0 Envelope Freq.																	0 - 3999
SCP Address 1 Oscillator Freq.																	0 - 3999
SCP Address 2 Oscillator Freq.																	0 - 3999
SCP Address 3 Oscillator Freq.																	0 - 3999
SCP Address 4 Oscillator Freq.																	0 - 3999
SCP Address 5 Oscillator Freq.																	0 - 3999
SCP Address 6 Distortion Level																	0 - 255
SCP Address 7 Master Volume																	0 - 255
SCP Address 8 Envelope Ctrl.									S2	S1					ENV	ENV	
SCP Address 9 RESERVED																	X
SCP Address 10 RESERVED																	X
SCP Address 11 Osc. 1 Level																	0 - 31
SCP Address 12 Osc. 2 Level																	0 - 31
SCP Address 13 Osc. 3 Level																	0 - 31
SCP Address 14 Osc. 4 Level																	0 - 31
SCP Address 15 Osc. 5 Level																	0 - 31

Table B:
Synthesizer Registers

EEPROM:

The EEPROM is based on 256 locations and is broken up into 3 areas of interest:

1. Address Pointer for Phrases Storage Area.
2. Phrase Storage Area.
3. Chip Control Area.

Address Pointer Area:

The Address Pointer Area is located from address 0 to 15 in the EEPROM and is the pointer to the start of each phrase. By utilizing a pointer system, each phrase can have different lengths and start points in the main area of the EEPROM. These pointers are 8 bits in length.

Phrase Storage Area:

The Phrase Storage Area starts at address 16 and goes to address 236. In this area, each phrase is started and contains the phonetic code, instruction or control and the end phrase code. Any of the codes listed in Table D or Table E can be placed in this area. The end of a phrase is marked with a hexadecimal value of (FF).

Chip Control Area:

The Chip Control Area starts at address 237 and goes to 255. In this area of the EEPROM, this area is broken into to parts. Address 237, 238 and 239 contain the bits for control of the Startup Phrase, Chip I/O operations and SCP node address. The second part of this area, starting at address 240 through 255 contains the Event control Address.

Address 0 – 15: Phrase Pointer Address

Address 16 – 236: Phrase Storage Area

Address 237: Power-up/Reset Phrase:

Bit 7 Play=0 Silence=1
Bit 6 always=1
Bit 5 always=1
Bit 4 always=1
Bit 3 Address Pointer to call Power-up/Reset Phrase Bit3
Bit 2 Address Pointer to call Power-up/Reset Phrase Bit2
Bit 1 Address Pointer to call Power-up/Reset Phrase Bit1
Bit 0 Address Pointer to call Power-up/Reset Phrase Bit0

Address 238: PortCTL, AutoSilence, RC/TTL Mode

Bit 7
Bit 6
Bit 5 RC0/E6 (1 = TTL 0 = RC input)
Bit 4 RC1/E7 (1 = TTL 0 = RC input)
Bit 3 Auto Silence (1 = AutoSilence 0 = Continuous)
Bit 2 D2/Buffer Half Full (1 = Chip 0 = Phrase Control)
Bit 1 D1/Speaking (1 = Chip 0 = Phrase Control)
Bit 0 D0/Ready (1 = Chip 0 = Phrase Control)

Address 239: SCP Node, PortControl

Bit 7 always=1
Bit 6 SCP Node Bit 2
Bit 5 SCP Node Bit 1
Bit 4 SCP Node Bit 0
Bit 3 always=1
Bit 2 D2/Buffer Half Full (1 = on 0 = off)
Bit 1 D1/Speaking (1 = on 0 = off)
Bit 0 D0/Ready (1 = on 0 = off)

Address 240, 242, 244, 246, 248, 250, 252 and 254

Event inputs E0 - E7 Low to High Transitions

Bit 7 1 = Play Phrase with event 0 = No Event Phrase
Bit 6 1 = Do not Clear buffer 0 = clear buffer before Phrase
Bit 5 1 = Call Phrase 0 = Do not call phrase
Bit 4 1 = Normal 0 = Restart from Start on event
Bit 3 Event Phrase Pointer to call - Phrase Bit3
Bit 2 Event Phrase Pointer to call - Phrase Bit2
Bit 1 Event Phrase Pointer to call - Phrase Bit1
Bit 0 Event Phrase Pointer to call - Phrase Bit0

Address 241, 243, 245, 247, 249, 251, 253 and 255

Event inputs E0 - E7 High to Low Transitions

Bit 7 1 = Play Phrase with event 0 = No Event Phrase
Bit 6 1 = Do not Clear buffer 0 = clear buffer before Phrase
Bit 5 1 = Call Phrase 0 = Do not call phrase
Bit 4 1 = Normal 0 = Restart from Start on event
Bit 3 Event Phrase Pointer to call - Phrase Bit3
Bit 2 Event Phrase Pointer to call - Phrase Bit2
Bit 1 Event Phrase Pointer to call - Phrase Bit1
Bit 0 Event Phrase Pointer to call - Phrase Bit0

ALLOPHONE SPEECH SYNTHESIS PRIMER

Introduction:

The sounds that are used to form the words of any particular language are called phonemes. During the articulation of the words of that language, variations of phonemes called allophones are vocalized one after another producing the spoken words and Phrases. Allophone speech synthesis is a method of synthesizing a reproduction of a language by providing a technique of playing allophone like sounds, one after another in much the same way that the human mouth does.

The SpeakJet implementation of the allophone speech synthesis method is done via the Mathematical Sound Architecture™ (MSA). The function of MSA is to mathematically model the sounds that the human mouth produces as it moves from one position to the next. Seventy-Two discrete speech sound elements (one for each allophone) are stored in the SpeakJet's MSA Sound Component Database. Each MSA allophone component was created to duplicate a specific allophone sound made by the human mouth during speech.

To produce speech, a list of selected allophones is sent to the SpeakJet. As the SpeakJet is vocalizing this list of allophones, MSA actively and continuously calculates all the sound components of the allophones including the transitional sounds made between the allophones, producing the same sounds that the human mouth does as it moves from one position to another position.

Selecting the appropriate combination of allophones and pauses can thusly create any English word or phrase. Further tuning with the Rate, Pitch, Bend and Volume parameters adds to the delivery of the phrase and can change the emotion in which the phrase is perceived.

Stressing the Rate, Pitch, Bend and Volume parameters to levels outside the human range can result in some interesting sounds that go way beyond what a normal human mouth can produce. In addition, several other sounds effects, which are included in the MSA Sound Component Database, of which, some use vocalization and some do not, can be integrated into the phrases.

The result is a system that gives the user the ability to not only produce an unlimited vocabulary, but also to produce slang, gibberish, moans, groans, yodels and other weird vocalized sounds not normally included in a canned TTS system.

Producing English Speech:

Five basic linguistic concepts will help you to create highly intelligible sounding speech with the SpeakJet.

- First, there is no one-to-one correspondence between written letters and speech sounds. More than one letter may represent each sound in a language and, conversely each letter may represent more than one sound. (See the sample words in Table C.) Because of these spelling irregularities, it is necessary to think in terms of sounds, not letters, when creating phrases.
- Second, speech sounds are acoustically different depending upon their position within a word. For example the initial B sound in "Beep" is acoustically different from the B sound in "Box" The B sounds differ due to the influence of the vowels, which follow them.
- Third, the human ear may perceive the same acoustic signal differently in the context of different sounds. Therefore, an allophone may sound slightly different when used in various phrases.
- Fourth, some sounds in words are not actually pronounced and/or others are added when followed or preceded by certain other words. For example the two words "Night" and "Time". When played separately, they both will articulate the "T" sound. However, played together they need to be articulated as "Ni-Time".
- Fifth, The Vocalization Pitch, Play Rate and Frequency Bend parameters are just as important as the selection of the phonemes used. For instance, playing a phrase that does not change the pitch at any point in time sounds very monotonic and robotic. While increasing the Pitch at the end of a sentence produces a questioning tone.

Phonemes of English Language:

Table C contains a chart of all the consonant and vowel phonemes of the English language.

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, 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 Figure 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, OH, AW).

Vowel chart used in the North American linguistics.

		← position of the tongue →		
		front	central	back
↑	high	i		u
		ɪ		ʊ
J a w	mid	e	ə	o
		ɛ		ɔ
↓	low	æ	a	ɑ

Vowel chart used in the SpeakJet

		← position of the tongue →		
		front	central	back
↑	high	IY		UW
		IH		UH
J a w	mid	EY	AX	OW
		EH		OH
↓	low	AY	UX	AW

Figure 4

How to Use the Allophone Set:

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.

The following is a brief tutorial on creating speech using the SpeakJet allophone set.

Note that these are suggestions, not rules.

The Phonetic Usage Chart (Refer to Table C) references the variations of each phoneme of the English language and gives suggestions for the appropriate times that they are used. For example, there are 4 B sounds. "BE" and "BO" sound good in initial position, as in the words "Beep" and "Box" while "EB" and "OB" sound good in final position, as in "Rib" and "Club". A vowel modifier is also associated with the "BE", "BO", "EB" and "OB" sounds. The BE is used when followed by a front vowel sound and the BO is used when followed by a back vowel sound. Note that either can be used when followed by a central vowel sound. Also note that a B sound in the middle of a word can be either a initial position or a final position sound. For example, the word rabbit; is it RAB-IT or RA-BIT? Local dialect can be the deciding factor in cases like this.

Typically the first allophone in a phrase is longer than the rest of the allophones used with the phrase. Therefore, to create an initial SS, you can use the SLOW function before the SS allophone, which will cause the SS sound to play for 1 and 1/2 the normal speed. If an even longer sound is needed then the SS allophone can be played twice. (Note that this cannot be done with all allophones.) Repeating Diphthongs for example will cause the diphthong slide to play twice which will not result in just a longer sound.

Diphthongs are perceived as single vowel sounds, but in reality they are sliding sounds that transition from one vowel sound into another vowel sound. For example the "A" sound in "Make" isn't a single vowel sound. It is a diphthong that transitions from the "EY" sound to the "IY" sound and thusly the name for the diphthong is "EYIY". This sliding sound is repeated when diphthongs are repeated. For example: "EYIY, EYIY" does not have the same affect as "IY, IY". Two "IY" s played back to back will produce an "IY" sound that lasts twice as long while the "EYIY, EYIY" will just repeat the slide. Five of the "R" sounds are diphthongs that begin with a vowel and end with the "R" sound. For example, the "AWRR" in "alarm" and the "OHRR" in "score".

Determining when to use a diphthong and when to use the independent sound again largely relies on person preference and local dialect.

Some sounds (P, B, T, D, K, G, CH, and JH) require a brief duration of silence before them. For these, the silence has already been added but you may decide you want to add more. To increase the duration of silence the "SLOW" command can be used and optionally, a pause can be inserted before it.

There are several different types and lengths of pauses that can be inserted in front of an allophone but be aware that different pauses will affect the way the MSA calculates the transitions from the last allophone, through the silence and into the next allophone which may not produce the desired flow of sounds. You may want to add a short pause between words and a long pause between clauses.

Stress can be accomplished in two ways. One is to cause vowels to play for a longer period of time. For example, in the word "extent" use the "Fast" command in front of the "EH" in the first syllable, which is unstressed and a "SLOW" command, or and additional "EH" in front of the "EH" in the second syllable which is stressed. A second way is to precede the allophone with the "STRESS" and RELAX commands. The STRESS command duplicates the affect of slightly contracting the muscles of the mouth and the relax command duplicates the affects of slightly relaxing the muscles of the mouth. For example; "STRESS, IH" sounds more like (but not quite) the "IY" sound. Likewise, "RELAX, IY" sounds more like (but not quite) an "IH" sound. Note that if you elect to use the "STRESS" or "RELAX" command in combination with a phoneme that has been doubled, then two command will be needed, one in front of each of the phonemes.

Remember that you must always think about how a word sounds, not how it is spelled. For example, The "N" sound in "Link" is actually the "NGE" sound and the ending sounds in the words "letter" and "little" use the diphthongs "AXRR" and "EHLL". Some sounds may not even be represented in words by any letters, as the "IYUW" in "computer".

You will want to experiment with all the possible sounds to discover which version works best in any particular cluster of allophones.

Phonetic Usage Table

• Vowels		
Long A - "Gate" & "Ate"	\EYIY	
Long E - "See" & "Even"	\IY	
Long I - "Sky" & "Five"	\OHIH	Also see IE
Long O - "Comb" & "Over"	\OW	Also see OA
Long U - "June" & "Food"	\UW	Also see OO
Short A - "Hat" & "Fast"	\AY	
Short E - "Cent" & "Egg"	\EY	Stressed
Short E - "Met" & "Check"	\EH	Normal
Short E - "Cotton" & "dust"	\AX	Relaxed
Short I - "Sit" & "Fix"	\IH	
Short O - "Hot" & "Clock"	\OH	Also see AW
Short U - "Luck" & "Up"	\UX	
Pair OO - "Book" & "Could"	\UH	Also see Long U
Pair AW - "Saw" & "Father"	\AW	Also see Short O
Pair OA - "Coat" & "Hello"	\OWWW	Also see Long O
Pair EW - "New" & "Two"	\IHWW	eh-oo
Pair EW - "Few" & "Cute"	\IYUW	ee-oo
Pair IE - "Tie" & "Fight"	\OHIIY	Also see Long I
Pair OW - "Owl" & "Our"	\AYWW	ah-ww
Pair OW - "Brown"	\AXUW	eh-uw
Pair OY - "Boy" & "Toy"	\OWIY	
Y - "Yes" & "Yarn"	\IYEH	
• Vowels with R		
R - "Ray" & "Brain"	\RR	
AIR - "Hair" & "Stair"	\EYRR	
AR - "Part" & "Farm"	\AWRR	
EAR - "Clear" & "Hear"	\IYRR	
ER - "Center" & "Fir"	\AXRR	
OR - "Corn" & "Four"	\OWRR	
• Resonates		
EL - "Saddle" & "Angle"	\EHL	
L - "Lake" & "Alarm"	\LE	Front
L - "Clock" & "Plus"	\LO	Back
W - "Wool" & "Sweat"	\WW	
• Nasal		
M - "Milk" & "Famous"	\MM	
N - "Nip" & "Danger"	\NE	Front
N - "No" & "Snow"	\NO	Back
N - "Think" & "Ping"	\NGE	Front
N - "Hung" & "Song"	\NGO	Back

Phonetic Usage Table

• Voiced Fictive		
V - "Vest" & "Even"	\VV	
Z - "Zoo" & "Zap"	\ZZ	
ZH - "Azure" & "Treasure"	\ZH	
TH - "There" & "That"	\DH	
• Voiceless Fricative		
H - "Help" & "Hand"	\HE	Front
H - "Hoe" & "Hot"	\HO	Back
WH - "Who" & "Whale"	\WH	
F - "Food" & "Effort"	\FF	
S - "See" & "Vest"	\SE	Front
S - "So" & "Sweat"	\SO	Back
SH - "Ship" & "Fiction"	\SH	
TH - "Thin" & "month"	\TH	
• Voiced Stop		
B - "Bear" & "Bird"	\BE	Front - Initial
B - "Bone" & "Book"	\BO	Back - Initial
B - "Cab" & "Crib"	\EB	Front
B - "Job" & "Sub"	\OB	Back
D - "Deep" & "Date"	\DE	Front - Initial
D - "Do" & "Dust"	\DO	Back - Initial
D - "Could" & "Bird"	\ED	Front
D - "Bud" & "Food"	\OD	Back
G - "Get" & "Gate"	\GE	Front - Initial
G - "Got" & "Glue"	\GO	Back - Initial
G - "Peg" & "Wig"	\EG	Front
G - "Dog" & "Peg"	\OG	Back
• Voiceless Stop		
T - "Part" & "Little"	\TT	
T - "Tea" & "Take"	\TU	Front - Initial
TS - "Parts" & "Costs"	\TS	
K - "Can't" & "Clown"	\KE	Front - Initial
K - "Comb" & "Quick"	\KO	Back - Initial
K - "Speak" & "Task"	\EK	Front
K - "Book" & "Took"	\OK	Back
P - "People" & "Carpet"	\PE	Front
P - "Pod" & "Paw"	\PO	Back
• Affricate		
JH - "Dodge" & "Jet"	\JH	
CH - "Church" & "Feature"	\CH	

(Front) = Usually sounds best when associated with a front or center vowel
 (Back) = Usually sounds best when associated with a center or back vowel
 (Initial) = Usually sounds best when used in the initial position of word

Table C

MSA Command Set:

Dec.	SpeakJet Use
000	Pause 0
001	Pause 1
002	Pause 2
003	Pause 3
004	Pause 4
005	Pause 5
006	Pause 6
007	Play Next Sound Fast
008	Play Next Sound Slow
014	Play Next Sound High Tone
015	Play Next Sound Low Tone
016	Wait
020	Volume, X
021	Speed, X
022	Pitch, X
023	Bend, X
024	PortCtr, X
025	Port, X
026	Repeat, X
028	Call Phrase, X
029	Goto Phrase, X
030	Delay, X
031	Reset Defaults

032	Reserved
- to -	
127	

128	127 Sound codes
- to -	
254	

255	End of Phrase.

Table D

Control Codes Details:

0 - 6 = Pauses.
 Pauses of various durations, these will cause the volume to ramp down, wait a specified amount of time and the ramp back up. 1, 2 & 3, ramp the volume while the format frequencies are being changed. 4, 5 & 6 wait for silence before changing the format frequencies.

0 = 0ms	1 = 100ms	2 = 200ms	3 = 700ms
4 = 30ms	5 = 60ms	6 = 90ms	

7 = Fast.
 Plays the next phoneme at 1/2 the time it normally would play.

8 = Slow
 Plays the next phoneme at 1 and 1/2 the time it normally would play.

14 = Stress.
 Plays the next phoneme with a small amount of stress in the voice.

15 = Relax
 Plays the next phoneme with a small amount of relaxation in the voice.

16 = Wait
 This command will stop the voicing and wait for a start command. The Start command can be issued by either sending the SCP start command or by changing the state of one of the input lines that has been previously set to do a Start.

20 = Volume, X
 This command sets the master volume level. A value will need to be sent after the volume command that specifies the desired volume. Volume levels can range from 0 to 127. The default is 96.

21 = Speed, X
 This command sets the play speed. A value will need to be sent after the speed command that specifies the desired speed. Speeds can range from 0 to 127. The default is 114.

22 = Pitch, X
 This command sets the Vocalization Pitch in Hertz. A value will need to be sent after the pitch command that specifies the desired pitch. The vocalization pitch is what makes a voice sound High pitched or Low pitched. For singing, the pitch has a range of 3 full octaves (32Hz to 240hz). The Vocalization Pitch works only on sounds that are voiced. Pitches can range from 0 to 255. The default is 88. Note that anything under 30 starts to sound like clicks instead of a voice. Also Note that a value of 0 = 0 Hz and thusly, will not actually vocalize.

23 = Bend, X
 This command sets the frequency Bend. A value will need to be sent after the Bend command that specifies the desired Bend. The frequency Bend adjusts the output frequencies of the oscillators. This will change the voicing from a deep-hollow sounding voice to a High-metallic sounding voice. Bends can range from 0 to 15. The default is 5.

24 = PortCtr, X
 This command sets the Port Control Value. A value will need to be sent after the PortCtr command that specifies the desired function of the output lines. The Output line control bits are binaurally encoded where a 1 indicates that the output function is chip controlled and a 0 indicates that the output function is user controlled. Bit 0 corresponds to OUT0, etc... PortCtr values can range from 0 to 7. The default is 7.

25 = Port, X
 This command sets the Port Output Value. A value will need to be sent after the Port command that specifies the desired state of the output lines. When the Output line control bits are set to 0, the corresponding port bit is represented on the output line. Bit 0 corresponds to OUT0, etc... Port values can range from 0 to 7. The default is 0.

26 = Repeat, X
 This command sets a number of times to Repeat the next code. A value will need to be sent after the Repeat command that specifies the number of times to repeat the next command.
 The Repeat range is from 0 to 255.

28 = Call Phrase, X
 This command specifies which EEPROM phrase to play then to return from.
 This can be nested 3 deep maximum.

29 = Goto Phrase, X
 This command specifies which EEPROM phrase to play.

30 = Delay, X
 This command specifies the number of 10ms intervals to delay before continuing on to the next code. The Delay range is from 0 to 255.

31 = Reset
 This command resets the Volume, Speed, Pitch and Bend to the default values.

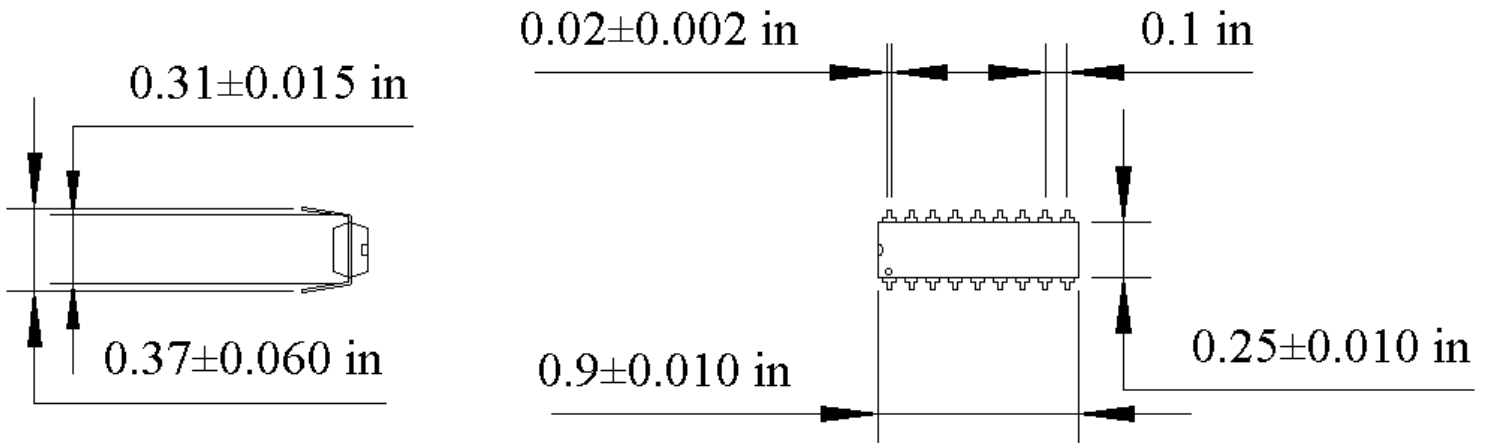
MSA Sound Allophone Component List:

Code	Phoneme	Samle Words	Msec.	Phoneme Type
128	IY	See, Even, Feed	70	Voiced Long Vowel
129	IH	Sit, Fix, Pin	70	Voiced Short Vowel
130	EY	Hair, Gate, Beige	70	Voiced Long Vowel
131	EH	Met, Check, Red	70	Voiced Short Vowel
132	AY	Hat, Fast, Fan	70	Voiced Short Vowel
133	AX	Cotten	70	Voiced Short Vowel
134	UX	Luck, Up, Uncle	70	Voiced Short Vowel
135	OH	Hot, Clock, Fox	70	Voiced Short Vowel
136	AW	Father, Fall	70	Voiced Short Vowel
137	OW	Comb, Over, Hold	70	Voiced Long Vowel
138	UH	Book, Could, Should	70	Voiced Short Vowel
139	UW	Food, June	70	Voiced Long Vowel
140	MM	Milk, Famous,	70	Voiced Nasal
141	NE	Nip, Danger, Thin	70	Voiced Nasal
142	NO	No, Snow, On	70	Voiced Nasal
143	NGE	Think, Ping	70	Voiced Nasal
144	NGO	Hung, Song	70	Voiced Nasal
145	LE	Lake, Alarm, Lapel	70	Voiced Resonate
146	LO	Clock, Plus, Hello	70	Voiced Resonate
147	WW	Wool, Sweat	70	Voiced Resonate
148	RR	Ray, Brain, Over	70	Voiced Resonate
149	IYRR	Clear, Hear, Year	200	Voiced R Color Vowel
150	EYRR	Hair, Stair, Repair	200	Voiced R Color Vowel
151	AXRR	Fir, Bird, Burn	190	Voiced R Color Vowel
152	AWRR	Part, Farm, Yarn	200	Voiced R Color Vowel
153	OWRR	Corn, Four, Your	185	Voiced R Color Vowel
154	EYIY	Gate, Ate, Ray	165	Voiced Diphthong
155	OHYI	Mice, Fight, White	200	Voiced Diphthong
156	OWIY	Boy, Toy, Voice	225	Voiced Diphthong
157	OHIH	Sky, Five, I	185	Voiced Diphthong
158	IYEH	Yes, Yarn, Million	170	Voiced Diphthong
159	EHLL	Saddle, Angle, Spell	140	Voiced Diphthong
160	IYUW	Cute, Few,	180	Voiced Diphthong
161	AXUW	Brown, Clown, Thousand	170	Voiced Diphthong
162	IHWU	Two, New, Zoo	170	Voiced Diphthong
163	AYWU	Our, Ouch, Owl	200	Voiced Diphthong
164	OWWU	Go, Hello, Snow	131	Voiced Diphthong
165	JH	Dodge, Jet, Savage	70	Voiced Affricate
166	VV	Vest, Even,	70	Voiced Fictive
167	ZZ	Zoo, Zap	70	Voiced Fictive
168	ZH	Azure, Treasure	70	Voiced Fictive
169	DH	There, That, This	70	Voiced Fictive
170	BE	Bear, Bird, Beed	45	Voiced Stop
171	BO	Bone, Book Brown	45	Voiced Stop
172	EB	Cab, Crib, Web	10	Voiced Stop
173	OB	Bob, Sub, Tub	10	Voiced Stop
174	DE	Deep, Date, Divide	45	Voiced Stop
175	DO	Do, Dust, Dog	45	Voiced Stop
176	ED	Could, Bird	10	Voiced Stop
177	OD	Bud, Food	10	Voiced Stop
178	GE	Get, Gate, Guest,	55	Voiced Stop
179	GO	Got, Glue, Goo	55	Voiced Stop
180	EG	Peg, Wig	55	Voiced Stop
181	OG	Dog, Peg	55	Voiced Stop
182	CH	Church, Feature, March	70	Voiceless Affricate
183	HE	Help, Hand, Hair	70	Voiceless Fricative
184	HO	Hoe, Hot, Hug	70	Voiceless Fricative
185	WH	Who, Whale, White	70	Voiceless Fricative
186	FF	Food, Effort, Off	70	Voiceless Fricative
187	SE	See, Vest, Plus	40	Voiceless Fricative
188	SO	So, Sweat	40	Voiceless Fricative
189	SH	Ship, Fiction, Leash	50	Voiceless Fricative
190	TH	Thin, month	40	Voiceless Fricative
191	TT	Part, Little, Sit	50	Voiceless Stop
192	TU	To, Talk, Ten	70	Voiceless Stop
193	TS	Parts, Costs, Robots	170	Voiceless Stop
194	KE	Can't, Clown, Key	55	Voiceless Stop
195	KO	Comb, Quick, Fox	55	Voiceless Stop
196	EK	Speak, Task	55	Voiceless Stop
197	OK	Book, Took, October	45	Voiceless Stop
198	PE	People, Computer	99	Voiceless Stop
199	PO	Paw, Copy	99	Voiceless Stop

MSA Sound Effects Component List:

Code	Phoneme	Sample Words	MS	Phoneme Type
200	R0		80	Robot
201	R1		80	Robot
202	R2		80	Robot
203	R3		80	Robot
204	R4		80	Robot
205	R5		80	Robot
206	R6		80	Robot
207	R7		80	Robot
208	R8		80	Robot
209	R9		80	Robot
210	A0		300	Alarm
211	A1		101	Alarm
212	A2		102	Alarm
213	A3		540	Alarm
214	A4		530	Alarm
215	A5		500	Alarm
216	A6		135	Alarm
217	A7		600	Alarm
218	A8		300	Alarm
219	A9		250	Alarm
220	B0		200	Beeps
221	B1		270	Beeps
222	B2		280	Beeps
223	B3		260	Beeps
224	B4		300	Beeps
225	B5		100	Beeps
226	B6		104	Beeps
227	B7		100	Beeps
228	B8		270	Beeps
229	B9		262	Beeps
230	C0		160	Biological
231	C1		300	Biological
232	C2		182	Biological
233	C3		120	Biological
234	C4		175	Biological
235	C5		350	Biological
236	C6		160	Biological
237	C7		260	Biological
238	C8		95	Biological
239	C9		75	Biological
240	D0	0	95	DTMF
241	D1	1	95	DTMF
242	D2	2	95	DTMF
243	D3	3	95	DTMF
244	D4	4	95	DTMF
245	D5	5	95	DTMF
246	D6	6	95	DTMF
247	D7	7	95	DTMF
248	D8	8	95	DTMF
249	D9	9	95	DTMF
250	D10	*	95	DTMF
251	D11	#	95	DTMF
252	M0	Sonar Ping	125	Miscellaneous
253	M1	Pistol Shot	250	Miscellaneous
254	M2	WOW	530	Miscellaneous

Table E



18 Pin Plastic DIP Package Mechanical Specifications

Glossary of Terms

al·lo·phone n.

A predictable phonetic variant of a phoneme. For example, the aspirated T of Top, the unaspirated T of sTop, and the TT (pronounced as a flap) of baTTer are allophones of the English phoneme /T/.

pho·neme n.

The smallest phonetic unit in a language that is capable of conveying a distinction in meaning, as the M of Mat and the B of Bat in the English language.

SCP

Serial Control Protocol

A communications and control standard developed by Savage Innovations and licensed by Magnevation for communications of data to internal registers.

syl·la·ble n.

A unit of spoken language consisting of a single uninterrupted sound formed by a vowel, diphthong, or syllabic consonant alone, or by any of these sounds preceded, followed, or surrounded by one or more consonants.

syn·the·sis n.

The combining of separate elements or substances to form a coherent whole.