

# **CORTLAND SOUND ERS**

**JUNE 25, 1986**

**Rev. 1**

**Apple Computer Inc.  
CONFIDENTIAL**

## GENERAL OVERVIEW

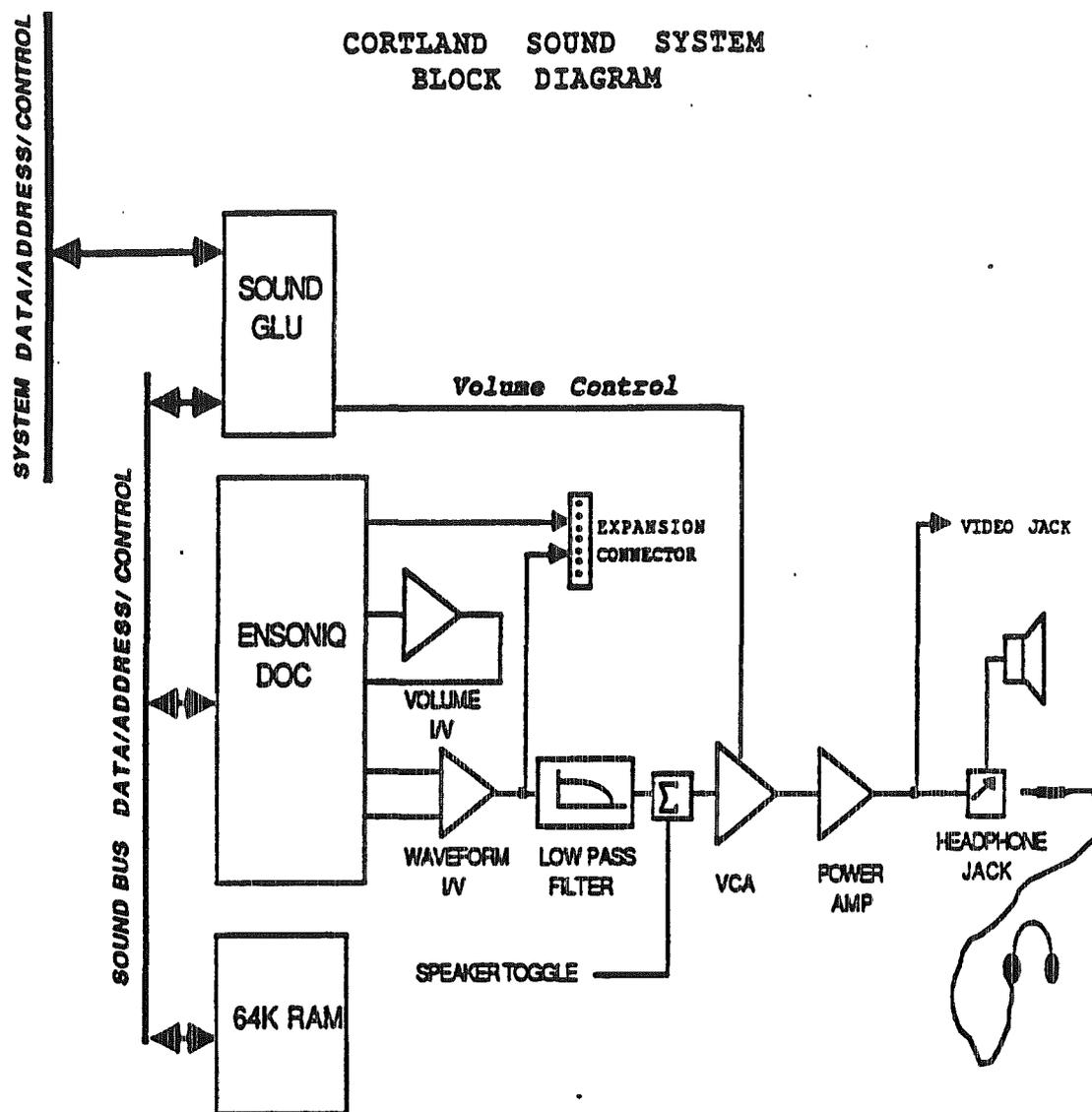
The Cortland sound system supports all current //e sound capabilities with some added features. These new features include:

- \* 32 voice custom sound chip
- \* Complex waveform generation with low processor intervention.
- \* 64k bytes of ram dedicated for digitized waveforms.
- \* Analog to Digital converter for digitizing waveforms<sup>1</sup>.
- \* Expandable to 8 separte output channels<sup>1</sup>.
- \* Software programmable volume control.
- \* Headphone jack.
- \* Output for use with video monitors or receivers that support sound.

1. Requires a small amount of additional circuitry.

## CIRCUIT DESCRIPTION

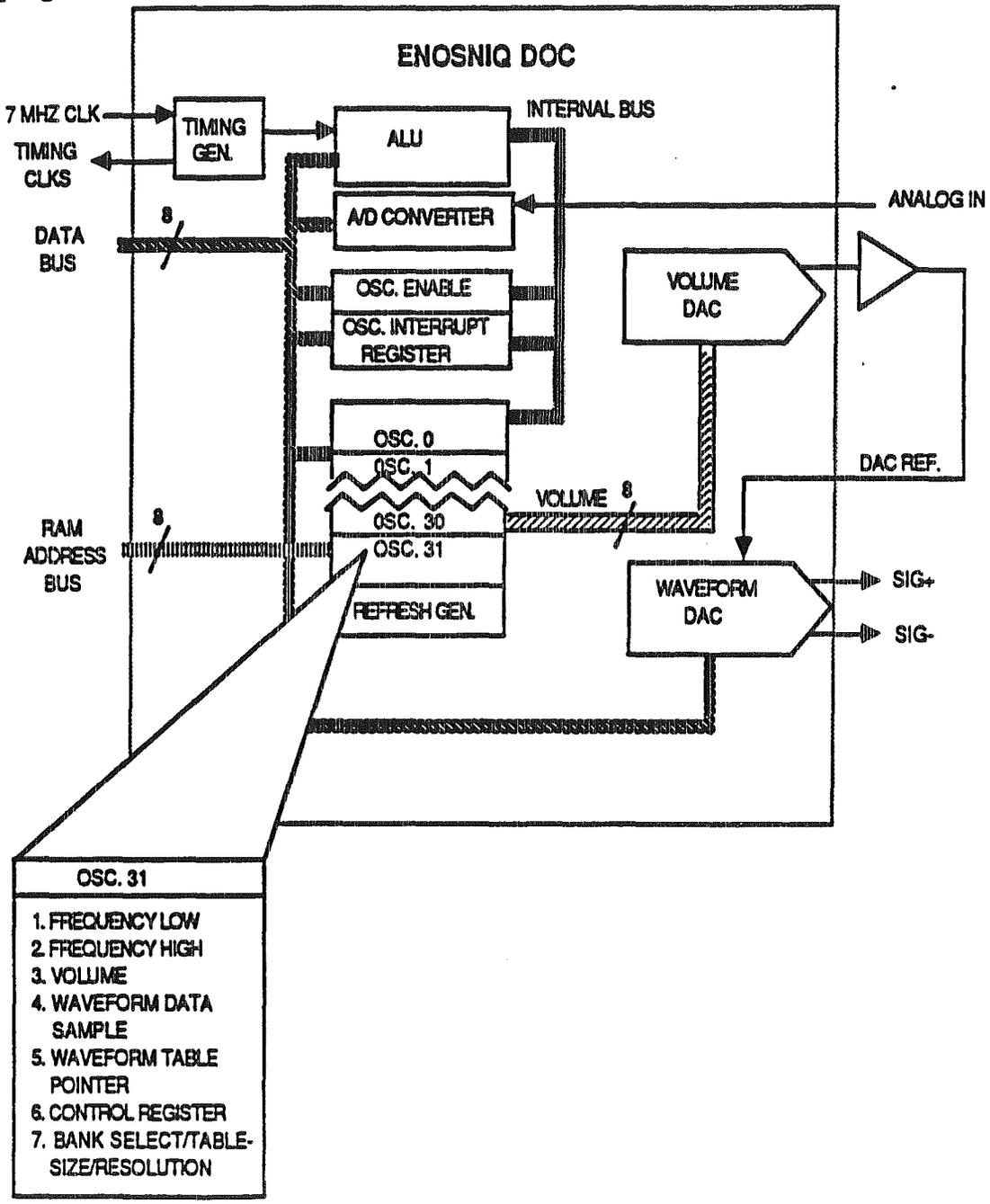
The Cortland sound circuit consists of four major components, Sound Glu, Ensoniq DOC, 64k dynamic ram, and the analog section. The analog section breaks down further into current to voltage converters, active filters, mixer, voltage controlled attenuator, and power amplifier. The following block diagram shows how these componets connect to one another followed by a brief description of the indivial components.



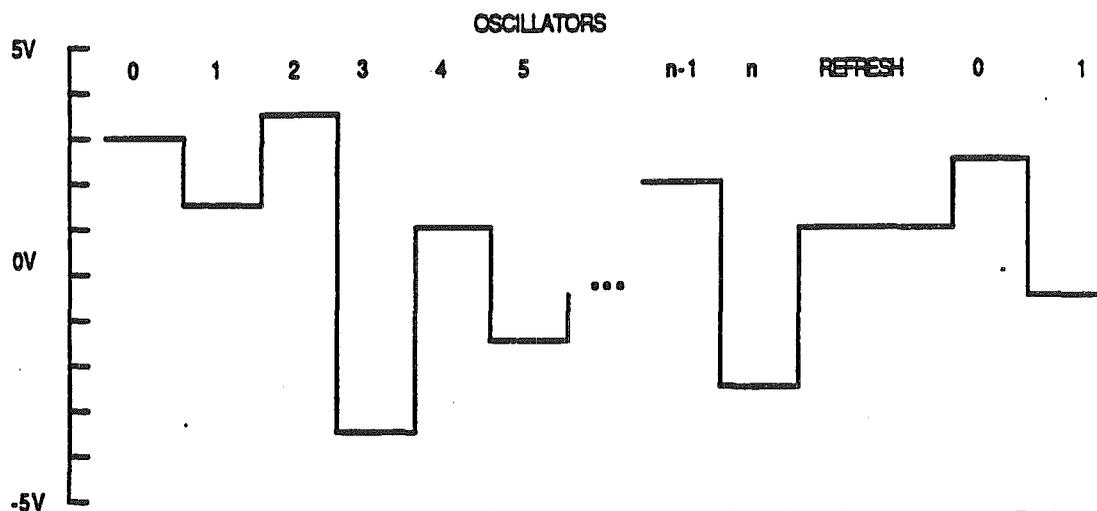
### ENSONIQ SOUND CHIP

The most important new audio feature found in the Cortland comes from the Ensoniq Digital Oscillator Chip (DOC). This is a digital sampling oscillator chip that has been designed by Ensoniq for use in their professional synthesizers products. Sound are produced from digitized waveforms stored in ram called wavetables. The DOC contains 32 time multiplexed digital oscillators to generate addresses that increment through the wavetable. The data that is read from the wavetable is sent to the output section of the DOC consisting of two cascaded eight bit Digital to Analog Converters (DACs). The

upper DAC contains the volume and the lower DAC contains the waveform information. The rate at which the oscillators step through the wavetable is programmable to give a sound a desired pitch. The size and starting address of the waveform tables are also programmable.



ENSONIQ CHIP DIAGRAM



This diagram represents the waveform output with  $n$  number of oscillators running. Each step represents an oscillator outputting the level of its waveform at a particular instant in time. After the last enabled oscillator has put out its waveform the level is sustained through the refresh period. The duration of each oscillator step is  $.894 \mu$  seconds, the refresh cycle takes two oscillator periods or  $1.789 \mu$  seconds.

## FILTER SECTION

The output waveform from the Waveform I/V must be filtered to remove the high frequency component before being amplified for its final output. The Cortland uses a 5 pole Chebyshev active filter with a roll-off at 10kHz. The filtered waveform is summed with the //e speaker toggle and then coupled to the VCA.

## VCA

The overall volume level for both the speaker toggle and the DOC is controlled by the Voltage Controlled Attenuator (VCA). The sound level can be programmed by software in 16 steps. This gives the user approximately a 90 db. range of sound control. The VCA can also be used to amplitude modulate the overall sound.

## SOUND OUTPUT

The final stage in the audio circuit is a power amplifier to drive an internal 2 inch, 8 ohm speaker. The audio out is also available on a mini stereo headphone jack. If a mini plug is inserted into the

The sampling rate of the oscillators can be determined by the main clock into the DOC and the number of oscillators that are enabled. Each enabled oscillator is given a time slot. There is a minimum of one oscillator enabled, and a maximum of 32 oscillators, along with two slots for refresh cycles. The DOC divides the input clock by 8 to get its basic timing. With the input clock equal to 7.159 Mhz the sample rate is equal to  $894.9 \text{ Khz} / (\text{number of enable oscillators} + 2)$ . Typically all oscillators are enabled so the sample rate is 26.32Khz

### **SOUND GLU**

The sound glu interfaces the DOC and 64k of dynamic ram to the system bus. The main function for the sound glu is to allow the DOC and the system to run asynchronous of each other. The sound glu contains a bi-directional latch, 16 bit address pointer, 4-bit volume control register. All communication with the DOC and RAM is done via the sound glu.

### **RAM**

The Cortland has 64k x 8 dynamic rams dedicated for digitized waveforms. The ram is shared in a similar way the 65816 microprocessor shares ram with the video generator, during the first phase of a symmetrical clock the sound glu can read or write to ram or DOC while during the alternate phase, the DOC performs a DMA cycle to the ram.

### **VOLUME I/V / WAVEFORM I/V**

The DOC has two internal eight bit DAC. The Volume I/V (Current to voltage converter) is fed back into the DOC where it is used as a reference voltage for the waveform DAC. The Waveform I/V has differential current outputs. The outputs are differentially amplified and sent to the expansion connector and also low pass filters (see the block diagram). The following diagram shows the waveform after it is converted to a voltage.

headphone jack the internal speaker is disabled. The mini jack output is capable of driving a 600 ohm load. Sound is also available on the video connector for use with video monitors that have sound capabilities or video modulators when using a television receiver. This output is capable of driving a 600 ohm load.

## **SOUND EXPANSION CONNECTOR**

The sound expansion connector is a 7 pin molex used to expand the capabilities of the Cortland sound circuit. This connector has the signals necessary for analog to digital conversion, and demultiplexing the oscillators into a maximum of eight channels.

1. ANALOG TO DIGITAL
2. ANALOG GROUND
3. WAVEFORM OUT
4. CHANNEL ADDRESS 0
5. CHANNEL ADDRESS 1
6. CHANNEL ADDRESS STROBE
7. CHANNEL ADDRESS 2

**ANALOG TO DIGITAL:** This is an input to an eight bit analog to digital converter. The input signal should be conditioned with a low pass filter and a sample and hold circuit. The input range is 0 to +2.5 volts. A conversion takes 31  $\mu$  seconds.

**ANALOG GROUND:** This is the ground reference for all analog signals. It connects to the system ground at pin 19 of the DOC.

**WAVEFORM OUT:** This is the waveform signal from the DOC. This signal looks like a series of steps in which the voltage level corresponds to the associated oscillators.

**CHANNEL ADDRESSES 0-2:** These outputs are used to assign the waveform signal to separate channels. These signals would be the address for an analog demultiplexer. This gives the possibility of stereo outputs or grouping into eight voices with programmable filters.

**CHANNEL ADDRESS STROBE:** This signal is used to qualify the channel address and the waveform signal. This is required to gate the waveform signal when using the self enveloping mode of the DOC.

## D.C. Characteristics

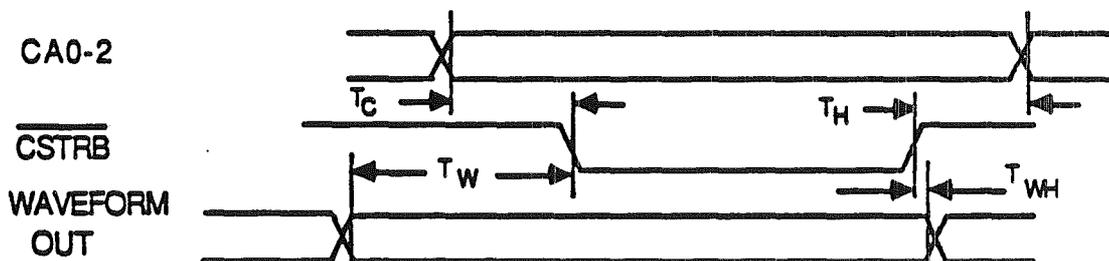
Outputs CSTRB, CA0-CA2, input A/D converter.

Parameter	Min	Max	Units
V <sub>ol</sub>		0.8	Volts
V <sub>oh</sub>	2.4		Volts
I <sub>ol</sub> (V <sub>ol</sub> =0.4)		2.0	mA
I <sub>oh</sub> (V <sub>oh</sub> =2.4)		-1100	mA
Analog in	0	2.5	Volts

## A.C. Characteristics

Parameter	Symbol	Min	Max	units
Channel address setup	T <sub>C</sub>	250		ns
Channel address hold	T <sub>H</sub>		250	ns
Waveform setup	T <sub>W</sub>	170		ns
Waveform hold	T <sub>WH</sub>		0	ns
Waveform level		-5	5	volts

## EXPANSION TIMING DIAGRAM



## FOR MORE INFORMATION

For more information on the Cortland sound custom circuits refer to the following:

- Ensoniq ERS. Apple Computer Inc.
- Sound Glu ERS. Apple Computer Inc.

For more information on digital sound reproduction and synthesis refer to the following book:

- Chamberlin, Hal. Musical Applications of Microprocessors.  
Hasbrouck Heights, New Jersey / Berkeley, California Hayden  
Book Company 1985