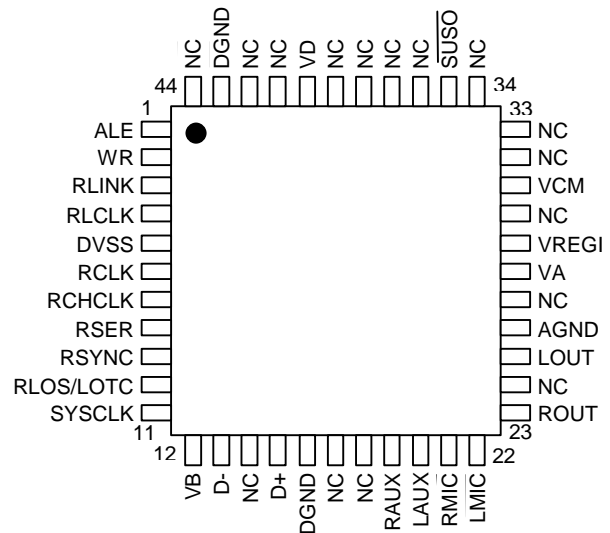# DALLAS SEMICONDUCTOR

DS4201
USB Audio DAC

FEATURES

- Fully USB Core Class v1.0 Compliant
- Fully USB Audio Device Class v1.0 Compliant
- Complete Stereo DAC System
- 16–bit ΣΔ DAC
- Analog Post Filter
- 44.1 KHz, 48 KHz Sampling Rates
- >80 dB S/N DAC Performance
- Audio System Power Management
- 8 and 16–Bit PCM Digital Data Formats
- Integrated USB Compliant Transceiver
- High Rate 12 Mbps USB Interface
- Analog Output Mixing for Auxiliary Inputs
- Multiple Power Configurations Including Completely USB Powered
- 3.3V – 5.0V Operating Range

PIN ASSIGNMENT

VD	1	28	NC
NC	2	27	NC
NC	3	26	NC
DGND	4	25	SUSO
SPM	5	24	VCM
X2I	6	23	VREFI
X2O	7	22	VA
DGND	8	21	AGND
X1I	9	20	LOUT
X1O	10	19	ROUT
VB	11	18	LMIC
D-	12	17	RMIC
D+	13	16	LAUX
DGND	14	15	RAUX

28-PIN DIP 600 MIL

Top pins (44→34): NC, DGND, NC, NC, VD, NC, NC, NC, SUSO, NC

Left pins (1→11): ALE, WR, RLINK, RLCLK, DVSS, RCLK, RCHCLK, RSER, RSYNC, RLOS/LOTC, SYSCLK

Right pins (33→23): NC, NC, VCM, NC, VREGI, VA, NC, AGND, LOUT, NC, ROUT

Bottom pins (12→22): VB, D-, NC, D+, DGND, NC, NC, RAUX, LAUX, RMIC, LMIC

44-PIN QFP (10mm x 10mm)

ORDERING INFORMATION

Part Number	Description
DS4201	28-pin DIP
DS4201F	44-pin QFP

DESCRIPTION

The DS4201 Universal Serial Bus (USB) audio device is a complete interface solution for USB based PC digital audio playback. Integrating a USB device core, stereo 16–bit sigma–delta DAC and fixed function DSP processing, as shown in Figure 1, the DS4201 is designed specifically for USB digital speaker implementations. Digital–to–analog audio data processing supports 8 and 16–bit PCM stereo/mono formats at 44.1 KHz and 48.0 KHz sampling rates. Additionally, analog output mixing of line and microphone inputs provide legacy and hybrid speaker capabilities.

102099

The DS4201 USB function core fully complies with both the USB Specification v1.0 and the USB Device Class Definition for Audio Devices v1.0. To complete the USB capability of the DS4201, a USB compliant transceiver is integrated to eliminate the need for any additional support chips. Organization of the DS4201 in an USB context is shown in Figure 2. For the USB enabled PC, the DS4201 is an ideal digital output solution for high quality audio and control within the speaker or monitor enclosure. Its USB control and capabilities as well as its high quality audio characteristics also comply with next generation PC system and audio standards put forth by industry leaders.

RELATED DOCUMENTS

This data sheet references or complies with the following USB specifications which are considered to be part of the DS4201 device specification. These documents may be obtained from the USB Implementers Forum web site: www.usb.org.

Universal Serial Bus Specification
Universal Serial Bus Device Class Definition for Audio Devices

FUNCTIONAL BLOCK DIAGRAM Figure 1
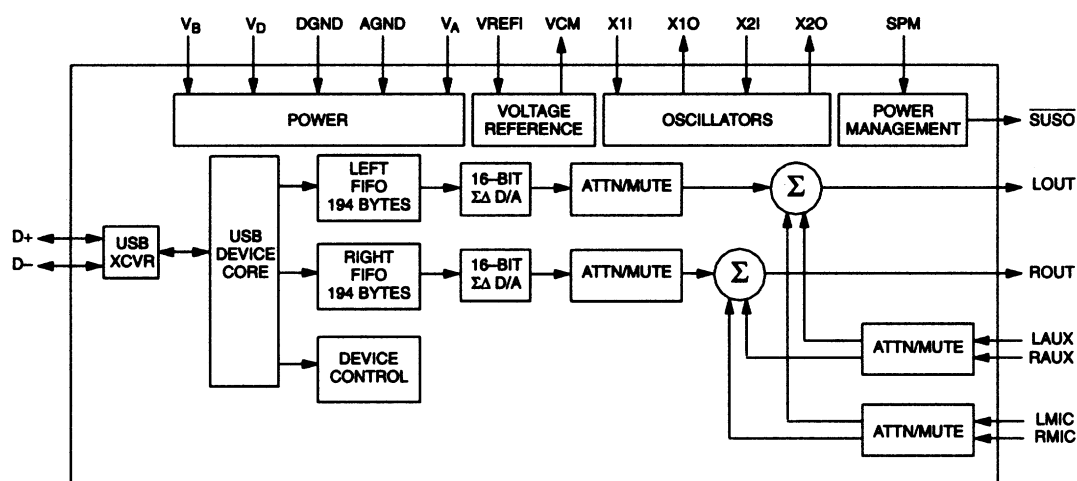
SIGNAL SUMMARY

SIGNAL NAME	TYPE	FUNCTION
D+	I/O	USB data – non-inverted signal of differential data pair.
D-	I/O	USB data – inverted signal of differential data pair.
SPM	I	Suspend Power Mode – controls device power configuration when a USB suspend state is entered.
$\overline{SUSO}$	O	Suspend Output – buffered USB suspend state output from USB device core. When HIGH the USB is in an active non-suspended state, when LOW the USB has entered a suspended state. This is an open drain output and requires a pull-up.
RMIC	I	Microphone right channel analog input to the analog output mixer.
LMIC	I	Microphone left channel analog input to the analog output mixer.

SIGNAL NAME	TYPE	FUNCTION
RAUX	I	Auxiliary right channel analog input to the analog output mixer.
LAUX	I	Auxiliary left channel analog input to the analog output mixer.
ROUT	O	Right channel analog audio output from the mixer, 0.5 V_{RMS} or 1.0 V_{RMS} centered about $V_{REF.}$
LOUT	O	Left channel analog audio output from the mixer, 0.5 V_{RMS} or 1.0 V_{RMS} centered about $V_{REF.}$
VCM	O	DC bias point to which all AC coupled inputs are centered. Nominally $V_{REF} = 0.4$ x VA.
VREFI	I	Filter capacitor connection for internal voltage reference node. Connect a 10µF and 0.1µF capacitor to V_{REFI}, very close to the pin, for best operation.
VA	I	Power supply input for analog functions. Range: 3.0 – 5.5V.
VD	I	Power supply input for digital functions. Range: 3.0 – 5.5V.
VB	I	USB I/F power supply input. Range: 3.0 – 3.6V.
DGND	I	Digital ground.
AGND	I	Analog ground.
X1I	I	Crystal 1 input. Use a 12.0 MHz, fundamental mode, parallel resonant crystal. A 12.0 MHz CMOS clock source may also be used.
X10	O	Crystal 1 output. Connect to other side of crystal 1 if used.
X2I	I	Crystal 2 input. Use a 12.888 MHz, fundamental mode, parallel resonant crystal. A 12.288 MHz CMOS clock source may also be used.
X2O	O	Crystal 2 output. Connect to other side of crystal 2 if used.
NC		No connect. Leave these pins unconnected.

DS4201 OPERATION

Operation of the DS4201 is described per the block diagram of Figure 2 and is divided into six sections:
- USB DEVICE
- USB TRANSCEIVER
- VOLTAGE REFERENCE
- ANALOG I/O
- POWER CONTROL
- OSCILLATORS

The following sections provide details regarding the operation of each of these elements. Additionally, APPENDIX C provides recommended connection information.

USB defined descriptors are passed to the host from the DS4201; these are used to communicate what capabilities and features are supported by the DS4201 as well as device characteristics. Contact Dallas Semiconductor for additional device descriptor documentation.

USB DEVICE OPERATION

As shown in Figure 1 and Figure 2, within the USB Device block resides the sigma–delta D/A converter for audio data playback, level adjustments for the D/A, microphone, and auxiliary signal paths, and mixing of the three signal channels to a single line output channel. Organization and control of these elements as well as the interface to the host controller in an USB Audio Device Class (ADC) framework is shown in Figure 3. This structure provides all the capabilities for the host system to communicate with and operate the various features within the DS4201. As shown in Figure 3, theDS4201 USB device structure will consist of one default device configuration, one AUDIO CONTROL interface, and one AUDIO STREAMING interface. The details of these interfaces are provided in the following paragraphs.

OPERATIONAL BLOCK DIAGRAM Figure 2
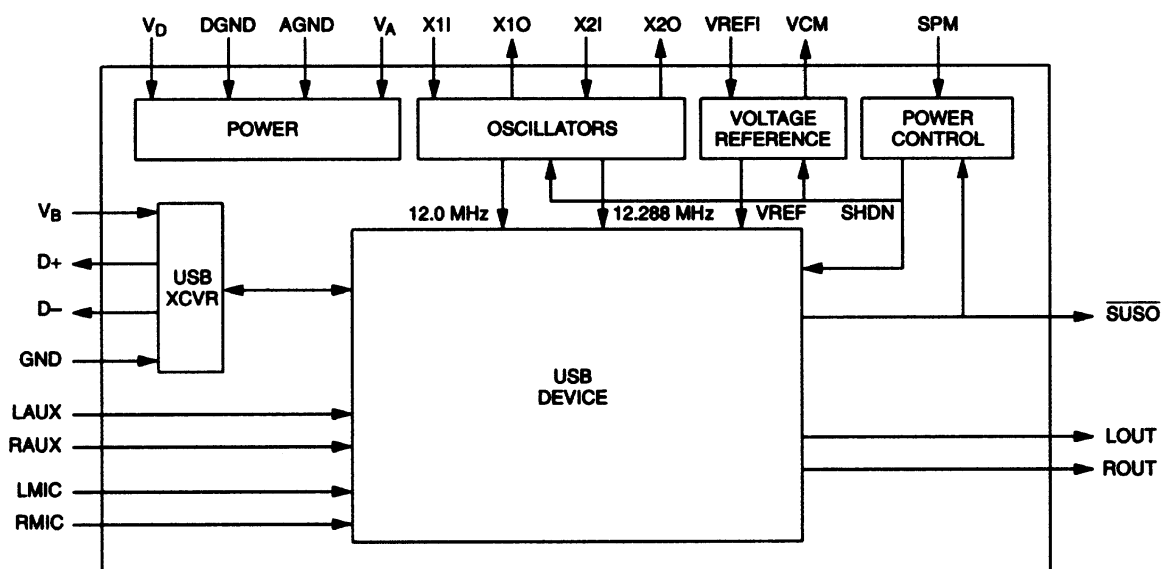
USB DEVICE STRUCTURE Figure 3
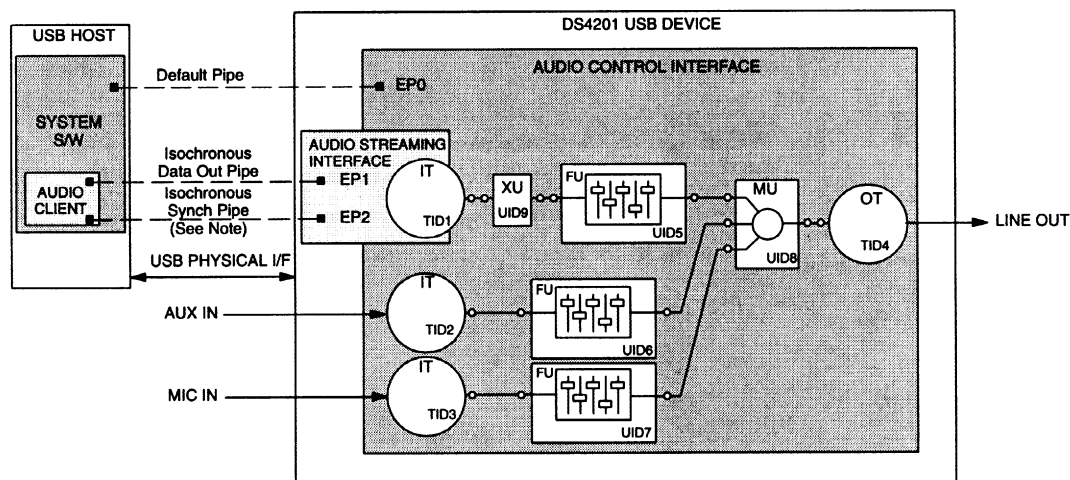
NOTE:

For the audio streaming interface alternate setting which selects adaptive synchronization, the isochronous synch pipe at endpoint 2 (EP2) does not exist.

AUDIO CONTROL INTERFACE

The CONTROL interface is used by the USB host to manipulate and monitor the operation of the DS4201. Additionally, all features, control capabilities, and characteristics of the DS4201 are communicated to the host through USB descriptors over this interface. Host communication with the CONTROL interface is performed over a default control pipe at Endpoint 0.

The USB Audio Device Class (ADC) specification defines audio function units and terminals to describe and operate a USB Audio device; the Endpoint 0 default control pipe is used to control the units and terminals. USB operation of the DS4201 Audio device is controlled through Feature Units (FU), a Mixer Unit (MU), Input Terminals (IT), an Extension Unit (XU), and an Output Terminal (OT) as shown in Figure 3. The Input Terminal associated with the STREAMING INTERFACE makes a logical connection to the isochronous data pipe feeding PCM coded data to the DS4201 at Endpoint 1. The DS4201 performs D/A processing of the incoming digital PCM data at this point and thus the output from this Input Terminal is a logical cluster of analog audio signals consisting of the left and right audio channels. The Input Terminals associated with the Auxiliary (AUX) and Microphone (MIC) inputs are for connection to the analog line inputs; the output from these terminals are logical clusters of the respective analog audio input source. The three Feature Units (FU) provide Mute capability for the three analog audio clusters. The Extension Unit (XU) provides a DS4201 specific control capability which can be used to select between two output level ranges from the sigma–delta D/A converter. The Mixer Unit (MU) provides control for level setting and mixing of the three analog audio clusters; the control capability consists of gain or attenuation to the incoming analog signals prior to mixing the left and right composite channels.

INPUT TERMINALS

The ADC Input Terminal (IT) is used to receive audio information into the audio function. It also converts the incoming audio stream into the separate logical channels embedded. USB OUT endpoints as well as analog audio inputs are supported. The DS4201 uses three ITs: IT:TID1 connects to Endpoint 1 carrying a USB isochronous audio stream, IT:TID2 connects to the analog AUX input, and IT:TID3 connects to the analog MIC input.

EXTENTION UNIT

The extension Unit (XU) is used to add vendor specific features to a USB audio function. The XU in the DS4201, XU:UID9, is used to select between two available output ranges for the sigma–delta DAC: 1.414 V_{PP} or 2.828 V_{PP} The XU control parameter, OUTPUT_ DOUBLE_CONTROL, is used to select or enable the output range mode. When set TRUE, the 2.828 V_{PP} range is selected; when FALSE, the 1.414 V_{PP} range is selected. When the DS4201 is operating from a 3V power source, the 1.414 V_{PP} range must be selected. For 5V operation, either range can be used. The command and control parameter used for the XU SET/GET request is defined in APPENDIX A.

EXTENTION UNIT DEFAULT SETTING

The power–on default setting of the XU is:
OUTPUT_DOUBLE_SELECTOR = FALSE
(DAC output range = 1.414 V_{PP})

Feature Units

As defined by the ADC specification, the Feature Unit (FU) provides basic property control of an audio signal. The FU descriptor reports what controls exist for each channel that passes through the FU as well as a master control. All FUs have a single input and output pin for the audio cluster being controlled. The audio cluster can contain multiple logical channels (left, right, etc.) which are individually or group controlled by FU commands. As shown in Figure 3, FU:UID5 operates on the cluster from XU:UID9, FU:UID6 operates on the cluster from IT:TID2 and FU:UID7 operates on the cluster from IT:TID3. Table 1 lists the cluster channels and properties supported by each FU. As shown in the table, MUTE is the only control property supported by the DS4201 FUs. FU commands are documented in APPENDIX A.

FEATURE UNIT PROPERTIES Table 1

FEATURE UNIT LOGICAL CHANNEL	SIGNAL	SUPPORTED PROPERTIES
FU:UID5 Channel 0	Master	MUTE
FU:UID5 Channel 1	Left DAC	MUTE
FU:UID5 Channel 2	Right DAC	MUTE
FU:UID6 Channel 0	Master	MUTE
FU:UID6 Channel 1	Left AUX	MUTE
FU:UID6 Channel 2	Right AUX	MUTE
FU:UID7 Channel 0	Master	MUTE
FU:UID7 Channel 1	Left MIC	MUTE
FU:UID7 Channel 2	Right MIC	MUTE

FEATURE UNITS DEFAULT SETTINGS

The power–on default settings of the three FU's are:
FU:UID5 – Channels 0–2, MUTE = false
FU:UID6 – Channels 0–2, MUTE = false
FU:UID7 – Channels 0–2, MUTE = false

MIXER UNIT

The ADC Mixer Unit (MU) definition provides the mixer with capability to mix all input channels into all output channels. In addition, mixing controls can be programmable or fixed. The MU descriptor reports channel mixing, control capability, and input signal source information to the host. As with all ADC audio units, the input pins and output pin of the MU connect to audio signal clusters; the clusters are made up of logical channels which enter or exit the MU.

The DS4201 MU, MU:UID8, has 3 input clusters, each of which has 2 logical channels, and 1 output cluster with 2 logical channels. Thus there are 6 logical inputs and 2 logical outputs. For this arrangement, the ADC MU defines a mixing capability that consists of 12 controls (6 input channels x 2 output channels). The MU descriptor field, **bmControls**, is used to indicate available programmable mixing controls. The value for the **bmControls** field is built from a two dimensional array which contains a row for each logical input channel and a column for each logical output channel. For a given array element, **bmControl[u,v]**, if [u,v] is set a programmable mixing control exists for input u to output v, if [u,v] is clear the connection is non–programmable and its fixed value can be retrieved through a MU request. The array corresponding to the DS4201 mixing capability is shown in Table 2.

For the DS4201, the array indicates the programmable mixing capability of left input channels with the left out-put channel and likewise for right channels. The value for the bmControl field is built from the values in Table 2 according to the method outlined in the ADC specification. For the DS4201 the field is comprised of two bytes with values of: 0x99, 0x90.

bmCONTROL ARRAY FOR MU:UID8 Table 2

INPUT CHANNEL	OUTPUT CHANNEL	
	1 (OUT-L)	2 (OUT-R)
1 (DAC-L)	1	0
2 (DAC-R)	0	1
3 (AUX-L)	1	0
4 (AUX-R)	0	1
5 (MIC-L)	1	0
6 (MIC-R)	0	1

For programmable mixer controls, the ADC provides request commands to obtain the maximum and minimum settings available for each control as well as control setting resolution. Programmable control ranges and resolutions are shown in Table 3. MU commands are documented in APPENDIX A.

MU:UID8 CONTROL RANGE Table 3

INPUT CLUSTER	MIXER CONTROL RANGE		
	MIN	MAX	RES
DAC	-96.0 dB (0xA000)	0.0 dB (0x0000)	2.0 dB (0x0200)
AUX	-32 dB (0xE000)	30.0 dB (0x1E00)	2.0 dB (0x0200)
MIC	-32 dB (0xE000)	30.0 dB (0x1E00)	2.0 dB (0x0200)

MIXER UNIT DEFAULT SETTINGS

The power–on default control settings of the MU are:
DAC channels: –20 dB
AUX channels: 0 dB
MIC channels: 0 dB

OUTPUT TERMINAL

The ADC Output Terminal (OT) is used to transmit audio information from the audio function. USB IN endpoints as well as analog outputs are supported by the ADC specification. The DS4201 uses OT:TID4 to connect the output cluster from the MU:UID8 to the analog line out.

ENDPOINT 0

Control of an audio function is performed over the default pipe through device requests and interface end-point and control settings. The ADC specification supports the standard device requests as defined in the USB core specification. It also defines Audio Device class–specific requests to control device operation. APPENDIX A contains USB core and ADC requests supported by the DS4201.

NOTE:

USB Core or ADC commands not listed in APPENDIX A are not supported by the DS4201. DS4201 response to these unsupported commands will be a STALL on the Endpoint 0 control pipe in accordance with the USB Core and ADC specifications.

AUDIO STREAMING INTERFACE

The STREAMING interface is used to receive the digital PCM audio stream from the host and to control host–de-vice data synchronization. Additionally, the STREAMING interface will support six alternative settings:

ALT–0: (default setting) zero isochronous bandwidth
ALT–1: Asynch synchronization, 16–bit PCM stereo
ALT–2: Asynch synchronization, 16–bit PCM mono
ALT–3: Asynch synchronization, 8–bit PCM stereo
ALT–4: Asynch synchronization, 8–bit PCM mono
ALT–5: Adaptive synchronization, 16–bit PCM stereo

The zero isoch bandwidth setting is included to provide the host system with a mechanism to manage USB bandwidth. This setting allows the host to reclaim isochronous bandwidth without deconfiguring the audio device. For alternate settings 1–4, two USB endpoints exist: Endpoint 1 for an isochronous data input (USB OUT from the host) with asynchronous synchronization, and Endpoint 2 for isochronous synchronization feed-back. For alternate setting 5, one USB endpoint exists: Endpoint 1 for an

isochronous data input with adaptive synchronization. Except for ALT−0, the DS4201 supports 44.1 KHz and 48.0 KHz audio data sampling rates at Endpoint 1. Sampling rate control is performed using ADC standard requests as described in APPENDIX A. PCM data formats are listed in APPENDIX B.

ENDPOINT 1

The USB isochronous data pipe at Endpoint 1, EP1, delivers PCM audio data to the DS4201. The data sampling frequency at EP1 can be set at either 44.1 KHz or 48.0 KHz. PCM data captured by the host at rates other than these two rates require sample rate conversion before being sent to the DS4201. Control of the sampling rate is performed with ADC endpoint commands as described in APPENDIX A. The USB isochronous audio data received at EP1 is delivered to Input Terminal 1 (IT:TID1) in the CONTROL interface. There is a one−to−one link between these two elements. The maximum packet size supported by EP1 varies with the PCM data type selected. The maximum packet sizes reported in the STREAMING interface descriptors corresponds to the PCM data format at a 48 KHz sampling rate plus an additional data sample for synchronization. The USB core specification requires a minimum 1 frame delay before a USB device can operate on isochronous data. The DS4201 produces a 1 frame delay and incorporates enough FIFO register storage space for 2 frames total (previous frame plus current frame).

ENDPOINT 2

For alternate settings 1−4, the DS4201 uses the asynchronous type of communication synchronization for the isochronous data pipe as defined in the USB core specification. The isochronous synchronization pipe from Endpoint 2 is used to provide the 3−byte data rate feedback value to the host.

USB TRANSCEIVER

Integrated within the DS4201 is a USB compliant bus transceiver. To comply with USB cable termination requirements, resistors external to the DS4201 must be installed as shown in Figure 4. The 24 ohm, 1% tolerance resistors are necessary to bring the total steady state resistance of each driver to the 28−43 ohms range required by the USB core specification. The 1.5K ohms pull−up resistor is required to identify the bus as high speed USB.

TRANSCEIVER TERMINATION Figure 4
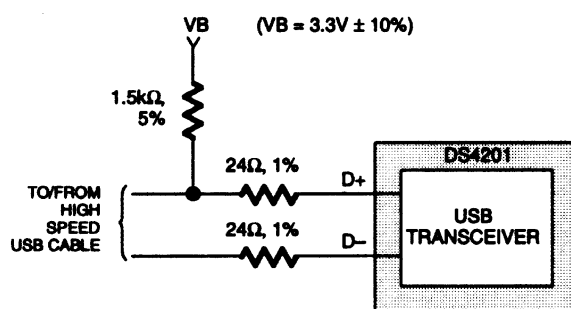
VOLTAGE REFERENCE

The VREFI input is a connection to a filter node of the internal voltage reference and is used to apply additional filtering of the reference to reduce noise. This is accomplished by connecting both a 0.1 µF and 10 µF capacitor across this input and analog ground. No other connection should be made to this input and the potential for coupling onto this input should be minimized to avoid degrading analog performance.

The VCM output provides the DC bias point to which AC signals are referenced and processed internally. This output provides a common mode signal that can be used by external circuitry operating from a single supply. The nominal level of this output is 0.4xVA. VCM cannot support dynamic loading and should be buffered if AC loading is needed. For typical use, a 0.47 µF capacitor should be connected across VCM and analog ground for filtering.

NOTE:
See APPENDIX C for additional application information regarding these reference signals.

ANALOG I/O
DS4201 analog I/O consists of two stereo inputs (AUX and MIC) and one stereo output (OUT). Full scale input and output signal levels supported depend on device operating voltage, the Mixer Unit (MU:UID8) control setting, and the control setting of the USB audio extension unit (XU:UID9) as listed in the Analog Performance Characteristics table.

ANALOG INPUTS
Analog signal levels at both the AUX and MIC inputs must be limited to the full scale range supported by the operating voltage: 0.5 Vrms for 3.3V operation, 1.0 Vrms for 5.0V operation. Additionally, the input signal must be either AC–coupled to the analog input or centered about the common mode reference level VCM. For optimal performance, analog input signals should be AC–coupled. External signal attenuation may be necessary to accommodate 1 Vrms and/or 2 Vrms line level swings that are typically output from audio equipment. See APPENDIX C for recommended connection diagrams and example interface circuits for additional information.

ANALOG OUTPUTS
Analog signal levels at the LOUT and ROUT outputs are DC biased about the common mode reference output VCM and should be AC–coupled to external circuitry. Depending on operating voltage, the DS4201 is designed to produce full–scale output levels of either 0.5 Vrms or 1.0 Vrms, see Analog Performance Characteristics. Again, see APPENDIX C for recommended connection diagrams and example interface circuits for additional information.

POWER

POWER SUPPLY
The three power inputs to the DS4201 provide power to the USB digital (VB), non–USB digital (VD), and analog circuitry (VA) within the device. These power inputs, combined with a USB suspend power mode input signal (SPM), provide a range of power configurations. The options include:

- Entire device powered from USB bus power.
- USB circuitry powered from USB bus power, analog and digital circuitry powered from a separate single source.
- USB circuitry powered from USB bus power, analog circuitry powered from an analog supply, digital circuitry powered from a digital supply.
- Entire device powered from non–USB bus power with multiple variations possible.

NOTE:
USB core specification power requirements must be considered for any power configuration that consumes power from the USB bus.

POWER MANAGEMENT

The power management features of the DS4201 are used to control device and external circuit power consumption whenever a USB suspend state is entered; the suspend power mode (SPM) input and suspend output (SUSO\) signals are used for this control.

SUSPEND POWER MODE

The DS4201 supports two modes of operation when the USB enters a suspend state; the suspend power mode input signal (SPM) is used to select which of the two modes the device will enter upon suspend. When the suspend state is entered, the SPM input level is used to selectively shut down specific DS4201 circuitry. Power consumption during the USB suspended state for the two suspend power modes and various input voltage conditions are listed in the DC Characteristics Table and are summarized in the following table and paragraphs:

SUSPEND POWER STATES Table 4

BUS STATE	SPM	POWER CONSUMPTION
Active	X	Active
Suspended	1	Reduced from active
Suspended	0	Minimum

When SPM=1 and the USB enters a suspend state, the DS4201 DAC and oscillators are powered down and digital circuitry enters a low power static state. All other analog circuitry remains powered so that the signal paths for the AUX and MIC inputs are active.

When SPM=0 and the USB enters a suspend state, power consumption is minimized. For this state\mode, all analog circuitry and oscillators are powered down and digital circuitry enters a low power static state.

NOTE:

For this state\mode the analog circuitry in the AUX and MIC paths are powered down and analog audio playback over the AUX and MIC channels will be turned off until the USB returns to an active state. Therefore it is recommended that the AUX and MIC inputs not be made available for analog input playback in an application where SPM=0.

Suspend Output

Whenever the USB enters a suspend state the DS4201 suspend output signal ($\overline{SUSO}$) is driven low. This signal could be used stand–alone or combined with other external signals to power down circuitry external to the DS4201, such as amplifiers and power sources, to manage audio system power consumption during periods of inactivity. The $\overline{SUSO}$ signal is an open drain output and requires an external pull–up to a positive supply no greater than 6.0V.

OSCILLATORS

The DS4201 requires two clock sources to operate: 12.0 MHz and 12.288 MHz. Crystals or CMOS crystal oscillators may be used to provide the clock sources.

For crystals, use parallel resonant, fundamental mode with a CL specification between 10 pF and 20 pF at the required frequency. Parallel loading capacitors with a value of approximately twice CL are also required. The connection scheme shown in APPENDIX C should be used.

For external CMOS crystal oscillators, make a connection directly to the DS4201 X1I and/or X2I inputs. The X1O and X2O outputs must be left floating for this arrangement.

ELECTRICAL CHARACTERISTICS
ABSOLUTE MAXIMUM RATINGS

Voltage on Any Pin Relative to Ground	–0.5V to +6.0V
V_D to V_A Differential	±0.2V
Operating Temperature	0°C to 70°C
Storage Temperature	–55°C to +125°C
Soldering Temperature	260°C for 10 seconds

*This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operation sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

ANALOG PERFORMANCE CHARACTERISTICS

CONDITIONS: t_A : 25°C, VD: 3.0V–5.5V, VA: 3.0V–5.5V, VB: 3.0V–3.6V

PARAMETER		MIN	TYP	MAX	UNITS	NOTES
DAC RESOLUTION		8		16	Bits	
DAC SAMPLING FREQUENCY		44.1		48	KHz	
DYNAMIC PERFORMANCE						
Signal-to-Noise Ration (SNR)	8-bit	40			dB	1
	16-bit	80			dB	1
Total Harmonic Distortion +	8-bit			-35	dB	1,2
Noise (THD+N)	16-bit			-75	dB	1,2
Dynamic Range	8-bit		40		dB	1,2
	16-bit		80		dB	1,2
Crosstalk between Input Channels		-70			dB	1,2
DIGITAL FILTER PERFOMANCE						
Frequency Response		-0.25		+0.25	dB	1,2
Passband		0		0.4xFs	KHz	3,2
Transition Band		0.4xFs		0.6xFs	KHz	3,2
Stop Band		0.6xFs			KHz	3,2
Stop Band Attenuation		-74			dB	2
DC ACCURACY						
Interchannel Gain/Attenuation Mismatch			0.5		dB	2
Gain/Attenuation Error			10		%	2
Gain/Attenuation Drift			100		ppm/°C	2
Offset Error				10	mV	2,6
ANALOG INPUT						
Full Scale Input Voltage	3V operation	1.27	1.41	1.55	V_{PP}	6
	5V operation	2.55	2.83	3.11	V_{PP}	6
Input Resistance		4.3	89.7	212.6	KΩ	7

ANALOG OUTPUT						
Full Scale Output Voltage	double control= FALSE	1.27	1.41	1.55	V_{PP}	5,6
	double control= TRUE	2.55	2.83	3.11	V_{PP}	5,6
External Load Impedance		10			KΩ	8
Common Mode Reference Output (VCM)		0.36xVA	0.4xVA	0.44xVA	V	5,6
VCM current drain (CM)				50	µA	4
MIXER PROGRAMMABILITY						
Programmable Mix Levels	DAC Inputs	-96.0		0	dB	
	MIC Inputs	-32.0		30.0	dB	
	AUX Inputs	-32.0		30.0	dB	
Programmable Mix Level Step Size	DAC Inputs		2.0		dB	
	MIC Inputs		2.0		dB	
	AUX Inputs		2.0		dB	

NOTES:

1. See APPENDIX D for parameter definition and measurement technique.
2. Values are guaranteed by characterization and sample testing but are not 100% production tested.
3. Frequency value obtained by multiplying by the DAC sampling rate.
4. DC current only. If dynamic loading exists, the voltage reference output must be buffered to prevent DAC performance degradation.
5. The USB audio extension unit control selector OUTPUT_DOUBLE is used to control the full scale DAC channel output level as specified. For 3V operation, the property must be set to FALSE. DAC signal range saturation will occur if operating at 3V with a property setting of TRUE. For 5V operation the property can be set to TRUE or FALSE. This property has no effect on the full–scale output level of the AUX and MIC analog signal channels before the output mixer.
6. Voltages referenced to ground.
7. Input impedance is a function of the mixer attenuation setting for the analog input channel. The min value is at the +30 dB setting, the nominal value is at the 0 dB setting, and the max value is at the –32 dB setting.
8. The minimum load impedance the LOUT and ROUT output amplifiers are designed to drive.

RECOMMENDED DC OPERATING CONDITIONS

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Analog Supply Voltage, 3V Operation	VA	3.0	3.3	3.6	V	1,2
Analog Supply Voltage, 5V Operation	VA	4.5	5.0	5.5	V	1,2
Digital Supply Voltage, 3V Operation	VD	3.0	3.3	3.6	V	1,2
Digital Supply Voltage, 5V Operation	VD	4.5	5.0	5.5	V	1,2
USB I/F Supply Voltage	VB	3.0	3.3	3.6	V	2
Input Logic 0	VIL	-0.3		0.3	V	2
Input Logic 1	VIH	2.8		VD+0.3	V	2
Operating Temperature	TA	0	25	70	°C	

NOTES:

1. Maximum allowable VA to VD differential is ±0.2 V.

2. Voltage referenced to ground.

DC CHARACTERISTICS

CONDITIONS: t_A: 25°C, VD: 3.0V–5.5V, VA: 3.0V–5.5V, VB: 3.0V–3.6V

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Output Logic 1 Voltage (IOUT = -1.0mA)	VOH	2.8			V	1,2
Output Logic 0 Voltage (IOUT = 3.0mA)	VOL			0.3	V	2
Input Leakage Current	IIL	-1		+1	µA	
Output Leakage Current	IOL	-1		+1	µA	
I/O Leakage Current	IIOL	-1		+1	µA	
USB STATE: UNCONFIGURED						
Analog Supply Current, 3V Operation	IA		30	45	mA	
Analog Supply Current, 5V Operation	IA		35	55	mA	
Digital Supply Current, 3V Operation	ID		10	15	mA	
Digital Supply Current, 5V Operation	ID		15	25	mA	
USB I/F Supply Current	IB		10	15	mA	
USB STATE: CONFIGURED						
Analog Supply Current, 3V Operation	IA		30	45	mA	
Analog Supply Current, 5V Operation	IA		35	55	mA	
Digital Supply Current, 3V Operation	ID		30	45	mA	
Digital Supply Current, 5V Operation	ID		50	75	mA	
USB I/F Supply Current	IB		10	15	mA	
USB STATE: SUSPENDED, SPM=1						
Analog Supply Current, 3V Operation	IA		30	45	mA	
Analog Supply Current, 5V Operation	IA		35	55	mA	
Digital Supply Current, 3V Operation	ID		75	115	µA	
Digital Supply Current, 5V Operation	ID		100	150	µA	
USB I/F Supply Current	IB		50	75	µA	
USB STATE: SUSPENDED, SPM=0						
Analog Supply Current,	IA		1	2	µA	

3V Operation						
Analog Supply Current, 5V Operation	IA		1	2	μA	
Digital Supply Current, 3V Operation	ID		75	115	μA	
Digital Supply Current, 5V Operation	ID		100	150	μA	
USB I/F Supply Current	IB		50	75	μA	

NOTES:

1. Max VOH for D+ and D– is VB. Max VOH for all other digital outputs is VD or the pull–up voltage level.
2. Voltage referenced to ground.

AC CHARACTERISTICS

CONDITIONS: t_A: 25°C, VD: 3.0V–5.5V, VA: 3.0V–5.5V, VB: 3.0V–3.6V

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Crystal 1 (X1) Frequency	F_{OSC1}		12.0		MHz	
Crystal 2 (X2) Frequency	F_{OSC2}		12.288		MHz	

CAPACITANCE

CONDITIONS: t_A: 25°C

| PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Input Capacitance	CIN			10	pF	
Output Capacitance	COUT			15	pF	
Input/Output Capacitance	CIO			15	pF	

SIGMA-DELTA DAC AND DSP CHARACTERISTICS

Figure 5-7 show the overal, pass band, and transition band sampling frequency response of the SD4201 sigma-delta DAC converter at Fs=44.1 KHz.
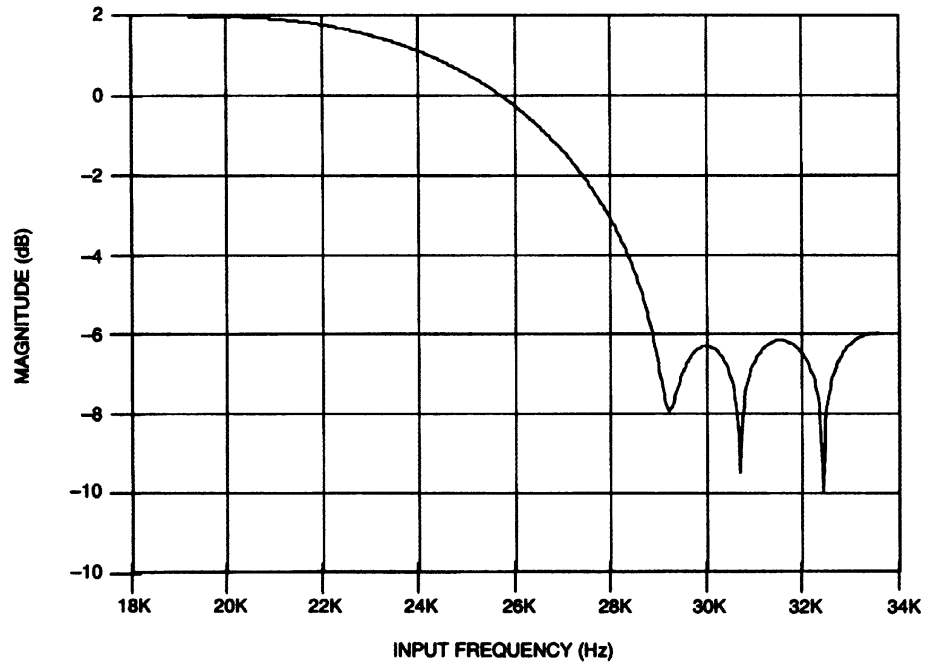
OVERALL FREQUENCY RESPONSE FIGURE 5
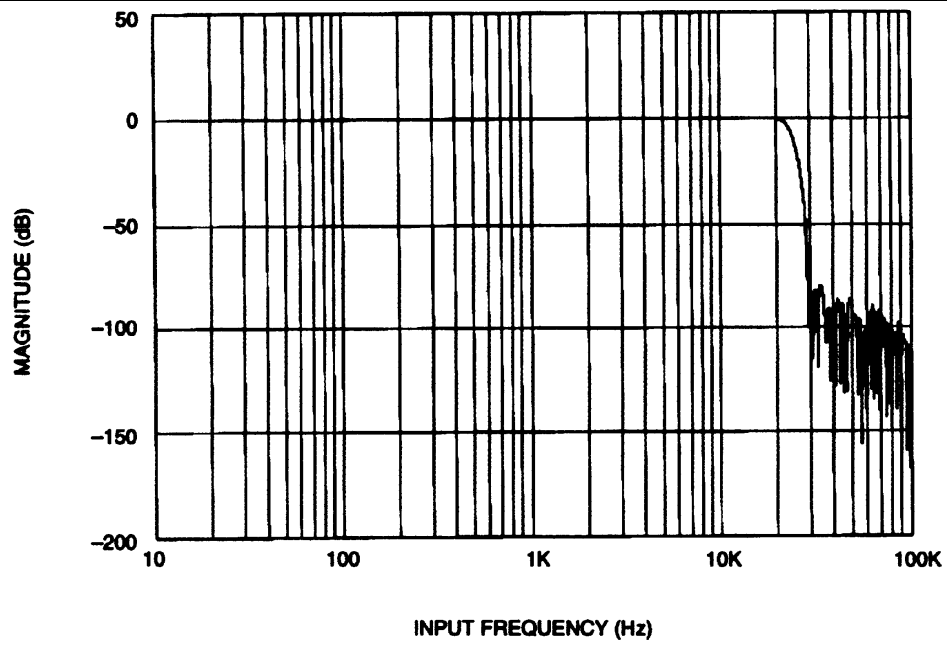
PASS-BAND RESPONSE FIGURE 6
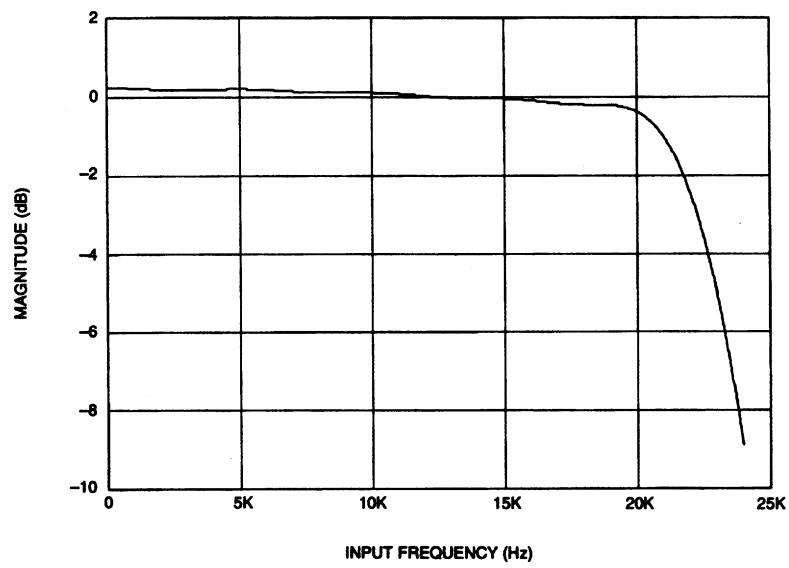
TRANSITION BAND RESPONSE FIGURE 7

APPENDIX A: DS4201 USB COMMANDS AND REQUESTS

USB commands and command forms not listed here are not supported by the DS4201. The DS4201 will respond to unsupported commands with a STALL handshake on the Control endpoint as defined in the USB core and ADC specifications.

USB CORE SPECIFICATION REQUESTS

DS4201 SUPPORTED USB CORE DEVICE REQUESTS			
STANDARD DEVICE REQUESTS	**TARGET ELEMENT**	**RANGE**	**NOTES**
SET_ADDRESS	Device	0x01 - 0xFF	
SET_CONFIGURATION	Device	0x00 – 0x01	1
GET_CONFIGURATION	Device	0x00 – 0x01	
GET_DESCRIPTOR	Device		2
GET_INTERFACE	STREAMING Interface	INFC0:0x00 INFC1:0x00 – 0x05	3,4
SET_INTERFACE	STREAMING Interface	INFC0:0x00 INFC1:0x00 – 0x05	3,4
GET_STATUS	Device, Interfaces, Endpoints 0-2		5,6,7

NOTES:

1. The only valid configuration values are 0 and 1 for the SET_CONFIGURATION request. Configuration value 0 corresponds to the non–configured state.
2. Only the DEVICE and CONFIGURATION descriptor types are supported for the GET_DESCRIPTOR request.
3. There are no alternate settings for the Control Interface (INFC0).
4. Interface settings for the Streaming Interface are defined in the Audio Streaming Interface section.
5. The DS4201 is intended, at a minimum, to be partially bus powered. GET_STATUS requests to the device will return a logic 0 for the self–powered bit field.
6. The DS4201 does not set the Halt field for the default or isochronous endpoints nor does it accept the SET_FEATURE ENDPOINT_HALT command for the default or isochronous endpoints. Therefore the Halt field for GET_STATUS requests to endpoints will always return a value of zero.
7. There is no USB core level status information defined for interfaces. The DS4201 will always return zero value data for GET_STATUS requests to interfaces.

USB ADC CLASS REQUESTS

DS4201 SUPPORTED USB ADC AUDIO STREAMING REQUESTS				
TARGET ELEMENT	**REQUESTS**	**CONTROL**	**VALID SETTINGS**	**DESCRIPTION**
Endpoint 1	SET_CUR	SAMPLING_FREQ_ CONTROL	0x00AC44 (44.1 KHz) 0x00BB80 (48.0 KHz)	Set sampling freq for audio data
	GET_CUR			Get sampling freq for audio data

DS 4201 SUPPORTED ADC AUDIO CONTROL REQUESTS			
TARGET ELEMENT	**REQUESTS**	**COMMAND FORMS**	**DESCRIPTION**
Mixer Unit	SET_CUR	ICN, OCN=valid channels	Set addressed control
		INC=0xFF OCN=0xFF	Set all progammable controls
	GET_CUR	ICN, OCN=valid address	Return addressed control setting
		ICN=0xFF, OCN=0xFF	Return setting of all progammable controls
		ICN=0x00, OCN=0x00	Return setting of all controls
	GET_MAX	ICN, OCN=valid address	Return max setting of addressed control
		INN=xFF, OCN=0xFF	Return max setting of all progammable controls
	GET_MIN	ICN, OCN=valid address	Return min setting of addressed control
		INC=0xFF, OCN=0xFF	Return min setting of all progammable controls
	GET_RES	ICN, OCN=valid address	Return resolution setting of addressed control
		INC=0xFF, OCN=0xFF	Return resolution setting of all progammable controls
Feature Units	SET_CUR	CS=MUTE_CONTROL CN=valid channel	Set mute control for addressed channel
		CS=MUTE_CONTROL CN=FF	Set mute for all channels
	GET_CUR	CS=MUTE_CONTROL CN=FF	Return mute control setting for addressed channel
		CS=MUTE_CONTROL CN=FF	Return mute control setting for all channels
Extension Unit	SET_CUR	CS=OUTPUT_DOUBLE_CONTROL	Set value of Output Double contol
	GET_CUR	CS=OUTPUT_DOUBLE_CONTROL	Return setting of Output Double contol

EXTENSION UNIT CONTROL PARAMETER BLOCK

CONTROL SELECTOR	**OUTPUT_DOUBLE_CONTROL**			
wLength	1			
OFFSET	**FIELD**	**SIZE**	**VALUE**	**DESCRIPTION**
0	bOn	1	Bool	The DAC full-scale (FS) output level setting. This control is used to select either 0.5 VRMS or 1.0 VRMS FS output level from the DAC. when TRUE, DAC FS output=1VRMS when FALSE, DAC FS output=0.5VRMS

EXTENSION UNIT CONTROL SELECTOR

CONTROL SELECTOR	VALUE
OUTPUT_DOUBLE_CONTROL	0x00

APPENDIX B: PCM DATA FORMATS

The DS4201 supports four linear PCM data formats: 16–bit signed stereo, 16–bit signed mono, 8–bit unsigned stereo, and 8–bit unsigned mono. Data for-mats for these four PCM types are shown in Figure 8–11. Coding for PCM 8 and 16 bit formats are shown in Figure 12. As shown in Figure 12, the 16–bit signed format, also know as 2's complement, uses the value -32768 (0x8000) to represent maximum negative amplitude and 32767 (0x7FFF) to represent maximum positive. The 8–bit unsigned format uses the value 0 (0x00) to represent maximum negative and 255 (0xFF) for maximum positive.

SIGNED 16–BIT STEREO DATA FORMAT Figure 8

						? Time	
. . .	SAMPLE 3		SAMPLE 2		SAMPLE 1		
. . .	RIGHT DATA	LEFT DATA	RIGHT DATA	LEFT DATA	RIGHT DATA	LEFT DATA	
. . .	31 16	15 0	31 16	15 0	31 16	15 0	(BIT POSN)

SIGNED 16–BIT MONO DATA FORMAT Figure 9

			? Time	
. . .	SAMPLE 3	SAMPLE 2	SAMPLE 1	
. . .	MONO DATA	MONO DATA	MONO DATA	
. . .	15 0	15 0	15 0	(BIT POSN)

UNSIGNED 8–BIT STEREO DATA FORMAT Figure 10

						? Time	
. . .	SAMPLE 3		SAMPLE 2		SAMPLE 1		
. . .	RIGHT DATA	LEFT DATA	RIGHT DATA	LEFT DATA	RIGHT DATA	LEFT DATA	
. . .	15 8	7 0	15 8	7 0	15 8	7 0	(BIT POSN)

UNSIGNED 8–BIT MONO DATA FORMAT Figure 11

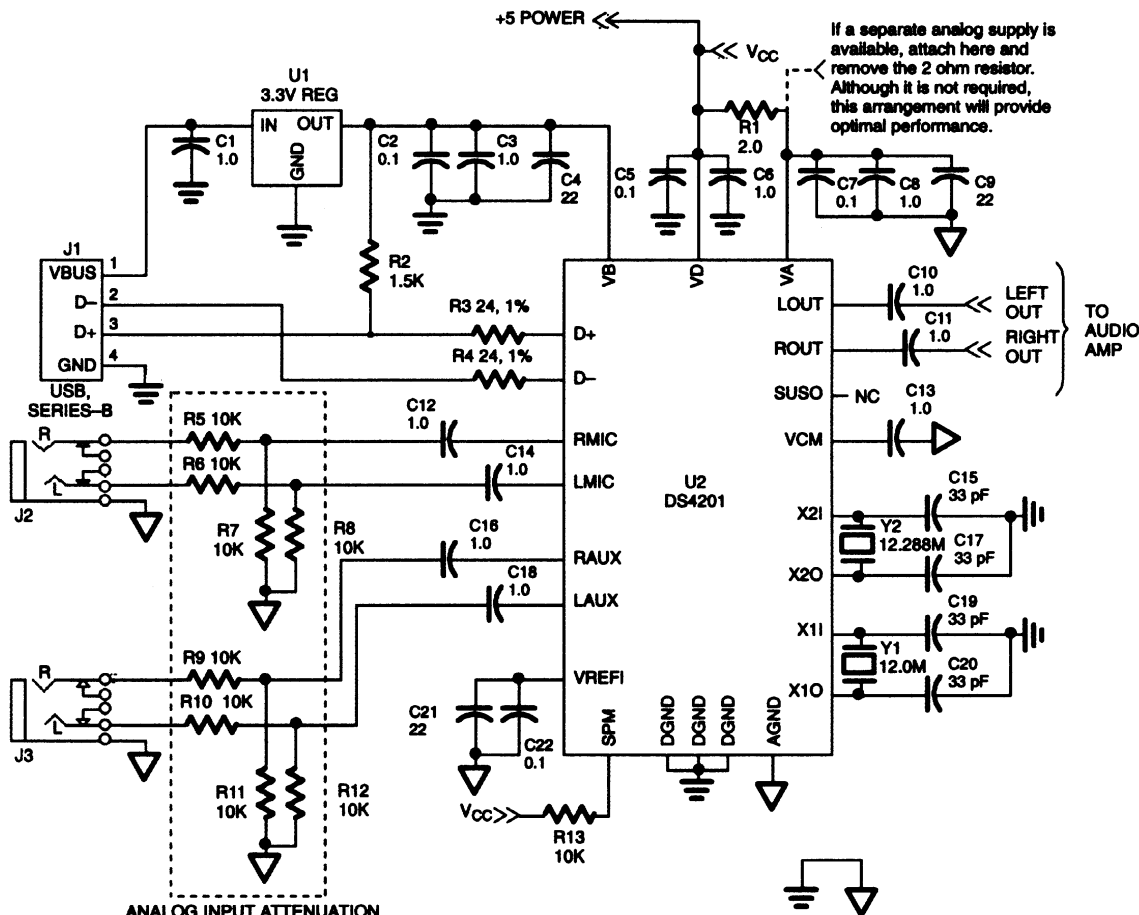|				
			? Time	
. . .	SAMPLE 3	SAMPLE 2	SAMPLE 1	
. . .	MONO DATA	MONO DATA	MONO DATA	
. . .	7 0	7 0	7 0	(BIT POSN)

LINEAR PCM SAMPLE CODING FIGURE 12
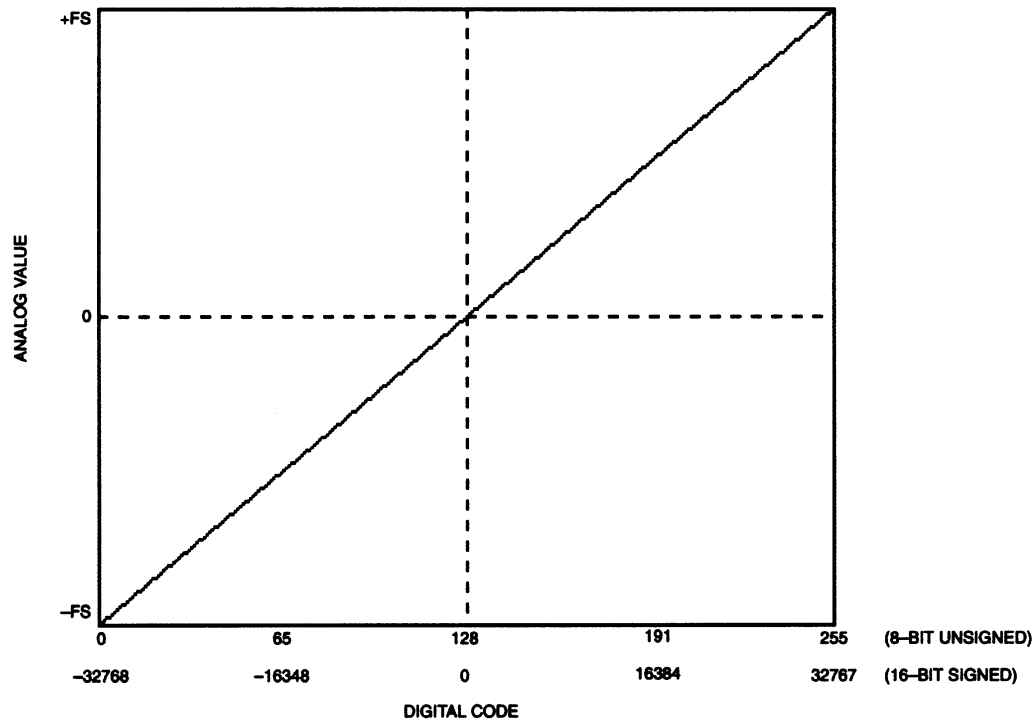
APPENDIX C: RECOMMENDED CONNECTION DIAGRAMS

The schematics in Figures C–1 and C–2 show possible DS4201 connections for the two suspend power mode (SPM) options. In both figures, resistor values are in ohms and capacitor values are in microfarads unless noted.

In Figure C–1, SPM=1 and the DS4201 non–USB power inputs operate from +5V. AUX and MIC analog inputs are attenuated and ac coupled. The analog attenuation is necessary if input levels can exceed the Vrms max input level with +5V analog operation.

SPM=1 CONFIGURATION FIGURE C-1

In Figure C–2, SPM=0 and all DS4201 power is supplied from 3.3V regulated USB VBUS power. Since DS4201 non–USB functions are powered down when SPM=0 and a USB suspend state is entered, AUX and MIC analog inputs are not used.

SPM=0 CONFIGURATION Figure C–2

APPENDIX D: PARAMETER DEFINITIONS

SIGNAL-TO-NOISE RATIO: The ratio of the rms output level with a 1 KHz F.S. input to the rms output level with a zero level input. Measured A–weighted over 20 – 20 KHz with 0V applied to the MIC and AUX inputs. All mixer control settings at 0 dB.

TOTAL HARMONIC DISTORTION + NOISE: The in–band harmonic distortion and noise response to a 1 KHz F.S. input. Measured by attenuating the 1 KHz F.S. fundamental with a narrow–band notch filter, then measuring the rms value of remaining harmonic and noise components over the 20 – 20 KHz bandwidth. All mixer control settings at 0 Db
.

DYNAMIC RANGE: The difference between the highest amplitude signal which the device can linearly handle and the device active noise level. Measured by adding 60 dB to the device rms response to a 1KHz input signal 60 dB below F.S. Measured A–Weighted over 20–20 KHz bandwidth by attenuating the fundamental frequency with a narrow– band notch filter then measuring the remaining in–band signal level. All mixer control settings at 0 dB.

FREQUENCY RESPONSE: The amplitude response variation relative the amplitude response at 1 kHz. Measured over a bandwidth of 20 Hz to 0.4x Fs, where Fs is the DAC sampling frequency. All mixer control settings at 0 dB.

CROSSTALK BETWEEN INPUT CHANNELS: Measured for each channel at the output with a zero level applied to the input under test and a 1 KHz F.S. signal applied to all the other input channels. Measured over a 20 – 20 KHz bandwidth. All mixer control settings at 0 dB.

INTERCHANNEL GAIN MISMATCH: The gain difference between left and right channels. Measured from the difference between the two 20 – 20 KHz band–limited rms outputs with a 1 KHz F.S. signal at both inputs. All mixer control settings at 0 dB.

GAIN ERROR: For each channel, the difference between the expected output and actual output for a 1 KHz input. Measured over the complete mixer control range and a 20 – 20 KHz bandwidth.

GAIN DRIFT: The change in gain value with temperature.

OFFSET ERROR: The difference between the output and the internal reference with zero level inputs. All mixer control settings at 0 dB.

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