



SM5816AF

6-channel DSD-PCM Converter

OVERVIEW

The SM5816AF is a 6-channel DSD data to 6-channel 8fs or 2fs PCM data converter IC. During conversion, decimation filtering is performed using a filter with selectable fixed coefficients (4 sets) or optional filter coefficients that are written to the built-in RAM. Also, DSD input/outputs and PCM outputs are available for use in master/slave clock mode operation, in a wide range of system configurations, making it easy to construct a multi-channel DSD/PCM reproduction system.

FEATURES

- 512fs master clock (22.5792MHz, fs = 44.1kHz)
- DSD inputs connected directly to outputs in through mode
- Clock master/slave switching for DSD input/outputs and PCM outputs
- 2-system external data inputs (3-wire), with 2fs output data BCK and LRCK pins switchable between external inputs and internal filter outputs
- Decimation filter characteristics
 - Fixed coefficients: 4 sets (8fs), 1 set (2fs)
 - Rewritable coefficients: 1 set (29 bit × 240 word)
- Dither rounding function in 8fs/24-bit output mode, with switchable ON/OFF and summing position
- PCM/DSD output independent muting operation
- 8fs output format: [MSB-first left-justified 32-bit] or [MSB-first right-justified 24-bit]
- 2fs output format: [MSB-first left-justified 32-bit] or [IIS 32-bit]
- +6dB DSD gain switching function
- System clock output switchable between external system clock and internal system clock
- 3.3V ± 10% supply voltage
- 5V tolerant inputs for direct connection to 5V logic outputs
- -20 to 70°C operating temperature range
- 80-pin QFP package

APPLICATIONS

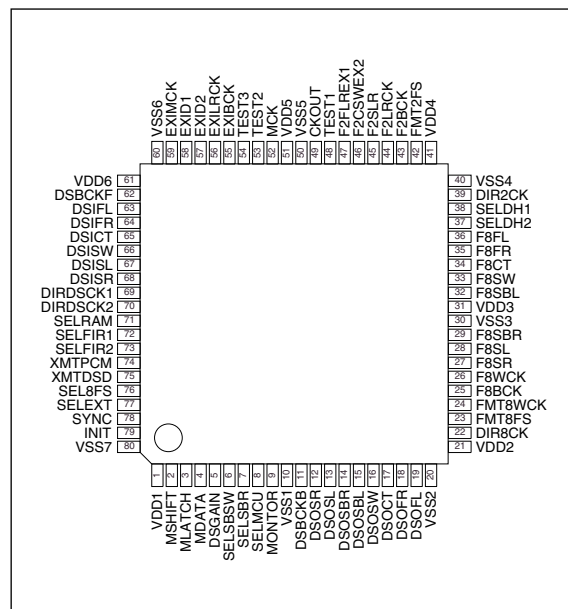
- Multi-channel SA-CD players
- SA-CD-compatible AV amplifiers

ORDERING INFORMATION

Device	Package
SM5816AF	80-pin QFP

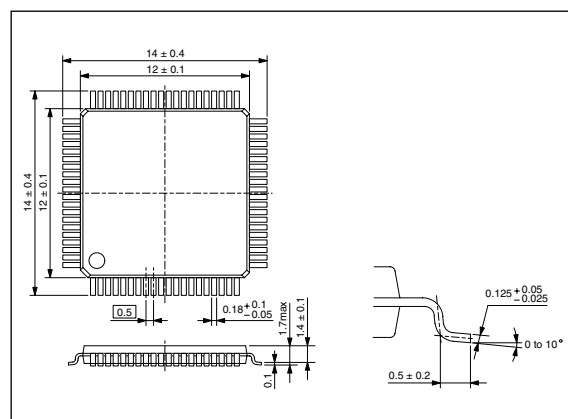
PINOUT

(Top view)



PACKAGE DIMENSIONS

(Unit: mm)



PIN DESCRIPTION

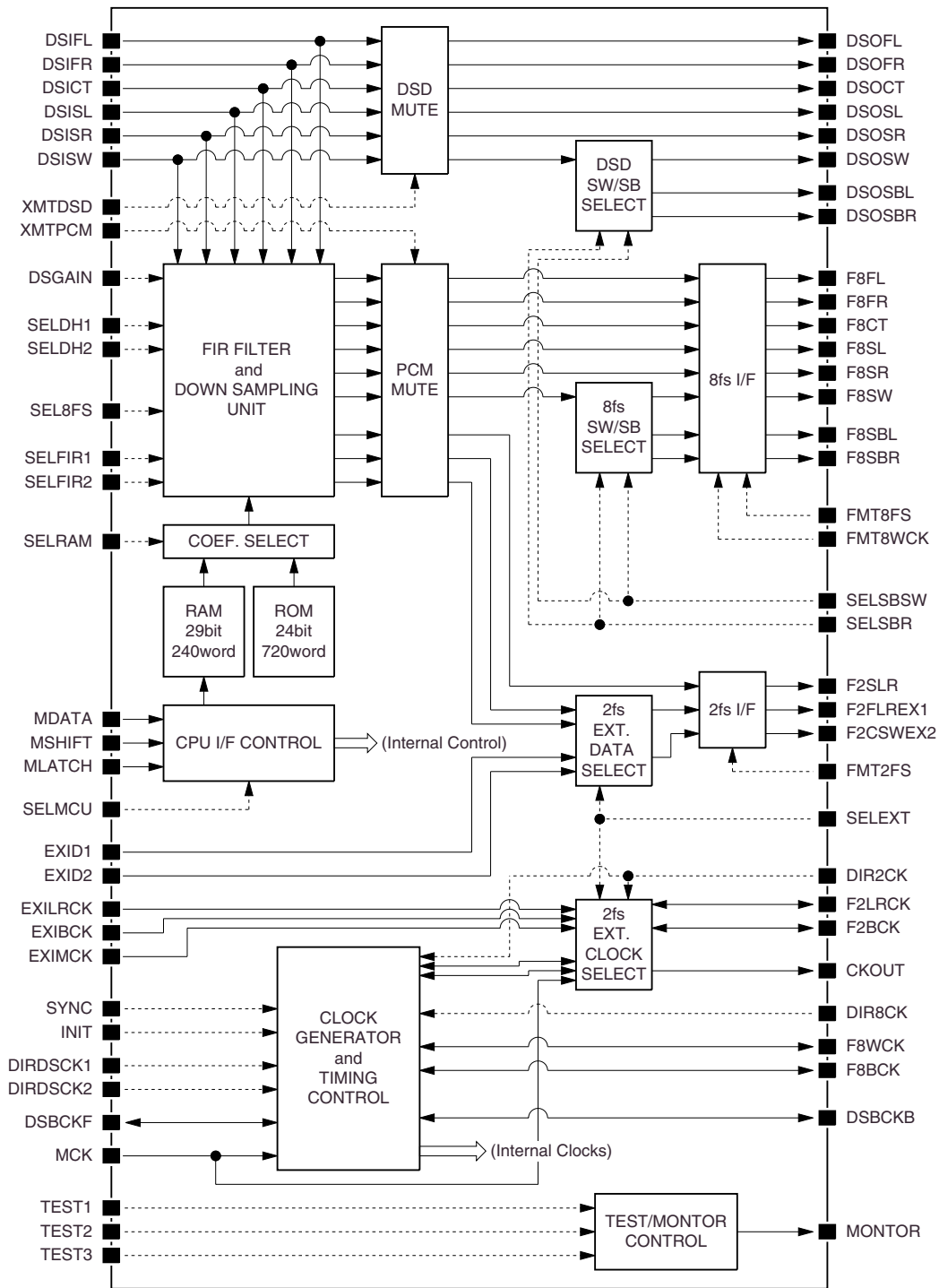
No.	Name	I/O	Property ¹	Output current	Input voltage	Description
1	VDD1	-	-	-	-	Supply pin 1
2	MSHIFT	I	S	-	3.3/5	Serial control: shift clock
3	MLATCH	I	S	-	3.3/5	Serial control: latch clock
4	MDATA	I	S	-	3.3/5	Serial control: command data
5	DSGAIN	I	PD	-	3.3/5	DSD signal gain setting L: 100% modulation = 0dB, H: 50% modulation = 0dB
6	SELSBSW	I	PD	-	3.3/5	DSD-SW input to SW/(SBL, SBR) output select L: SW input to SW output, H: SW input to (SBL, SBR) output Note: It effects both of DSD and 8fs outputs.
7	SELSBR	I	PD	-	3.3/5	DSD 8fs-(SBL, SBR) output select L: SBL output only, H: both SBL, SBR output Note: Valid only when SELSBSW is HIGH.
8	SELMCU	I	PD	-	3.3/5	Control method select L: pin control, H: serial interface data control
9	MONTOR	O	-	2mA	-	Parameter change monitor output
10	VSS1	-	-	-	-	Ground pin 1
11	DSBCKB	I/O	S	6mA	3.3/5	DSD through-mode data output: bit clock, controlled by DIRDSCK1, 2
12	DSOSR	O	-	2mA	-	DSD through-mode data output: surround right-channel
13	DSOSL	O	-	2mA	-	DSD through-mode data output: surround left-channel
14	DSOSBR	O	-	2mA	-	DSD through-mode data output: surround back right-channel
15	DSOSBL	O	-	2mA	-	DSD through-mode data output: surround back left-channel
16	DSOSW	O	-	2mA	-	DSD through-mode data output: subwoofer channel
17	DSOCT	O	-	2mA	-	DSD through-mode data output: center channel
18	DSOFR	O	-	2mA	-	DSD through-mode data output: front right-channel
19	DSOFL	O	-	2mA	-	DSD through-mode data output: front left-channel
20	VSS2	-	-	-	-	Ground pin 2
21	VDD2	-	-	-	-	Supply pin 2
22	DIR8CK	I	PD	-	3.3/5	8fs output F8BCK, F8WCK input/output select L: output (master mode), H: Input (slave mode)
23	FMT8FS	I	PD	-	3.3/5	8fs PCM format (MSB-first) L: MSB-first left-justified 32-bit, H: MSB-first right-justified 24-bit Note: In 8fs right-justified 24-bit format, there are a fixed 32 bit clock (F8BCK) cycles per word clock (F8WCK) cycle. Note: In 8fs right-justified 24-bit format, the upper empty bits are for sign extension.
24	FMT8WCK	I	PD	-	3.3/5	8fs PCMWCK format L: "H" → "L" (rising-edge word boundary) H: "L" → "H" (falling edge word boundary)
25	F8BCK	I/O	S	6mA	3.3/5	8fs PCM BCK (bit clock)
26	F8WCK	I/O	S	6mA	3.3/5	8fs PCM WCK (word clock)
27	F8SR	O	-	2mA	-	8fs PCM data output: surround right-channel
28	F8SL	O	-	2mA	-	8fs PCM data output: surround left-channel
29	F8SBR	O	-	2mA	-	8fs PCM data output: surround back right-channel
30	VSS3	-	-	-	-	Ground pin 3
31	VDD3	-	-	-	-	Supply pin 3
32	F8SBL	O	-	2mA	-	8fs PCM data output: surround back left-channel
33	F8SW	O	-	2mA	-	8fs PCM data output: subwoofer channel
34	F8CT	O	-	2mA	-	8fs PCM data output: center channel

No.	Name	I/O	Property ¹	Output current	Input voltage	Description										
35	F8FR	O	–	2mA	–	8fs PCM data output: front right-channel										
36	F8FL	O	–	2mA	–	8fs PCM data output: front left-channel										
37	SELDH2	I	PD	–	3.3/5	Output dither rounding ON/OFF and summing position select										
38	SELDH1	I	PD	–	3.3/5	<table border="1"> <tr> <td>SELDH (2, 1)</td> <td>(L, L)</td> <td>(L, H)</td> <td>(H, L)</td> <td>(H, H)</td> </tr> <tr> <td>Dither</td> <td>OFF</td> <td>1LSB</td> <td>2LSB</td> <td>4LSB</td> </tr> </table>	SELDH (2, 1)	(L, L)	(L, H)	(H, L)	(H, H)	Dither	OFF	1LSB	2LSB	4LSB
SELDH (2, 1)	(L, L)	(L, H)	(H, L)	(H, H)												
Dither	OFF	1LSB	2LSB	4LSB												
39	DIR2CK	I	PD	–	3.3/5	2fs output F2BCK, F2LRCK input/output select L: output (master mode), H: input (slave mode) Note: In 2fs-PCM output, when external inputs (EXID1, EXID2) are selected for output (SELEXT = "H"), the DIR2CK setting is inactive, and EXILRCK and EXIBCK are output as-is on F2LRCK and F2BCK, respectively.										
40	VSS4	–	–	–	–	Ground pin 4										
41	VDD4	–	–	–	–	Supply pin 4										
42	FMT2FS	I	PD	–	3.3/5	2fs PCM format L: MSB-first left-justified 32-bit, H: IIS 32-bit Note: In 2fs IIS 32-bit format, there are 64 F2BCK clock cycles per F2LRCK clock cycle.										
43	F2BCK	I/O	S	6mA	3.3/5	2fs or external data BCK										
44	F2LRCK	I/O	S	6mA	3.3/5	2fs or external data LRCK										
45	F2SLR	O	–	2mA	–	2fs PCM data output: surround left/right-channel										
46	F2CSWEX2	O	–	2mA	–	2fs PCM data output: center/subwoofer channel or external data 2 output										
47	F2FLREX1	O	–	2mA	–	2fs PCM data output: front left/right-channel or external data 1 output										
48	TEST1	I	PD, S	–	3.3/5	Test pin 1 (must be open or tie LOW for normal operation)										
49	CKOUT	O	–	12mA	–	System clock output. Clock output selected by SELEXT.										
50	VSS5	–	–	–	–	Ground pin 5										
51	VDD5	–	–	–	–	Supply pin 5										
52	MCK	I	–	–	3.3/5	Master clock input: 512fs (22.5792MHz, fs = 44.1kHz)										
53	TEST2	I	PD	–	3.3/5	Test pin 2 (must be open or tie LOW for normal operation)										
54	TEST3	I	PD	–	3.3/5	Test pin 3 (must be open or tie LOW for normal operation)										
55	EXIBCK	I	S	–	3.3/5	External PCM data BCK input										
56	EXILRCK	I	S	–	3.3/5	External PCM data LRCK input										
57	EXID2	I	–	–	3.3/5	External PCM data input 2										
58	EXID1	I	–	–	3.3/5	External PCM data input 1										
59	EXIMCK	I	–	–	3.3/5	External system clock input										
60	VSS6	–	–	–	–	Ground pin 6										
61	VDD6	–	–	–	–	Supply pin 6										
62	DSBCKF	I/O	S	6mA	3.3/5	DSD data input bit clock. Controlled by DIRDSCK1, 2										
63	DSIFL	I	–	–	3.3/5	DSD data input: front left-channel										
64	DSIFR	I	–	–	3.3/5	DSD data input: front right-channel										
65	DSICT	I	–	–	3.3/5	DSD data input: center channel										
66	DSISW	I	–	–	3.3/5	DSD data input: subwoofer channel										
67	DSISL	I	–	–	3.3/5	DSD data input: surround left-channel										
68	DSISR	I	–	–	3.3/5	DSD data input: surround right-channel										
69	DIRDSCK1	I	PD	–	3.3/5	DSBCKF I/O select L: input (slave), H: output (master)										
70	DIRDSCK2	I	PD	–	3.3/5	DSBCKB I/O select L: output (master), H: input (slave)										

No.	Name	I/O	Property ¹	Output current	Input voltage	Description										
71	SELRAM	I	PD	–	3.3/5	FIR coefficient ROM/RAM select L: ROM, H: RAM										
72	SELFIR1	I	PD	–	3.3/5	FIR coefficient (ROM) select										
73	SELFIR2	I	PD	–	3.3/5	<table border="1"> <tr> <td>SELFIR (2, 1)</td> <td>(L, L)</td> <td>(L, H)</td> <td>(H, L)</td> <td>(H, H)</td> </tr> <tr> <td>FIR coeff</td> <td>coeff 1</td> <td>coeff 2</td> <td>coeff 3</td> <td>coeff 4</td> </tr> </table>	SELFIR (2, 1)	(L, L)	(L, H)	(H, L)	(H, H)	FIR coeff	coeff 1	coeff 2	coeff 3	coeff 4
						SELFIR (2, 1)	(L, L)	(L, H)	(H, L)	(H, H)						
FIR coeff	coeff 1	coeff 2	coeff 3	coeff 4												
74	XMTPCM	I	PD	–	3.3/5	PCM output mute control input L: mute-ON, H: mute-OFF										
75	XMTDSD	I	PD	–	3.3/5	DSD output mute control input L: mute-ON, H: mute-OFF										
76	SEL8FS ^{2, 3}	I	PD	–	3.3/5	PCM output rate select L: 2fs, H: 8fs										
77	SELEXT ^{2, 3}	I	PD	–	3.3/5	2fs output/external data output select L: 2fs data, H: external data (EXID1, EXID2)										
78	SYNC ⁴	I	S	–	3.3/5	Forced sync control. Sync on rising edge										
79	INIT ^{4, 5}	I	S	–	3.3/5	Initialization control. Active-LOW. Resync on “L” → “H”										
80	VSS7	–	–	–	–	Ground pin 7										

1. S = Schmitt, PD = pull-down resistor
2. The SEL8FS setting takes precedence over the SELEXT setting. In other words, 8fs PCM output is selected when SEL8FS is HIGH, and the SELEXT settings are not effective. The SELEXT also selects relevant clock pins (F2LRCK, F2BCK, CKOUT).
3. Outputs not selected by SEL8FS and SELEXT are treated as described below:
 - Data signals are tied LOW.
 - When I/O pins F8WCK, F8BCK, F2LRCK, F2WCK are set as outputs, they function as outputs. When they are set as inputs, they are ignored in input mode.
4. The output data is synchronized each time by event-driven operation despite the clock input/output. The resynchronization operation occurs to avoid reading DSD input data at the falling edge of DSBCKF.
5. The internal flip-flops are all initialized in response to an active level on INIT, and outputs are tied HIGH or LOW during INIT active level input.

BLOCK DIAGRAM



SPECIFICATIONS

Absolute Maximum Ratings

$V_{SS} = 0V$

Parameter	Symbol	Rating	Unit
Supply voltage	V_{DD}	- 0.3 to 4.0	V
Input voltage 1 (3.3V)	V_{IN1}	- 0.3 to $V_{DD} + 0.5$	V
Input voltage 2 (3.3V/5V) ¹	V_{IN2}	- 0.3 to 7.0	V
Power dissipation	P_W	300	mW
Storage temperature	T_{STG}	- 55 to 125	°C

1. Input voltage 2 applies to pins with 5V input rating.

Recommended Operating Conditions

$V_{SS} = 0V$

Parameter	Symbol	Rating	Unit
Supply voltage	V_{DD}	3.0 to 3.6	V
Operating temperature	T_{OPR}	- 20 to 70	°C

DC Electrical Characteristics

$V_{DD} = 3.0$ to $3.6V$, $V_{SS} = 0V$, $T_{OPR} = - 20$ to $70^\circ C$ unless otherwise noted.

Parameter	Pin	Symbol	Condition	Rating			Unit
				min	typ	max	
Current consumption	VDD	I_{DD}	All pins no load	-	-	80	mA
Input voltage	"H" level (*1)	V_{IH}	$V_{DD} = 3.6V$	2.0	-	-	V
	"L" level (*1)	V_{IL}	$V_{DD} = 3.0V$	-	-	0.8	V
Schmitt-trigger voltage	Positive (*2)	V_{T+}		1.1	-	2.4	V
	Negative (*2)	V_{T-}		0.6	-	1.8	V
Hysteresis voltage	(*2)	V_H		0.1	-	-	V
Output voltage	"H" level (*3)	V_{OH}	$I_{OH} = - 2mA$ (Type1) $I_{OH} = - 6mA$ (Type2) $I_{OH} = - 12mA$ (Type3)	$V_{DD} - 0.4$	-	-	V
	"L" level (*3)	V_{OL}	$I_{OL} = 2mA$ (Type1) $I_{OL} = 6mA$ (Type2) $I_{OL} = 12mA$ (Type3)	-	-	0.4	V
Input leakage current	(*1, 2)	I_{LI}		- 1	-	1	μA
Pull-down resistance	(*4)	R_{PD}	$V_I = V_{DD}$	40	100	240	$k\Omega$

Pin summary

(*1)	Input pins and bidirectional (input/output) pins in input mode
(*2)	Inputs with Schmitt characteristic and bidirectional (input/output) pins in input mode
(*3)	Output pins and bidirectional (input/output) pins in output mode Type 3: CKOUT Type 2: DSBCKB, DSBCKF, F8BCK, F8WCK, F2BCK, F2LRCK Type 1: Outputs excluding those above
(*4)	Inputs with pull-down resistor

AC Electrical Characteristics

$V_{DD} = 3.0$ to $3.6V$, $V_{SS} = 0V$, $T_{OPR} = -20$ to $70^{\circ}C$, $f_s = 44.1kHz$ unless otherwise noted.

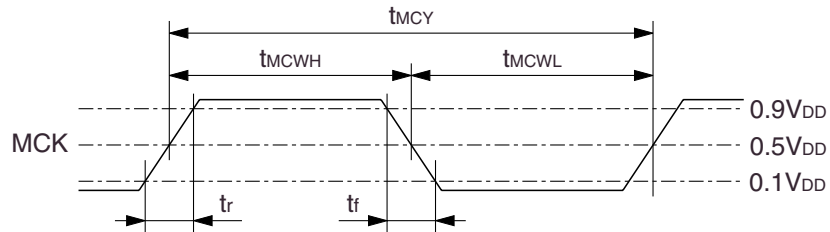
If DSBCKF, DSBCKB, F8WCK, F2LRCK clocks are input externally, by frequency division the clock input on MCK has the following relationships.

- (DSBCKF, DSBCKB) cycle = $8 \times$ MCK cycle (64fs)
- (F8WCK) cycle = $64 \times$ MCK cycle (8fs)
- (F2LRCK) cycle = $256 \times$ MCK cycle (2fs)

System clock

- MCK pin

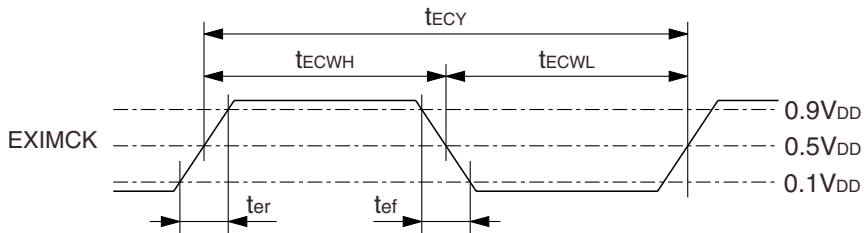
Parameter	Symbol	Rating			Unit
		min	typ	max	
"H"-level pulsewidth	t_{MCWH}	13	-	-	ns
"L"-level pulsewidth	t_{MCWL}	13	-	-	ns
Pulse cycle	t_{MCY}	40	44.29 (1/512fs)	-	ns
Rise/fall time	t_r, t_f	-	-	10	ns



External system clock

- EXIMCK pin

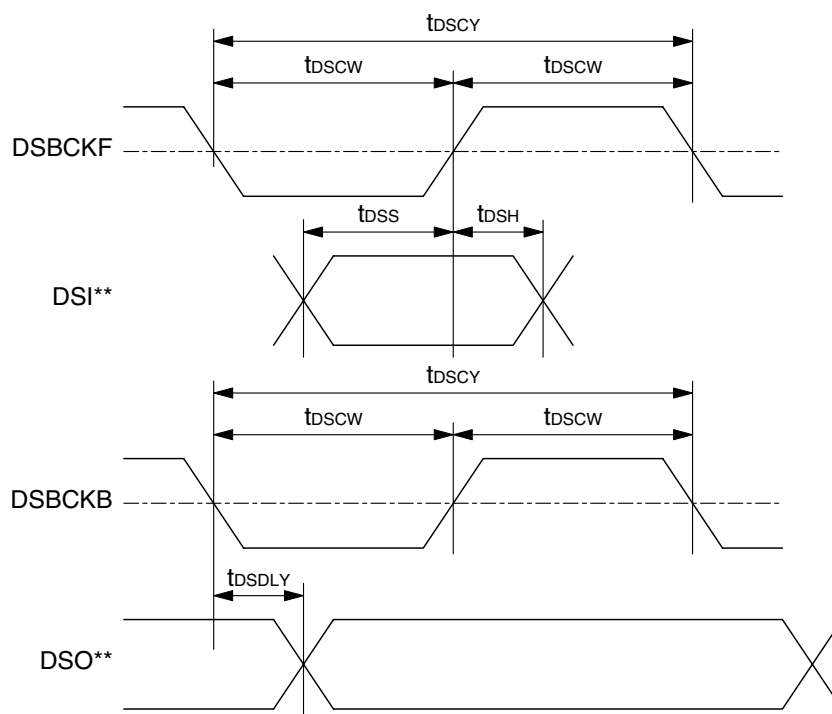
Parameter	Symbol	Rating			Unit
		min	typ	max	
"H"-level pulsewidth	t_{ECWH}	13	-	-	ns
"L"-level pulsewidth	t_{ECWL}	13	-	-	ns
Pulse cycle	t_{ECY}	40	-	-	ns
Rise/fall time	t_{er}, t_{ef}	-	-	10	ns



DSD input/output

- DSBCKF, DSBCKB pins
- DSIFL, DSIFR, DSISL, DSISR, DSICT, DSISW pins
- DSOFL, DSOFR, DSOSL, DSOSR, DSOCT, DSOSW, DSOSBL, DSOSBR pins

Parameter	Symbol	Rating			Unit
		min	typ	max	
DSD clock pulsewidth	t_{DSCW}	150	177.16	-	ns
DSD clock pulse cycle	t_{DSCY}	300	354.31 (1/64fs)	-	ns
DSD data setup time	t_{DSS}	50	-	-	ns
DSD data hold time	t_{DSH}	50	-	-	ns
DSD data delay time	t_{DSDLY}	0	-	15	ns



DSI**: DSIFL, DSIFR, DSISL, DSISR, DSICT, DSISW pins
 DSO**: DSOFL, DSOFR, DSOSL, DSOSR, DSOCT, DSOSW, DSOSBL, DSOSBR pins

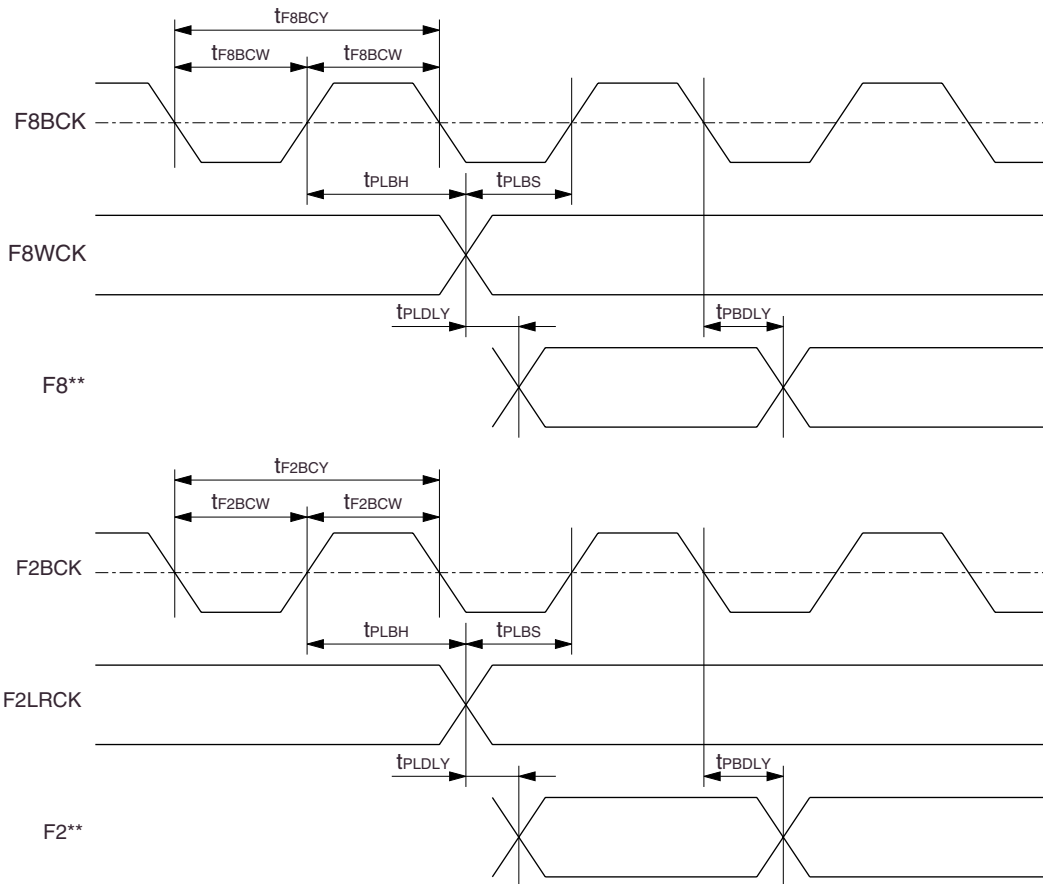
Note. The DSD clock pulsewidth and clock pulse cycle are with both DSBCKF and DSBCKB in input mode.

Note. Data is read internally using the falling edge of MCK, using the DSBCKF timing above as the base. When the timing changes, resynchronization must be performed using INIT or SYNC.

PCM output

- F8WCK, F8BCK, F8FL, F8FR, F8SL, F8SR, F8CT, F8SW, F8SBL, F8SBR pins
- F2LRCK, F2BCK, F2SLR, F2FLREX1, F2CSWEX2 pins

Parameter	Symbol	Rating			Unit
		min	typ	max	
8fs BCK clock pulsewidth	t_{F8BCW}	40	44.29	-	ns
8fs BCK clock pulse cycle	t_{F8BCY}	80	88.58 (1/256fs)	-	ns
2fs BCK clock pulsewidth	t_{F2BCW}	40	88.58	-	ns
2fs BCK clock pulse cycle	t_{F2BCY}	80	177.15 (1/128fs)	-	ns
Word CK setup time	t_{PLBS}	30	-	-	ns
Word CK hold time	t_{PLBH}	10	-	-	ns
Bit CK data delay time	t_{PBDLY}	0	-	15	ns
Word CK data delay time	t_{PLDLY}	0	-	15	ns



F8**: F8FL, F8FR, F8SL, F8SR, F8CT, F8SW, F8SBL, F8SBR pins
 F2**: F2SLR, F2FLREX1, F2CSWEX2 pins

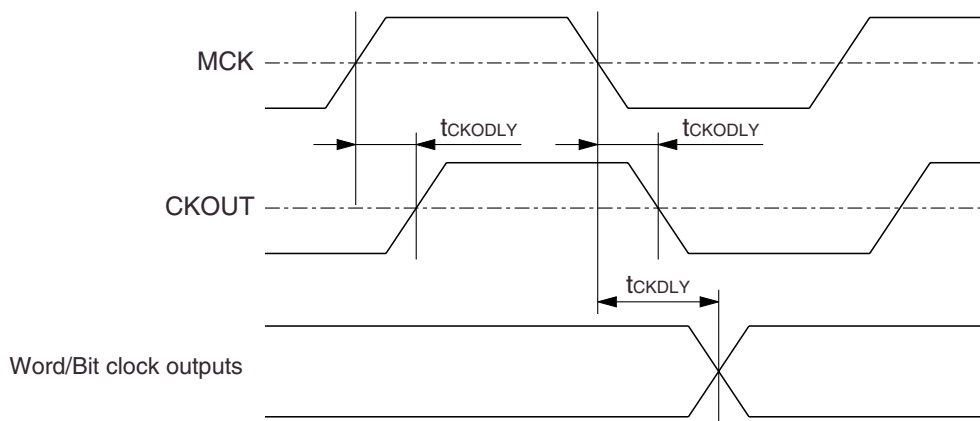
Note. The 2fs PCM output rating excludes external inputs (EXI**) in through mode.

Note. The 2fs/8fs bit clock and word clock relationship applies when F8BCK, F8WCK, F2BCK, F2LRCK pins are in input mode only.

Clock outputs

- CKOUT, DSBCKF, DSBCKB, F8WCK, F8BCK, F2LRCK, F2BCK pins

Parameter	Symbol	Rating			Unit
		min	typ	max	
CKOUT output delay time	t_{CKODLY}	0	-	10	ns
Clock output delay time	t_{CKDLY}	0	-	10	ns



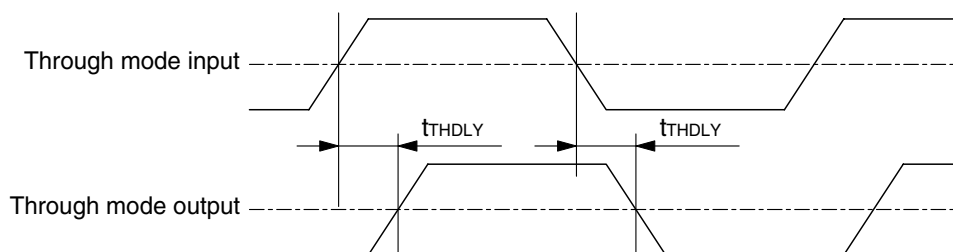
Note. Rating with MCK, in through mode, output on CKOUT.

Note. The word/bit clocks in output mode on pins F8BCK, F8WCK, F2BCK, F2LRCK, and DSBCKF, DSBCKB bidirectional pins in output mode.

Through-mode output

- DSBCKF, DSBCKB, CKOUT, F2BCK, F2LRCK, F2FLREX1, F2CSWEX2 pins

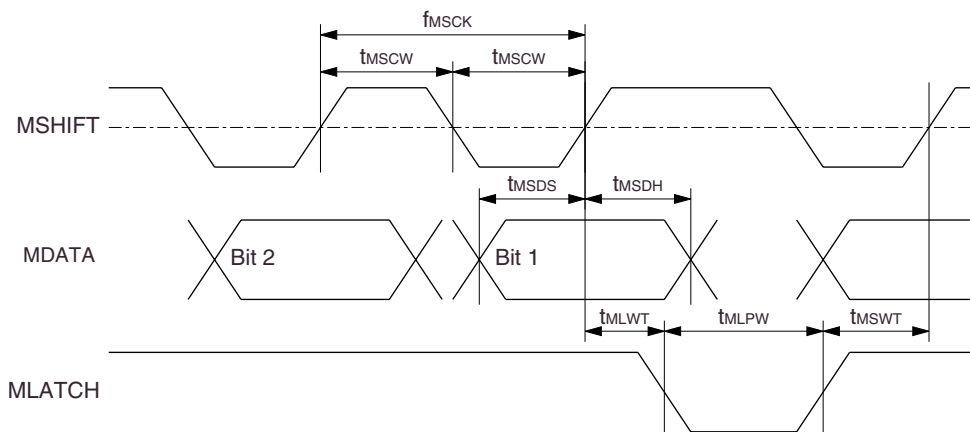
Through inputs	Through outputs	Conditions	t_{THDLY} MAX	Unit
DSBCKF	DSBCKB	DSBCKF in input mode, DSBCKB in output mode	10	ns
DSBCKB	DSBCKF	DSBCKF in output mode, DSBCKB in input mode	10	ns
EXIMCK	CKOUT	2fs PCM outputs with external inputs selected	10	ns
EXIBCK	F2BCK		10	ns
EXIWCK	F2LRCK		10	ns
EXID1	F2FLREX1		15	ns
EXID2	F2CSWEX2		15	ns



CPU serial control interface

■ MSHIFT, MDATA, MLATCH pins

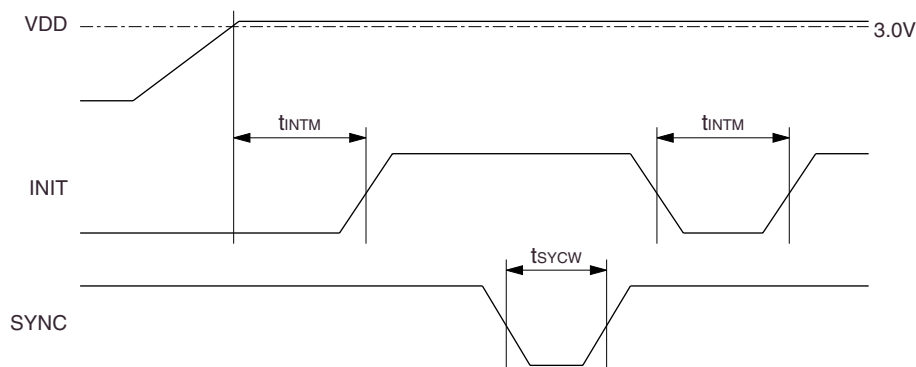
Parameter	Symbol	Rating			Unit
		min	typ	max	
MSHIFT clock pulse frequency	f_{MSCK}	-	-	1	MHz
MSHIFT clock pulsewidth	t_{MSCW}	480	-	-	ns
MDATA setup time	t_{MSDS}	200	-	-	ns
MDATA hold time	t_{MSDH}	200	-	-	ns
MLATCH wait time	t_{MLWT}	200	-	-	ns
MLATCH pulsewidth	t_{MLPW}	$10 \times t_{MCY}$	-	-	ns
MSHIFT wait time	t_{MSWT}	0	-	-	ns



Initialization and resynchronization

■ INIT, SYNC pins

Parameter	Symbol	Rating			Unit
		min	typ	max	
Initialization time	t_{INTM}	$6 \times t_{MCY}$	-	-	ns
Resynchronization pulsewidth	t_{SYCW}	$6 \times t_{MCY}$	-	-	ns

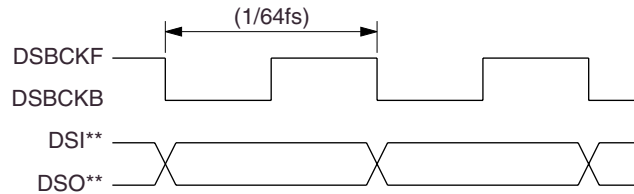


FUNCTIONAL DESCRIPTION

Data Input/Output Formats

DSD input/output format

DSD input data is read on the rising edge of the bit clock, and output data is output on the falling edge.

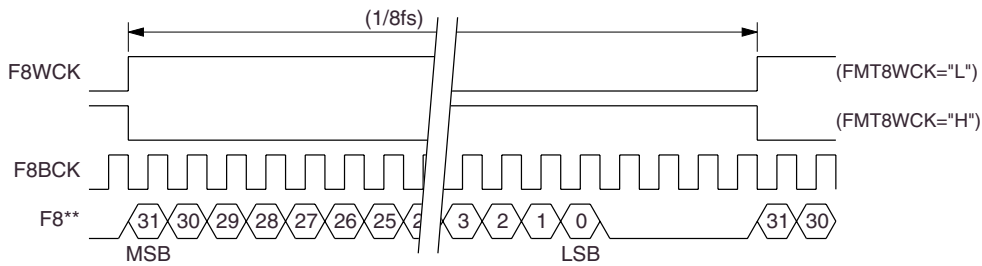


DSI**: DSI_{FL}, DSI_{FR}, DSI_{SL}, DSI_{SR}, DSI_{CT}, DSI_{SW} pins
 DSO**: DSO_{FL}, DSO_{FR}, DSO_{SL}, DSO_{SR}, DSO_{CT}, DSO_{SW}, DSO_{SBL}, DSO_{SBR} pins

8fs output format

There are two 8fs output formats that can be set using FMT8FS. Also, the F8WCK polarity can be inverted using FMT8WCK.

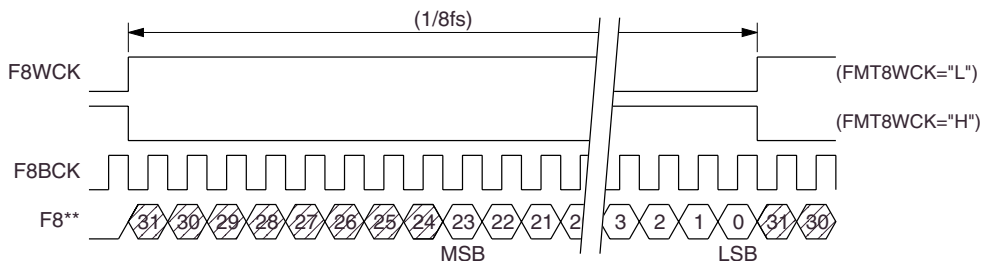
(1) MSB-first left-justified 32-bit (FMT8FS = "L")



F8**: F8_{FL}, F8_{FR}, F8_{SL}, F8_{SR}, F8_{CT}, F8_{SW}, F8_{SBL}, F8_{SBR} pins

- If more than 32 bit clock cycles are input during each word clock cycle, data following the 32nd bit are output as "0".
- When F8WCK and F8BCK are set as outputs, there are 32 fixed bit clock cycles per word clock cycle.
- Output data is in 32-bit 2s complement format.

(2) MSB-first right-justified 24-bit (FMT8FS = "H")



F8**: F8_{FL}, F8_{FR}, F8_{SL}, F8_{SR}, F8_{CT}, F8_{SW}, F8_{SBL}, F8_{SBR} pins

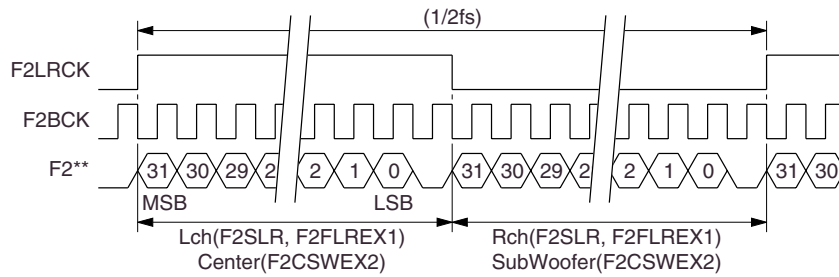
- In this format, there are 32 bit clock cycles per word clock cycle regardless of the input/output settings.
- The code bits are comprised by the 24-bit output data. The output data is output in 32-bit sign extended format (data bits are shown as slash lines)
- Output data is in 24-bit 2s complement format.

2fs output format

There are two 2fs output formats that can be set using FMT2FS. The output data is in 32-bit 2s complement format.

However, when external inputs (EXID1, EXID2, EXILRCK, EXIBCK) are selected, the signals are output as-is in through mode regardless of the format setting.

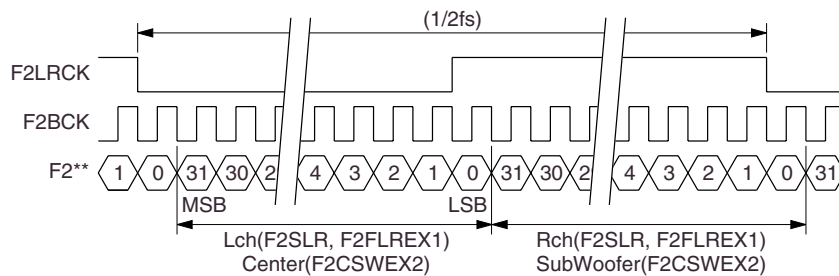
(1) MSB-first left-justified 32-bit (FMT2FS = "L")



F2**: F2SLR, F2FLREX1, F2CSWEX2 pins

- If more than 32 bit clock cycles are input during each word clock cycle HIGH-level or LOW-level interval, data following the 32nd bit are output as "0".
- When F2LRCK and F2BCK are set as outputs, there are 32 fixed bit clock cycles per word clock cycle HIGH-level or LOW-level interval.

(2) IIS 32-bit (FMT2FS = "H")



F2**: F2SLR, F2FLREX1, F2CSWEX2 pins

- In this format, there are 32 bit clock cycles per word clock cycle regardless of the input/output settings.

Data Output Selection

PCM output selection

The PCM output and decimation filter processing is set using SEL8FS and SELEXT, as shown in the following table.

Setting		PCM output system						Clock output	Filter processing
		8fs output		2fs output					
SEL8FS	SELEXT	F8**	F8WCK F8BCK	F2SLR	F2FLREX1	F2CSWEX2	F2LRCK F2BCK	CKOUT	
L	L	"0"	invalid	DSISL DSISR	DSIFL DSIFR	DSICT DSISW	2fs valid	MCK	2fs 480th-order
L	H	"0"	invalid	"0"	EXID1	EXID2	EXILRCK EXIBCK	EXIMCK	invalid
H	L or H	DSI**	8fs valid	"0"	"0"	"0"	invalid	MCK	8fs 240th-order

Note. F8**: F8FL, F8FR, F8SL, F8SR, F8CT, F8SW, F8SBL, F8SBR pins
 DSI**: DSIFL, DSIFR, DSISL, DSISR, DSICT, DSISW pins

- The 8fs/2fs select setting (SEL8FS) takes precedence over the 2fs output external data setting (SELEXT).
- The 8fs/2fs word clock (F8WCK, F2LRCK) and bit clock (F8BCK, F2BCK) are output, even when not selected ("invalid"), in output mode when external input is not selected.

8-channel subwoofer/surround back output switching

The DSD output and 8fs PCM output are set using SELSBSW and SELSBR, and the subwoofer output can be switched between surround back left and right channels.

Setting		PCM output system					
		DSD output			8fs PCM output		
SELSBSW	SELSBR	DSOSW	DSOSBL	DSOSBR	F8SW	F8SBL	F8SBR
L	L or H	DSOSW	Mute Pattern	Mute Pattern	F8SW	"0"	"0"
H	L	Mute Pattern	DSOSW	Mute Pattern	"0"	F8SW	"0"
H	H	Mute Pattern	DSOSW	DSOSW	"0"	F8SW	F8SW

- The DSD mute output has a 50% duty "55h" continuous mute pattern.

Clock Input/Output Selection and Synchronization Operation

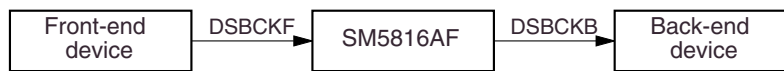
DSD clock input/output switching

The DSD input bit clock (DSBCKF) and DSD output bit clock (DSBCKB) are switched using DIRDSCK1, 2 as shown in the following table.

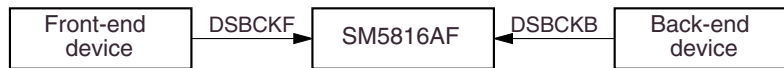
Setting		I/O state	
DIRDSCK1	DIRDSCK2	DSBCKF	DSBCKB
L	L	IN (Slave)	OUT (Master)
L	H	IN (Slave)	IN (Slave)
H	L	OUT (Master)	OUT (Master)
H	H	OUT (Master)	IN (Slave)

Reference connection diagram

(1) DIRDSCK1, 2 = (L, L)



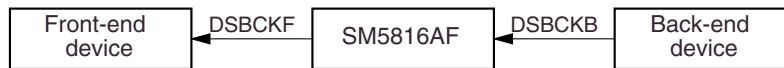
(2) DIRDSCK1, 2 = (L, H)



(3) DIRDSCK1, 2 = (H, L)



(4) DIRDSCK1, 2 = (H, H)



Note. In mode (1) and (4) in the diagram above, the input clocks are output as-is in through mode.

PCM clock input/output switching

The 8fs and 2fs word/bit input/output clocks can be switched using DIR8CK and DIR2CK.

Note when external data is selected using SEL8FS and SELEXT, F2LRCK and F2BCK become outputs despite the state of DIR2CK, so care must be taken with external connections.

The I/O settings for the data output mode selected are shown in the following table.

Mode	Mode setting		2fs clock I/O state		8fs clock I/O state	
	SEL8FS	SELEXT	DIR2CK	F2LRCK F2BCK	DIR8CK	F8WCK F8BCK
2fs	L	L	L	OUT (Master)	L	OUT (clock output)
			H	IN (Slave)	H	IN (invalid)
EXT	L	H	L	OUT (EXILRCK, EXIBCK)	L	OUT (clock output) ¹
			H	OUT (EXILRCK, EXIBCK)	H	IN (invalid)
8fs	H	L or H	L	OUT (clock output)	L	OUT (Master)
			H	IN (invalid)	H	IN (Slave)

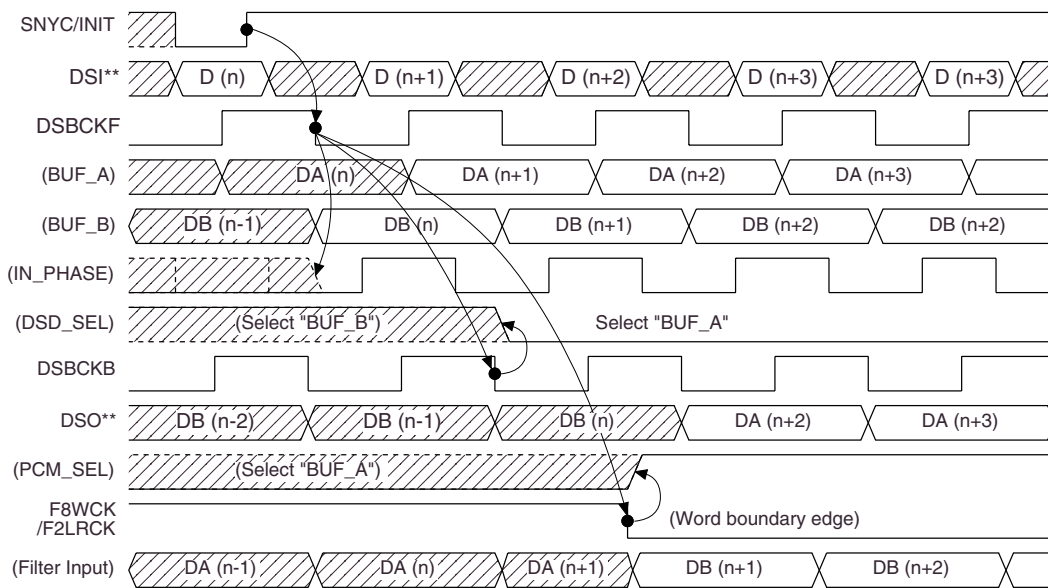
1. When external data is output in 2fs mode, MCK stops and the 8fs clock output stays stopped.

Input clock sync operation and resynchronization

The data output internal operation and interface processing occur as event driven operations using the word clock word boundary as the event trigger, hence the output signals are always synchronized regardless of the word clock and bit clock I/O state.

As regards DSD input, the data (BUF_A) on the rising edge of bit clock (DSBCKF) and data (BUF_B) one half of the bit clock period later are selected and read in when the DSD output and PCM output event starts, to avoid the transitions in the DSD input signal.

At this time, the sync operation that determines which data was read in, after the INIT and SYNC rising edge, occurs when the word clock word boundary is detected after the first DSBCKF falling edge.



DSI**: DSIFL, DSIFR, DSISL, DSISR, DSICT, DSISW pins
 DSO**: DSOFL, DSOFR, DSOSL, DSOSR, DSOCT, DSOSW, DSOSBL, DSOSBR pins

Figure 1. Input timing sync operation due to INIT, SYNC

- 1) After the SYNC/INIT rising edge is detected, the phase reference signal (IN_PHASE) for the input data buffer selected is determined on the first DSBCKF falling edge.
- 2) Then, after the IN_PHASE transition, the subsequent data buffer is determined on the first DSBCKB edge and F8WCK/F2LRCK word boundary edge.
 (The input data buffer selection for DSD output and PCM output is independent.)

Synchronization adjustment due to INIT/SYNC edge may cause 1 DSD data bit to be lost or made redundant due to input/output clock phase difference. If this would be problem, individual outputs should be muted for the following intervals.

- [DSD output] 4 DSBCKB (64fs) clock cycles
- [8fs PCM output] 34 F8WCK (8fs) clock cycles
- [2fs PCM output] 18 F2LRCK (2fs) clock cycles

2fs PCM select external input data and external system clock output switching

(1) Switching to external input data

When SELEXT goes from LOW to HIGH, F2FLREX1 and F2CSWEX2 PCM data outputs are directly switched from EXID1 and EXID2 inputs.

Similarly, F2LRCK and F2BCK are directly switched, regardless of the DIR2CK setting, from EXILRCK and EXIBCK inputs.

(2) Switching to external system clock

The CKOUT output is switched from MCK or EXIMCK inputs, according to the state of SELEXT

SELEXT = "L": MCK output

SELEXT = "H": EXIMCK output

However, both MCK and EXIMCK should not be stopped during the switching interval to avoid a momentary pulse from occurring when switching.

Also, the switching interval, from initial setting until both clocks have each switched 4 times, has a LOW-level pulse that continues longer than the clock pulsewidth of each input clock.

After the switching operation finishes, the unused clock input may be stopped.

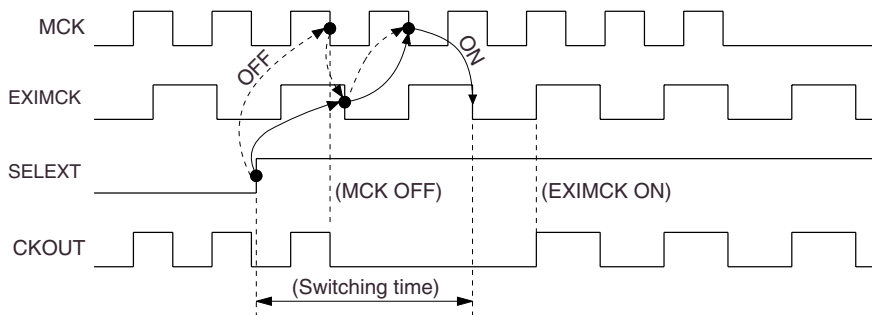


Figure 2. MCK → EXIMCK switching

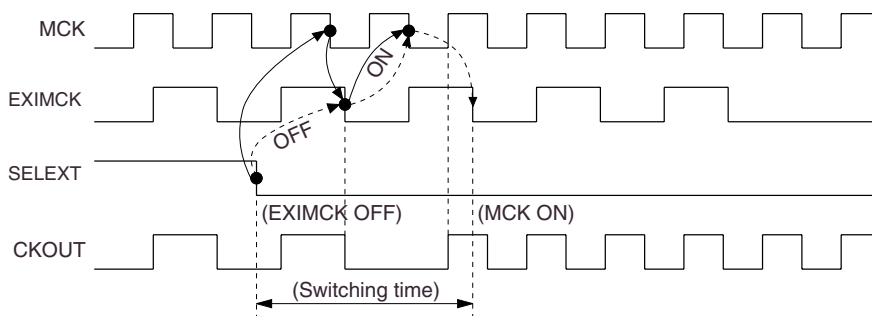


Figure 3. EXIMCK → MCK switching

Decimation Filter Selection

The decimation filter coefficient set can be selected from 5 sets of fixed coefficients (8fs: 4 sets, 2fs: 1 set) and 1 set of programmable coefficients (8fs or 2fs). The coefficient set is selected using SELRAM and SELFIR1,2.

Fixed coefficient selection

The fixed coefficients are selected when SELRAM = "L". The filter characteristic is 240th-order for 8fs, and 480th-order for 2fs. When 8fs PCM output is selected, 4 sets of characteristic filter coefficients are available for selection using SELFIR1, 2.

SELFIR2	SELFIR1	Filter characteristic	
L	L	coeff1	NPC standard filter
L	H	coeff2	40kHz cutoff filter
H	L	coeff3	50kHz cutoff filter
H	H	coeff4	70kHz cutoff filter

RAM coefficient selection

A RAM coefficient set is selected when SELRAM = "H".

Initially, the data in RAM is indeterminate, so coefficient data must first be written to the RAM. While data is being written to RAM, the result of any RAM coefficient operation is not guaranteed, hence a fixed coefficient set should be used before switching to RAM coefficients or the PCM outputs should be muted.

The RAM supports 29-bit × 240 words for combined 8fs and 2fs output. The filter characteristic is 240th-order for 8fs, and 480th-order for 2fs. The filter structure uses an even number order of symmetrical coefficients, reducing by half the number of coefficients to write to RAM. The coefficient data for 8fs and 2fs is in 29-bit 2s complement format.

Details about writing coefficient data are described in "RAM coefficient write mode".

DSD Gain Switching

The DSD signal 50% level can be set to 0dB, in 8fs/2fs output modes, using DSGAIN.

DSGAIN = "L" : 100% modulation = 0dB (PCM)

DSGAIN = "H" : 50% modulation = 0dB (PCM) *+ 6dB internal amplification

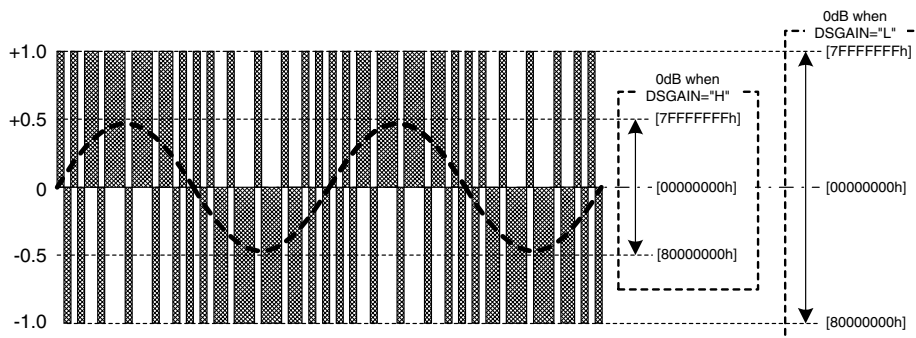


Figure 4. DSD modulation level

Note. With DSGAIN = "H" and 50% DSD modulation or greater, a limiter is needed to prevent output signal clipping.

Dither Rounding Function

In 8fs PCM output mode with 24-bit right-justified format only, a dither function (TPDF)* can be added to the output. The dither ON/OFF and rounding bit position are set by SELDH1 and SELDH2. After the initial setting is made, rounded data is output 2 words later.

*: Triangular Probability Density Function

SELDH2	SELDH1	Function
L	L	Dither OFF
L	H	Dither ON: 1 LSB (Bit 0)
H	L	Dither ON: 2 LSB (Bit 1)
H	H	Dither ON: 4 LSB (Bit 2)

Mute Function

The DSD outputs and PCM outputs can be muted independently. Muting is applied directly to the outputs.

(1) DSD mute

The DSD outputs are directly muted by a 50% duty (55h) pattern.

XMTDSD = "L" : all DSD outputs with muting ON

XMTDSD = "H" : all DSD outputs with muting OFF

(2) PCM mute

The PCM outputs are directly muted with value "0".

XMTPCM = "L" : all PCM outputs muting ON

XMTPCM = "H" : all PCM outputs muting OFF

Monitor Function

The internal status changes can be monitored using the monitor pin. The MONTOR pin goes HIGH whenever any of the following parameter conditions occur.

- SEL8FS changes state
- SELEXT changes state
- SELRAM, SELFIR1, 2 changes state

The MONTOR pin is reset to LOW using the INIT or SYNC inputs.

CPU Interface

Timing diagrams

The CPU interface comprises 3-wire serial inputs MDATA, MSHIFT, and MLATCH.

- MDATA bit data is read into an internal interface buffer on the rising edge of MSHIFT.
- When MLATCH goes LOW, data is latched and processed.

At this point, the data read on the previous MSHIFT rising edge is treated as bit 1, and the most recently input data bits are valid bits.

- The internal processing mode is determined by the state of bit 1.
 - Bit 1 = "L": system set mode (16 valid bits)
 - Bit 1 = "H": RAM coefficient write mode (40 valid bits)

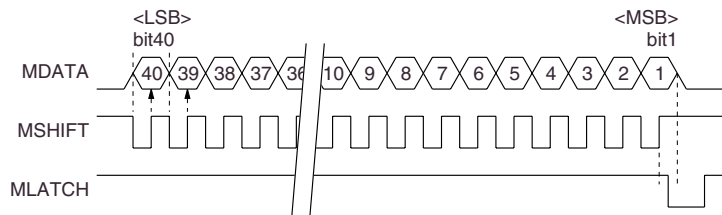


Figure 5. Timing diagram

System setting mode (bit 1 = "L")

In system set mode, each bit represents a function set flag, with the first 16 bits being valid. Each flag function, when SELMCU is HIGH, performs the same function as the pin with the same name, while the state of those pins is ignored.

Table 1. Flag set function table

Bit	Flag name	Function	"H"	"L"	Default													
1	MODE	System set mode select	–	Tied "L"	–													
2	SEL8FS	PCM output data select	8fs PCM output	2fs PCM output	"L"													
3	SELECT	2fs PCM external data output select	External data select	2fs PCM output	"L"													
4	(Reserved)	(Reserved)	–	Tied "L"	"L"													
5	(Reserved)	(Reserved)	–	Tied "L"	"L"													
6	SELSBSW	Subwoofer output select	Surround back output	Subwoofer output	"L"													
7	SELSBR	Surround back Rch output select	Both Lch, Rch outputs	Lch output only	"L"													
8	SELRAM	Fixed/RAM coefficient select	RAM coefficient	Fixed coefficient	"L"													
9	SELFIR1	8fs FIR fixed coefficient 1-4 select	<table border="1"> <tr> <td>SELFIR (2, 1)</td> <td>(L, L)</td> <td>(L, H)</td> <td>(H, L)</td> <td>(H, H)</td> </tr> <tr> <td>FIR coeff</td> <td>coeff 1</td> <td>coeff 2</td> <td>coeff 3</td> <td>coeff 4</td> </tr> </table>					SELFIR (2, 1)	(L, L)	(L, H)	(H, L)	(H, H)	FIR coeff	coeff 1	coeff 2	coeff 3	coeff 4	"L"
SELFIR (2, 1)	(L, L)		(L, H)	(H, L)	(H, H)													
FIR coeff	coeff 1	coeff 2	coeff 3	coeff 4														
10	SELFIR2					"L"												
11	SELDH1	Dither rounding setting	<table border="1"> <tr> <td>SELDH (2, 1)</td> <td>(L, L)</td> <td>(L, H)</td> <td>(H, L)</td> <td>(H, H)</td> </tr> <tr> <td>Dither</td> <td>OFF</td> <td>1LSB</td> <td>2LSB</td> <td>4LSB</td> </tr> </table>					SELDH (2, 1)	(L, L)	(L, H)	(H, L)	(H, H)	Dither	OFF	1LSB	2LSB	4LSB	"L"
SELDH (2, 1)	(L, L)		(L, H)	(H, L)	(H, H)													
Dither	OFF	1LSB	2LSB	4LSB														
12	SELDH2					"L"												
13	DSGAIN	DSD signal gain setting	50% modulation = 0dB	100% modulation = 0dB	"L"													
14	MTPCM	PCM signal mute	Mute-OFF	Mute-ON	"L"													
15	MTDSD	DSD signal mute	Mute-OFF	Mute-ON	"L"													
16	SYNC	Forced sync	Resync when "L" → "H"		"L"													

Note. All 16 bits need to be written even when only changing one portion of the data.

RAM coefficient write mode (bit 1 = "H")

In RAM coefficient write mode, the bit represent a RAM write address and coefficient write data, with the first 40 bits of data being valid.

Table 2. Flag function table

Bit	Flag name	Function	Value or state	
1	MODE	RAM coefficient write mode	Tied "H"	
2	(Reserved)	Reserved flag	Tied "L"	
3	(Reserved)	Reserved flag	Tied "L"	
4	COEF28	Coefficient data (MSB)	Coefficient data must conform with the following conditions. * Coefficient word length = 29 bits (± 1.0) * Coefficient sum total not to exceed 0.5 (18000000)h to (07FFFFFF)h * Depending on the coefficient, the result may pass the overflow limit. * RAM initial state is indeterminate, thus address-field data must be written before use.	
5	COEF27	Coefficient data		
6	COEF26	Coefficient data		
7	COEF25	Coefficient data		
8	COEF24	Coefficient data		
9	COEF23	Coefficient data		
10	COEF22	Coefficient data		
11	COEF21	Coefficient data		
12	COEF20	Coefficient data		
13	COEF19	Coefficient data		
14	COEF18	Coefficient data		
15	COEF17	Coefficient data		
16	COEF16	Coefficient data		
17	COEF15	Coefficient data		
18	COEF14	Coefficient data		
19	COEF13	Coefficient data		
20	COEF12	Coefficient data		
21	COEF11	Coefficient data		
22	COEF10	Coefficient data		
23	COEF9	Coefficient data		
24	COEF8	Coefficient data		
25	COEF7	Coefficient data		
26	COEF6	Coefficient data		
27	COEF5	Coefficient data		
28	COEF4	Coefficient data		
29	COEF3	Coefficient data		
30	COEF2	Coefficient data		
31	COEF1	Coefficient data		
32	COEF0	Coefficient data (LSB)		
33	RA7	RAM write address (MSB)		Coefficient address should be assigned as follows. * Even-order symmetrical coefficients restriction means that only half need be written from the edges to the center. * For 2fs, half 480th-order implies to address 240. RA = (00)h is the edge, RA = (EF)h is the center. * For 8fs, half 240th-order implies to address 120. RA = (00)h, the edge, to RA = (3B)h are the first 60 addresses RA = (80)h to RA = (BB)h are the last 60 addresses.
34	RA6	RAM write address		
35	RA5	RAM write address		
36	RA4	RAM write address		
37	RA3	RAM write address		
38	RA2	RAM write address		
39	RA1	RAM write address		
40	RA0	RAM write address (LSB)		

Note. Writing RAM coefficients always takes precedence. As a result, coefficient writing while a RAM coefficient is selected, will mean the coefficients are read incorrectly, generating an output noise. To prevent this problem, the outputs should be muted when writing RAM coefficients or a ROM coefficient should be temporarily selected.

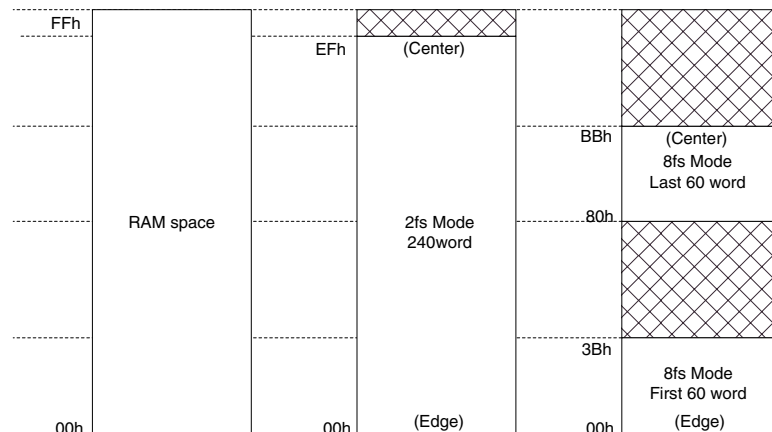


Figure 6. Usable address space diagram

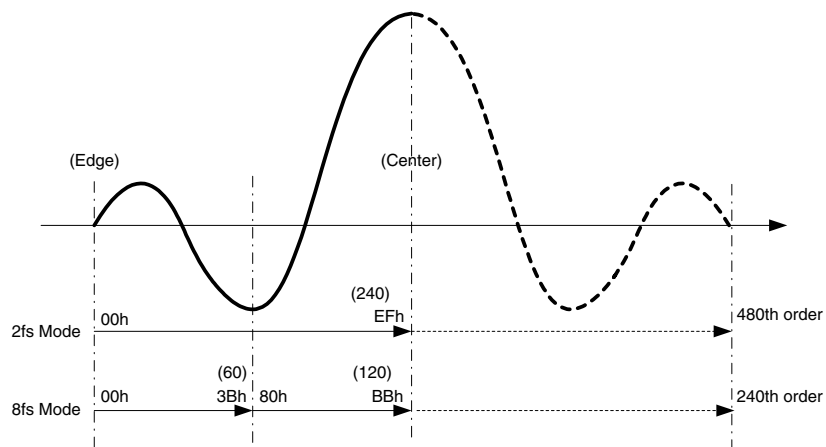


Figure 7. Filter coefficient example of RAM address (RA) assignment

Note that in 8fs mode, the usable address area is separated into 2 portions.

Pin-control/Flag-control Relation Table

Function	System setting Description		Pin control		Serial I/F control												
	"H"	"L"	Pin name	No.	Flag name	Bit	Default										
Control method select	Serial I/F control	Pin control	SELMCU	8	-	-	-										
Initialization control	Normal operation	Initialize and resync	INIT	79	-	-	-										
DSD data input clock (DSBCKF) I/O select	Output (Master)	Input (Slave)	DIRDSCK1	69	-	-	-										
DSD data output clock (DSBCKB) I/O select	Input (Slave)	Output (Master)	DIRDSCK2	70	-	-	-										
8fs data output clock (F8BCK, F8WCK) I/O select	Input (Slave)	Output (Master)	DIR8CK	22	-	-	-										
2fs data output clock (F2BCK, F2LRCK) I/O select	Input (Slave) ¹	Output (Master)	DIR2CK	39	-	-	-										
8fs PCM data format select	MSB-first right-justified 24-bit	MSB-first left-justified 32-bit	FMT8FS	23	-	-	-										
8fs PCM word clock format select	"L" → "H" (falling edge word boundary)	"H" → "L" (rising edge word boundary)	FMT8WCK	24	-	-	-										
2fs PCM data format select	IIS 32bit	MSB-first left-justified 32-bit	FMT2FS	42	-	-	-										
PCM output data select	8fs PCM output	2fs PCM output	SEL8FS	76	SEL8FS	2	"L"										
2fs PCM external data output select	External data select	2fs PCM output	SELEXT	77	SELEXT	3	"L"										
Subwoofer output select	Surround Back output	Subwoofer output	SELSBSW	6	SELSBSW	6	"L"										
Surround Back Rch output select	Both Rch, Lch select	Lch output only	SELSBR	7	SELSBR	7	"L"										
Fixed/RAM coefficient select	RAM coefficient	Fixed coefficient	SELRAM	71	SELRAM	8	"L"										
8fs FIR fixed coefficient 1-4 select	<table border="1"> <tr> <td>SELFIR (2, 1)</td> <td>(L, L)</td> <td>(L, H)</td> <td>(H, L)</td> <td>(H, H)</td> </tr> <tr> <td>FIR coeff</td> <td>coeff 1</td> <td>coeff 2</td> <td>coeff 3</td> <td>coeff 4</td> </tr> </table>		SELFIR (2, 1)	(L, L)	(L, H)	(H, L)	(H, H)	FIR coeff	coeff 1	coeff 2	coeff 3	coeff 4	SELFIR1	72	SELFIR1	9	"L"
	SELFIR (2, 1)	(L, L)	(L, H)	(H, L)	(H, H)												
FIR coeff	coeff 1	coeff 2	coeff 3	coeff 4													
			SELFIR2	73	SELFIR2	10	"L"										
Dither rounding setting	<table border="1"> <tr> <td>SELDH (2, 1)</td> <td>(L, L)</td> <td>(L, H)</td> <td>(H, L)</td> <td>(H, H)</td> </tr> <tr> <td>Dither</td> <td>OFF</td> <td>1LSB</td> <td>2LSB</td> <td>4LSB</td> </tr> </table>		SELDH (2, 1)	(L, L)	(L, H)	(H, L)	(H, H)	Dither	OFF	1LSB	2LSB	4LSB	SELDH1	38	SELDH1	11	"L"
	SELDH (2, 1)	(L, L)	(L, H)	(H, L)	(H, H)												
Dither	OFF	1LSB	2LSB	4LSB													
			SELDH2	37	SELDH2	12	"L"										
DSD signal gain setting	50% modulation = 0dB	100% modulation = 0dB	DSGAIN	5	DSGAIN	13	"L"										
PCM signal mute	Mute-OFF	Mute-ON	XMTPCM	74	MTPCM	14	"L"										
DSD signal mute	Mute-OFF	Mute-ON	XMTDSD	75	MTDSD	15	"L"										
Forced sync	Resync when "L" → "H"		SYNC	78	SYNC	16	"L"										

1. In 2fs PCM mode, when external inputs are selected for output(SELEXT="H"), the DIR2CK setting is inactive, and F2BCK, F2LRCK are output.

Initialization Operation

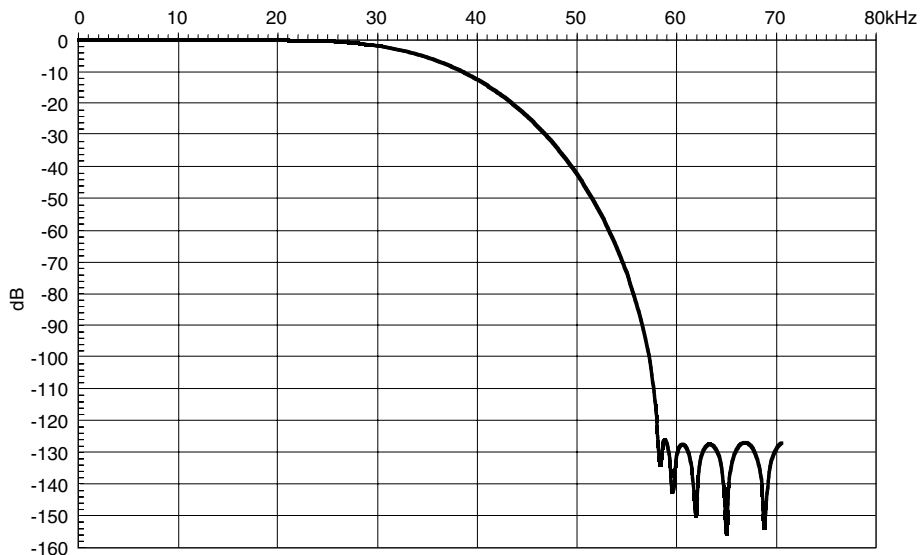
When power is applied, the INIT pin must be held LOW for the rated time to initialize the device. Initialization sets all the CPU interface system control registers to their default values, and the outputs have the states as described below.

Pin	State
DSD data outputs	All "L"
8fs PCM data outputs	All "L"
2fs PCM data outputs	In internal 2fs output mode, all "L" In external data output mode, output as-is in through mode
DSBCKF, DSBCKB	When both output modes are set, "H" When one input mode is set, through mode output
F8BCK	In output mode, "H"
F8WCK	In output mode using FMT8WCK = "L", "L" In output mode using FMT8WCK = "H", "H"
F2BCK	In internal data output mode, "H" In external data output mode, external bit clock is output in through mode
F2LRCK	In left-justified 32-bit output mode, "L" In IIS output mode, "H" In external data output mode, external word clock is output in through mode
CKOUT	MCK or EXIMCK, whichever is selected, is output in through mode
MONITOR	Cleared to "L"

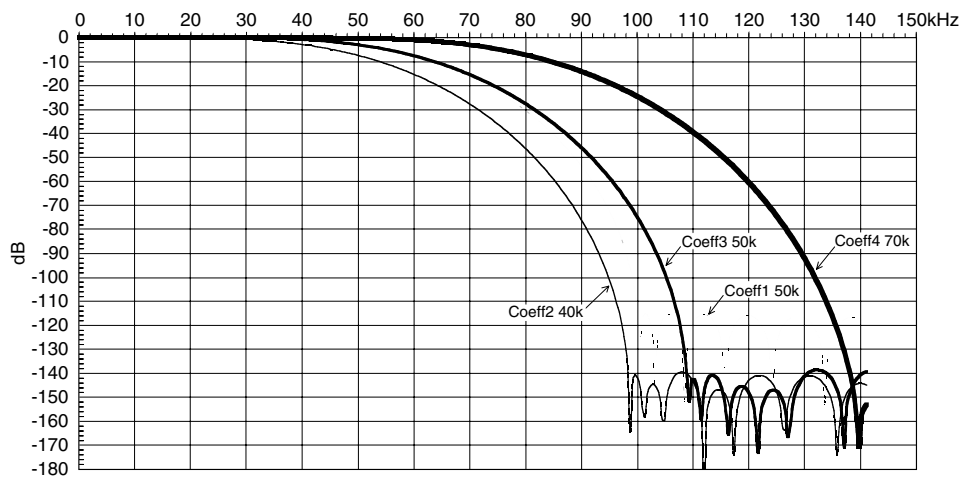
When INIT goes "H", the sync adjustment operation described in section "Input clock sync operation and resynchronization" starts. Also, if DSD or PCM output is muted, the mute condition continues as-is until released.

BUILT-IN FILTER CHARACTERISTICS

64fs → 2fs Mode



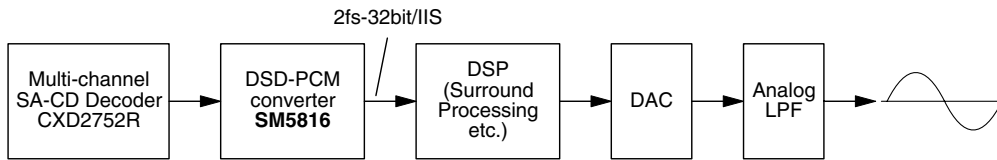
64fs → 8fs Mode



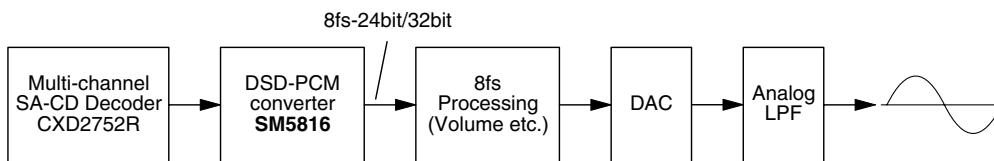
Note. These characteristics were obtained by simulation.

TYPICAL APPLICATION CIRCUITS

Surround Processor



DSD-to-PCM Conversion Reproduction



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