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108 dB, 192 kHz 6-In, 8-Out TDM CODEC

FEATURES

- ◆ Six 24-bit A/D, Eight 24-bit D/A Converters
- ◆ ADC Dynamic Range
 - 105 dB Differential
 - 102 dB Single-Ended
- ◆ DAC Dynamic Range
 - 108 dB Differential
 - 105 dB Single-Ended
- ◆ ADC/DAC THD+N
 - -98 dB Differential
 - -95 dB Single-Ended
- ◆ Compatible with Industry-Standard Time Division Multiplexed (TDM) Serial Interface
- ◆ DAC Sampling Rates up to 192 kHz
- ◆ ADC Sampling Rates up to 96 kHz
- ◆ Programmable ADC High-Pass Filter for DC Offset Calibration
- ◆ Logarithmic Digital Volume Control
- ◆ Hardware Mode or Software I²C™ and SPI™
- ◆ Supports Logic Levels Between 5 V and 1.8 V

GENERAL DESCRIPTION

The CS42438 CODEC provides six multi-bit analog-to-digital and eight multi-bit digital-to-analog delta-sigma converters. The CODEC is capable of operation with either differential or single-ended inputs and outputs, in a 52-pin MQFP package.

Six fully differential, or single-ended, inputs are available on stereo ADC1, ADC2, and ADC3. When operating in Single-Ended Mode, an internal MUX before ADC3 allows selection from up to four single-ended inputs. Digital volume control is provided for each ADC channel, with selectable overflow detection.

All eight DAC channels provide digital volume control and can operate with differential or single-ended outputs.

An auxiliary serial input is available for an additional two channels of PCM data.

The CS42438 is available in a 52-pin MQFP package in Commercial (-10°C to +70°C) and Automotive (-40°C to +105°C) grades. The CDB42438 Customer Demonstration Board is also available for device evaluation and implementation suggestions. Please refer to [“Ordering Information” on page 61](#) for complete ordering information.

The CS42438 is ideal for audio systems requiring wide dynamic range, negligible distortion and low noise, such as A/V receivers, DVD receivers, and automotive audio systems.

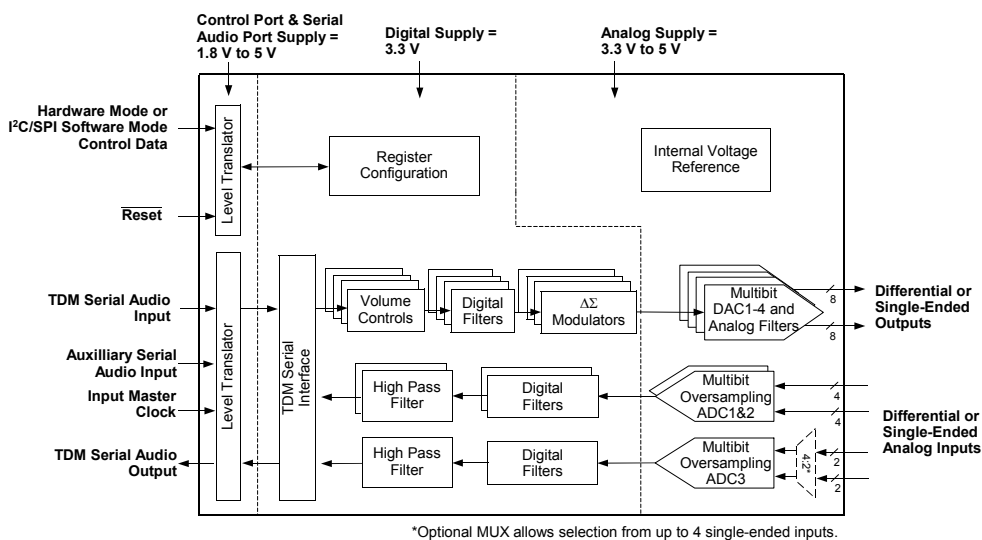


TABLE OF CONTENTS

1. PIN DESCRIPTIONS - SOFTWARE MODE	6
1.1 Digital I/O Pin Characteristics	8
2. PIN DESCRIPTIONS - HARDWARE MODE	9
3. TYPICAL CONNECTION DIAGRAMS	11
4. CHARACTERISTICS AND SPECIFICATIONS	13
RECOMMENDED OPERATING CONDITIONS	13
ABSOLUTE MAXIMUM RATINGS	13
ANALOG INPUT CHARACTERISTICS (COMMERCIAL)	14
ANALOG INPUT CHARACTERISTICS (AUTOMOTIVE)	15
ADC DIGITAL FILTER CHARACTERISTICS	16
ANALOG OUTPUT CHARACTERISTICS (COMMERCIAL)	17
ANALOG OUTPUT CHARACTERISTICS (AUTOMOTIVE)	18
COMBINED DAC INTERPOLATION & ON-CHIP ANALOG FILTER RESPONSE	20
SWITCHING SPECIFICATIONS - ADC/DAC PORT	21
SWITCHING CHARACTERISTICS - AUX PORT	22
SWITCHING SPECIFICATIONS - CONTROL PORT - I ² C MODE	23
SWITCHING SPECIFICATIONS - CONTROL PORT - SPI FORMAT	24
DC ELECTRICAL CHARACTERISTICS	25
DIGITAL INTERFACE SPECIFICATIONS & CHARACTERISTICS	25
5. APPLICATIONS	26
5.1 Overview	26
5.2 Analog Inputs	27
5.2.1 Line-Level Inputs	27
5.2.1.1 Hardware Mode	27
5.2.1.2 Software Mode	27
5.2.2 ADC3 Analog Input	28
5.2.3 Hardware Mode	29
5.2.4 Software Mode	29
5.2.5 High-Pass Filter and DC Offset Calibration	29
5.2.5.1 Hardware Mode	29
5.2.5.2 Software Mode	29
5.3 Analog Outputs	30
5.3.1 Initialization	30
5.3.2 Line-Level Outputs and Filtering	30
5.3.3 Digital Volume Control	32
5.3.3.1 Hardware Mode	32
5.3.3.2 Software Mode	32
5.3.4 De-Emphasis Filter	32
5.4 System Clocking	33
5.4.1 Hardware Mode	33
5.4.2 Software Mode	33
5.5 CODEC Digital Interface	33
5.5.1 TDM	33
5.5.2 I/O Channel Allocation	34
5.6 AUX Port Digital Interface Formats	34
5.6.1 Hardware Mode	34
5.6.2 Software Mode	34
5.6.3 I ² S	34
5.6.4 Left-Justified	35
5.7 Control Port Description and Timing	35
5.7.1 SPI Mode	35
5.7.2 I ² C Mode	36

5.8 Recommended Power-Up Sequence	37
5.8.1 Hardware Mode	37
5.8.2 Software Mode	38
5.9 Reset and Power-Up	38
5.10 Power Supply, Grounding, and PCB Layout	38
6. REGISTER QUICK REFERENCE	39
7. REGISTER DESCRIPTION	41
7.1 Memory Address Pointer (MAP)	41
7.1.1 Increment (INCR)	41
7.1.2 Memory Address Pointer (MAP[6:0])	41
7.2 Chip I.D. and Revision Register (Address 01h) (Read Only)	41
7.2.1 Chip I.D. (CHIP_ID[3:0])	41
7.2.2 Chip Revision (REV_ID[3:0])	41
7.3 Power Control (Address 02h)	42
7.3.1 Power Down ADC Pairs (PDN_ADCX)	42
7.3.2 Power Down DAC Pairs (PDN_DACX)	42
7.3.3 Power Down (PDN)	42
7.4 Functional Mode (Address 03h)	43
7.4.1 MCLK Frequency (MFREQ[2:0])	43
7.5 Miscellaneous Control (Address 04h)	43
7.5.1 Freeze Controls (FREEZE)	43
7.5.2 Auxiliary Digital Interface Format (AUX_DIF)	43
7.6 ADC Control & DAC De-Emphasis (Address 05h)	44
7.6.1 ADC1-2 High-Pass Filter Freeze (ADC1-2_HPFFREEZE)	44
7.6.2 ADC3 High Pass Filter Freeze (ADC3_HPFFREEZE)	44
7.6.3 DAC De-Emphasis Control (DAC_DEM)	44
7.6.4 ADC1 Single-Ended Mode (ADC1_SINGLE)	44
7.6.5 ADC2 Single-Ended Mode (ADC2_SINGLE)	44
7.6.6 ADC3 Single-Ended Mode (ADC3_SINGLE)	45
7.6.7 Analog Input Ch. 5 Multiplexer (AIN5_MUX)	45
7.6.8 Analog Input Ch. 6 Multiplexer (AIN6_MUX)	45
7.7 Transition Control (Address 06h)	45
7.7.1 Single Volume Control (DAC_SNGVOL, ADC_SNGVOL)	46
7.7.2 Soft Ramp and Zero Cross Control (ADC_SZC[1:0], DAC_SZC[1:0])	46
7.7.3 Auto-Mute (AMUTE)	46
7.7.4 Mute ADC Serial Port (MUTE_ADC_SP)	47
7.8 DAC Channel Mute (Address 07h)	47
7.8.1 Independent Channel Mute (AOUTX_MUTE)	47
7.9 AOUTX Volume Control (Addresses 08h- 0Fh)	47
7.9.1 Volume Control (AOUTX_VOL[7:0])	47
7.10 DAC Channel Invert (Address 10h)	48
7.10.1 Invert Signal Polarity (INV_AOUTX)	48
7.11 AINX Volume Control (Address 11h-16h)	48
7.11.1 AINX Volume Control (AINX_VOL[7:0])	48
7.12 ADC Channel Invert (Address 17h)	49
7.12.1 Invert Signal Polarity (INV_AINX)	49
7.13 Status (Address 19h) (Read Only)	49
7.13.1 CLOCK ERROR (CLK_ERROR)	49
7.13.2 ADC Overflow (ADCX_OVFL)	49
7.14 Status Mask (Address 1Ah)	49
8. EXTERNAL FILTERS	50
8.1 ADC Input Filter	50
8.1.1 Passive Input Filter	51
8.1.2 Passive Input Filter w/Attenuation	52

8.2 DAC Output Filter	53
9. ADC FILTER PLOTS	54
10. DAC FILTER PLOTS	56
11. PARAMETER DEFINITIONS	58
12. REFERENCES	59
13. PACKAGE INFORMATION	60
13.1 Thermal Characteristics	60
14. ORDERING INFORMATION	61
15. REVISION HISTORY	61

LIST OF FIGURES

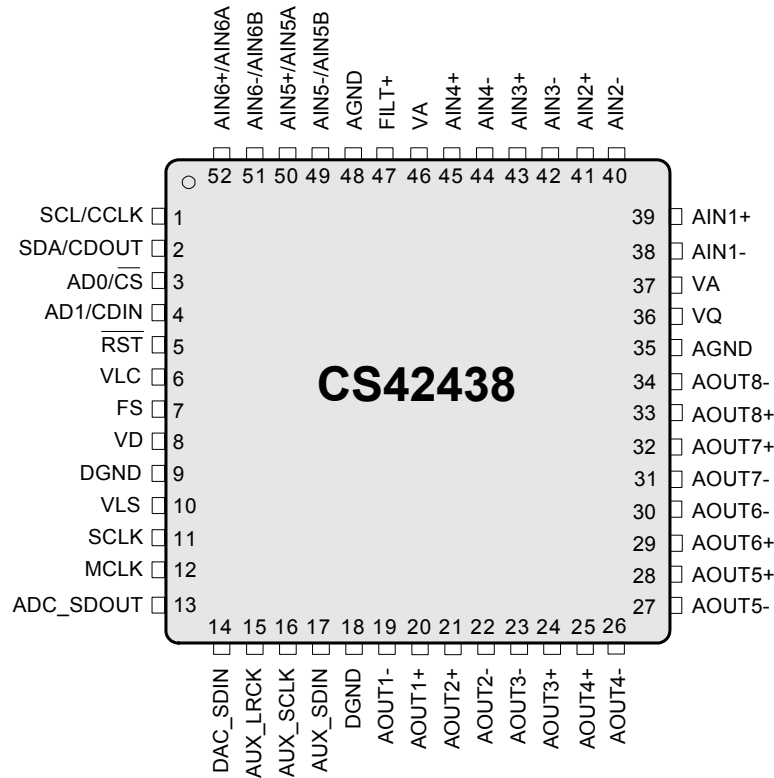
Figure 1. Typical Connection Diagram (Software Mode)	11
Figure 2. Typical Connection Diagram (Hardware Mode)	12
Figure 3. Output Test Circuit for Maximum Load	19
Figure 4. Maximum Loading	19
Figure 5. TDM Serial Audio Interface Timing	21
Figure 6. Serial Audio Interface Slave Mode Timing	22
Figure 7. Control Port Timing - I ² C Format	23
Figure 8. Control Port Timing - SPI Format	24
Figure 9. Full-Scale Input	28
Figure 10. ADC3 Input Topology	28
Figure 11. Audio Output Initialization Flow Chart	31
Figure 12. Full-Scale Output	32
Figure 13. De-Emphasis Curve	33
Figure 14. TDM Serial Audio Format	34
Figure 15. AUX I ² S Format	34
Figure 16. AUX Left-Justified Format	35
Figure 17. Control Port Timing in SPI Mode	36
Figure 18. Control Port Timing, I ² C Write	36
Figure 19. Control Port Timing, I ² C Read	37
Figure 20. Single to Differential Active Input Filter	50
Figure 21. Single-Ended Active Input Filter	50
Figure 22. Passive Input Filter	51
Figure 23. Passive Input Filter w/Attenuation	52
Figure 24. Active Analog Output Filter	53
Figure 25. Passive Analog Output Filter	53
Figure 26. SSM Stopband Rejection	54
Figure 27. SSM Transition Band	54
Figure 28. SSM Transition Band (Detail)	54
Figure 29. SSM Passband Ripple	54
Figure 30. DSM Stopband Rejection	54
Figure 31. DSM Transition Band	54
Figure 32. DSM Transition Band (Detail)	55
Figure 33. DSM Passband Ripple	55
Figure 34. SSM Stopband Rejection	56
Figure 35. SSM Transition Band	56
Figure 36. SSM Transition Band (detail)	56
Figure 37. SSM Passband Ripple	56
Figure 38. DSM Stopband Rejection	56
Figure 39. DSM Transition Band	56
Figure 40. DSM Transition Band (detail)	57
Figure 41. DSM Passband Ripple	57
Figure 42. QSM Stopband Rejection	57

Figure 43.QSM Transition Band	57
Figure 44.QSM Transition Band (detail)	57
Figure 45.QSM Passband Ripple	57

LIST OF TABLES

Table 1. I/O Power Rails	8
Table 2. Hardware Configurable Settings	26
Table 3. AIN5 Analog Input Selection	29
Table 4. AIN6 Analog Input Selection	29
Table 5. MCLK Frequency Settings	33
Table 6. Serial Audio Interface Channel Allocations	34
Table 7. MCLK Frequency Settings	43
Table 9. Example AIN Volume Settings	48
Table 8. Example AOUT Volume Settings	48

1. PIN DESCRIPTIONS - SOFTWARE MODE



Pin Name	#	Pin Description
SCL/CCLK	1	Serial Control Port Clock (Input) - Serial clock for the control port interface.
SDA/CDOUT	2	Serial Control Data I/O (Input/Output) - Input/Output for I ² C data. Output for SPI data.
AD0/ \overline{CS}	3	Address Bit [0]/ Chip Select (Input) - Chip address bit in I ² C Mode. Control signal used to select the chip in SPI Mode.
AD1/CDIN	4	Address Bit [1]/ SPI Data Input (Input) - Chip address bit in I ² C Mode. Input for SPI data.
\overline{RST}	5	Reset (Input) - The device enters a low-power mode and all internal registers are reset to their default settings when low.
VLC	6	Control Port Power (Input) - Determines the required signal level for the control port interface. See "Digital I/O Pin Characteristics" on page 8.
FS	7	Frame Sync (Input) - Signals the start of a new TDM frame in the TDM digital interface format.
VD	8	Digital Power (Input) - Positive power supply for the digital section.
DGND	9,18	Digital Ground (Input) - Ground reference for the digital section.
VLS	10	Serial Port Interface Power (Input) - Determines the required signal level for the serial port interfaces. See "Digital I/O Pin Characteristics" on page 8.
SCLK	11	Serial Clock (Input) - Serial clock for the serial audio interface. Input frequency must be 256 x Fs.
MCLK	12	Master Clock (Input) - Clock source for the delta-sigma modulators and digital filters.
ADC_SDOUT	13	Serial Audio Data Output (Output) - TDM output for two's complement serial audio data.
DAC_SDIN	14	DAC Serial Audio Data Input (Input) - TDM Input for two's complement serial audio data.
AUX_LRCK	15	Auxiliary Left/Right Clock (Output) - Determines which channel, Left or Right, is currently active on the Auxiliary serial audio data line.

AUX_SCLK	16	Auxiliary Serial Clock (Output) - Serial clock for the Auxiliary serial audio interface.
AUX_SDIN	17	Auxiliary Serial Input (Input) - The 42438 provides an additional serial input for two's complement serial audio data.
AOUT1 +,-	20,19	Differential Analog Output (Output) - The full-scale differential analog output level is specified in the Analog Characteristics specification table. Each positive leg of the differential outputs may also be used single-ended.
AOUT2 +,-	21,22	
AOUT3 +,-	24,23	
AOUT4 +,-	25,26	
AOUT5 +,-	28,27	
AOUT6 +,-	29,30	
AOUT7 +,-	32,31	
AOUT8 +,-	33,34	
AGND	35,48	Analog Ground (Input) - Ground reference for the analog section.
VQ	36	Quiescent Voltage (Output) - Filter connection for internal quiescent reference voltage.
VA	37,46	Analog Power (Input) - Positive power supply for the analog section.
AIN1 +,-	39,38	Differential Analog Input (Input) - Signals are presented differentially to the delta-sigma modulators. The full-scale input level is specified in the Analog Characteristics specification table. Single-ended inputs may be applied to the positive terminals when the ADCx SINGLE bit is enabled. Once in Single-Ended Mode, the negative terminal of AIN1-AIN4 must be externally driven to common mode. See below for a description of AIN5-AIN6 in Single-Ended Mode.
AIN2 +,-	41,40	
AIN3 +,-	43,42	
AIN4 +,-	45,44	
AIN5 +,-	50,49	
AIN6 +,-	52,51	
AIN5 A,B	50,49	Single-Ended Analog Input (Input) - In Single-Ended Mode, an internal analog mux allows selection between two channels for both analog inputs AIN5 and AIN6 (see Sections 7.6.6-7.6.8 for details). The unused leg of each input is internally connected to common mode. The full-scale input level is specified in the Analog Characteristics specification table.
AIN6 A,B	52,51	
FILT+	47	Positive Voltage Reference (Output) - Positive reference voltage for the internal sampling circuits.

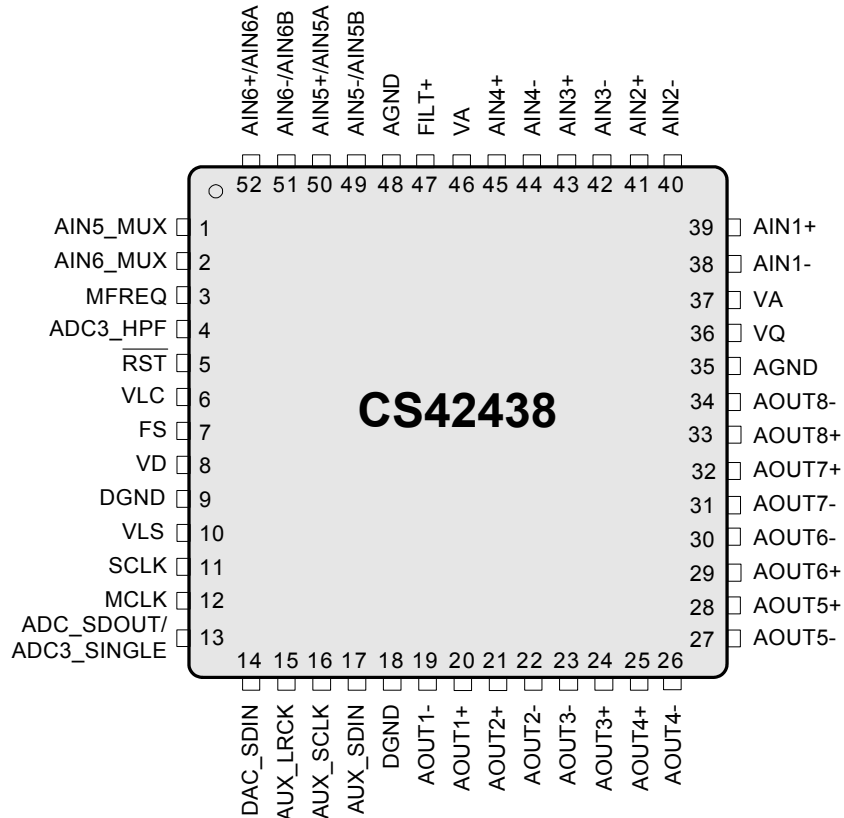
1.1 Digital I/O Pin Characteristics

Various pins on the CS42438 are powered from separate power supply rails. The logic level for each input should adhere to the corresponding power rail and should not exceed the maximum ratings.

Power Rail	Pin Name SW/(HW)	I/O	Driver	Receiver
VLC	$\overline{\text{RST}}$	Input	-	1.8 V - 5.0 V, CMOS
	SCL/CCLK (AIN5_MUX)	Input	-	1.8 V - 5.0 V, CMOS, with Hysteresis
	SDA/CDOUT (AIN6_MUX)	Input/ Output	1.8 V - 5.0 V, CMOS/Open Drain	1.8 V - 5.0 V, CMOS, with Hysteresis
	AD0/CS (MFREQ)	Input	-	1.8 V - 5.0 V, CMOS
	AD1/CDIN (ADC3_HPF)	Input	-	1.8 V - 5.0 V, CMOS
VLS	MCLK	Input	-	1.8 V - 5.0 V, CMOS
	LRCK	Input	-	1.8 V - 5.0 V, CMOS
	SCLK	Input	-	1.8 V - 5.0 V, CMOS
	ADC_SDOUT3 (ADC3_SINGLE)	Input/ Output	1.8 V - 5.0 V, CMOS	-
	DAC_SDIN	Input	-	1.8 V - 5.0 V, CMOS
	AUX_LRCK	Output	1.8 V - 5.0 V, CMOS	-
	AUX_SCLK	Output	1.8 V - 5.0 V, CMOS	-
	AUX_SDIN	Input	-	1.8 V - 5.0 V, CMOS

Table 1. I/O Power Rails

2. PIN DESCRIPTIONS - HARDWARE MODE



Pin Name	#	Pin Description
AIN5_MUX	1	Analog Input Multiplexer (Input) - Allows selection between the A and B single-ended inputs of ADC3.
AIN6_MUX	2	
MFREQ	3	MCLK Frequency (Input) - Sets the required frequency range of the input Master Clock.
ADC3_HPF	4	ADC3 High-Pass Filter Freeze (Input) - When this pin is driven high, the internal high-pass filter will be disabled for ADC3. The current DC offset value will be frozen and continue to be subtracted from the conversion result.
$\overline{\text{RST}}$	5	Reset (Input) - The device enters a low-power mode and all internal registers are reset to their default settings when low.
VLC	6	Control Port Power (Input) - Determines the required signal level for the control port interface. See “Digital I/O Pin Characteristics” on page 8.
FS	7	Frame Sync (Input) - Signals the start of a new TDM frame in the TDM digital interface format.
VD	8	Digital Power (Input) - Positive power supply for the digital section.
DGND	9,18	Digital Ground (Input) - Ground reference for the digital section.
VLS	10	Serial Port Interface Power (Input) - Determines the required signal level for the serial port interfaces. See “Digital I/O Pin Characteristics” on page 8.
SCLK	11	Serial Clock (Input) - Serial clock for the serial audio interface. Input frequency must be 256 x Fs.
MCLK	12	Master Clock (Input) - Clock source for the delta-sigma modulators and digital filters.
ADC_SDOUT	13	Serial Audio Data Output (Output) - TDM output for two’s complement serial audio data.
DAC_SDIN	14	DAC Serial Audio Data Input (Input) - TDM Input for two’s complement serial audio data.

AUX_LRCK	15	Auxiliary Left/Right Clock (Output) - Determines which channel, Left or Right, is currently active on the Auxiliary serial audio data line.
AUX_SCLK	16	Auxiliary Serial Clock (Output) - Serial clock for the Auxiliary serial audio interface.
AUX_SDIN	17	Auxiliary Serial Input (Input) - The 42438 provides an additional serial input for two's complement serial audio data.
AOUT1 +,-	20,19	Differential Analog Output (Output) - The full-scale differential analog output level is specified in the Analog Characteristics specification table. Each positive leg of the differential outputs may also be used single-ended.
AOUT2 +,-	21,22	
AOUT3 +,-	24,23	
AOUT4 +,-	25,26	
AOUT5 +,-	28,27	
AOUT6 +,-	29,30	
AOUT7 +,-	32,31,	
AOUT8 +,-	33,34	
AGND	35,48	Analog Ground (Input) - Ground reference for the analog section.
VQ	36	Quiescent Voltage (Output) - Filter connection for internal quiescent reference voltage.
VA	37,46	Analog Power (Input) - Positive power supply for the analog section.
AIN1 +,-	39,38	Differential Analog Input (Input) - Signals are presented differentially to the delta-sigma modulators. The full-scale input level is specified in the Analog Characteristics specification table. Single-ended inputs may be applied to the positive terminals when the ADCx SINGLE bit is enabled. Once in Single-Ended Mode, the negative terminal of AIN1-AIN4 must be externally driven to common mode. See below for a description of AIN5-AIN6 in Single-Ended Mode.
AIN2 +,-	41,40	
AIN3 +,-	43,42	
AIN4 +,-	45,44	
AIN5 +,-	50,49	
AIN6 +,-	52,51	
AIN5 A,B	50,49	Single-Ended Analog Input (Input) - In Single-Ended Mode, an internal analog mux allows selection between two channels for both analog inputs AIN5 and AIN6 (see Sections 7.6.6-7.6.8 for details). The unused leg of each input is internally connected to common mode. The full-scale input level is specified in the Analog Characteristics specification table.
AIN6 A,B	52,51	
FILT+	47	Positive Voltage Reference (Output) - Positive reference voltage for the internal sampling circuits.

3. TYPICAL CONNECTION DIAGRAMS

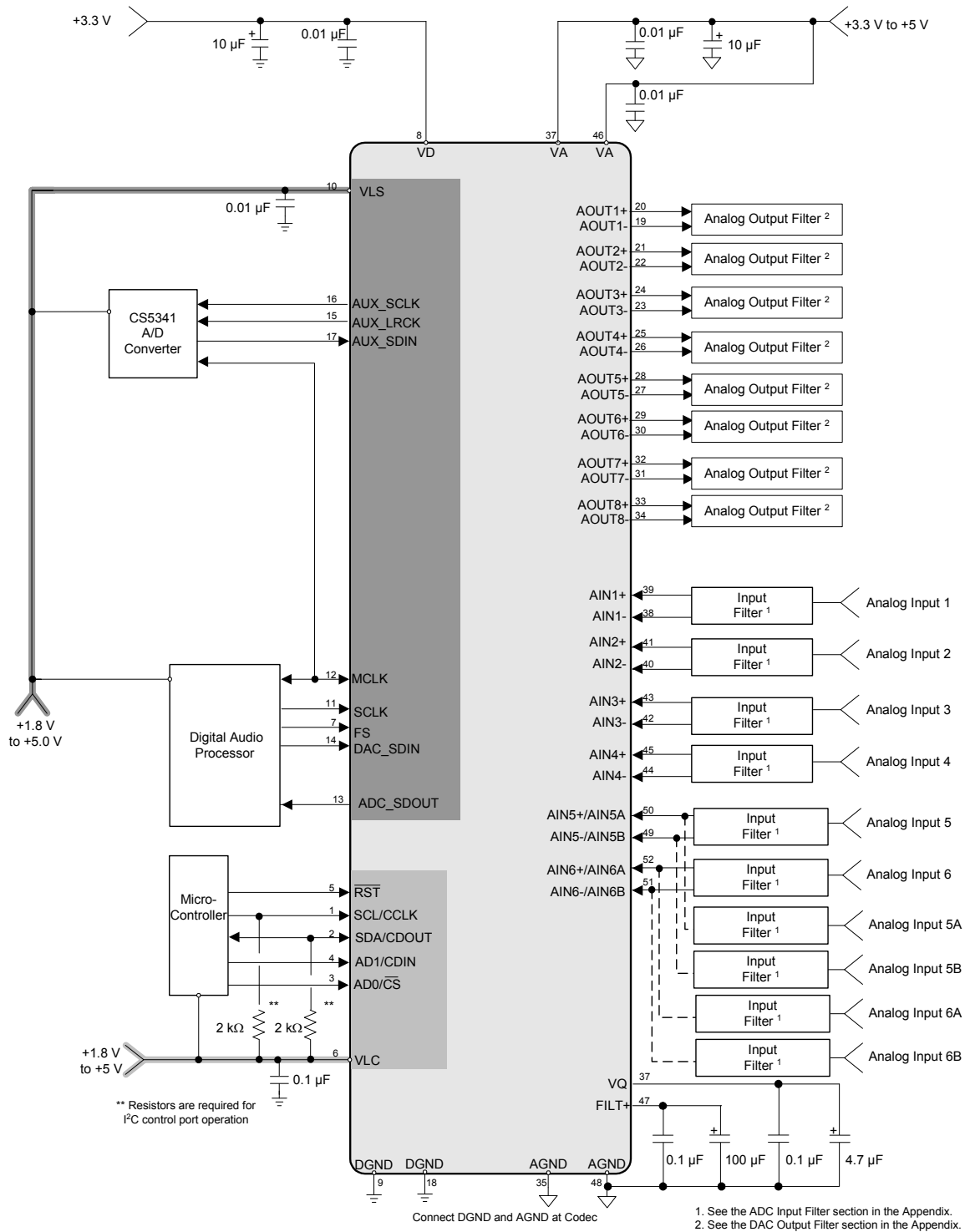


Figure 1. Typical Connection Diagram (Software Mode)

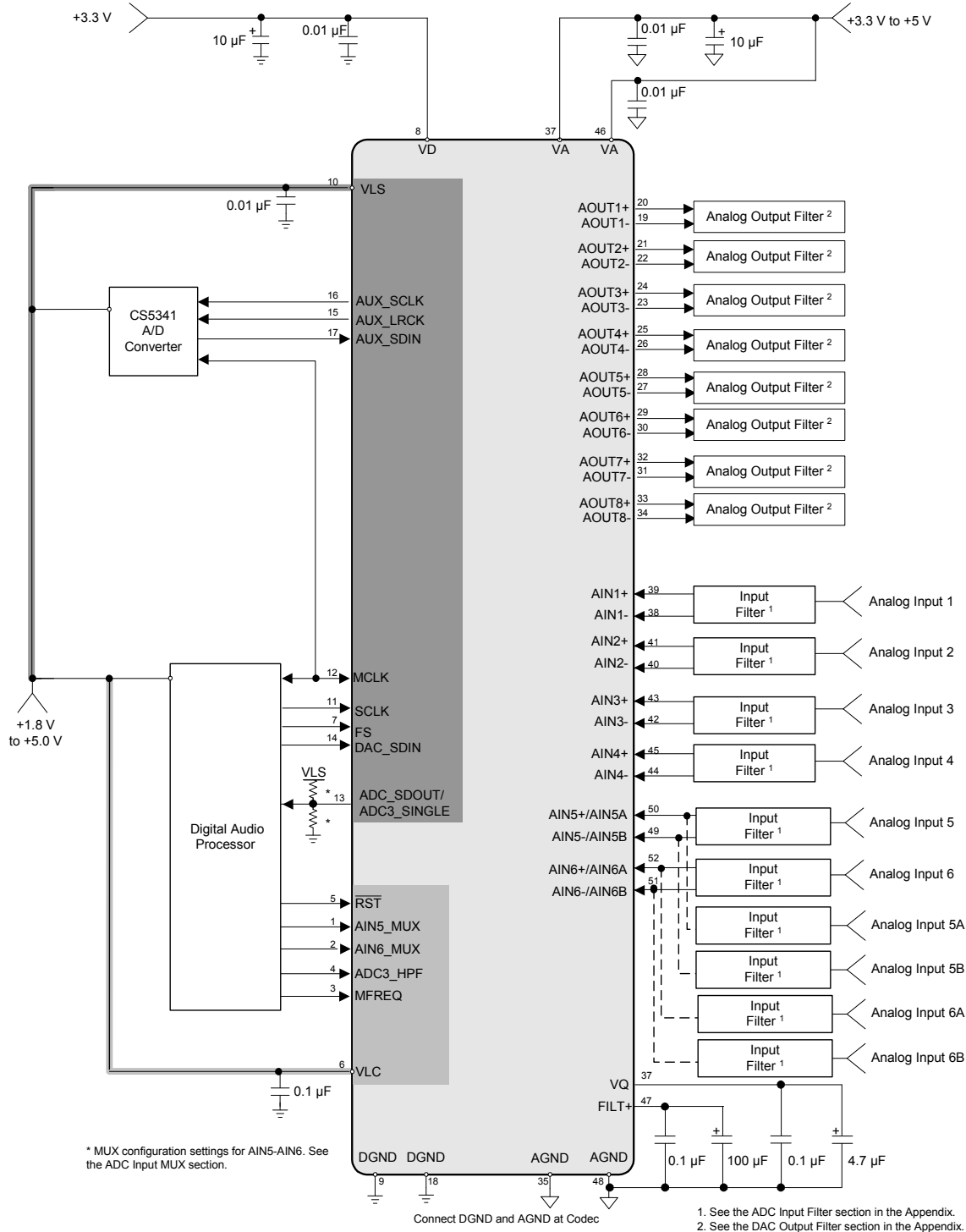


Figure 2. Typical Connection Diagram (Hardware Mode)

4. CHARACTERISTICS AND SPECIFICATIONS

RECOMMENDED OPERATING CONDITIONS

(AGND=DGND=0 V, all voltages with respect to ground.)

Parameters	Symbol	Min	Max	Units
DC Power Supply				
Analog (Note 1)	VA	3.14	5.25	V
Digital	VD	3.14	3.47	V
Serial Audio Interface (Note 2)	VLS	1.71	5.25	V
Control Port Interface	VLC	1.71	5.25	V
Ambient Temperature				
Commercial -CMZ	T _A	-10	+70	°C
Automotive -DMZ		-40	+105	°C

ABSOLUTE MAXIMUM RATINGS

(AGND = DGND = 0 V; all voltages with respect to ground.)

Parameters	Symbol	Min	Max	Units
DC Power Supply	Analog VA	-0.3	6.0	V
	Digital VD	-0.3	6.0	V
	Serial Port Interface VLS	-0.3	6.0	V
	Control Port Interface VLC	-0.3	6.0	V
Input Current (Note 3)	I _{in}	-	±10	mA
Analog Input Voltage (Note 4)	V _{IN}	AGND-0.7	VA+0.7	V
Digital Input Voltage (Note 4)	Serial Port Interface V _{IND-S}	-0.3	VLS+ 0.4	V
	Control Port Interface V _{IND-C}	-0.3	VLC+ 0.4	V
Ambient Operating Temperature (power applied)	T _A	-50	+125	°C
Storage Temperature	T _{stg}	-65	+150	°C

WARNING: Operation at or beyond these limits may result in permanent damage to the device. Normal operation is not guaranteed at these extremes.

Notes:

1. Typical Analog input/output performance will slightly degrade at VA = 3.3 V.
2. The ADC_SDOOUT may not meet timing requirements in Double-Speed Mode.
3. Any pin except supplies. Transient currents of up to ±100 mA on the analog input pins will not cause SCR latch-up.
4. The maximum over/under voltage is limited by the input current.

ANALOG INPUT CHARACTERISTICS (COMMERCIAL)

(Test Conditions (unless otherwise specified): $T_A = -10$ to $+70^\circ\text{C}$; $V_D = V_{LS} = V_{LC} = 3.3\text{ V} \pm 5\%$, $V_A = 5\text{ V} \pm 5\%$ or $3.3\text{ V} \pm 5\%$; Full-scale input sine wave: 1 kHz through the active input filter in [Figure 20 on page 50](#) and [Figure 21 on page 50](#); Measurement Bandwidth is 10 Hz to 20 kHz.)

Parameter		Differential			Single-Ended			Unit
		Min	Typ	Max	Min	Typ	Max	
Fs=48 kHz, 96 kHz								
Dynamic Range	A-weighted	99	105	-	96	102	-	dB
	unweighted	96	102	-	93	99	-	dB
	40 kHz bandwidth unweighted	-	99	-	-	96	-	dB
Total Harmonic Distortion + Noise (Note 5)	-1 dB	-	-98	-92	-	-95	-89	dB
	-20 dB	-	-82	-	-	-79	-	dB
	-60 dB	-	-42	-	-	-39	-	dB
	40 kHz bandwidth -1 dB	-	-90	-	-	-90	-	dB
ADC1-3 Interchannel Isolation		-	90	-	-	90	-	dB
ADC3 MUX Interchannel Isolation		-	90	-	-	90	-	dB
DC Accuracy								
Interchannel Gain Mismatch		-	0.1	-	-	0.1	-	dB
Gain Drift		-	± 100	-	-	± 100	-	ppm/ $^\circ\text{C}$
Analog Input								
Full-Scale Input Voltage		1.06*VA	1.12*VA	1.18*VA	0.53*VA	0.56*VA	0.59*VA	Vpp
Differential Input Impedance (Notes 7 & 9)		23	29	32				k Ω
Single-Ended Input Impedance (Notes 8 & 9)		-	-	-	23	29	32	k Ω
Common Mode Rejection Ratio (CMRR)		-	82	-	-	-	-	dB

ANALOG INPUT CHARACTERISTICS (AUTOMOTIVE)

(Test Conditions (unless otherwise specified): $T_A = -40$ to $+85^\circ\text{C}$; $V_D = V_{LS} = V_{LC} = 3.3\text{ V} \pm 5\%$, $V_A = 5\text{ V} \pm 5\%$ or $3.3\text{ V} \pm 5\%$; Full-scale input sine wave: 1 kHz through the active input filter in [Figure 20 on page 50](#) and [Figure 21 on page 50](#); Measurement Bandwidth is 10 Hz to 20 kHz.)

Parameter		Differential			Single-Ended			Unit
		Min	Typ	Max	Min	Typ	Max	
Fs=48 kHz, 96 kHz								
Dynamic Range	A-weighted	97	105	-	94	102	-	dB
	unweighted	94	102	-	91	99	-	dB
	40 kHz bandwidth unweighted	-	99	-	-	96	-	dB
Total Harmonic Distortion + Noise (Note 5)							(Note 6)	
	-1 dB	-	-98	-90	-	-95	-87/-79	dB
	-20 dB	-	-82	-	-	-79	-	dB
	-60 dB	-	-42	-	-	-39	-	dB
	40 kHz bandwidth -1 dB	-	-87	-	-	-87	-	dB
ADC1-3 Interchannel Isolation		-	90	-	-	90	-	dB
ADC3 MUX Interchannel Isolation		-	85	-	-	85	-	dB
DC Accuracy								
Interchannel Gain Mismatch		-	0.1	-	-	0.1	-	dB
Gain Drift		-	± 100	-	-	± 100	-	ppm/ $^\circ\text{C}$
Analog Input								
Full-Scale Input Voltage		1.04*VA	1.12*VA	1.20*VA	0.52*VA	0.56*VA	0.60*VA	Vpp
Differential Input Impedance (Notes 7 & 9)		23	29	32				k Ω
Single-Ended Input Impedance (Notes 8 & 9)		-	-	-	23	29	32	k Ω
Common Mode Rejection Ratio (CMRR)		-	82	-	-	-	-	dB

Notes:

5. Referred to the typical full-scale voltage.
6. Specification for $V_A = 5\text{V}$ /specification for $V_A = 3.3\text{ V}$.
7. Measured between AINx+ and AINx- .
8. Measured between AINxx and AGND .
9. The input impedance scales inversely proportionate to the sample rate of the ADC modulator

ADC DIGITAL FILTER CHARACTERISTICS

Parameter (Notes 10, 11)		Min	Typ	Max	Unit
Single-Speed Mode (Note 11)					
Passband (Frequency Response)	to -0.1 dB corner	0	-	0.4896	Fs
Passband Ripple		-	-	0.08	dB
Stopband		0.5688	-	-	Fs
Stopband Attenuation		70	-	-	dB
Total Group Delay		-	12/Fs	-	s
Double-Speed Mode (Note 11)					
Passband (Frequency Response)	to -0.1 dB corner	0	-	0.4896	Fs
Passband Ripple		-	-	0.16	dB
Stopband		0.5604	-	-	Fs
Stopband Attenuation		69	-	-	dB
Total Group Delay		-	9/Fs	-	s
High-Pass Filter Characteristics					
Frequency Response	-3.0 dB	-	1	-	Hz
	-0.13 dB	-	20	-	Hz
Phase Deviation	@ 20 Hz	-	10	-	Deg
Passband Ripple		-	-	0	dB
Filter Settling Time		-	10 ⁵ /Fs	0	s

Notes:

10. Filter response is guaranteed by design.
11. Response is clock-dependent and will scale with Fs. Note that the response plots (Figures 26 to 33) have been normalized to Fs and can be de-normalized by multiplying the X-axis scale by Fs.

ANALOG OUTPUT CHARACTERISTICS (COMMERCIAL)

(Test Conditions (unless otherwise specified): $T_A = -10$ to $+70^\circ\text{C}$; $V_D = V_{LS} = V_{LC} = 3.3\text{ V} \pm 5\%$, $V_A = 5\text{ V} \pm 5\%$ or $3.3\text{ V} \pm 5\%$; Full-scale 997 Hz output sine wave (see [Note 14](#)) into passive filter in [Figure 26 on page 54](#) and active filter in [Figure 26 on page 54](#); Measurement Bandwidth is 10 Hz to 20 kHz.)

Parameter	Differential			Single-Ended			Unit	
	Min	Typ	Max	Min	Typ	Max		
<i>F_s = 48 kHz, 96 kHz, 192 kHz</i>								
Dynamic Range								
18 to 24-Bit	A-weighted	102	108	-	99	105	-	dB
	unweighted	99	105	-	96	102	-	dB
16-Bit	A-weighted	-	99	-	-	96	-	dB
	unweighted	-	96	-	-	93	-	dB
Total Harmonic Distortion + Noise								
18 to 24-Bit	0 dB	-	-98	-92	-	-95	-89	dB
	-20 dB	-	-85	-	-	-82	-	dB
	-60 dB	-	-45	-	-	-42	-	dB
16-Bit	0 dB	-	-93	-	-	-90	-	dB
	-20 dB	-	-76	-	-	-73	-	dB
	-60 dB	-	-36	-	-	-33	-	dB
Interchannel Isolation	(1 kHz)	-	100	-	-	100	-	dB
<i>Analog Output</i>								
Full-Scale Output		1.235•V _A	1.300•V _A	1.365•V _A	0.618•V _A	0.650•V _A	0.683•V _A	V _{pp}
Interchannel Gain Mismatch		-	0.1	0.25	-	0.1	0.25	dB
Gain Drift		-	±100	-	-	±100	-	ppm/°C
Output Impedance		-	100	-	-	100	-	Ω
DC Current draw from an AOUT pin	(Note 13)	-	-	10	-	-	10	μA
AC-Load Resistance (R _L)	(Note 15)	3	-	-	3	-	-	kΩ
Load Capacitance (C _L)	(Note 15)	-	-	100	-	-	100	pF

ANALOG OUTPUT CHARACTERISTICS (AUTOMOTIVE)

(Test Conditions (unless otherwise specified): $T_A = -40$ to $+85^\circ\text{C}$; $V_D = V_{LS} = V_{LC} = 3.3\text{ V} \pm 5\%$, $V_A = 5\text{ V} \pm 5\%$ or $3.3\text{ V} \pm 5\%$; Full-scale 997 Hz output sine wave (see [Note 14](#)) in [Figure 26 on page 54](#) and [Figure 26 on page 54](#); Measurement Bandwidth is 10 Hz to 20 kHz.)

Parameter	Differential			Single-Ended			Unit	
	Min	Typ	Max	Min	Typ	Max		
<i>F_s = 48 kHz, 96 kHz, 192 kHz</i>								
Dynamic Range	(Note 12)			(Note 12)				
18 to 24-Bit	A-weighted	100/97	108	-	97/94	105	-	dB
	unweighted	97/94	105	-	94/91	102	-	dB
16-Bit	A-weighted	-	99	-	-	96	-	dB
	unweighted	-	96	-	-	93	-	dB
Total Harmonic Distortion + Noise								
18 to 24-Bit	0 dB	-	-98	-90	-	-95	-87	dB
	-20 dB	-	-85	-	-	-82	-	dB
	-60 dB	-	-45	-	-	-42	-	dB
16-Bit	0 dB	-	-93	-	-	-90	-	dB
	-20 dB	-	-76	-	-	-73	-	dB
	-60 dB	-	-36	-	-	-33	-	dB
Interchannel Isolation (1 kHz)	(1)	-	100	-	-	100	-	dB
<i>Analog Output</i>								
Full-Scale Output		1.210•V _A	1.300•V _A	1.392•V _A	0.605•V _A	0.650•V _A	0.696•V _A	V _{pp}
Interchannel Gain Mismatch		-	0.1	0.25	-	0.1	0.25	dB
Gain Drift		-	±100	-	-	±100	-	ppm/°C
Output Impedance		-	100	-	-	100	-	Ω
DC current draw from an AOUT pin (Note 13)		-	-	10	-	-	10	μA
AC-Load Resistance (R _L) (Note 15)		3	-	-	3	-	-	kΩ
Load Capacitance (C _L) (Note 15)		-	-	100	-	-	100	pF

Notes:

12. Specification for $V_A = 5\text{ V}$ /specification for $V_A = 3.3\text{ V}$.
13. Guaranteed by design. The DC current draw represents the allowed current draw from the AOUT pin due to typical leakage through the electrolytic DC-blocking capacitors.
14. One LSB of triangular PDF dither is added to data.
15. Guaranteed by design. See [Figure 3](#). R_L and C_L reflect the recommended minimum resistance and maximum capacitance required for the internal op-amp's stability and signal integrity. In this circuit topology, C_L will effectively move the dominant pole of the two-pole amp in the output stage. Increasing this value beyond the recommended 100 pF can cause the internal op-amp to become unstable. See ["External Filters" on page 50](#) for a recommended output filter.

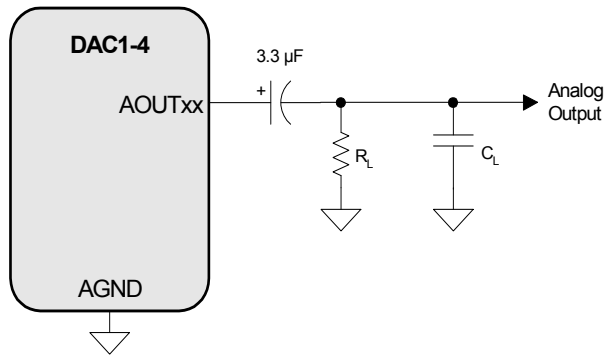


Figure 3. Output Test Circuit for Maximum Load

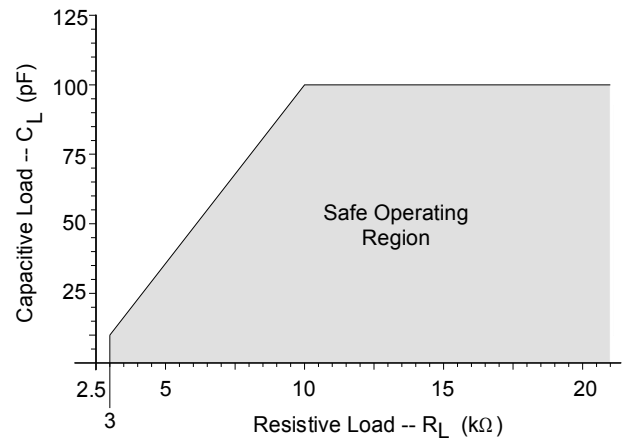


Figure 4. Maximum Loading

COMBINED DAC INTERPOLATION & ON-CHIP ANALOG FILTER RESPONSE

Parameter (Notes 10, 16)	Min	Typ	Max	Unit	
Single-Speed Mode					
Passband (Frequency Response)	to -0.05 dB corner	0	-	0.4780	Fs
	to -3 dB corner	0	-	0.4996	Fs
Frequency Response 10 Hz to 20 kHz	-0.2	-	+0.08	dB	
StopBand	0.5465	-	-	Fs	
StopBand Attenuation (Note 17)	50	-	-	dB	
Group Delay	-	10/Fs	-	s	
De-emphasis Error (Note 18)	Fs = 32 kHz	-	-	+1.5/+0	dB
	Fs = 44.1 kHz	-	-	+0.05/-0.25	dB
	Fs = 48 kHz	-	-	-0.2/-0.4	dB
Double-Speed Mode					
Passband (Frequency Response)	to -0.1 dB corner	0	-	0.4650	Fs
	to -3 dB corner	0	-	0.4982	Fs
Frequency Response 10 Hz to 20 kHz	-0.2	-	+0.7	dB	
StopBand	0.5770	-	-	Fs	
StopBand Attenuation (Note 17)	55	-	-	dB	
Group Delay	-	5/Fs	-	s	
Quad-Speed Mode					
Passband (Frequency Response)	to -0.1 dB corner	0	-	0.397	Fs
	to -3 dB corner	0	-	0.476	Fs
Frequency Response 10 Hz to 20 kHz	-0.2	-	+0.05	dB	
StopBand	0.7	-	-	Fs	
StopBand Attenuation (Note 17)	51	-	-	dB	
Group Delay	-	2.5/Fs	-	s	

Notes:

16. Response is clock-dependent and will scale with Fs. Note that the response plots (Figures 34 to 45) have been normalized to Fs and can be de-normalized by multiplying the X-axis scale by Fs.
17. Single- and Double-Speed Mode Measurement Bandwidth is from Stopband to 3 Fs.
Quad-Speed Mode Measurement Bandwidth is from Stopband to 1.34 Fs.
18. De-emphasis is only available in Single-Speed Mode.

SWITCHING SPECIFICATIONS - ADC/DAC PORT

(Inputs: Logic 0 = DGND, Logic 1 = VLS, ADC_SDOOUT C_{LOAD} = 15 pF.)

Parameters	Symbol	Min	Max	Units	
Slave Mode					
RST pin Low Pulse Width (Note 19)		1	-	ms	
MCLK Frequency		0.512	50	MHz	
MCLK Duty Cycle (Note 20)		45	55	%	
Input Sample Rate (FS pin)	Single-Speed Mode	F _s	4	50	kHz
	Double-Speed Mode (Note 21)	F _s	50	100	
	Quad-Speed Mode (Note 22)	F _s	100	200	
SCLK Duty Cycle		45	55	%	
SCLK High Time	t _{sckh}	8	-	ns	
SCLK Low Time	t _{sckl}	8	-	ns	
FS Rising Edge to SCLK Rising Edge	t _{fss}	5	-	ns	
SCLK Rising Edge to FS Falling Edge	t _{fsh}	16	-	ns	
DAC_SDIN Setup Time Before SCLK Rising Edge	t _{ds}	3	-	ns	
DAC_SDIN Hold Time After SCLK Rising Edge	t _{dh}	5	-	ns	
DAC_SDIN Hold Time After SCLK Rising Edge	t _{dh1}	5	-	ns	
ADC_SDOOUT Hold Time After SCLK Rising Edge	t _{dh2}	10	-	ns	
ADC_SDOOUT Valid Before SCLK Rising Edge	t _{dval}	15	-	ns	

Notes:

19. After powering up the CS42438, $\overline{\text{RST}}$ should be held low after the power supplies and clocks are settled.
20. See [Table 7 on page 43](#) for suggested MCLK frequencies.
21. VLS is limited to nominal 2.5 V to 5.0 V operation only.
22. ADC does not meet timing specification for Quad-Speed Mode.

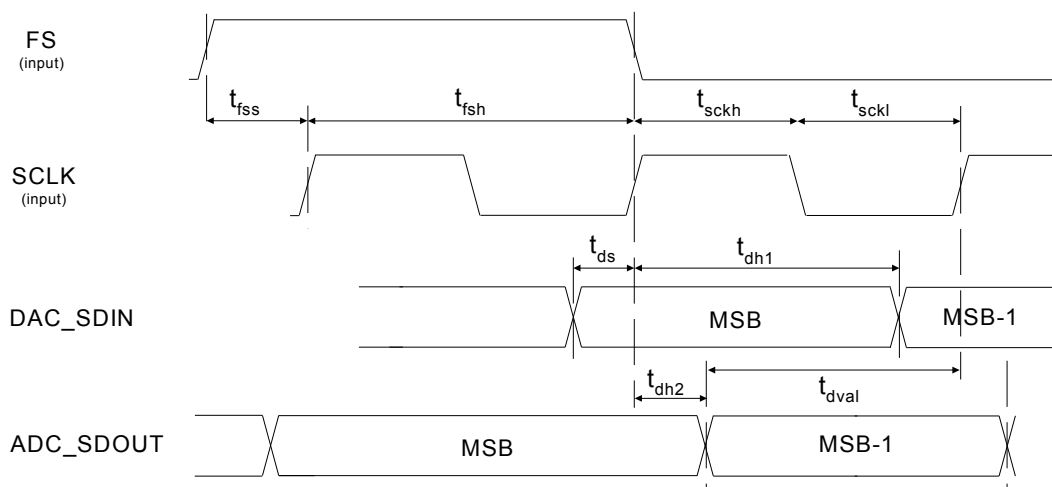


Figure 5. TDM Serial Audio Interface Timing

SWITCHING CHARACTERISTICS - AUX PORT

(Inputs: Logic 0 = DGND, Logic 1 = VLS.)

Parameters	Symbol	Min	Max	Units
Master Mode				
Output Sample Rate (AUX_LRCK) All Speed Modes	F_s	-	LRCK	kHz
AUX_SCLK Frequency		-	$64 \cdot \text{LRCK}$	kHz
AUX_SCLK Duty Cycle		45	55	%
AUX_LRCK Edge to SCLK Rising Edge	t_{lcks}	-	5	ns
AUX_SDIN Setup Time Before SCLK Rising Edge	t_{ds}	3	-	ns
AUX_SDIN Hold Time After SCLK Rising Edge	t_{dh}	5	-	ns

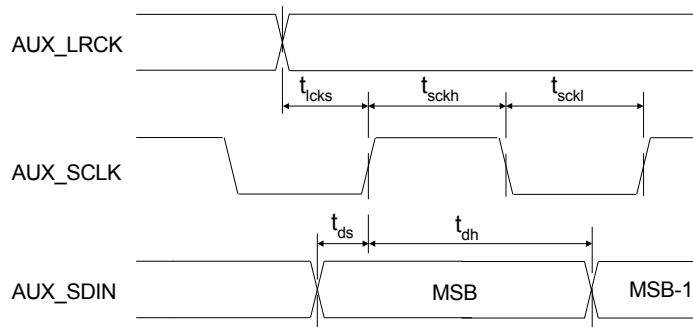


Figure 6. Serial Audio Interface Slave Mode Timing

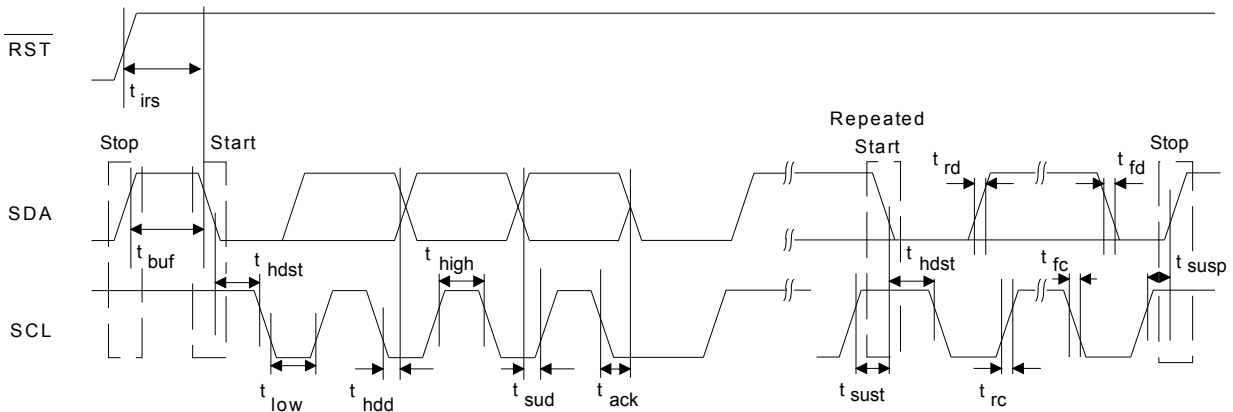
SWITCHING SPECIFICATIONS - CONTROL PORT - I²C MODE

 (VLC = 1.8 V - 5.0 V, VLS = VD = 3.3 V, VA = 5.0 V; Inputs: Logic 0 = DGND, Logic 1 = VLC, SDA C_L = 30 pF)

Parameter	Symbol	Min	Max	Unit
SCL Clock Frequency	f_{scl}	-	100	kHz
RST Rising Edge to Start	t_{irs}	500	-	ns
Bus Free Time Between Transmissions	t_{buf}	4.7	-	μ s
Start Condition Hold Time (prior to first clock pulse)	t_{hdst}	4.0	-	μ s
Clock Low time	t_{low}	4.7	-	μ s
Clock High Time	t_{high}	4.0	-	μ s
Setup Time for Repeated Start Condition	t_{sust}	4.7	-	μ s
SDA Hold Time from SCL Falling (Note 23)	t_{hdd}	0	-	μ s
SDA Setup time to SCL Rising	t_{sud}	250	-	ns
Rise Time of SCL and SDA (Note 24)	t_{rc}	-	1	μ s
Fall Time SCL and SDA (Note 24)	t_{fc}	-	300	ns
Setup Time for Stop Condition	t_{susp}	4.7	-	μ s
Acknowledge Delay from SCL Falling	t_{ack}	300	1000	ns

Notes:

- 23. Data must be held for sufficient time to bridge the transition time, t_{fc} , of SCL.
- 24. Guaranteed by design.


Figure 7. Control Port Timing - I²C Format

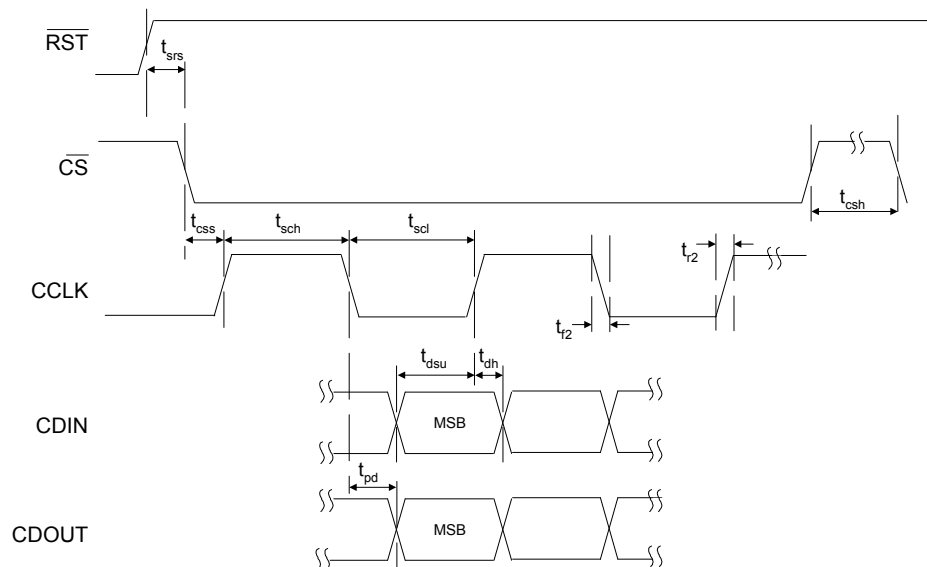
SWITCHING SPECIFICATIONS - CONTROL PORT - SPI FORMAT

 (VLC = 1.8 V - 5.0 V, VLS = VD = 3.3 V, VA = 5.0 V; Inputs: Logic 0 = DGND, Logic 1 = VLC, CDOUT C_L = 30 pF)

Parameter	Symbol	Min	Max	Units
CCLK Clock Frequency	f_{sck}	0	6.0	MHz
RST Rising Edge to \overline{CS} Falling	t_{srs}	20	-	ns
\overline{CS} Falling to CCLK Edge	t_{css}	20	-	ns
\overline{CS} High Time Between Transmissions	t_{csh}	1.0	-	μ s
CCLK Low Time	t_{scl}	66	-	ns
CCLK High Time	t_{sch}	66	-	ns
CDIN to CCLK Rising Setup Time	t_{dsu}	40	-	ns
CCLK Rising to DATA Hold Time	(Note 25) t_{dh}	15	-	ns
CCLK Falling to CDOUT Stable	t_{pd}	-	50	ns
Rise Time of CDOUT	t_{r1}	-	25	ns
Fall Time of CDOUT	t_{f1}	-	25	ns
Rise Time of CCLK and CDIN	(Note 26) t_{r2}	-	100	ns
Fall Time of CCLK and CDIN	(Note 26) t_{f2}	-	100	ns

Notes:

25. Data must be held for sufficient time to bridge the transition time of CCLK.

 26. For $f_{sck} < 1$ MHz.

Figure 8. Control Port Timing - SPI Format

DC ELECTRICAL CHARACTERISTICS

(AGND = 0 V; all voltages with respect to ground.)

Parameters	Symbol	Min	Typ	Max	Units
Normal Operation (Note 27)					
Power Supply Current	VA = 5.0 V	-	80	-	mA
	VLS = VLC = VD = 3.3 V (Note 28)	-	60.6	-	mA
Power Dissipation	VLS = VLC = VD = 3.3 V, VA = 5 V	-	600	850	mW
Power Supply Rejection Ratio (Note 29)	1 kHz	-	60	-	dB
	60 Hz	-	40	-	dB
Power-Down Mode (Note 30)					
Power Dissipation	VLS = VLC = VD = 3.3 V, VA = 5 V	-	1.25	-	mW
VQ Characteristics					
Nominal Voltage		-	0.5•VA	-	V
Output Impedance		-	23	-	kΩ
DC Current Source/Sink (Note 31)		-	-	10	μA
FILT+ Nominal Voltage		-	VA	-	V

Notes:

27. Normal operation is defined as $\overline{RST} = HI$ with a 997 Hz, 0 dBFS input to the DAC and AUX port, and a 1 kHz, -1 dB analog input to the ADC port sampled at the highest F_s for each speed mode. DAC outputs are open, unless otherwise specified.
28. I_{DT} measured with no external loading on pin 2 (SDA).
29. Valid with the recommended capacitor values on FILT+ and VQ. Increasing the capacitance will also increase the PSRR.
30. Power-Down Mode is defined as $\overline{RST} = LO$ with all clocks and data lines held static and no analog input.
31. Guaranteed by design. The DC current draw represents the allowed current draw from the VQ pin due to typical leakage through the electrolytic de-coupling capacitors.

DIGITAL INTERFACE SPECIFICATIONS & CHARACTERISTICS

Parameters (Note 32)	Symbol	Min	Typ	Max	Units
High-Level Output Voltage at $I_o=2$ mA	Serial Port	VLS-1.0	-	-	V
	Control Port	VLC-1.0	-	-	V
Low-Level Output Voltage at $I_o=2$ mA	Serial Port	-	-	0.4	V
	Control Port	-	-	0.4	V
High-Level Input Voltage	Serial Port	0.7xVLS	-	-	V
	Control Port	0.7xVLC	-	-	V
Low-Level Input Voltage	Serial Port	-	-	0.2xVLS	V
	Control Port	-	-	0.2xVLC	V
Leakage Current	I_{in}	-	-	±10	μA
Input Capacitance (Note 24)		-	-	10	pF

Notes:

32. See “Digital I/O Pin Characteristics” on page 8 for serial and control port power rails.