Features

- **16 Tracks (up to 64 Voices)**
- **4-bit ADPCM, 8-/16-bit PCM, MIDI Format**
- **Up to 256 Mbits of External Memory**
- **8 kHz to 48 kHz Sampling Rate**
- **Reverb, Chorus, EQ, 3D**
- **2-/4-speaker Output**
- **Flash Download Capability**
- **RS-232 Serial Interface**
- **144-lead TQFP Package**
- **Evaluation Board and Development Tools**

Description

The SAM9723 is a powerful sound processor that plays 16 tracks simultaneously. Each track can play either a PCM/ADPCM sample or a musical sequence (MIDI) performed in real time by the DSP. The formats PCM/ADPCM/MIDI provide the best compression ratio for mixed musical and speech applications. The effect unit (EQ, Reverb, Chorus, 3D) adds realism and depth to the sound.

Thanks to the high-level integration (built-in DSP, processor and RAM), the SAM9723 requires only two external components (DAC and ROM/Flash) for a complete hardware configuration. Quick time-to-market is ensured by the easy control protocol for host and the development tools (software and evaluation board).

A typical application is gaming equipment.

Figure 1. SAM9723 Block Diagram

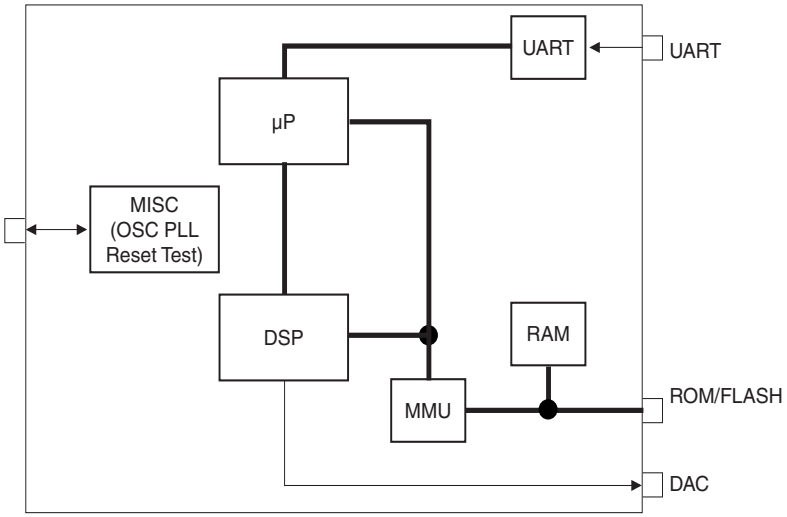
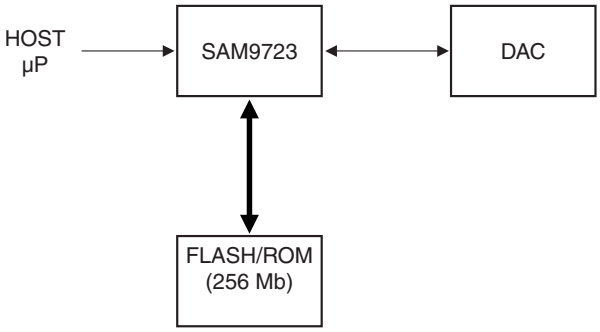


Figure 2. Typical Hardware Configuration



ADPCM & MIDI Player

SAM9723

Rev. 1713A–03/01

Pin Description

Pins by Function

Table 1. Power Supply Pins

Pin Name	Type	Function
GND	PWR	Digital ground All pins should be connected to a ground plane.
VCC[1]	PWR	Power supply, 5V ± 10% All pins should be connected to a VCC plane.
VC3	PWR	Core power, 3.3V nominal (3.3V ± 10%). All VC3 pins should be returned to 3.3V.

Note: 1. Like all high-speed HCMOS ICs, proper decoupling is mandatory for reliable operation and RFI reduction. The recommended decoupling is 100 nF at each corner of the IC with an additional 10 µFT bulk capacitor close to the X1, X2 pins.

Table 2. Serial MIDI Pins

Pin Name	Type	Function
MIDIIN	IN	Serial MIDI IN
MIDIOUT	OUT	Serial MIDI OUT

Table 3. External PCM RAM/ROM/IO Pins

Pin Name	Type	Function
WA[23:0]	OUT	External memory I/O address Up to 16M x 16 for direct ROM/RAM connection
WD[15:0]	I/O	External memory I/O data Data is read (input) when $\overline{RD}$ is low, written (output) when $\overline{WR}$ is low.
$\overline{RD}$	OUT	External ROM/RAM/Peripheral read
$\overline{WR}$	OUT	External RAM/Peripheral write
$\overline{CS0}$ - $\overline{CS1}$	OUT	Programmable chip select Can be configured to handle several ROMs or mixed RAM/ROM/Flash.
$\overline{XIO0}$ - $\overline{XIO1}$	OUT	External peripheral chip select Each peripheral maps into 4K bytes of address space for optional further decoding.

Table 4. Digital Audio Group

Pin Name	Type	Function
DACLK	OUT	Master clock for S/delta DAC (256 x Fs)
DABD[1:0]	OUT	Serial data for two stereo output channels
DAAD	IN	Serial data for one stereo input channel
CLBD	OUT	Digital audio bit clock
WSBD	OUT	Digital audio left/right select

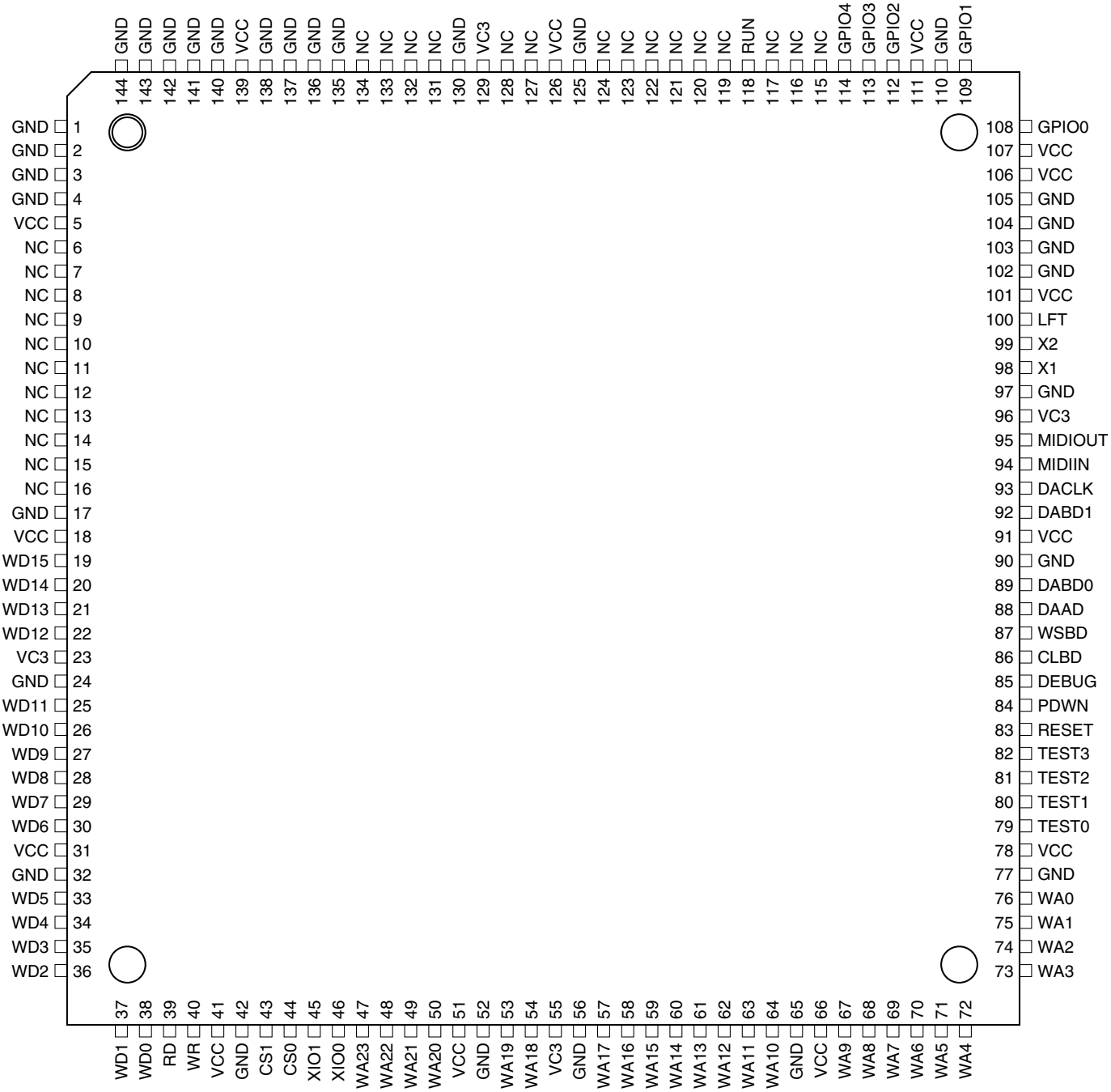
Note: The SAM9723 connects to a variety of stereo DACs or codecs from 16 to 20 bits with Japanese or I2S format. This includes AD1857JRS, PCM1718, PCM3001, TDA1305, TDA1543, TDA1545 and TDA1311. When Japanese format is used, only 16-bit format is supported without external circuitry.

Table 5. Miscellaneous Group Pins

Pin Name	Type	Function
GPIO[4:0]	I/O	These pins can be individually used as general-purpose I/Os.
$\overline{\text{DEBUG}}$	IN	Configuration pin Low for codeview debugging. Should be tied to V_{CC} for normal operation.
$\overline{\text{RESET}}$	IN	Reset input Active low. This is a Schmitt trigger input, allowing direct connection of an RC network.
RUN	OUT	Indicates that the DSP is up and running. Can be used as external DAC reset.
$\overline{\text{PDWN}}$	IN	Power-down Active low. When power-down is active, all output pins will be floating except GPIO1. The crystal oscillator will be stopped. To exit from power-down mode, $\overline{\text{PDWN}}$ should be high and $\overline{\text{RESET}}$ applied.
X1 - X2	IN	11.2896 MHz (nominal) crystal connection An external clock can also be used at X1.
TEST[1:0]	IN	Test pins Should be grounded.
LFT	–	PLL external RC network

Pinout

Figure 3. SAM9723 in 144-lead PQFP Package



Functional Description

Musical Instrument Digital Interface (MIDI)

MIDI defines the standard used by all electronic instruments. MIDI specifies:

- a hardware interface (UART operating at 31.25K baud)
- the format of the data exchanged (the 9753 MIDI ADPCM uses a more simplified and compact format inspired by the MIDI)
- a list of 128 instruments (G for General MIDI) that ensures that any MIDI sequence will sound the same on any MIDI synthesizer. To “sound the same” means that the guitar track will play the nylon guitar and not the muted trumpet. Nonetheless, each synthesizer has its own nylon guitar sound.
- a format for musical sequence: Standard MIDI files, where *.mid is the extension for files on the PC. The SAM9753 sequences are developed as standard MIDI files and compressed to save space on ROM/Flash.

ADPCM and MIDI Overview

From the user’s point of view, the DSP provides 16 tracks that can be assumed to be 16 individual players. For each track, the user selects the program (data in ADPCM4, PCM8, PCM16 or MIDI sequence), plays, pauses or stops the track. The user can also set the volume, the pan and the reverb amount.

Each voice reads the data from the external ROM or Flash (up to 32 Mbits) in either 4-bit ADPCM, 8-bit PCM or 16-bit PCM formats. The nominal frequency of the output DAC is 44.1 kHz. The PCM data can be stored in any sampling rate from 8 kHz to 48 kHz. The playback algorithm performs linear interpolation to adjust the sampling rate to 44.1 kHz. The source samples for ADPCM data can range from 8 kHz to 48 kHz. ADPCM data are converted and stored in memory at a 22.05 kHz sampling rate. Each track plays a sample among 6 (bank) • 128 (program). Banks 0 to 3 include ADPCM programs; banks 4 and 5 include MIDI sequences.

The data stored in the external ROM/Flash includes:

- program list
- ADPCM programs: parameter (type, size, loop, default volume and pan) and data
- sound bank for MIDI program (parameter and PCM data)
- MIDI sequence (compressed MIDI files)

The host processor controls the voices using a compact and efficient protocol to select the bank or program, modify the parameters, play and stop. ADPCM or MIDI tracks are controlled in the same way.

Polyphony

Polyphony is the number of notes that can be played simultaneously. The basic unit that uses polyphony is the “voice”. The built-in DSP in the SAM9723 can play 64 voices. Maximum polyphony for a MIDI player without negative effects is 64. The ADPCM4/PCM8/PCM16 track player works like a basic generator (e.g., a CD player). Each track plays only one note (ADPCM or PCM stream).

The MIDI track player is more complex in that it is a sequencer that controls many basic generators.

The basic generator requires one or two voices, depending on whether the format is MIDI or ADPCM/PCM. 64 voices are shared by the track players and the effect unit.

Table 6. Units and Voices

Unit	Voices
ADPCM/PCM Player	2
MIDI Player	1 per MIDI note 2 per ADPCM note
Reverb	13
Chorus	3
3D Spatializer	2
2-band EQ	4
4-band EQ	8

Table 7. Polyphony Examples

Configuration	Player Voices	Polyphony
ADPCM/PCM Player + Full Effect	38	16 (max. track)
MIDI Player + Full Effect	38	38
15 ADPCM Players + MIDI Player + Reverb, Chorus	48	15 ADPCMs, 18 MIDIs
2 ADPCM Players + MIDI Player (1 note ADPCM + other note MIDI) + Reverb, Chorus, 2-band EQ	44	2 ADPCMs, 39 MIDIs (1-note ADPCM + 38-note MIDI)

DSP Mixer and Effect Unit

The 16-track players are connected to a 16/4 mixer (16 mono inputs, 2 stereo outputs). Each mono input provides the following control:

- Volume
- Pan
- Output select (front or rear)
- Reverb send
- Chorus send

The reverb unit and the chorus unit stereo outputs are down-mixed into the front and the rear buses. The spatializer enhances the stereo image on the front or rear bus. The stereo equalizer processes the front bus.

Host Interface

The host microprocessor is connected to the SAM9723 with a single wire serial link RXD. The UART interface operates at 57.6K baud, start bit (0), 8-bit data (LSB first) and a stop bit (1). The host sends 7-bit commands (MSB = 1) or 7-bit data (MSB = 0). All messages include one command followed by 0-to-2 data items.

Figure 4. Effect Unit Block Diagram

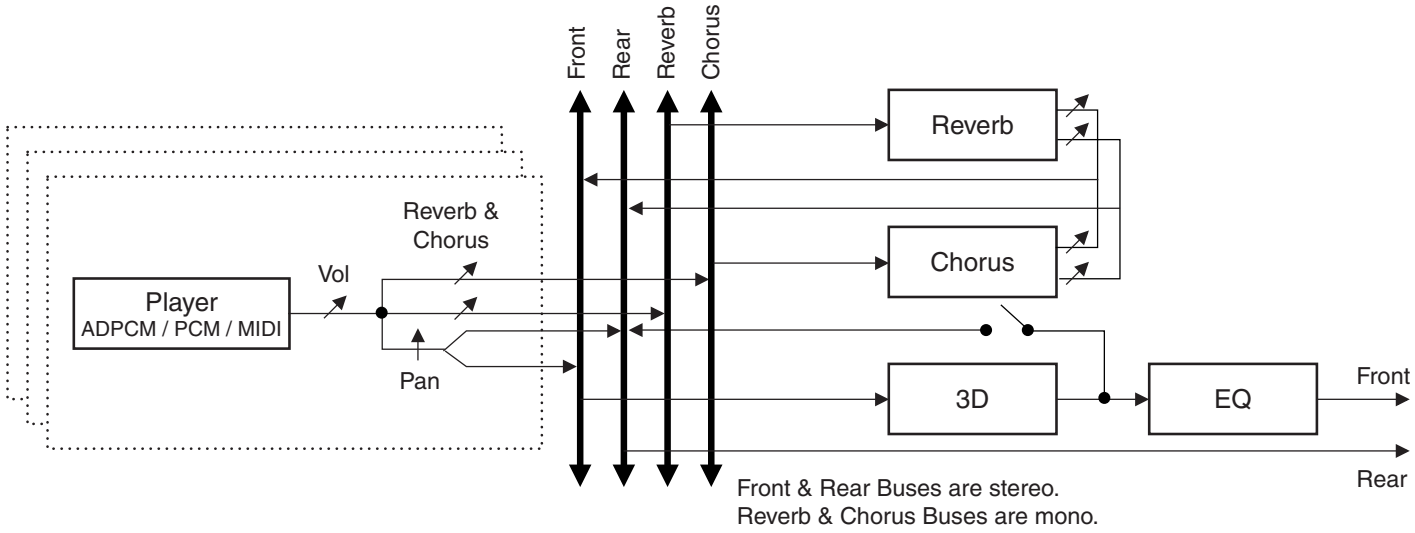


Table 8. Command Format

7	6	5	4	3	2	1	0	Hex	Data	Comment
1	0	0	0	v	v	v	v	80 - 8F		Plays voice vvvv
1	0	0	1	v	v	v	v	90 - 9F		Stops voice vvvv
1	0	1	0	v	v	v	v	A0 - AF	Program Number	Selects voice program (0 to 7FH)
1	0	1	1	v	v	v	v	B0 - AF	Bank Number	Selects voice bank (0 to 5)
1	1	0	0	v	v	v	v	C0 - CF	Volume	Sets voice volume (0 to 7FH)
1	1	0	1	v	v	v	v	D0 - DF	Pan	Sets voice pan (0 left, 40H center, 7FH right)
1	1	1	0	v	v	v	v	E0 - EF	Ctrl Number + data	Extends voice control (see Table 9)
1	1	1	1	0	x	x	x	F0 - F7	Ctrl Number + data	Effects control (see Table 10)
1	1	1	1	1	0	0	1	F9		Tests hardware (generates a sine wave when test OK)
1	1	1	1	1	0	1	0	FA	(see note)	Flash Programming
1	1	1	1	1	0	1	1	FB	Volume	Master volume (0 to 7FH)
1	1	1	1	1	1	0	0	FC		Pauses all voices
1	1	1	1	1	1	0	1	FD		Resumes all voices
1	1	1	1	1	1	1	0	FE		Stops all voices
1	1	1	1	1	1	1	1	FF		Reset (stops all voices & resets all parameters)

Note: Data for Flash programming: all data items are 8 bits long (no more MSB = 0).
- 4-byte address (32-bit address, low byte first)
- 2-byte count (16-bit count, low byte first). Maximum block size is 64K.
- 2n bytes of data (low byte first)
- 2-byte checksum (low byte first). An invalid checksum can be checked with the F9 command (hardware test).

Table 9. Voice Control Number

7	6	5	4	3	2	1	0	Hex	Data	Comment
0	0	0	0	0	0	0	0	00		Pauses voice
0	0	0	0	0	0	0	1	01		Resumes voice from pause
0	0	0	0	0	0	1	0	02		Loop on (loop from end to start)
0	0	0	0	0	0	1	1	03		Loop off
0	0	0	0	0	1	0	0	04		Output to front speakers (default)
0	0	0	0	0	1	0	1	05		Output to rear speakers
0	0	0	0	0	1	1	0	06	Volume	“Send to Chorus” volume (0 to 7FH)
0	0	0	0	0	1	1	1	07	Volume	“Send to Reverb” volume (0 to 7FH)

Table 10. Effects Control Number

7	6	5	4	3	2	1	0	Hex	Data	Comment	Notes
0	0	0	0	0	0	0	0	00		Remove EQ	1
0	0	0	0	0	0	0	1	01	Preset Number	EQ preset (0 to 7)	
0	0	0	0	0	1	1	0	02	Level	Bass level	2
0	0	0	0	0	1	1	1	03	Level	Med-low band level	2
0	0	0	0	0	1	1	0	04	Level	Med-high band level	2
0	0	0	0	0	1	1	0	05	Level	Treble level	2
0	0	0	1	0	0	0	0	10		Remove chorus	1
0	0	0	1	0	0	0	1	11	Preset Number	Chorus preset (0 to 7)	
0	0	0	1	0	0	1	0	12	Volume	Chorus front volume	3
0	0	0	1	0	0	1	1	13	Volume	Chorus rear volume	3
0	0	0	1	0	1	0	0	14	Delay	Chorus delay	3
0	0	0	1	0	1	0	1	15	Feedback	Chorus feedback	3
0	0	0	1	0	1	1	0	16	Rate	Chorus rate	3
0	0	0	1	0	1	1	1	17	Depth	Chorus depth	3
0	0	1	0	0	0	0	0	20		Remove reverb	1
0	0	1	0	0	0	0	1	21	Preset Number	Reverb preset (0 to 7)	
0	0	1	0	0	0	1	0	22	Volume	Reverb front volume	3
0	0	1	0	0	0	1	1	23	Volume	Reverb rear volume	3
0	0	1	0	0	1	0	0	24	Time	Reverb time	3
0	0	1	0	0	1	0	1	25	Feedback	Reverb feedback	3
0	0	1	1	0	0	0	0	30		Remove spatializer	1
0	0	1	1	0	0	0	1	31	Preset Number	Spatializer preset (0 to 7)	
0	0	1	1	0	0	1	0	32	Volume	Spatializer volume	3
0	0	1	1	0	0	1	1	33	Delay	Spatializer delay	3

Notes:
1. All effects can be removed using x0H control. Removing effects frees voices for polyphony.
2. EQ level range from -12 dB to +12 dB: 0 = -12 dB, 40H = 0 dB, 7FH = +12 dB. These parameters are optional. They are automatically set by the preset.
3. These parameters are optional. They are automatically set by the preset.

Absolute Maximum Ratings

Table 11. Absolute Maximum Ratings

Symbol	Parameter/Condition	Min	Typ	Max	Unit
V_{CC}	Supply Voltage	-0.5		6.5	V
V_{C3}	Supply Voltage	-0.5		4.5	V
	Voltage on All Inputs (except X1)	-0.5		V_{CC} + 0.5	V
X1	Voltage on X1 Pin			V_{C3} + 0.5	V
T_A	Operating Temperature	-40		85	°C
	Storage Temperature	-65		150	°C
	I_{OL} per I/O Pin			10	mA

DC Characteristics

Table 12. DC Characteristics (0°C ≤ T_A ≤ 70°C; V_{CC} = +5V ± 0.5V, V_{C3} = +3.3V ± 0.3V

Symbol	Parameter/Condition	V_{CC}	Min	Typ	Max	Unit
V_{CC}	Supply Voltage (I/O)	 	3 4.5	3.3 5	3.6 5.5	V V
V_{C3}	Supply Voltage (Core)		3	3.3	3.6	V
V_{IH}	Input High-level Voltage	3.3 5	2.3 3.3		V_{CC}+ 0.5 V_{CC}+ 0.5	V V
V_{IL}	Input Low-level Voltage	3.3 5	-0.5 -0.5		1.0 1.7	V V
V_{OH}	Output High-level Voltage (I_{OH} = -0.8 mA)	3.3 5	2.8 4.5			V V
V_{OL}	Output Low-level Voltage (I_{OL} = 3.2 mA)	3.3 5			0.45 0.45	V V
I_{CC}	Power Supply Current[1]	3.3 5		45 20	60 30	mA mA
–	Power-down Supply Current			100	150	µA

Note: 1. Crystal frequency = 11.2896 MHz

External ROM/RAM/IO

Figure 5. External ROM/RAM/IO Read/Write Cycle

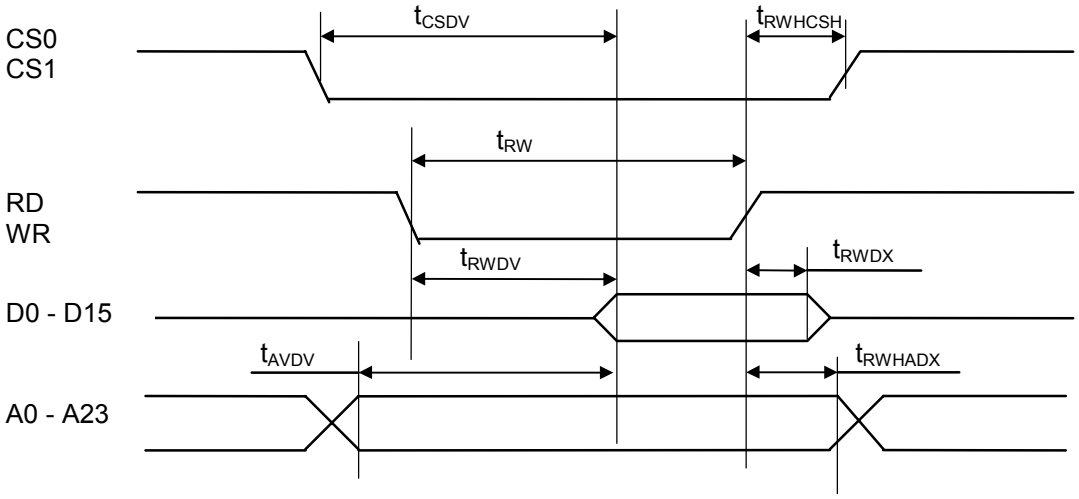
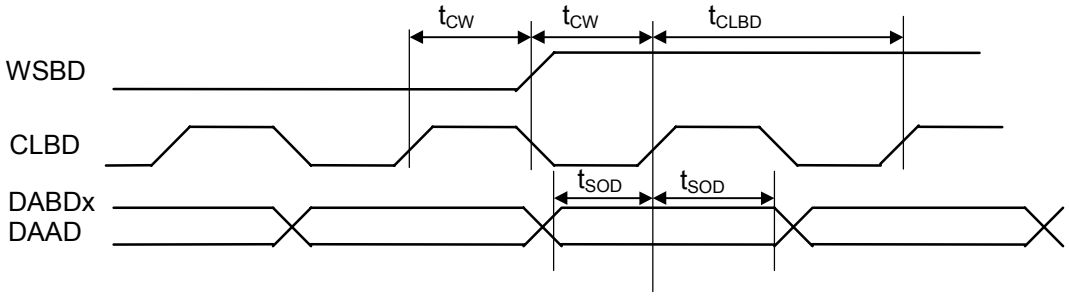


Table 13. Timing Parameters

Symbol	Parameter	Min	Typ	Max	Unit
t_{CSDV}	Access Time from $\overline{CSx}$ Low				ns
t_{RWDV}	Access Time from $\overline{RD}$, $\overline{WR}$ Low				ns
t_{AVDV}	Access Time from Address Valid				ns
t_{RW}	$\overline{RD}$, $\overline{WR}$ Pulse Width				ns
t_{RWHCSH}	$\overline{CSx}$ High from Rising $\overline{RD}$ or $\overline{WR}$				ns
t_{RWHADX}	Address Valid after Rising $\overline{RD}$ or $\overline{WR}$				ns
t_{RWDX}	Data Hold Time from Rising $\overline{RD}$ or $\overline{WR}$				ns

Digital Audio

Figure 6. Digital Audio Timing



Digital Audio Frame

Figure 7. Digital Audio Frame Format

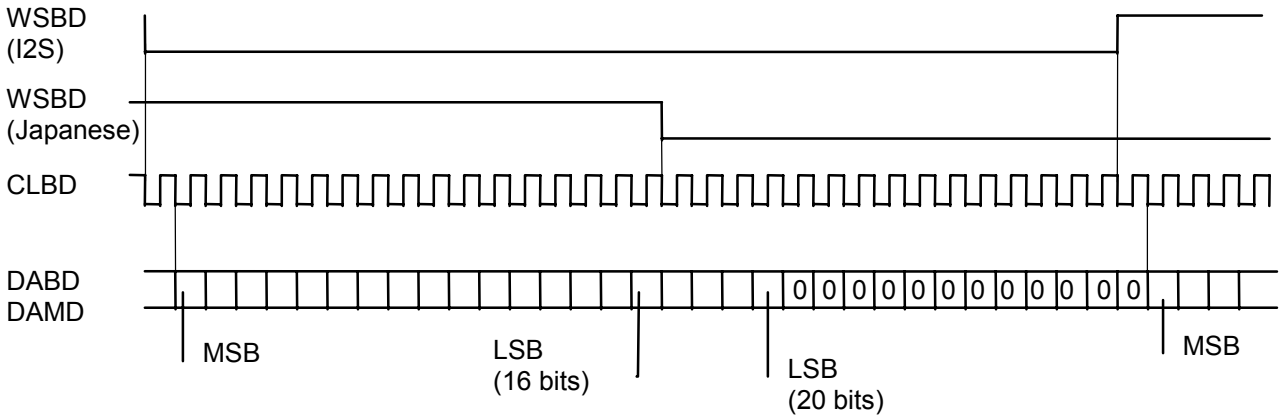


Table 14. Timing Parameters

Symbol	Parameter	Min	Typ	Max	Unit
t_{CW}	CLBD Rising to WSBD Change				ns
t_{SOD}	DABDx Valid prior to/after CLBD rising				ns
t_{CLBD}	CLBD Cycle Time				ns

Mechanical Dimensions

Figure 8. 144-lead Plastic Lead Quad Flat Pack

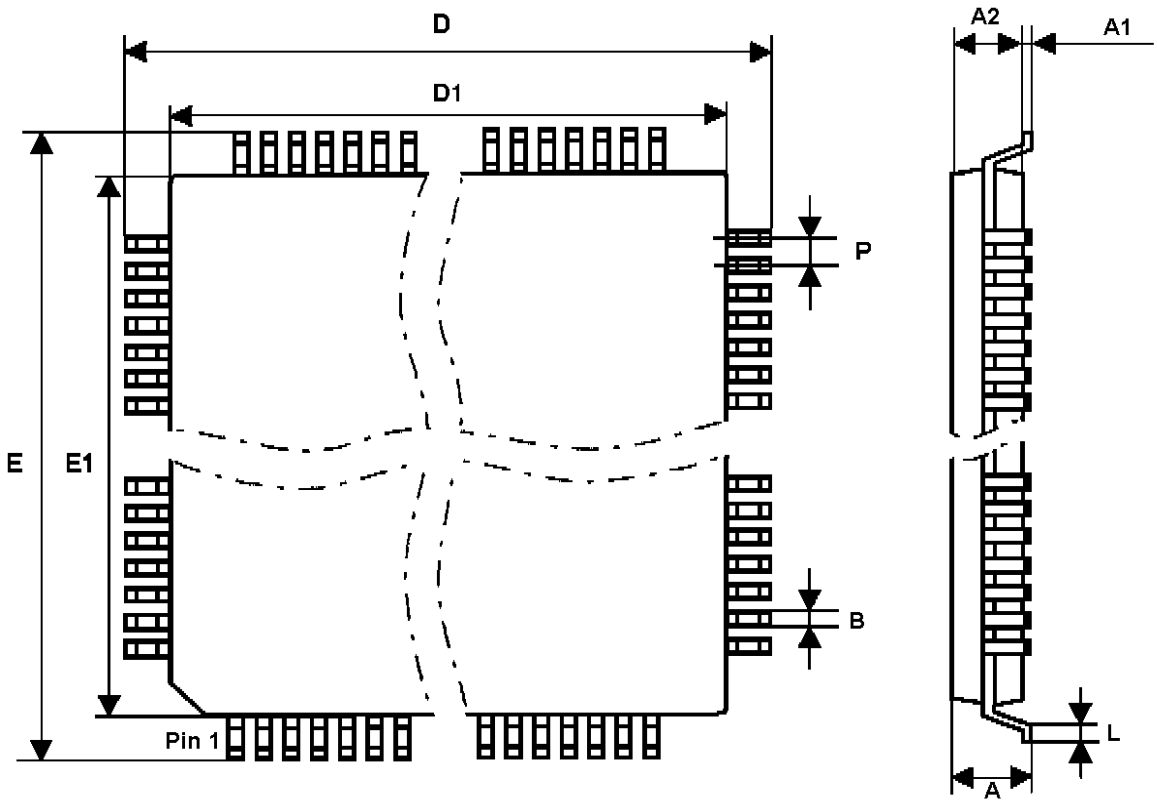


Table 15. Package Dimensions

Dimension	Min	Typ	Max
A			4.07
A1	0.25		
A2	3.17	3.42	3.67
D		31.9	
D1		28	
E		31.9	
E1		28	
L	0.65	0.88	1.03
P		0.65	
B	0.22		0.38

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