Z89340
DIGITAL WAVETABLE ENGINE

FEATURES

Part Number	Speed	Package
Z89340	50 MHz	160-Pin QFP

■ 64 High-Speed Audio Processing Units (APUs) or 128 Half-Speed APUs

■ 3-D Sound Capability

■ Downloadable Sample Capability

■ 8-Channel, 20-Bit Linear PCM Audio Generator

■ Output Sampling Rates up to 50 kHz

■ Supports 16-, 18-, and 20-Bit Serial DACS – Greater than 96 Db Dynamic Range

■ Supports 16- and 8-Bit Linear PCM Sampling, ADPCM, and Wavetable Synthesis, Variable Playback Rates for ADPCM

■ Internal 24-Bit Audio Accumulators

■ Addresses 16M x 16 Sample ROM Directly (No Paging Necessary)

■ Jumperless Configurable ISA Bus Interface

■ Sound Blaster and OPL3 Register Compatibility, MPU401 UART Mode Compatible

■ Built-In 64-Channel Bus-Mastering DMA Controller

■ FM Emulation

GENERAL DESCRIPTION

The Z89340 is a high-performance, programmable wave-table engine designed for musical instruments, general MIDI (Musical Instrument Digital Interface) sound modules, digital mixing consoles with high-quality PC sound cards, and computer-controlled multimedia applications.

This device features a 24-bit address bus for addressing16-bit sample-storage ROM and DRAM (DRAM refresh controller on-board), a 12x16 two's-complement scaler, eight 24-bit accumulators with clipping circuitry, a 2x8x16 interpolator to allow a high resolution of phase angles between input samples, CD-quality sampling rates, and 64 high-speed audio processing units (APUs) that can be split into two low-speed APUs that operate at half the sampling rate, allowing up to 128 notes to play simultaneously. All APUs are independent and can address any part of data storage at any time.

The Z89340 can operate at output sampling rates up to 50 kHz, and offers eight channels of 16- to 20-bit serial output data. The microprocessor interface allows full control of frequency, amplitude, and sample data input to each oscillator. The Z89340 features eight output registers, and their contents can be sent to DAC or CODEC. Four of these can be used for quadraphonic output, and have a panning mechanism called Polar Pan that supports motion in all four quadrants.

The other four output registers are used internally as effects channels, but can still send their data streams to a DAC, a second Z89340, or other digital signal processor. The Z89340 also has eight serial input data registers. In addition, there are 24 stereo submix register pairs for use in sending output data from one APU to be used as the input to another.

In particular, the Z89340 is well-suited for 8- and 16-bit linear PCM recording/playback, wave synthesis, Sound Blaster command set, and ADPCM (IMA/DVI) real-time decompression.
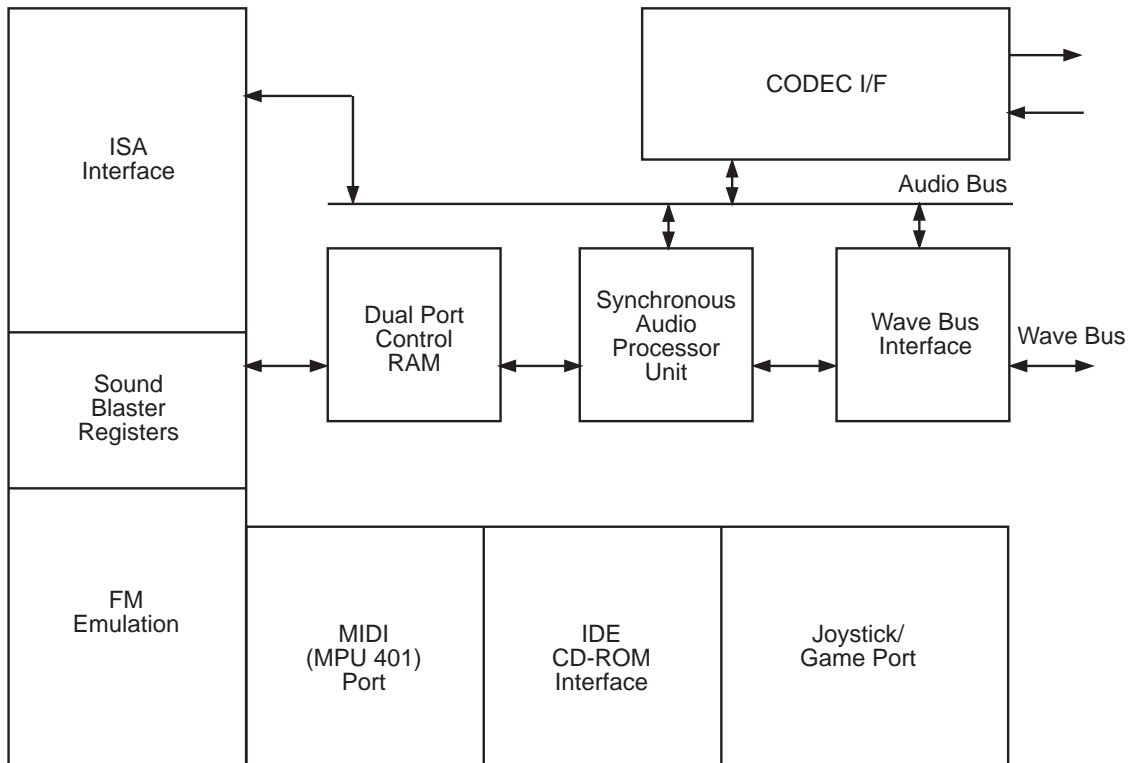
GENERAL DESCRIPTION (Continued)

Figure 1. Z89340 Simplified Functional Block Diagram
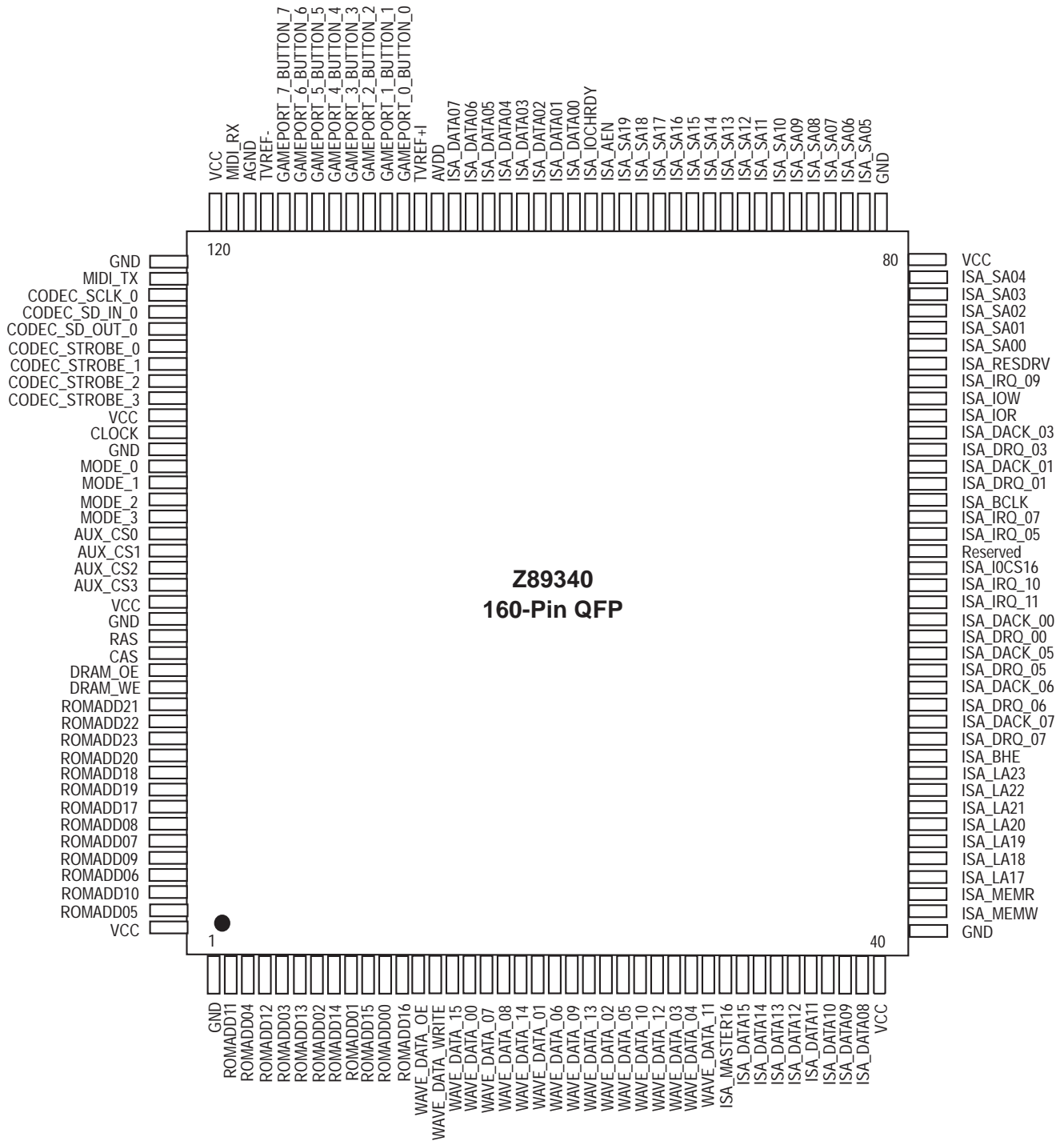
PIN IDENTIFICATION

Figure 2. 160-Pin QFP Pin Configuration

PIN IDENTIFICATION (Continued)

Table 1. 160-Pin QFP Pin Identification

Pin #	Symbol	Function	Direction
1	GND	Ground	–
2	ROMADD11	Wavetable ROM Address Bus	Output
3	ROMADD04	Wavetable ROM Address Bus	Output
4	ROMADD12	Wavetable ROM Address Bus	Output
5	ROMADD03	Wavetable ROM Address Bus	Output
6	ROMADD13	Wavetable ROM Address Bus	Output
7	ROMADD02	Wavetable ROM Address Bus	Output
8	ROMADD14	Wavetable ROM Address Bus	Output
9	ROMADD01	Wavetable ROM Address Bus	Output
10	ROMADD15	Wavetable ROM Address Bus	Output
11	ROMADD00	Wavetable ROM Address Bus	Output
12	ROMADD16	Wavetable ROM Address Bus	Output
13	WAVE_DATA_OE	External Memory Output Enable	Output
14	WAVE_DATA_WRITE	External Memory Write	Output
15	WAVE_DATA_15	External Waveform Mem. Data Bus	Input/Output
16	WAVE_DATA_00	External Waveform Mem. Data Bus	Input/Output
17	WAVE_DATA_07	External Waveform Mem. Data Bus	Input/Output
18	WAVE_DATA_08	External Waveform Mem. Data Bus	Input/Output
19	WAVE_DATA_14	External Waveform Mem. Data Bus	Input/Output
20	WAVE_DATA_01	External Waveform Mem. Data Bus	Input/Output
21	WAVE_DATA_06	External Waveform Mem. Data Bus	Input/Output
22	WAVE_DATA_09	External Waveform Mem. Data Bus	Input/Output
23	WAVE_DATA_13	External Waveform Mem. Data Bus	Input/Output
24	WAVE_DATA_02	External Waveform Mem. Data Bus	Input/Output
25	WAVE_DATA_05	External Waveform Mem. Data Bus	Input/Output
26	WAVE_DATA_10	External Waveform Mem. Data Bus	Input/Output
27	WAVE_DATA_12	External Waveform Mem. Data Bus	Input/Output
28	WAVE_DATA_03	External Waveform Mem. Data Bus	Input/Output
29	WAVE_DATA_04	External Waveform Mem. Data Bus	Input/Output
30	WAVE_DATA_11	External Waveform Mem. Data Bus	Input/Output
31	ISA_MASTER16	ISA Master 16-Bit Transfer	Tri-State Input
32–39	ISA_SD_15–8	ISA Data Bus	Input/Output
40	V_{CC}	Power Supply	–
41	GND	GND	–
42	ISA_MEMW	ISA Memory Write	Input/Output
43	ISA_MEMR	ISA Memory Read	Input/Output
44–50	ISA_LA 17–23	ISA Address Bus	Tri-State Output
51	ISA_BHE	ISA Bus High Byte Enable	Input/Output
52	ISA_DRQ_07	ISA DMA Request 07	Tri-State Output
53	ISA_DACK_07	ISA DMA Acknowledge 07	Input
54	ISA_DRQ_06	ISA DMA Request 06	Tri-State Output
55	ISA_DACK_06	ISA DMA Acknowledge 06	Input
56	ISA_DRQ_05	ISA DMA Request 05	Tri-State Output
57	ISA_DACK_05	ISA DMA Acknowledge 05	Input
58	ISA_DRQ_00	ISA DMA Request 00	Tri-State Outputt
59	ISA_DACK_00	ISA DMA Acknowledge 00	Input

Table 1. 160-Pin QFP Pin Identification

Pin #	Symbol	Function	Direction
60	ISA_IRQ_11	ISA Interrupt Request 11	Tri-State Output
61	ISA_IRQ_10	ISA Interrupt Request 10	Tri-State Output
62	ISA_IOCS16	ISA I/O Select 16-Bit Transfer	Tri-State Output
63	Reserved	Reserved	N/A
64	ISA_IRQ_05	ISA Interrupt Request 05	Tri-State Output
65	ISA_IRQ_07	ISA Interrupt Request 07	Output
66	CLKOUT	Clock Output	Output
67	ISA_DRQ_01	ISA DMA Request 01	Tri-State Output
68	ISA_DACK_01	ISA DMA Acknowledge 01	Input
69	ISA_DRQ_03	ISA DMA Request 03	Tri-State Output
70	ISA_DACK_03	ISA DMA Acknowledge 03	Input
71	ISA_IOR	ISA I/O Read	Input/Output
72	ISA_IOW	ISA I/O Write	Input/Output
73	ISA_IRQ_09	ISA Interrupt Request 09	Tri-State Output
74	ISA_RESDRV	Chip Reset	Input
75–79	ISA_SA00–SA04	ISA Address Bus	Input/Output
80	V_{CC}	Power Supply	–
81	GND	Ground	–
82–96	ISA_SA05–SA19	Address Bus	82–92: I/O; 93-96: Tri O
97	ISA_AEN	ISA Bus Address Enable	Input
98	ISA_I0CHRDY	ISA Channel Ready	Open-Drain Output
99–106	ISA_SD_00–07	ISA Data Bus	Input/Output
107	AV_{DD}	Analog Supply	–
108	ADC_VREF_HI	ADC Voltage Reference High	Input
109–112	ADC_0–3	Joystick Button 00–03	Input/Output
113–116	ADC_4–7	Gameport ADC 04–07	Input
117	ADC_VREF_LO	ADC Voltage Reference Low	Input
118	AGND	Analog Ground	–
119	MIDI_RX	MIDI Input	Input
120	V_{CC}	Power Supply	–
121	GND	Ground	–
122	MIDI_TX	MIDI Output	Output
123	CODEC_SCLK	Serial Clock Signal	Output
124	CODEC_SD_IN	Serial Data In	Input
125	CODEC_SD_OUT	Serial Data Out	Output
126–129	CODEC_STROBE_0–3	Serial CODEC Chip Select Strobe	Output
130	V_{CC}	Power Supply	–
131	CLK	System Clock	Input
132	GND	Ground	–
133–136	MODE_0–3	Operation Mode Select 00–S3	Input
137–140	AUX_CS0–3	Auxiliary Chip Select 00–03	Output
141	V_{CC}	Power Supply	Input
142	GND	Ground	–
143	RAS	Ext. DRAM Row Address Strobe	Output

PIN IDENTIFICATION (Continued)

Table 1. 160-Pin QFP Pin Identification

Pin #	Symbol	Function	Direction
144	CAS	Ext. DRAM Col. Address Strobe	Output
145	DRAM_OE	Ext. DRAM Output Enable	Output
146	DRAM_WE	Ext. DRAM Write Enable	Output
147–149	ROMADD21–23	Wavetable ROM Address Bus	Output
150	ROMADD20	Wavetable ROM Address Bus	Output
151–153	ROMADD18,19, 17	Wavetable ROM Address Bus	Output
154	ROMADD08	Wavetable ROM Address Bus	Output
155	ROMADD07	Wavetable ROM Address Bus	Output
156	ROMADD09	Wavetable ROM Address Bus	Output
157	ROMADD06	Wavetable ROM Address Bus	Output
158	ROMADD10	Wavetable ROM Address Bus	Output
159	ROMADD05	Wavetable ROM Address Bus	Output
160	V_{CC}	Power Supply	–

ZiLOG

ABSOLUTE MAXIMUM RATINGS

Sym	Description	Min	Max	Units
V_{CC}	Supply Voltage	−0.5	+6.5	V
T_{STG}	Storage Temp	−65	+150	°C
–	Voltage on any Pin	−0.5	V_{CC}	V
I_{OL}	Maximum Output Leakage per I/O Pin			mA
T_A	Oper Ambient Temp.	0	70	°C

Stresses greater than those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; operation of the device at any condition above those indicated in the operational sections of these specifications is not implied. Exposure to absolute maximum rating conditions for an extended period may affect device reliability.

RECOMMENDED OPERATING CONDITIONS

Sym	Description	Min	Max	Units
V_{CC}	Supply Voltage	4.75	+5.25	V
T_A	Oper Ambient Temp	0	70	°C

DC CHARACTERISTICS

V_{CC} = 4.5 V to 5.5V @ 0°C to +70°C

Sym	Parameter	Min	Typ.	Max	Unit
V_{IL}	Low-Level Input Voltage	−0.5	–	0.8	V
V_{IH}	High-Level Input Voltage	2.0	–	V_{CC}	V
V_{OL}	Low-Level Output Voltage	–	–	0.4	V
V_{OH}	High-Level Output Voltage	2.4	–	–	V
I_{CC}	Power Supply Current (crystal freq. = 50 MHz)	–	25	TBD	mA

AC CHARACTERISTICS

DMA Write/Playback Timing
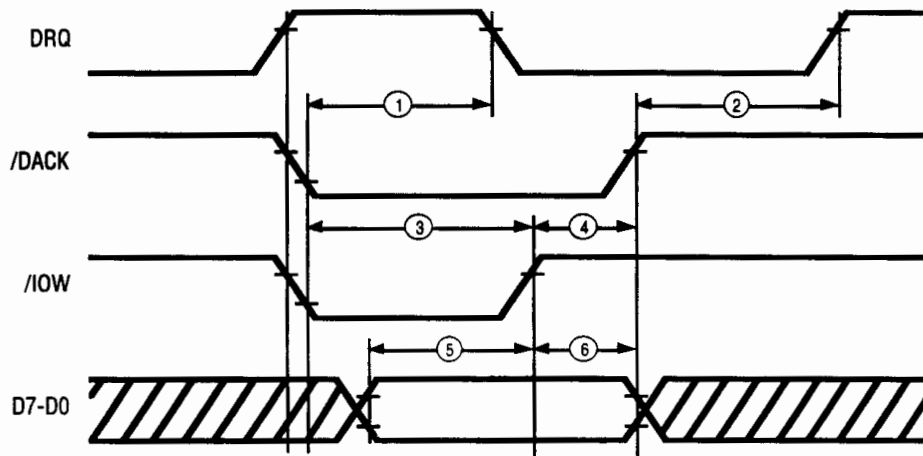
Figure 3. DMA Write Timing Diagram

No.	Description	Min	Max	Units
1	DRQ Low from /DACK Low	130	-	ns
2	/DACK High to DRQ High	30	-	ns
3	Write Enable Width	100	-	ns
4	/DACK Hold from End of /IOW	0	-	ns
5	Data Setup to End of Write Enable	50	-	ns
6	Data Hold Time from End of /IOW	40	-	ns

P R E L I M I N A R Y

DMA Read/Record Timing Diagram
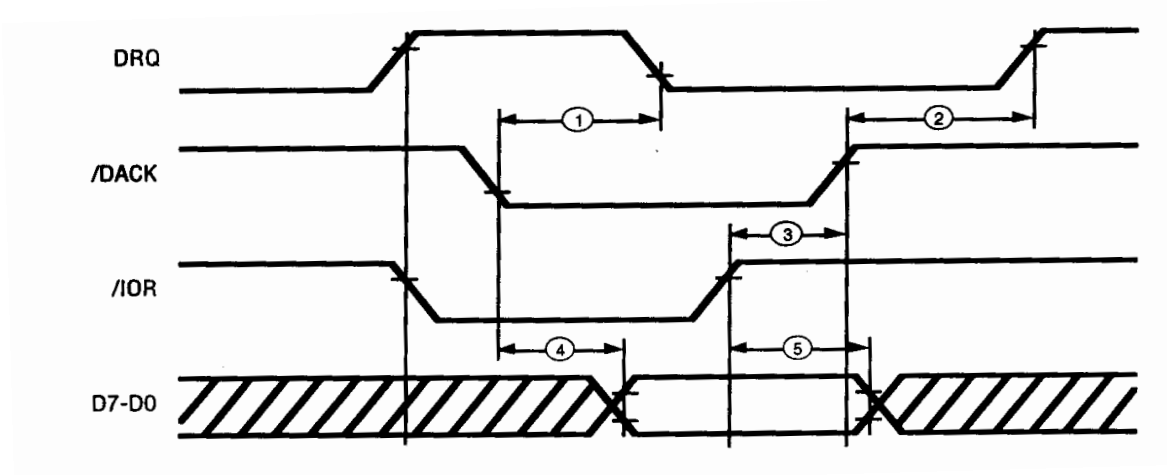
Figure 4. DMA Read Timing Diagram

No.	Description	Min	Max	Units
1	DRQ Low from /DACK Low	130	-	ns
2	/DACK High to DRQ High	30	-	ns
3	/DACK Hold Time from End of /IOR	0	-	ns
4	Data Access Time from Read Enable	115	-	ns
5	Data Hold Time from End of /IOR	20	-	ns

AC CHARACTERISTICS (Continued)
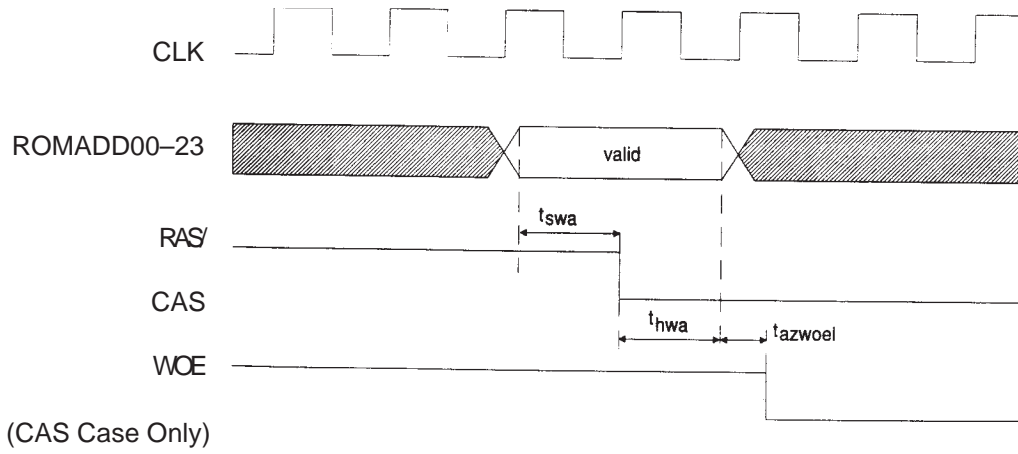
External ROM Reading Timing Diagram

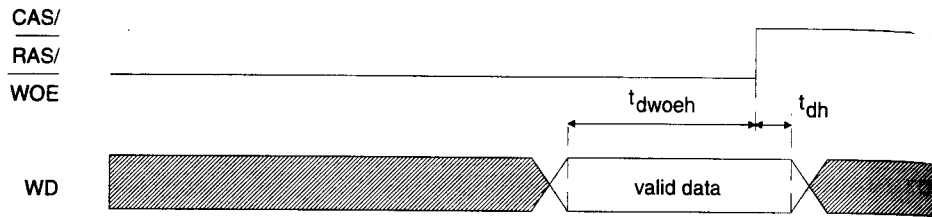**Figure 5. Sample Memory Address Timing Diagram**

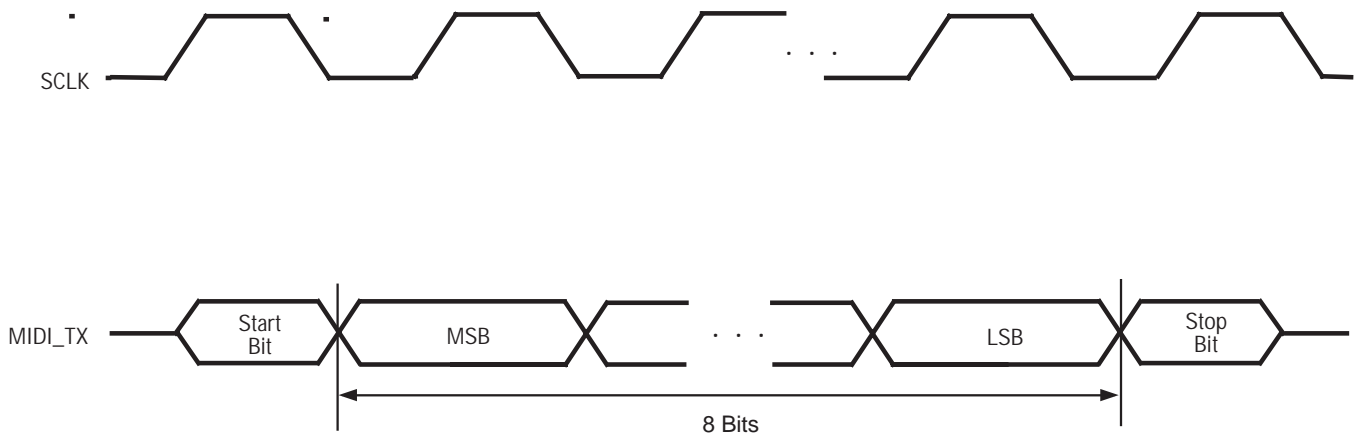**Figure 6. Sample Memory Read Timing Diagram**

MIDI Timing Diagrams
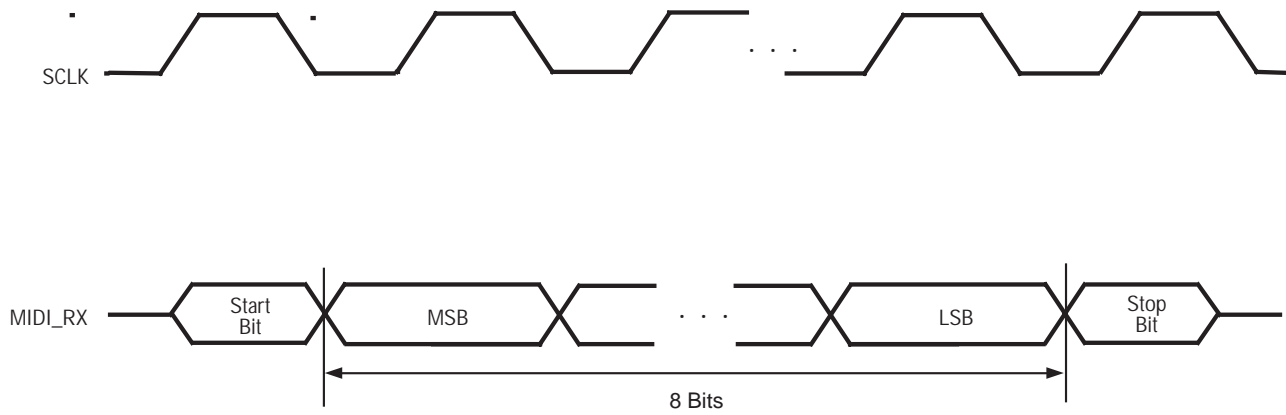

Figure 7. MIDI Transmit Timing Diagram

Figure 8. MIDI Receive Timing Diagram
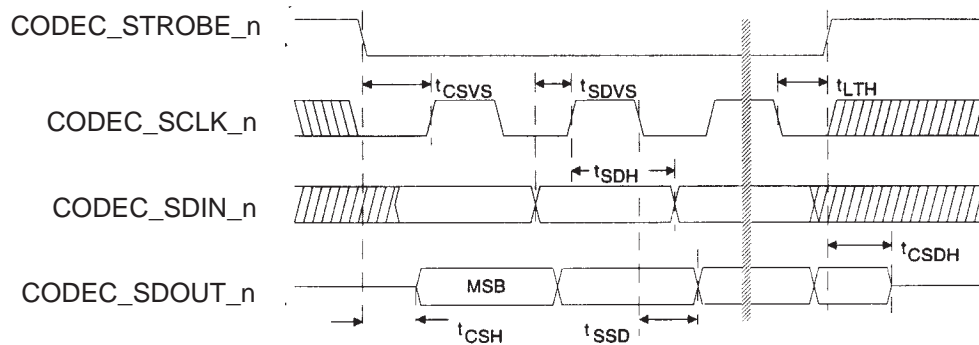
CODEC INTERFACE TIMING DIAGRAM

Figure 9. CODEC Interface Timing Diagram

PIN FUNCTIONS

ADC_VREF_HI, ADC_VREF_LO. Analog-to-Digital Converter Voltage Reference.

ADC_0–3 (I/O). Joystick button 0-3.

ADC_4–7 (Input). Game port 4-7.

AGND. Analog Ground.

AUX_CS0–3 (Ouput). Auxiliary chip-select. These pins are used to select the CD-ROM interfaces.

AVDD. Analog Supply.

CAS (Output). Column Address Strobe Output. This memory address strobe is used in conjunction with the address lines ROMADD01–R0MADD23.

CLKOUT (Output). Clock Output.

CODEC_SCLK (Output). Serial clock signal 0-1.

CODEC_SD_IN (Input). Serial data in 0-1.

CODEC_SD_OUT (Output). Serial data out 0-1.

CODEC_STROBE_0–3 (Output) Serial CODEC chip select strobe 0-3.

GND. Ground.

ISA_AEN (Input). ISA Bus Address Enable. This is the address enable line and should be connected to the ISA bus signal of the same name.

ISA_BHE (I/O). ISA Bus High Byte Enable.

ISA_DACK_01,03,05,06,07 (Input). ISA DMA Acknowledge 01,03,05,06,07. These are DMA acknowledge pins and should be connected to the appropriate ISA bus lines.

ISA_DRQ_01,03,05,06,07 (Tristate/Output). ISA DMA Request 01,03,05,06,07. These are DMA request pins and should be connected to the appropriate ISA bus lines.

ISA_IOCHRDY (Output). Connected to the ISA bus signal of the same name.

ISA_IOCS16 (Tristate/Output). ISA I/0 Select 16-bit Transfer. This pin is used during 16-bit DMA transfers and should be connected to the ISA bus signal of the same name.

ISA_IOR (I/O). ISA I/0 Read. This is the I/0 Read. The I/0 read pulse should be connected to the ISA bus signal of the same name.

ISA_IOW (I/O). ISA I/0 Write. This is the I/0 write pulse line that should be connected to the ISA bus signal of the same name.

ISA_IRQ_05,07,09,10,11 (Output). ISA Interrupt Request 05,07,09,10,11. These are Interrupt request pins and should be connected to the appropriate ISA bus lines.

ISA_LA_17–23 (Tri-State Output). ISA Address Bus. These lines map directly to the PC address bus; the pins should be connected to the ISA bus address lines of the same name.

ISA_MASTER16 (Tr-State Output). ISA Master Mode 16-bit Transfer.

ISA_MEMR (I/O). ISA Memory Read.

PIN FUNCTIONS (Continued)

ISA_MEMW (I/O). ISA Memory Write.

ISA_SA_0–4 (I/O). ISA Address Bus.

ISA_SD_08–15 (I/O). Data Bus. This data bus is used to transfer data between PC and the Z89340. The lines map directly to the PC data bus; the pins should be connected to the ISA bus address lines of the same name.

MIDI_RX (Input). Receives data from MIDI interface.

MIDI_TX (Output). Sends data to MIDI interface.

MODE_S0–3 (Input). Mode Selection pins that are general purpose input pins.

DRAM_OE (Output). External DRAM Output Enable. This signal is an output enable strobe for external DRAM.

DRAM_WE (Output). External DRAM Write Enable. This signal is a write enable strobe for external DRAM.

RAS (Output). Row Address Strobe Output. This memory address strobe is used in conjunction with the address lines ROMADD01–R0MADD23.

RESET. (Input). Device Reset.

ROMADD01–ROMADD23 (Output). Wavetable ROM Address Bus. These lines are used to address external sample memory.

V$_{CC}$. Power supply that connects to 5V ±5%.

Wave_Data_0E (Output). External Memory Output Enable. This signal is an output enable strobe for external sample memory.

Wave_Data_00-15 (I/O). Waveform Memory DRAM/SRAM/ROM Data Bus. These lines are used to pass sample data between the Z89340 and external sample memory.

FUNCTIONAL DESCRIPTION

Digital Audio Input and Output

The Z89340 has eight output registers with signals that can be sent to a DAC or CODEC. Four of these can be used for quadraphonic output and have a panning mechanism called Polar Pan that supports motion in all four quadrants. The other four output registers are used internally as effects channels, but can still send their serial streams to a DAC, a second Z89340, or other digital signal processor. The Z89340 also has eight serial input registers whose signals can be accessed and processed.

Submix Registers

The Z89340 has 16 stereo submix registers. The submix registers are needed to chain together the various components of the reverb, chorus, echo, and flange algorithms. When the data in a submix register is no longer needed, it is cleared with bit 7 of the Data Source register in the parameter block of the pertinent oscillator types. The host CPU can read and write all oscillator parameter RAM, including the submix registers.

Oscillators

The Z89340 is a special-purpose audio processor with an instruction set designed for music synthesis. Fundamental to the Z89340 are the 64 full-speed oscillators, the first 48 of which have a half-speed counterpart. Control of an oscillator is handled by setting the parameters in the oscillator's 24-byte parameter block. An oscillator can be used to generate sound, or it can be used to perform other operations-input device, tape-loop reverberator, dual tap-reader, input mixer, and so on. Typical implementations would include an Z89340, waveform ROM and RAM, and a CPU to control the Z89340. The CPU is normally connected via the ISA bus interface. (Refer to Figure 10 for General Purpose Oscillator Address Map.)

The following subsections briefly introduce each of the oscillator types. (A detailed description of the Oscillator Parameter Blocks for each oscillator type follows.)

Half-Speed Oscillators

Half-Speed Oscillators are best suited for playing lower notes where the upper bandwidth is not critical, since they operate at half the sampling rate.

Oscillators 0 through 47 (0x2f) can each be split into two oscillators operating at half the clock rate. This yields 112 oscillators total (2 · 48 + 16). Oscillators 48 through 63 (0x30 through 0x3f) can only operate at the full clock rate since the parameter RAM that would be needed for their half-speed counterparts is unavailable

They can also be used for higher notes with simple waveforms that have few significant upper harmonics. For ex-

ample, at a sampling rate of 48 kHz, the Half-Speed Oscillators will have a sampling rate of 24 kHz, so the maximum frequency that can be produced by these oscillators without aliasing is under 12 kHz. This bandwidth is adequate for many sounds, but not suitable for high strings, cymbals, or other crisp or bright sounds. An empirical listening test will help determine if a Half-Speed Oscillator can be used for a particular situation. The obvious advantage to using Half-Speed Oscillators wherever possible is that more notes can be played at the same time.

Sample Loop Oscillators/Wavetable Mode Oscillators

For music synthesis, the Z89340 Sample Loop and Wavetable Mode Oscillators are the main workhorses. They are interpolating wavetable look-up oscillators and perform the tasks of fetching two adjacent samples from waveform memory. They interpolate between them based on the current phase angle (frequency and time), filtering, scaling, and routing the resulting signal to multiple effects sends and output channels. These oscillators can use 8- or 16-bit linear PCM samples. The ADPCM oscillators described later are similar in function and use ADPCM (IMA and DVI 4- or 8-bit samples).

Sample Loop Oscillators

Sampling
One of the more popular methods of re-creating or re-synthesizing the sound of a traditional acoustic musical instrument is through a process referred to as sampling or PCM (pulse-code modulation) synthesis. A sample, in the strictest sense, is a value taken at a specified point in time that represents the instantaneous amplitude of the subject waveform. A digital recording consists of a sequence of amplitude values sampled at evenly spaced intervals of time. The term "sample" sometimes refers to the sequence of samples found in a digital recording. (This usage is especially popular throughout the music industry.) This digital recording is much like the recording that would be captured with a tape recorder, except that it can be stored in digital memory, and as such, can be randomly accessed.

Looping
To reduce the length of the recording to make it fit in a limited memory space, the most common form of processing used with sampling is looping. The process of looping can be briefly described as follows: The synthesizer plays the original recording of a note up to a designated time point, whereupon it plays a short sequence of samples that describe one or more periods of the temporally varying waveform-the "loop." The loop is then repeated until the note stops. A decaying amplitude envelope is often imposed upon the loop so that the sound will decay naturally. The Sample Loop Oscillator is designed to facilitate looping algorithms with single or multiple loops.

Wavetable Synthesis

Another method of synthesizing sound is sometimes called wavetable synthesis. The Wavetable Mode Oscillator has some wavetable-synthesis extensions that set it apart from the Sample Loop Oscillator. With wavetable synthesis, one or more complete periods of a waveform are recorded and stored in a wavetable. The wavetable is then played at the desired frequency. This is similar to the loop described earlier except that the wavetable is often not a recording, but a single period of a sound created through additive synthesis. The Z89340 can move to other wavetables or stay on the same wavetable during the life of a note.

To play a note or sample sequence from waveform ROM, you would set the following: desired frequency, wave begin and end addresses, wave loop length, the initial amplitude envelope begin and end values, envelope rate, Amplitude/Tremolo/Filter/Pan (ATFP) envelope type to amplitude, output channel(s), effects send(s), pan location, and filter tuning values. All of these settings can be changed during the life a note as desired. All oscillators are completely independent of each other, even for features such as vibrato rate and filter cutoff points.

The Z89340 assumes that the amplitude envelope will occur in multiple segments-attack segment, several initial decay segments, possibly a sustained segment, and several final decay segments. On-chip support is given for one envelope segment at a time. An interrupt is generated when the segment end is reached, at which time the host CPU will set up the next amplitude segment, supplying a new amplitude end value and envelope rate (the slope that defines how long it will take to reach the end amplitude). It is not critical that the interrupt be serviced immediately; a delay of 10–20 milliseconds (ms) normally is not noticed; the amplitude merely remains stationary until the new segment is initiated. The Z89340 has amplitude steps well below the threshold of perceptibility, so there is no zipper noise. If there is a sustained segment (one where the amplitude does not change), the Envelope-type ATFP controls can be used to define the envelope rate parameter as tremolo rate; tremolo depth can then be set. If tremolo is not needed, the ATFP envelope system can also be used for variable pan or swept filter. (Refer to the Oscillator Parameter Block section for a detailed description of each control bit.)

Vibrato is independent of the ATFP system. There are 16 settings of vibrato rate ranging from 0.1–10 Hz, and 16 different settings of vibrato depth ranging from plus or minus a few cents to two semitones.

Note: A semitone is equivalent to $2^1/12$ frequency multiples; a cent is equivalent to $2^1/1200$ frequency multiples.

The vibrato value, which is derived from a sinewave indexed by the vibrato phase accumulator, is added to or subtracted from the frequency. The initial vibrato phase can be set by writing a value to the 8-bit vibrato phase accumulator-value of 64 is $\pi/2$ radians, which would start the vibrato at maximum positive swing.

Each oscillator has its own second-order (two-pole, two-zero) digital filter. At the initialization of an oscillator, the two delays should be given values of 0 unless a click is desired. The filter Q (in the Control Byte) and the filter tuning value are used together to set the desired characteristics of the filter. Low-pass filters with varying amounts of Q are available. A few useful high-pass and band-pass filter settings are also provided. The ATFP envelope system can be used to create a variable or swept low-pass filter. (Refer to the tables in the Oscillator Parameter Block section for details.)

The Polar Pan Control provides selection of output channels and pan between or among up to four output channels. When four channel quadraphonic output is selected, the spatial location is specified with a modified polar coordinate-a value of 16 is $\pi/2$ radians. The radius select is a two-bit number with 2 at the edge of the circle and 0 near the center of the circle. A radius of 3 is reserved for stereo panning when only two output channels are needed. (Other items such as effects channels and submix channels are covered in sections that follow.) All parameters in the Oscillator Parameter Block can be modified by the CPU during the life of a note.

FUNCTIONAL DESCRIPTION (Continued)

89340	7	6	5	4	3	2	1	0
Control byte	Oscillator Type		1/2 speed	Dual Effect Sends	Filter Q			
Freq Lo								
Freq Mid								Envelope-Type ATFP
Freq Hi								
Phase								
Wave Pointer Hi	ROM 23/DMA	ROM 22	ROM 21	ROM 20	ROM 19	ROM 18	ROM 17	ROM 16
Wave Pointer Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ROM 1	ROM 0
Wave Pointer Mid	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Wave End Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ATFP Flags	
Wave End Hi	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Wave Loop Length Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ROM 1	ROM 0
Wave Loop Length Hi	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Effect Send Control	Effect Channel(s)				Effect Attenuation (Splits In Two For Dual Sends)			
Envelope Rate	Envelope Rate (Hi) / Tremolo Rate				Envelope Rate (Lo) / Tremolo Depth			
Vibrato Control	Vibrato Depth				Vibrato Rate			
Vibrato Phase Accumulator	Vibrato Phase Accumulator							
Amp / Filt / Pan Next	Cont Loop For Pan	Right/Left For Pan						
Amplitude Now								
Polar Pan Control	Radius Select			Polar Pan (64 angles)				
Filter Tuning								
Delay 1A								
Delay 1B								
Delay 2A								
Delay 2B								

	Oscillator Type	
OFF	0	0
ON Strange Data	0	1
ON Normal	1	0
ON Extended Opcode	1	1

	ATFP Type	
Amplitude	0	0
Tremolo	0	1
Filter	1	0
Pan	1	1

	ATFP Flags (except Tremolo)	
Off	0	0
Wait	0	1
Done	1	0
In Process	1	1

ATFP Flags (Tremolo)	
Direction	On/Off

OPCODE SUMMARY

normal

Extended opcodes		ADPCM Enable	Extended Opcode		
tape loop	0	0	0	0	0
dual tap reader	1	0	0	0	1
correlator	2	0	0	1	0
input device	3	0	0	1	1
wave table mode	4	0	1	0	0
input data streamer	5	0	1	0	1
reserved	6	0	1	1	0
reserved	7	0	1	1	1
ADPCM -IMA/DVI	8-F	1	X	X	X

Figure 10. General-Purpose Oscillator Address Map

ADPCM Oscillator

The ADPCM Oscillator works in much the same way as the Sample Loop and Wavetable Oscillators. The main differences are that, due to the nature of ADPCM, the frequency cannot be negative (you cannot with the Sample Loop Oscillator you can play a sound backwards, with Wavetable Mode and ADPCM), and ADPCM will not allow playing a sound faster than the sampling rate at which it is stored in ROM. Also, the wavetable synthesis extensions of the Wavetable Mode Oscillator are not available. The Z89340 handles IMA/DVI format ADPCM in 4- and 8-bit modes. The ADPCM Oscillator provides a way to compact the data, but with some degree of sound degradation. However, in many applications the trade-off may be worthwhile. (Refer to Figure 11 for ADPCM-IMA/DVI Oscillator Address Map).

ADPCM-IMA/DVI Oscillator

89340	7	6	5	4	3	2	1	0
Control byte			1/2 speed	Dual Effect Sends		Filter Q		
Freq Lo								
Freq Mid							Env-Type ATFP	
Freq Hi	8/4-bit ADPCM							
Phase Mid		1		7-bit Predictor Storage Element				
Wave Pointer Hi	ROM 23/DMA	ROM 22	ROM 21	ROM 20	ROM 19	ROM 18	ROM 17	ROM 16
Wave Pointer Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ROM 1	ROM 0
Wave Pointer Mid	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Wave End Lo	ROM 7	ROM 6	ROM 5	ROM 4	ADPCM Expo Table		ATFP Flags	
Wave End Mid	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Wave Loop Length Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ROM 1	ROM 0
Wave Loop Length Hi	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Effect Send Control	Effect Channel(s)			Effect Attenuation (Splits In Two For Dual Sends)				
Envelope Rate	Envelope Rate (Hi) / Tremolo Rate				Envelope Rate (Lo) / Tremolo Depth			
Vibrato Control	vibrato depth				vibrato rate			
Vibrato Phase Accumulator	vibrator phase accumulator							
Amp / Filt / Pan Next	Cont Loop For Pan	Right/Left For Pan						
Amplitude Now								
Polar Pan Control	Radius Select			Polar Pan (64 angles)				
Filter Value	Filter Tuning							
Delay 1A								
Delay 1B								
Delay 2A								
Delay 2B								

Figure 11. The ADPCM-IMA/DVI Oscillator Address Map

FUNCTIONAL DESCRIPTION (Continued)

Tape Loop Oscillator

The Tape Loop Oscillator takes its input from an input register, an effects channel, or a submix register. It then reads a sample from wave RAM, and writes the scaled input value plus the scaled and filtered sample from wave RAM back to the same location in wave RAM. It behaves very much like a tape recorder with a loop of tape, hence the name "Tape Loop." Echo and single-delay reverberation can be accomplished with the Tape Loop Oscillator. The amount of delay is set with the Wave Loop Length registers, and can be more than a second if you are willing to dedicate the necessary RAM. This oscillator can also be used to transfer input from a ADC that is connected to one of the input registers. In this way the input can be buffered in RAM for later use by the CPU host, or processing can be done by the Z89340 before sending the signal to a stereo submix register pair or one or more output channels. The Tape Loop Oscillator can also perform the function of the comb filter component of reverb algorithms (Figure 12).

Tape Loop oscillator 89340	7	6	5	4	3	2	1	0
Control byte	1		1	1/2 Speed	Dual Effect Sends		Filter Q	
Freq Lo				00				
Freq Mid					00		Env-Type ATFP	
Freq Hi	0		0	0	0		1	
Phase Mid				Regeneration				
Wave Pointer Hi	ROM 23/DMA	ROM 22	ROM 21	ROM 20	ROM 19	ROM 18	ROM 17	ROM 16
Wave Pointer Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ROM 1	ROM 0
Wave Pointer Mid	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Wave End Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ATFP Flags	
Wave End Mid	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10		
Wave Loop Length Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ROM 1	ROM 0
Wave Loop Length Hi	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Effect Send Control	Effect Channel(s)			Effect Attenuation (Splits In Two For Dual Sends)				
Envelope Rate	Envelope Rate (Hi) / Tremolo Rate			Envelope Rate (Lo) / Tremolo Depth				
Vibrato Control	Clear Submix			Data Source				
Vibrato Phase Accumulator								
Amp / Filt / Pan Next	Cont Loop For Pan	Right/Left For Pan						
Amplitude Now								
Polar Pan Control	Radius Select			Polar Pan (64 angles)				
Filter Value				Filter Tuning				
Delay 1A								
Delay 1B								
Delay 2A								
Delay 2B								

Figure 12. The Tape Loop Oscillator Address Map

Dual Tap-Reader

As part of the reverb algorithm, the Dual Tap-Reader Oscillator can pick additional taps in the Tape Loop delay line. The samples gathered are then scaled, summed, filtered, and sent to a submix register or one or more output channels. Note that the filtering takes place after scaling and summing since there is only one filter in the Dual Tap-Reader. The taps supplied by the Dual Tap-Reader can be used to simulate early reflections. The two taps can be up to 4096 samples apart, which is about 80 ms at a 50 kHz sampling rate. However, the reverb system is typically run with Half-Speed Oscillators, making possible 160 ms or more between taps. As many Dual Tap-Readers as desired can be used with a single Tape Loop Oscillator providing the input (Figure 13).

Dual tap reader oscillator

89340	7	6	5	4	3	2	1	0
Control byte	1	1	1/2 Speed	Dual Effect Sends		Filter Q		
Freq Lo			00				Env-Type ATFP	
Freq Mid				00				
Freq Hi (recommended freq=1)	0		0	0	1		1	
Phase Mid				Balance				
Wave Pointer Hi	ROM 23/DMA	ROM 22	ROM 21	ROM 20	ROM 19	ROM 18	ROM 17	ROM 16
Wave Pointer Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ROM 1	ROM 0
Wave Pointer Mid	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Wave End Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ATFP Flags	
Wave End Mid	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Wave Loop Length Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ROM 1	ROM 0
Wave Loop Length Hi	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Effect Send Control	Effect Channel(s)			Effect Attenuation (Splits In Two For Dual Sends)				
Envelope Rate	Envelope Rate (Hi) / Tremolo Rate				Envelope Rate (Lo) / Tremolo Depth			
Vibrato Control			Step Size Between Taps					
Vibrato Phase Accumulator								
Amp / Filt / Pan Next	Cont Loop For Pan	Right/Left For Pan						
Amplitude Now								
Polar Pan Control	Radius Select			Polar Pan (64 angles)				
Filter Value			Filter Tuning					
Delay 1A								
Delay 1B								
Delay 2A								
Delay 2B								

Figure 13. The Dual Tap-Reader Oscillator Address Map

FUNCTIONAL DESCRIPTION (Continued)

Input Mixer

The Input Mixer reads input from two sources (input registers, submix registers or effects channels), scales the two samples, sums, filters, and sends the output to the desired channel(s). The Input Mixer also performs the DRAM refresh task (Figure 14).

Input Mixer 89340	7	6	5	4	3	2	1	0
Control Byte			1/2 speed	Dual Effect Sends	Filter Q			
Freq Lo (freq lo must be 0)			00				Env-Type ATFP	
Freq Mid (freq mid must be 0)				00				
Freq Hi (freq hi must be 0)	0		0	1	1		0	
Phase Mid				Balance				
Wave Pointer Hi	ROM 23/DMA	ROM 22	ROM 21	ROM 20	ROM 19	ROM 18	ROM 17	ROM 16
Wave Pointer Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ROM 1	ROM 0
Wave Pointer Mid	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Wave End Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ATFP Flags	
Wave End Mid	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Wave Loop Length Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ROM 1	ROM 0
Wave Loop Length Hi	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Effect Send Control	Effect Channel(s)			Effect Attenuation (Splits In Two For Dual Sends)				
Envelope Rate	Envelope Rate (Hi) / Tremolo Rate				Envelope Rate (Lo) / Tremolo Depth			
Vibrato Control	Clear Submix		Data Source A					
Vibrato Phase Accumulator	Clear Submix		Data Source B					
Amp / Filt / Pan Next	Cont Loop For Pan	Right/Left For Pan						
Amplitude Now								
Polar Pan Control	Radius Select		Polar Pan (64 angles)					
Filter Value			Filter Tuning					
Delay 1A								
Delay 1B								
Delay 2A								
Delay 2B								

Note: input mixers perform an implicit DRAM refresh cycle in lieu of reading samples from DRAM

Figure 14. The Input Mixer Address Map

Input Data Streamer

Samples can be moved via DMA from the CPU host RAM to the Z89340 wavetable RAM space. Up to 48 channels of bus-mastered DMA are available (Figure 15).

Input Data Streamer 89340	7	6	5	4	3	2	1	0
Control byte	1	1	1/2 Speed	Dual Effect Sends	Filter Q			
Freq Lo	00						Env-Type ATFP	
Freq Mid	00							
Freq Hi	0	1	0	1		1		
Phase Mid								
Wave Pointer Hi	ROM 23/DMA	ROM 22	ROM 21	ROM 20	ROM 19	ROM 18	ROM 17	ROM 16
Wave Pointer Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ROM 1	ROM 0
Wave Pointer Mid	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Wave End Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ATFP Flags	
Wave End Mid	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Wave Loop Length Lo	ROM 7	ROM 6	ROM 5	ROM 4	ROM 3	ROM 2	ROM 1	ROM 0
Wave Loop Length Hi	ROM 15	ROM 14	ROM 13	ROM 12	ROM 11	ROM 10	ROM 9	ROM 8
Effect Send Control	Effect Channel(s)			Effect Attenuation (Splits in Two For Dual Sends)				
Envelope Rate	Envelope Rate (Hi) / Tremolo Rate			Envelope Rate (Lo) / Tremolo Depth				
Vibrato Control	Clear Submix		Data Source					
Vibrato Phase Accumulator								
Amp / Filt / Pan Next	Cont Loop For Pan	Right/Left For Pan						
Amplitude Now								
Polar Pan Control	Radius Select		Polar Pan (64 angles)					
Filter Value	Filter Tuning							
Delay 1A								
Delay 1B								
Delay 2A								
Delay 2B								

Figure 15. The Input Data Streamer Address Map

OSCILLATOR PARAMETER BLOCKS

An oscillator is controlled by the host CPU by writing commands in the on-chip RAM that is associated with the oscillator. This RAM is called the Oscillator Parameter Block. The following pages present, for each of the oscillator types, a description of the bit fields in the 24 bytes of the Oscillator Parameter Block. Address 0 in the block is the Control Byte.

The two bits of Oscillator Type deserve special mention. Extended Opcodes are enabled when both of these bits are set, and the high four bits of Frequency Hi specify which extended opcode to use. Because the Sample Loop and Wavetable Mode oscillators are so similar, they are presented together. The Wavetable Mode oscillator, however, is an extended opcode.

Sample Loop/Wavetable Mode Oscillators

Control Byte   **address 0**

Filter Q   bits 0-3
Each oscillator has a variable filter. These bits allow adjustment of the filter Q. (Refer to Filter Tuning Value for more information.)

Dual Effect Sends   bit 4
When this bit is set, the oscillator talks to two effect channels-the effect channel chosen with Effect Channel in the Effect Send Control Byte, and the subsequent channel (wraps to effects channel 0 if the last channel is chosen).

This system allows choosing two of the four effects channels at a time in all but two of the possible combinations.

Half-Speed   bit 5
Half-speed: Oscillators 0 through 47 (0x2f) can each be split into two oscillators operating at half the clock rate. This yields 112 oscillators total ($2 \cdot 48 + 16$).

Oscillators 48 through 63 (0x30 through 0x3f) can only operate at the full clock rate since the parameter RAM is unavailable that would be used as their half-speed counterparts.

Oscillator-type   bits 6-7
These bits define the operating mode of the oscillator:

00-If all 8 bits of the Control Byte are 0, the oscillator shuts off completely regardless of the settings of the other parameters. To prevent an oscillator from sending output to any channel without shutting it down, use the special silence command in the Polar Pan control.

01-8-bit linear PCM wavetable data.
10-16-bit linear PCM wavetable data.
11-extended opcode. For Wavetable Mode, set the upper four bits of Frequency Hi to 0100.

OSCILLATOR PARAMETER BLOCKS (Continued)

Frequency Low   **address 1**

Envelope-type ATFP   bits 0 and 1
Four types of envelope segments are supported, but only one at a time. Amplitude/Tremolo/Filter/Pan Envelope-type control bits.

00-Amplitude
01-Tremolo
10-Filter
11-Pan.

Frequency Low   bits 2-7
These are the lowest six bits of the 22-bit linear frequency

Frequency Mid   **address 2**

                                  bits 0-7
These are the middle eight bits of the 22-bit linear frequency.

Frequency Hi   **address 3**

Frequency Hi   bits 0-7
(Sample Loop Oscillator only)
These are the highest eight bits of the 22-bit linear frequency. Frequency is represented as a linear two's-complement value. A negative frequency plays the sound backwards.

Frequency Hi   bits 0-3
(Wavetable Mode Oscillator only)
These are the highest four bits of the 18-bit linear frequency. Frequency is represented as an unsigned linear value. With the Wavetable Mode Oscillator, the upper four bits are an extended opcode and must be 0100; negative frequencies are not possible with the remaining 18 bits of linear frequency.

Extended Opcode   bits 4-7
(Wavetable Mode Oscillator only)
With the Wavetable Mode Oscillator, the upper four bits of Frequency Hi are one of the extended opcodes and must be 0100.

Phase   **address 4**

Phase   bits 0-7
The eight bits of Phase, along with the 16 bits of Wave Pointer Mid and Lo, are that part of the wave address that is modified by the oscillator through the life of the note as it steps from sample to sample based on frequency. The upper bits of the wave ROM address are set at initialization and remain fixed (Wave Pointer Hi). Wave Pointer Lo points to a sample in ROM or RAM. Phase gives the distance between the sample and the subsequent sample.

The oscillator does a piecewise linear interpolation between the two samples. To further reduce conversion error, eight bits of smoothing are added below Phase in the internal processing. Phase is generally given a value of 0 at the start of a note.

Wave Pointer Hi   **address 5**

ROM16-ROM23   bits 0-7
The eight bits of Wave Pointer Hi control wave ROM or RAM address lines 16-23, which are the highest address bits. This value remains fixed throughout the life of a note. The lower bits of Wave Pointer are changed by the Z89340 during the life of a sound until they equal Wave Endpoint.

ROM23/DMA   bit 7
If DMA bus-mastering mode is enabled, this bit enables DMA for the oscillator. The address then becomes an ISA Bus host CPU RAM address. DMA has system consequences and should be used with caution. In particular, fewer oscillators can be active at the same time. Tape Loops should not be used because of limitations of data transmission across the ISA bus.

Wave Pointer Lo   **address 6**

ROM0-ROM7   bits 0-7
The eight bits of Wave Pointer Lo are part of the wave address that is modified by the oscillator through the life of the note as it steps from sample to sample based on frequency corresponding to ROM or RAM address bits 0-7. The upper bits of the wave ROM address are set at initialization and remain fixed (Wave Pointer Hi). Wave Pointer Lo points to a sample in ROM or RAM. (Refer to Phase and Wave Pointer Mid.) Wave Pointer Lo contains the lowest bits of the start address when a note is begun.

Wave Pointer Lo and Wave Pointer Mid are changed by the Z89340 during the life of a sound until they are equal Wave Endpoint.

Wave Pointer Mid   **address 7**

ROM8-ROM15   bits 0-7
The eight bits of Wave Pointer Mid point to a block of 256 samples. This 256 sample block can be considered a wavetable for use in wavetable synthesis. For sample-sequence playback, Wave Pointer Mid forms the upper eight bits of the 16-bit sample pointer; Wave Pointer Lo holds the lower eight bits. This allows sample sequences of up to 64K samples. Wave Pointer Mid contains eight bits of the start address when a note is begun. Wave Pointer Lo and Wave Pointer Mid are changed by the Z89340 during the life of a sound until they equal Wave Endpoint.

Wave Endpoint Lo/
AWS/Interleave Size   **address 8**

ATFP Flags   bits 0 and 1
These bits are active for the selected envelope types in Frequency Lo. The bits have a separate meaning for Tremolo from the other types.

Amplitude/Filter/Pan envelope flag bits:

00-Off
01-Wait
10-In process
11-Done

Tremolo envelope flag bits:

bit 0-Enable
bit 1-Polarity

Interleave Size   bits 2-3
(Wavetable Mode Oscillator only)
With wavetable synthesis, one or more complete periods of a waveform are stored in a wavetable. Interleave is the distance between wavetables. Normally Interleave Size will equal Table Size so that the wavetable will be contiguous. For compatibility with existing sound libraries, other interleaves are available.

00-64 Samples
01-128 Samples
10-256 Samples
11-512 Samples

AWS   bit 4
(Wavetable Mode Oscillator only)
With wavetable synthesis, one or more complete periods of a waveform are stored in a wavetable. We Change the Wave Endpoint when we want to move to the next wavetable. How the sound moves from the current wavetable to the next is controlled by AWS (Automatic Wave Select). When AWS is 0, the sound loops on the current wavetable as long as Wave Endpoint equals Wave Pointer. When Wave Endpoint is changed, the Z89340 jumps to the wavetable pointed to by Wave Endpoint as soon as it plays the last sample of the current wavetable pointed to by Wave Pointer. Wave Pointer is then set equal to Wave Endpoint. When AWS is 1, all samples in the wavetables between Wave Pointer and Wave Endpoint are also played. The Z89340 the loops on the wavetable pointed to by Wave Endpoint.

ROM5-ROM7   bits 5-7
(Wavetable Mode Oscillator only)
With wavetable synthesis, one or more complete periods of a waveform are stored in a wavetable. The wavetable can be played at any desired frequency.

ROM2-ROM7   bits 2-7
(Sample Loop Oscillator only)
For sample loop systems, Wave Endpoint is the last sample in the sample sequence. When this last sample is played, the Z89340 subtracts Wave Loop Length from the Wave Pointer. Note that since only six bits are available for Wave Endpoint Lo, the sample sequence can only end on every fourth address. Wave Loop Length does not have this restriction.

Wave Endpoint Hi   **address 9**

ROM8-ROM15   bits 0-7
(Refer to Wave Endpoint Lo.)

Wave Loop Length Lo   **address A**

Table Size   bits 0 and 1
(Wavetable Mode Oscillator only)
With wavetable synthesis, one or more complete periods of a waveform are stored in a wavetable. Table Size is the size of the wavetable. Interleave is the distance between wavetables. Normally Interleave Size will equal Table Size so that the wavetable will be contiguous. For compatibility with existing sound libraries, other interleaves are available.

00-64 Samples
01-128 Samples
10-256 Samples
11-512 Samples

ROM2-ROM7   bits 2-7
(Wavetable Mode Oscillator only)
For Wavetable Mode Oscillators, this should be 0.

ROM0-ROM7   bits 0-7
(Sample Loop Oscillator only)
A sample sequence is played by setting Wave Pointer to the first sample in the sequence and Wave Endpoint to the last sample in the sequence. For many sounds, we then repeat or loop the last portion of the sequence. Wave Loop Length is the length of the loop.

Wave Loop Length Hi   **address B**

ROM8-ROM15   bits 0-7
(Refer to Wave Loop Length Lo.)
For Wavetable Mode Oscillators, this should be 0.

OSCILLATOR PARAMETER BLOCKS (Continued)

Effects Send Control **address C**

Effects Attenuation(s) bits 0-5
These six bits control the amount of signal that will be sent to the selected Effects Channel (bits 6-7). Since the signal will be sent to two effects output channels if the Dual Effect Sends bit in the Control Byte is set, the Effects attenuation splits into two 3-bit attenuation values, with bits 0-2 as the attenuation for the channel selected by the Effects Channel, and bits 3-5 as the attenuation for the subsequent channel.

Effects Channel bits 6-7
These two bits are used to select one of four effects output channels. These output channels can be used internally by the Z89340, and they can also be sent to a DAC or CODEC. If the Dual Effect Sends bit in the Control Byte is set, the signal will be sent to two effects channels, the one selected here and the subsequent channel.

Envelope rate **address D**

When ATFP selects Amplitude, Filter, or Pan:

Envelope Rate bits 0-7
With Amplitude, the eight bits of Envelope Rate are an unsigned exponential representation of the slope between the amplitudes at the two envelope segment ends. This is the rate that defines how long it will take to reach the end amplitude, Amplitude Next. An interrupt is generated when the segment end is reached, at which time the host CPU will set up the next amplitude segment, supplying a new Amplitude Next value and Envelope rate. A similar procedure is followed when ATFP selects Filter or Pan.

When ATFP selects Tremolo:

Tremolo Rate bits 0-3
The four bits of Rate are an unsigned exponential number that give rates ranging from 0.1 to 10 Hz.

Tremolo Depth bits 4-7
These four bits specify depths of 1.5 to 24 decibels.

Amp/Filt/Pan Next **address E**

When ATFP selects Amplitude:

Amplitude Next bits 0-7
Amplitude is expressed in an unsigned logarithmic unit called a hexadecibel or "hexabel" for short. The upper four bits of the hexabel are a base-two exponent and the lower four bits form the mantissa. There are 256 hexabel steps in 96 decibels, so 2.667 hexabels = 1 decibel. At the initialization of a note, set Amplitude Now and Amplitude Next with the endpoints of an amplitude envelope segment. Also set the Envelope Rate. For subsequent amplitude en-velope segments, only set Amplitude Next and Envelope Rate, because Amplitude Now always equals Amplitude Next at the end of an envelope segment.

When ATFP selects Filter:

Filter Tuning Next bits 0-7
Filter Tuning Next works in a way similar to Amplitude Next. At the initialization of a filter envelop segment, set Filter Tuning value and Filter Tuning Next with the endpoints of the filter envelope segment. Also set the Envelope Rate.

When ATFP selects Pan:

Pan Angle Next bits 0-5
Pan Next works in a way similar to Amplitude Next or Filter Tuning Next, except that there are only six bits of pan position. At the initialization of a pan segment, set Polar Pan Angle and Pan Angle Next with the endpoints of the pan envelope segment. Also set the Envelope Rate.

Pan Direction bit 6
A 1 indicates counterclockwise rotation, and a 0 indicates clockwise rotation.

Pan Continuous Loop bit 7
If this bit is a 0, an interrupt is generated to let the host CPU know that the panning has completed. If this bit is set, pan continues around this circle indefinitely. No interrupt is generated when Pan Angle Next is reached.

Amplitude Now **address F bits 0-7**

(Refer to the previous discussion on Amplitude Next.) If ATFP amplitude envelopes are not being used, this will be the amplitude of the oscillator—a steady or sustained amplitude segment. Amplitude Now can be changed whenever desired; however, changing Amplitude Now more than 1 hexabel will usually cause a noticeable click. Even a 1 hexabel change will sometimes cause a click. To eliminate clicks or zipper noise, use the amplitude envelope system.

Polar Pan Control **address 10**

Polar Pan Angle bits 0-5
There are four main output channels. The spatial location among them is specified with a modified polar coordinate—a value of 16 is $\pi/2$ radians, 32 is π radians, 48 is $3\pi/2$ radians, and so on.

Polar Pan Radius bits 6-7
The radius select is a two-bit number with 2 at the edge of the circle and 0 near the center of the circle. A radius of 3 is reserved for stereo panning when only two output channels are needed. When the radius is 3, the following special values of Pan Polar Angle are defined:

0-f   stereo pan FRONT channels left to right.

20-2f   stereo pan REAR channels left to right.

3d   sent to one of 32 submix registers. The submix register is chosen with low five bits of the Effects Send Control. Submix registers can be selected as inputs by Tape Loop oscillators (an extended opcode).

3e   mute the oscillator. The oscillator continues to do everything else except connect to an output channel.

3f   sends output to all four output channels equally, effectively at the center of the circle.

Filter Tuning Value   **address 11**

                                 bits 0-7

This byte specifies what the coefficients of the second-order (two-pole, two-zero) digital filter should be in order to characterize the response. The filter Q can also be adjusted.

Vibrato Control   **address 12**

Vibrato Rate   bits 0-3
The four bits of Rate are an unsigned exponential number that give rates ranging from 0.1 to 10 Hz.

Vibrato Depth   bits 4-7
These four bits specify depths ranging from plus and minus a few cents to about two semitones.

Vibrato Phase
Accumulator   **address 13**

The vibrato value is derived from a sinewave represented by the 8-bit vibrato phase accumulator and is added to or subtracted from the frequency. The initial vibrato phase can be set by writing a value to the 8-bit vibrato phase accumulator—a value of 64 is $\pi/2$ radians, which would start the vibrato at maximum positive swing. If you want the vibrato to swing flat first, initialize the Vibrato Phase Accumulator to 128, corresponding to π radians, a zero crossing in the sinewave just before it swings negative.

Delay 1A   **address 14**
Delay 1B   **address 15**
Delay 2A   **address 16**
Delay 2B   **address 17**

Each oscillator has its own second-order (two-pole, two-zero) digital filter. At the initialization of an oscillator, these two delays should be given values of 0 unless a click is wanted. If desired, the oscillator audio stream can be examined or modified by accessing the delay registers.

Oscillator Parameter Block for the Tape Loop Oscillator

Control Byte   **address 0**

Filter Q   bits 0-3
Each oscillator has a variable filter. These bits allow adjustment of the filter Q. (Refer to Filter Tuning value for more information.)

Dual Effect Sends   bit 4
When this bit is set, the oscillator talks to two effect channel, so the effect channel chosen with Effect Channel in the Effect Send Control Byte, and the subsequent channel (wraps to effects channel 0 if the last channel is chosen). This system allows choosing two of the four effects channels at a time in all but two of the possible combinations.

Half-Speed   bit 5
Half-Speed: Oscillators 0 through 47 (0x2f) can each be split into two oscillators operating at half the clock rate. This yields 112 oscillators total ($2 \cdot 48 + 16$).

Oscillators 48 through 63 (0x30 through 0x3f) can only operate at the full clock rate since the parameter RAM that would be used as their half-speed counterparts is unavailable.

Oscillator-type   bits 6-7   11-extended
                                         opcode

These bits define the operating mode of the oscillator. Since Tape Loop is an extended opcode, both bits will be set to 1. For Tape Loop, set the upper four bits of Frequency Hi to 0000.

Frequency Low   **address 1**

Envelope-type ATFP   bits 0 and 1
Four types of envelope segments are supported, but only one at a time. Amplitude/Tremolo/Filter/Pan Envelope-type control bits.

00-Amplitude
01-Tremolo
10-Filter
11-Pan

Frequency Low   bits 2-7
Always 0 for Tape Loop.

Frequency Mid   **address 2**

                                 bits 0-7
Always 0 for Tape Loop.

OSCILLATOR PARAMETER BLOCKS (Continued)

Frequency Hi   **address 3**

Frequency Hi   bits 0-3
These are:
Extended Opcode   bits 4-7
With the Tape Loop Oscillator, the upper four bits of Frequency Hi are one of the extended opcodes and must be 0000.

Phase   **address 4**

Regeneration   bits 0-7
This value controls the amount of delayed signal that gets mixed back into the input of the delay line.

Wave Pointer Hi   **address 5**

ROM16-ROM23   bits 0-7
The eight bits of Wave Pointer Hi control wave ROM or RAM address lines 16-23, which are the highest address bits. This value remains fixed throughout the life of a note. The lower bits of Wave Pointer are changed by the Z89340 during the life of a sound until they equal Wave Endpoint.

ROM23/DMA   bit 7
If DMA bus-mastering mode is enabled, this bit enables DMA for the oscillator. The address then becomes an ISA Bus host CPU RAM address. DMA has system consequences and should be used with caution. In particular, fewer oscillators can be active at the same time. Tape Loops should not be used because of limitations of data transmission across the ISA Bus.

Wave Pointer Lo   **address 6**

ROM0-ROM7   bits 0-7
The eight bits of Wave Pointer Lo are part of the wave address that is modified by the oscillator through the life of the note as it steps from sample to sample, based on frequency, corresponding to ROM or RAM address bits 0-7. The upper bits of the wave ROM address are set at initialization and remain fixed (Wave Pointer Hi). Wave Pointer Lo points to a sample in ROM or RAM. (Refer to Phase and Wave Pointer Mid.) Wave Pointer Lo contains the lowest bits of the start address when a note is begun. Wave Pointer Lo and Wave Pointer Mid are changed by the Z89340 during the life of a sound until they equal Wave Endpoint.

Wave Pointer Mid   **address 7**

ROM8-ROM15   bits 0-7
The eight bits of Wave Pointer Mid point to a block of 256 samples. This 256 sample block can be considered a wavetable for use in wavetable synthesis. For sample-sequence playback, Wave Pointer Mid forms the upper eight bits of the 16-bit sample pointer; Wave Pointer Lo holds the lower eight bits. This allows sample sequences of up to 64K samples. Wave Pointer Mid contains eight bits of the start address when a note is begun. Wave Pointer Lo and Wave Pointer Mid are changed by the Z89340 during the life of a sound until they equal Wave Endpoint.

Wave Endpoint Lo   **address 8**

ATFP Flags   bits 0 and 1
These bits are active for the selected envelope types in Frequency Lo. The bits have a separate meaning for Tremolo from the other types.

Amplitude/Filter/Pan envelope flag bits:

00-Off
01-Wait
10-In process
11-Done

Tremolo envelope flag bits:

bit 0-Enable
bit 1-Polarity

ROM2-ROM7   bits 2-7
Wave Endpoint is the last sample in the delay line. When this last sample location is used, the Z89340 subtracts Wave Loop Length from the Wave Pointer. Note that since only six bits are available for Wave Endpoint Lo, the sample sequence can only end on every fourth address. Wave Loop Length does not have this restriction.

Wave Endpoint Hi   **address 9**

ROM8-ROM15   bits 0-7
(Refer to Wave Endpoint Lo.)

Wave Loop Length Lo   **address A**

Table Size   bits 0 and 1
(Wavetable Mode Oscillator only)
With wavetable synthesis, one or more complete periods of a waveform are stored in a wavetable. Table Size is the size of the wavetable. Interleave is the distance between wavetables. Normally Interleave Size will equal Table Size so that the wavetable will be contiguous. For compatibility with existing sound libraries, other interleaves are available.

00-64 Samples
01-128 Samples
10-256 Samples
11-512 Samples

ROM2-ROM7   bits 2-7
(Wavetable Mode Oscillator only)
For Wavetable Mode Oscillators this should be 0.

ROM0-ROM7   bits 0-7
(Sample Loop Oscillator only)
A sample sequence is played by setting Wave Pointer to
the first sample in the sequence and Wave Endpoint to the
last sample in the sequence. For many sounds, we then
repeat or loop the last portion of the sequence. Wave Loop
Length is the length of the loop.

Wave Loop Length Hi   address B

ROM8-ROM15   bits 0-7
(Refer to Wave Loop Length Lo.)
For Wavetable Mode Oscillators this should be 0.

Effects Send Control   address C

Effects Attenuation(s)   bits 0-5
These six bits control the amount of signal that will be sent
to the selected Effects Channel (bits 6-7). Since the signal
will be sent to two effects output channels if the Dual Effect
Sends bit in the Control Byte is set, the Effects attenuation
splits into two three-bit attenuation values, with bits 0-2 as
the attenuation for the channel selected by the Effects
Channel, and bits 3-5 as the attenuation for the subse-
quent channel.

Effects Channel   bits 6-7
These two bits are used to select one of four effects output
channels. These output channels can be used internally by
the Z89340, and they can also be sent to a DAC or CO-
DEC. If the Dual Effect Sends bit in the Control Byte is set,
the signal will be sent to two effects channels, the one se-
lected here and the subsequent channel.

Envelope rate   address D

When ATFP selects Amplitude, Filter, or Pan:

Envelope Rate   bits 0-7
With Amplitude, the eight bits of Envelope Rate are an un-
signed exponential representation of the slope between
the amplitudes at the two envelope segment ends. This is
the rate that defines how long it will take to reach the end
amplitude, Amplitude Next. An interrupt is generated when
the segment end is reached, at which time the host CPU
will set up the next amplitude segment, supplying a new
Amplitude Next value and Envelope rate. A similar proce-
dure is followed when ATFP selects Filter or Pan.

When ATFP selects Tremolo:

Tremolo Rate   bits 0-3
The four bits of Rate are an unsigned exponential number
that give rates ranging from 0.1 to 10 Hz.

Tremolo Depth   bits 4-7
These four bits specify depths of 1.5 to 24 decibels.

Amp/Filt/Pan Next   address E

When ATFP selects Amplitude:
Amplitude Next   bits 0-7
Amplitude is expressed in an unsigned logarithmic unit
called a hexadecibel or "hexabel" for short. The upper four
bits of the hexabel are a base-two exponent and the lower
four bits form the mantissa. There are 256 hexabel steps
in 96 decibels, so 2.667 hexabels = 1 decibel. At the initial-
ization of a note, set Amplitude Now and Amplitude Next
with the endpoints of an amplitude envelope segment.
Also set the Envelope Rate. For subsequent amplitude en-
velope segments, only set Amplitude Next and Envelope
Rate, because Amplitude Now always equals Amplitude
Next at the end of an envelope segment.

When ATFP selects Filter:

Filter Tuning Next   bits 0-7
Filter Tuning Next works in a way similar to Amplitude
Next.At the initialization of a filter envelop segment, set Fil-
ter Tuning value and Filter Tuning Next with the endpoints
of the filter envelope segment. Also set the Envelope Rate.

When ATFP selects Pan:

Pan Angle Next   bits 0-5
Pan Next works in a way similar to Amplitude Next or Filter
Tuning Next, except that there are only six bits of pan po-
sition. At the initialization of a pan segment, set Polar Pan
Angle and Pan Angle Next with the endpoints of the pan
envelope segment. Also set the Envelope Rate.

Pan Direction   bit 6
A 1 indicates counterclockwise rotation, and a 0 indicates
clockwise rotation.

Pan Continuous Loop   bit 7
If this bit is a 0, an interrupt is generated to let the host CPU
know that the panning has completed. If this bit is set, pan
continues around this circle indefinitely. No interrupt is
generated when Pan Angle Next is reached.

Amplitude Now   address F

                                  bits 0-7
(Refer to the previous discussion on Amplitude Next.)
If ATFP amplitude envelopes are not being used, this will
be the amplitude of the oscillator—a steady or sustained
amplitude segment. Amplitude Now can be changed
whenever desired; however, changing Amplitude Now
more than 1 hexabel will usually cause a noticeable click.
Even a 1 hexabel change will sometimes cause a click. To
eliminate clicks or zipper noise, use the amplitude enve-
lope system.

OSCILLATOR PARAMETER BLOCKS (Continued)

Polar Pan Control   **address 10**

Polar Pan Angle   bits 0-5
There are four main output channels. The spatial location among them is specified with a modified polar coordinate—a value of 16 is $\pi/2$ radians, 32 is π radians, 48 is $3\pi/2$ radians, and so on.

Polar Pan Radius   bits 6-7
The radius select is a two-bit number with 2 at the edge of the circle and 0 near the center of the circle. A radius of 3 is reserved for stereo panning when only two output channels are needed. When the radius is 3, the following special values of Pan Polar Angle are defined:

0-f   stereo pan FRONT channels left to right.

20-2f   stereo pan REAR channels left to right.

3d   instead of sending to the output channels, output is sent to one of 32 submix registers. The submix register is chosen with low five bits of the Effects Send Control. Submix registers can be selected as inputs by Tape Loop oscillators (an extended opcode).

3e   mute the oscillator. The oscillator continues to do everything else except connect to an output channel.

3f   sends output to all four output channels equally, effectively at the center of the circle.

Filter Tuning Value   **address 11**

                              bits 0-7
This byte specifies what the coefficients of the second-order (two-pole, two-zero) digital filter should be in order to characterize the response. The filter Q can also be adjusted.

Vibrato Control   **address 12**

Vibrato Rate   bits 0-3
The four bits of Rate are an unsigned exponential number that give rates ranging from 0.1 to 10 Hz.

Vibrato Depth   bits 4-6
These three bits specify depths ranging from plus and minus a few cents to about 1 semitone.

Clear Submix   bit 7
Set this bit when this oscillator should clear the submix register before placing an output value in it.

Vibrato Phase
Accumulator   **address 13**

The vibrato value is derived from a sinewave represented by the 8-bit Vibrato Phase Accumulator, and is added to or subtracted from the frequency. The initial vibrato phase can be set by writing a value to the 8-bit Vibrato Phase Accumulator—a value of 64 is $\pi/2$ radians, which would start the vibrato at maximum positive swing. If you want the vibrato to swing flat first, initialize the vibrato phase accumulator to 128 corresponding to π radians, a zero crossing in the sinewave just before it swings negative.

Delay 1A   **address 14**
Delay 1B   **address 15**
Delay 2A   **address 16**
Delay 2B   **address 17**

Each oscillator has its own second-order (two-pole, two-zero) digital filter. At the initialization of an oscillator, these two delays should be given values of 0 unless a click is wanted. If desired, the oscillator audio stream can be examined or modified by accessing the delay registers.

PACKAGE INFORMATION
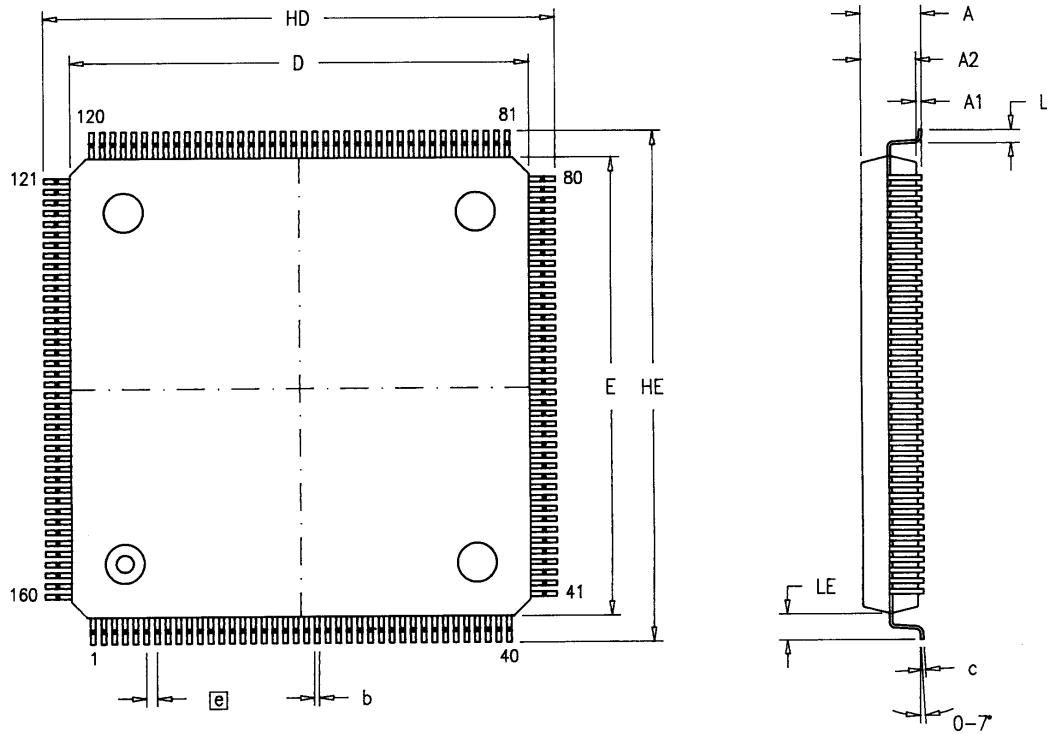
1. CONTROLLING DIMENSIONS : mm
2. MAX. COPLANARITY   : 10mm
                             0.004"

SYMBOL	MILLIMETER		INCH	
	MIN	MAX	MIN	MAX
A	–	4.07	–	0.160
A1	0.25	–	0.010	–
A2	3.17	3.67	0.125	0.144
b	0.23	0.38	0.009	0.015
c	0.13	0.23	.005	.009
HD	30.95	31.45	1.219	1.238
D	27.90	28.10	1.098	1.106
HE	30.95	31.45	1.219	1.238
E	27.90	28.10	1.098	1.106
e	0.65 TYP		.0256 TYP	
L	0.65	0.95	0.026	0.037
LE	1.60 REF		0.063	

160-Pin QFP Package Diagram

ORDERING INFORMATION

Z89340

50 MHz
160-Pin QFP
Z8934050FSC

For fast results, contact your local Zilog sales office for assistance in ordering the part desired.

Package
F = Quad Flat Pack (QFP)

Temperature
S = 0°C to +70°C

Speed
50 = 50 MHz

Environmental
C = Plastic Standard

Example:
Z 889340 50 F S C   is a Z89340, 50 MHz, QFP, 0°C to +70°C, Plastic Standard Flow

Environmental Flow
Temperature
Package
Speed
Product Number
Zilog Prefix