

#### OVERVIEW

The SM5841A/B are digital filters for digital audio, fabricated in Molybdenum-gate CMOS.

The SM5841A/B feature selectable digital de-emphasis digital attenuation and soft mute functions. The serial data format uses 16-bit input words and 16-, 18- or 20-bit output words. They can operate from a standard 5 V supply or a low-voltage 3.2 V supply.

The SM5841A/B are available in 22-pin SOPs and 18-pin plastic DIPs.

#### FEATURES

- Filter configuration
  - 2-channel, 4-times or 8-times oversampling (interpolation) filter
  - 3-stage interpolation (69-tap + 13-tap + 9-tap)
  - IIR deemphasis filter for accurate gain and phase response
  - Digital attenuator
  - Overflow limiter
  - Crystal oscillator
- Filter characteristics ( $f_s$  = sampling frequency)
  - $0.20 \pm 0.03$  dB passband (0 to  $0.4535f_s$ ) ripple
  - 53 dB (min) stopband attenuation ( $0.5465f_s$  to  $7.4535f_s$  in 8fs mode and  $0.5465f_s$  to  $3.4535f_s$  in 4fs mode)
  - Linear phase (zero group delay)
- Input/output
  - 16-bit serial data input (2s-complement, MSB-first, normal/IIS selectable)
  - 16-, 18- or 20-bit serial data output (4fs L/R alternating or 8fs L/R simultaneous, 2s-complement, MSB-first, stereo/bilingual mode select)
  - DC offset (approximately 0.8%) correction (SM5841B only)
  - TTL-compatible
- 256fs/384fs system clock selectable
- Supply voltage
  - 5 V normal-voltage operation
  - 3.2 V low-voltage operation
- 18-pin plastic DIP or 22-pin SOP
- Molybdenum-gate CMOS process

#### Filter functions

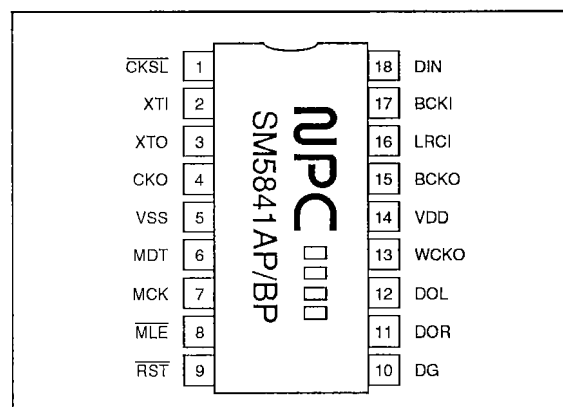
- 1st-order noise shaper (ON/OFF selectable)
- Soft muting
- Digital attenuation
- Digital deemphasis (for 32, 44.1 and 48 kHz)

#### APPLICATIONS

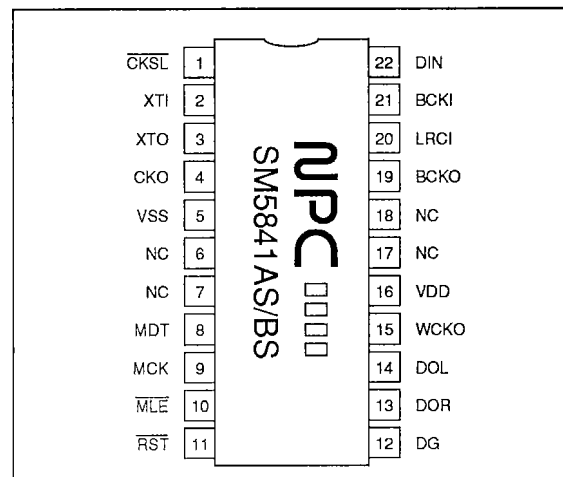
- CD playback systems
- DAT playback systems
- PCM playback systems

#### PINOUTS

##### 18-pin DIP



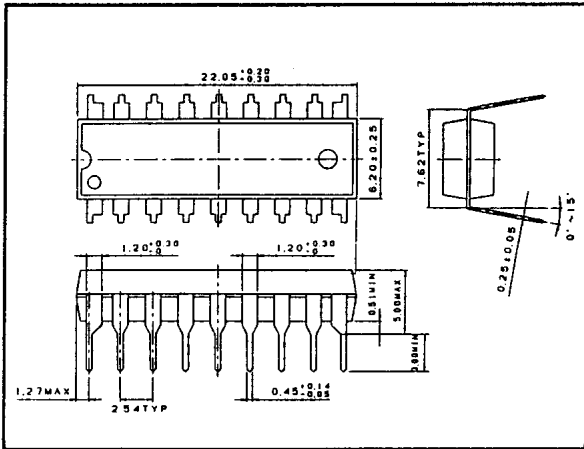
##### 22-pin SOP



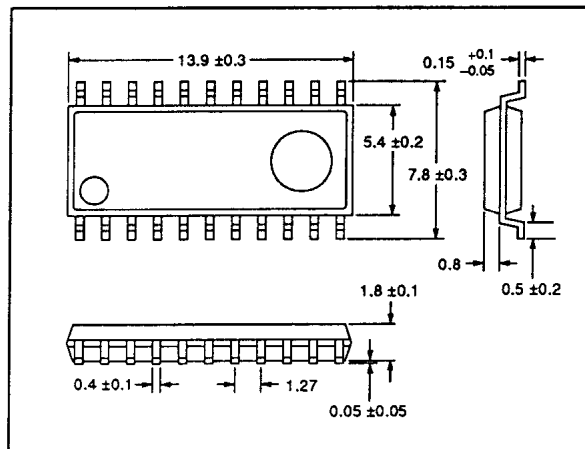
**PACKAGE DIMENSIONS**

Unit: mm

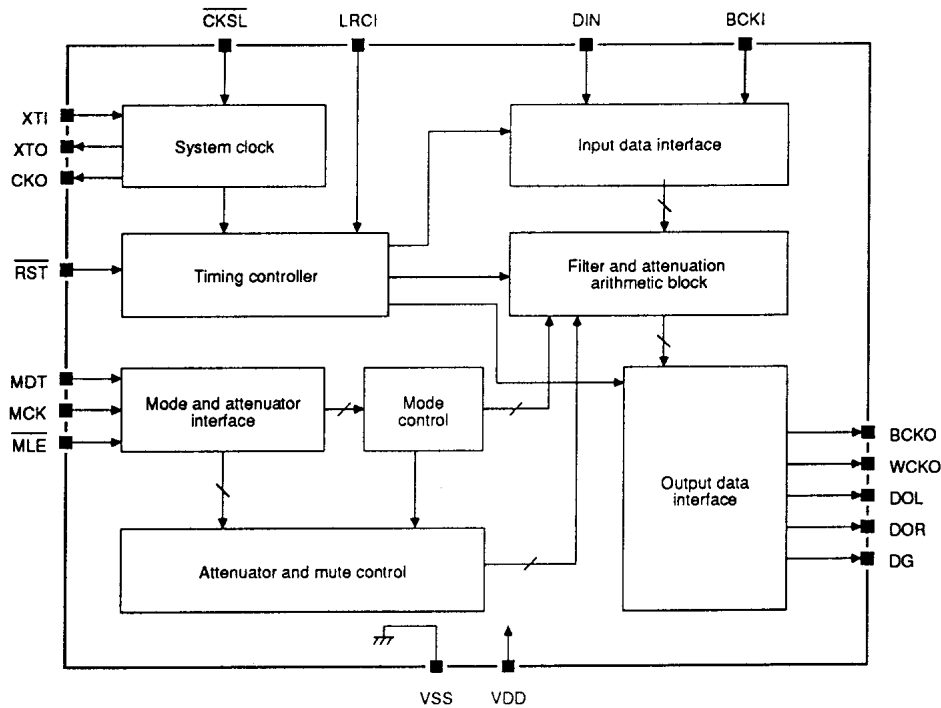
**18-pin DIP**



**22-pin SOP**



**BLOCK DIAGRAM**



**PIN DESCRIPTION**

Number		Name	I/O	Description
SOP	DIP			
1	1	$\overline{\text{CKSL}}$	ip	Oscillator and input frequency select. 384fs when HIGH, and 256fs when LOW.
2	2	XTI	i	Oscillator input connection
3	3	XTO	o	Oscillator output connection
4	4	CKO	o	Oscillator output clock (same frequency as XTI)
5	5	VSS		Ground

**SM5841A/B**

Number		Name	I/O	Description
SOP	DIP			
6	–	NC		No connection
7	–	NC		No connection
8	6	MDT	ip	Digital attenuator and mode set data
9	7	MCK	ip	Digital attenuator and mode set clock
10	8	MLE	ip	Digital attenuator and mode set latch enable
11	9	RST	ip	System reset
12	10	DG	o	8fs left/right simultaneous or 4fs left/right alternating de-glitched output
13	11	DOR	o	Right-channel data output when in 8fs L/R simultaneous mode, and LR clock output in 4fs L/R alternating mode.
14	12	DOL	o	Left-channel data output when in 8fs L/R simultaneous mode, and left/right-channel data output in L/R alternating mode.
15	13	WCKO	o	Output word clock
16	14	VDD		5 V supply
17	–	NC		No connection
18	–	NC		No connection
19	15	BCKO	o	Output bit clock
20	16	LRCl	ip	Input data sample rate (fs) clock
21	17	BCKI	ip	Input bit clock
22	18	DIN	ip	Data input

**Note**

i = input, ip = input with pull-up resistance, o = output

**SPECIFICATIONS**

**Absolute Maximum Ratings**

$V_{SS} = 0\text{ V}$

Parameter	Symbol	Rating	Unit
Supply voltage range	$V_{DD}$	–0.3 to 7.0	V
Input voltage range	$V_{IN}$	–0.3 to $V_{DD} + 0.3$	V
Power dissipation	$P_D$	250	mW
Storage temperature range	$T_{stg}$	–40 to 125	deg. C
Soldering temperature	$T_{sld}$	255	deg. C
Soldering time	$t_{sld}$	10	s

**Recommended Operating Conditions**

$V_{SS} = 0\text{ V}$

Parameter	Symbol	Rating	Unit
Supply voltage range	$V_{DD}$	3.2 to 5.5	V
Operating temperature range	$T_{opr}$	–20 to 80	deg. C

## DC Electrical Characteristics

### Normal-voltage mode

$V_{DD} = 4.5$  to  $5.5$  V,  $V_{SS} = 0$  V,  $T_a = -20$  to  $80$  deg. C unless otherwise noted

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Supply current	$I_{DD}$	$V_{DD} = 5.0$ V, $f_{SYS} = 256$ fs = 13 MHz, no load	–	–	40	mA
XTI HIGH-level input voltage	$V_{IH1}$		$0.7V_{DD}$	–	–	V
XTI LOW-level input voltage	$V_{IL1}$		–	–	$0.3V_{DD}$	V
HIGH-level input voltage	$V_{IH2}$	See note 1.	2.4	–	–	V
LOW-level input voltage	$V_{IL2}$		–	–	0.5	V
HIGH-level output voltage	$V_{OH}$	$I_{OH} = -0.4$ mA. See note 2.	2.5	–	–	V
LOW-level output voltage	$V_{OL}$	$I_{OL} = 1.6$ mA. See note 2.	–	–	0.4	V
XTI HIGH-level input leakage current	$I_{LH}$	$V_{IN} = V_{DD}$	–	10	20	$\mu$ A
XTI LOW-level input leakage current	$I_{LL}$	$V_{IN} = 0$ V	–	10	20	$\mu$ A
HIGH-level input leakage current	$I_{LH}$	$V_{IN} = V_{DD}$ . See note 1.	–	–	1.0	$\mu$ A
LOW-level input current	$I_{IL}$	$V_{IN} = 0$ V. See note 1.	–	10	20	$\mu$ A

### Notes

1. Pins LRCI, DIN, BCKI,  $\overline{CKSL}$ , MDT, MCK,  $\overline{MLE}$  and  $\overline{RST}$
2. Pins CKO, DOL, DOR, BCKO, WCKO and DG

### Low-voltage mode

$V_{DD} = 3.2$  to  $4.5$  V,  $V_{SS} = 0$  V,  $T_a = -20$  to  $70$  deg. C unless otherwise noted

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Supply current	$I_{DD}$	$V_{DD} = 3.4$ V, $f_{SYS} = 256$ fs = 11.5 MHz, no load	–	–	20	mA
XTI HIGH-level input voltage	$V_{IH1}$		$0.7V_{DD}$	–	–	V
XTI LOW-level input voltage	$V_{IL1}$		–	–	$0.3V_{DD}$	V
HIGH-level input voltage	$V_{IH2}$	See note 1.	2.4	–	–	V
LOW-level input voltage	$V_{IL2}$		–	–	0.5	V
HIGH-level output voltage	$V_{OH}$	$I_{OH} = -0.2$ mA. See note 2.	2.5	–	–	V
LOW-level output voltage	$V_{OL}$	$I_{OL} = 0.8$ mA. See note 2.	–	–	0.4	V
XTI HIGH-level input leakage current	$I_{LH}$	$V_{IN} = V_{DD}$	–	–	12	$\mu$ A

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Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
XTI LOW-level input leakage current	$I_{LL}$	$V_{IN} = 0\text{ V}$	–	–	12	$\mu\text{A}$
HIGH-level input leakage current	$I_{LH}$	$V_{IN} = V_{DD}$ . See note 1.	–	–	1.0	$\mu\text{A}$
LOW-level input current	$I_{IL}$	$V_{IN} = 0\text{ V}$ . See note 1.	–	–	12	$\mu\text{A}$

### Notes

1. Pins LRCI, DIN, BCKI,  $\overline{\text{CKSL}}$ , MDT, MCK,  $\overline{\text{MLE}}$  and  $\overline{\text{RST}}$
2. Pins CKO, DOL, DOR, BCKO, WCKO and DG

### AC Electrical Characteristics

$V_{DD} = 4.5$  to  $5.5\text{ V}$ ,  $V_{SS} = 0\text{ V}$ ,  $T_a = -20$  to  $80\text{ deg. C}$  for normal-voltage operation.

$V_{DD} = 3.2$  to  $4.5\text{ V}$ ,  $V_{SS} = 0\text{ V}$ ,  $T_a = -20$  to  $70\text{ deg. C}$  for low-voltage operation.

Typical values are measured at  $f_s = 44.1\text{ kHz}$ .

### System clock

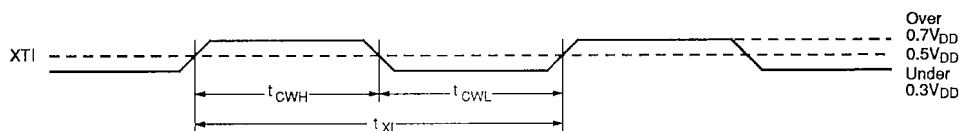
#### Crystal oscillator operation

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Oscillator frequency	$f_{MAX}$	384fs, $\overline{\text{CKSL}} = \text{HIGH}$	4.0	16.9	19.3	MHz
		256fs, $\overline{\text{CKSL}} = \text{LOW}$	4.0	11.3	13.0	

#### External clock input operation

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
XTI HIGH-level clock pulsewidth	$t_{CWH}$	384fs, $\overline{\text{CKSL}} = \text{HIGH}$	21.7	29.5	125	ns
		256fs, $\overline{\text{CKSL}} = \text{LOW}$	34	44.3	125	
XTI LOW-level clock pulsewidth	$t_{CWL}$	384fs, $\overline{\text{CKSL}} = \text{HIGH}$	21.7	29.5	125	ns
		256fs, $\overline{\text{CKSL}} = \text{LOW}$	34	44.3	125	
XTI clock pulse time	$t_{XI}$	384fs, $\overline{\text{CKSL}} = \text{HIGH}$	51.7	59.0	250	ns
		256fs, $\overline{\text{CKSL}} = \text{LOW}$	77	88.6	250	

#### System clock timing waveform



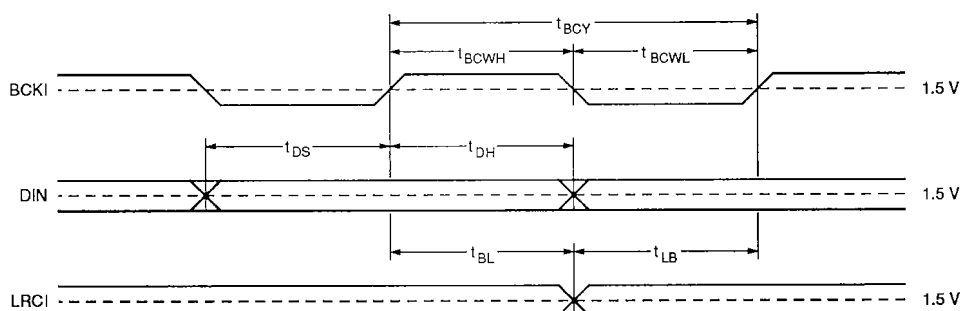
#### Serial input timing (BCKI, DIN, LRCI)

Parameter	Symbol	Rating			Unit
		min	typ	max	
BCKI HIGH-level pulsewidth	$t_{BCWH}$	50	–	–	ns
BCKI LOW-level pulsewidth	$t_{BCWL}$	50	–	–	ns

## SM5841A/B

Parameter	Symbol	Rating			Unit
		min	typ	max	
BCKI pulse period	$t_{BCY}$	100	–	–	ns
DIN setup time	$t_{DS}$	50	–	–	ns
DIN hold time	$t_{DH}$	50	–	–	ns
Last BCKI rising edge to LRCI edge	$t_{BL}$	50	–	–	ns
LRCI edge to first BCKI rising edge	$t_{LB}$	50	–	–	ns

### BCKI, DIN and LRCI input timing waveform



### Reset timing

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
$\overline{\text{RST}}$ LOW-level pulsewidth	$t_{\text{RST}}$	At power-on	1	–	–	$\mu\text{s}$
		At other times	50	–	–	ns

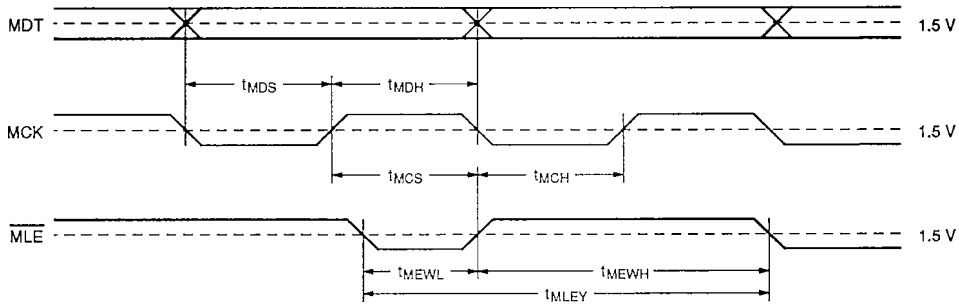
### Control input timing (MDT, MCK, $\overline{\text{MLE}}$ )

Parameter	Symbol	Rating			Unit
		min	typ	max	
MDT setup time	$t_{\text{MDS}}$	40	–	–	ns
MDT hold time	$t_{\text{MDH}}$	40	–	–	ns
$\overline{\text{MLE}}$ setup time	$t_{\text{MCS}}$	60	–	–	ns
$\overline{\text{MLE}}$ hold time	$t_{\text{MCH}}$	40	–	–	ns
$\overline{\text{MLE}}$ LOW-level pulsewidth	$t_{\text{MEWL}}$	40	–	–	ns
$\overline{\text{MLE}}$ HIGH-level pulsewidth	$t_{\text{MEWH}}$	40	–	–	ns
$\overline{\text{MLE}}$ pulse interval	$t_{\text{MLEY}}$	6	–	–	$t_{\text{sys}}$
MCK and $\overline{\text{MLE}}$ rise time	$t_r$	–	–	100	ns
MCK and $\overline{\text{MLE}}$ fall time	$t_f$	–	–	100	ns

### Note

$t_{\text{sys}}$  = system clock cycle time (1/384fs when  $\overline{\text{CKSL}} = \text{HIGH}$  and 1/256fs when  $\overline{\text{CKSL}} = \text{LOW}$ )

Control input timing waveform



Output timing

Normal-voltage mode

$V_{DD} = 4.5$  to  $5.5$  V,  $V_{SS} = 0$  V,  $T_a = -20$  to  $80$  deg. C

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Oscillator input to output delay	$t_{XTO}$	XTI falling edge to XTO rising edge	3	–	20	ns
Oscillator input to clock output delay	$t_{CKO}$	XTI falling edge to CKO falling edge	7	–	30	ns
Oscillator input to bit clock output delay (CKSL = HIGH)	$t_{sbH}$	XTI falling edge to BCKO rising edge	10	–	60	ns
	$t_{sbL}$	XTI falling edge to BCKO falling edge	10	–	60	ns
Oscillator input to bit clock output delay (CKSL = LOW)	$t_{sbH}$	XTI rising edge to BCKO rising edge	10	–	60	ns
	$t_{sbL}$	XTI falling edge to BCKO falling edge	10	–	60	ns
Bit clock output to data output and word clock output delay	$t_{bdH1}$	BCKO falling edge to rising-edge output	0	–	20	ns
	$t_{bdL1}$	BCKO falling edge to falling-edge output	0	–	20	ns
Bit clock output to de-glitched output delay	$t_{bdH2}$	BCKO rising edge to rising-edge output	0	–	20	ns
	$t_{bdL2}$	BCKO rising edge to falling-edge output	0	–	20	ns

Notes

All measurements with 15 pF load

## SM5841A/B

### Low-voltage mode

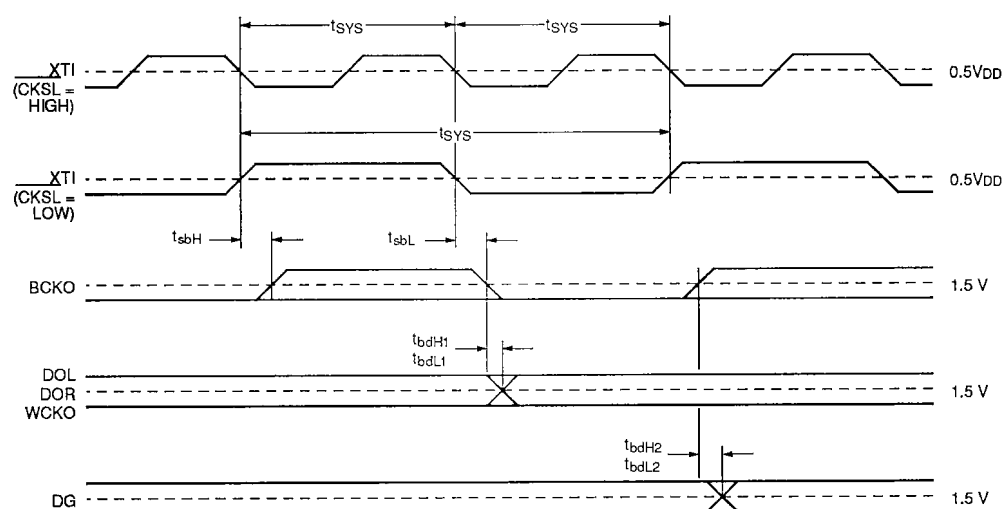
$V_{DD} = 3.2$  to  $4.5$  V,  $V_{SS} = 0$  V,  $T_a = -20$  to  $70$  deg. C

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Oscillator input to output delay	$t_{XTO}$	XTI falling edge to XTO rising edge	3	–	30	ns
Oscillator input to clock output delay	$t_{CKO}$	XTI falling edge to CKO falling edge	7	–	45	ns
Oscillator input to bit clock output delay (CKSL = HIGH)	$t_{sbH}$	XTI falling edge to BCKO rising edge	10	–	100	ns
	$t_{sbL}$	XTI falling edge to BCKO falling edge	10	–	100	ns
Oscillator input to bit clock output delay (CKSL = LOW)	$t_{sbH}$	XTI rising edge to BCKO rising edge	10	–	100	ns
	$t_{sbL}$	XTI falling edge to BCKO falling edge	10	–	100	ns
Bit clock output to data output and word clock output delay	$t_{bdH1}$	BCKO falling edge to rising-edge output	0	–	30	ns
	$t_{bdL1}$	BCKO falling edge to falling-edge output	0	–	30	ns
Bit clock output to de-glitched output delay	$t_{bdH2}$	BCKO rising edge to rising-edge output	0	–	30	ns
	$t_{bdL2}$	BCKO rising edge to falling-edge output	0	–	30	ns

### Notes

All measurements with 15 pF load

### Output timing waveform



### Note

The output timing shows the timing relationship between DOL/DOR/WCKO/DG and XTI and BCKO. It does not show the timing relationship between outputs.

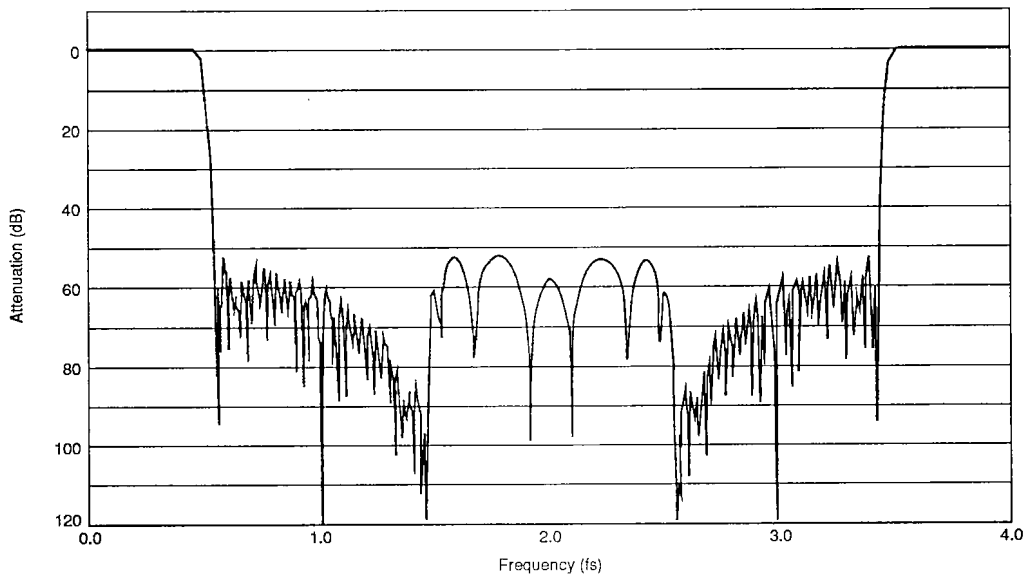


**Filter Characteristics**

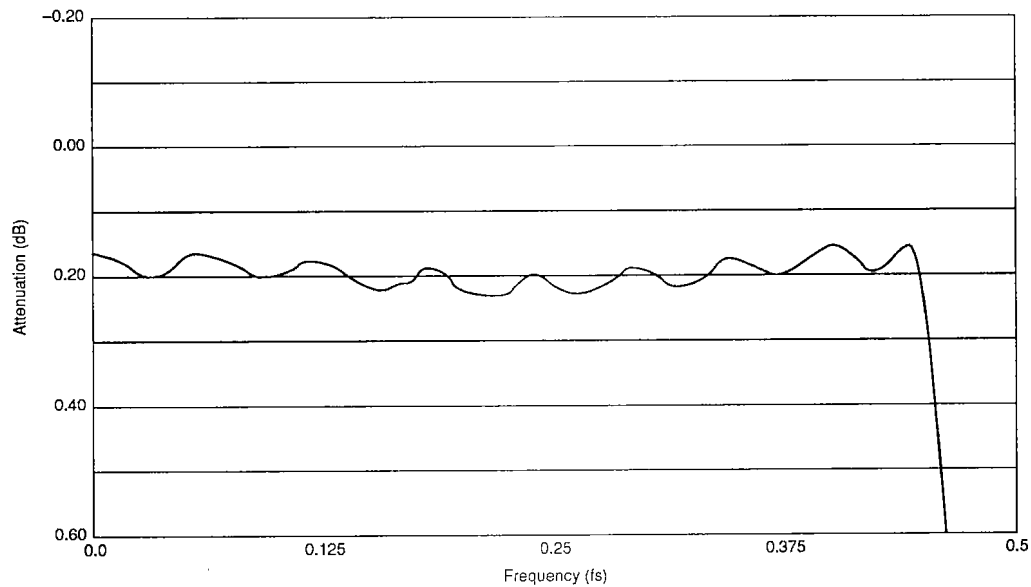
**SM5841A 4-times interpolation filter**

Parameter	Frequency		Rating (dB)		
	f	@fs = 44.1 kHz	min	typ	max
Passband attenuation	0 to 0.4535fs	0 to 20 kHz	-	0.20	-
Passband ripple			-0.03	-	0.03
Stopband attenuation	0.5465fs to 3.4535fs	24.1 to 152 kHz	53	-	-

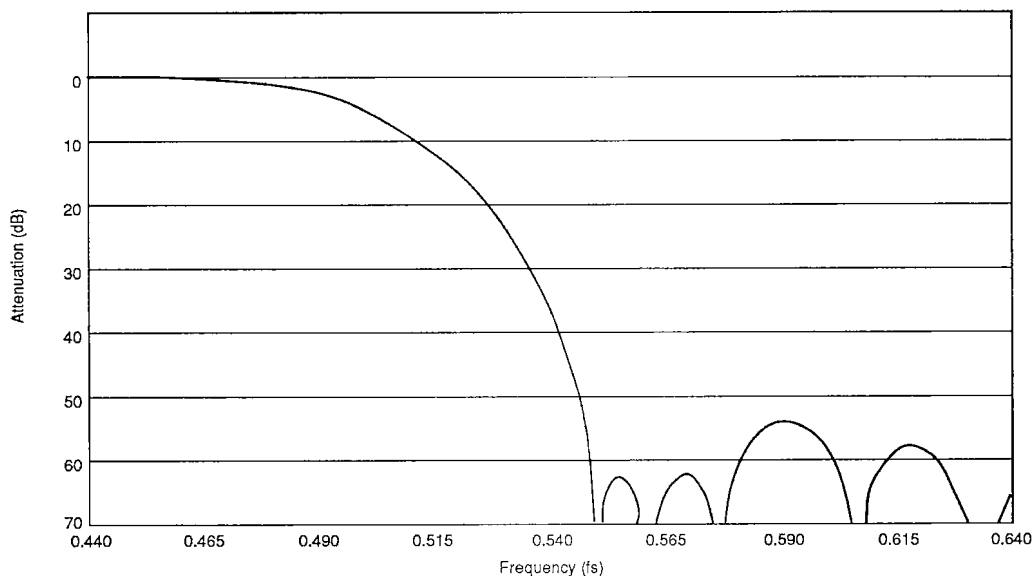
**4fs filter frequency characteristic (Deemphasis OFF)**



**4fs filter passband characteristic (Deemphasis OFF)**



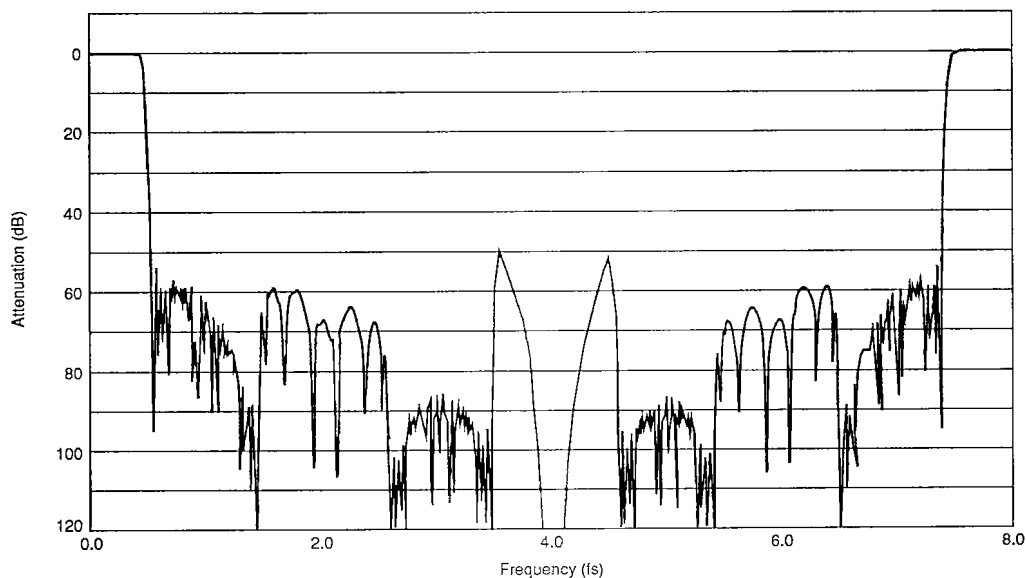
4fs filter band-transition characteristic (Deemphasis OFF)



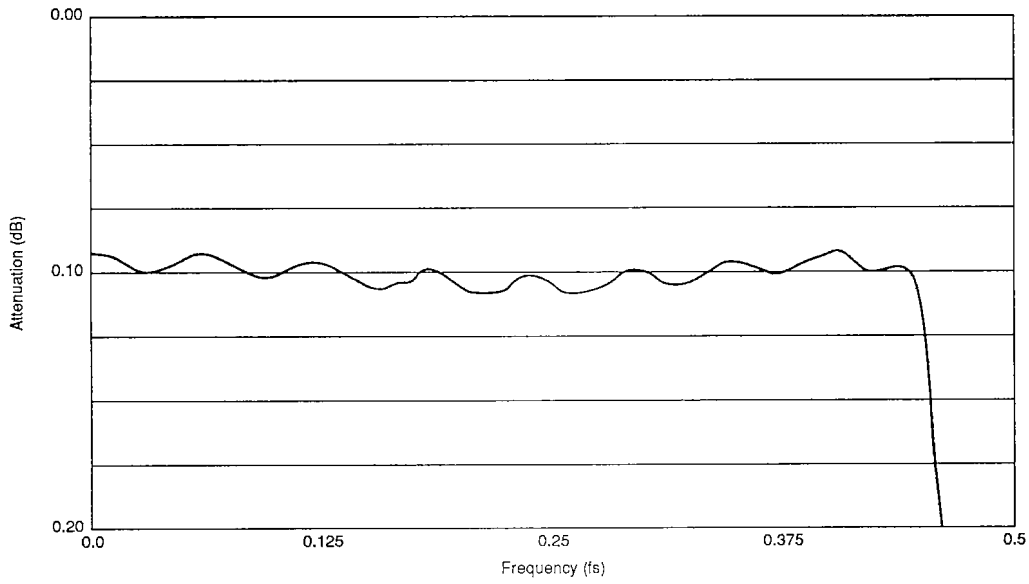
SM5841A 8-times interpolation filter

Parameter	Frequency		Rating (dB)		
	f	@fs = 44.1 kHz	min	typ	max
Passband attenuation	0 to 0.4535fs	0 to 20 kHz	-	0.20	-
Passband ripple			-0.03	-	0.03
Stopband attenuation	0.5465fs to 3.4535fs	24.1 to 152 kHz	53	-	-
	3.4535fs to 4.5465fs	152 to 201 kHz	50	-	-
	4.5465fs to 7.4535fs	201 to 328 kHz	53	-	-

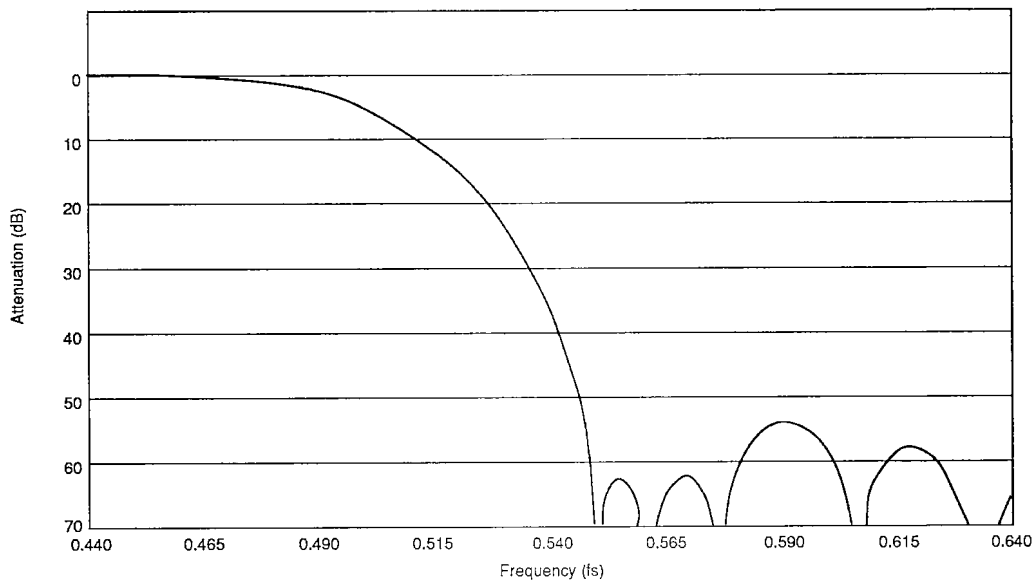
8fs filter frequency characteristic (Deemphasis OFF)



8fs filter passband characteristic (Deemphasis OFF)



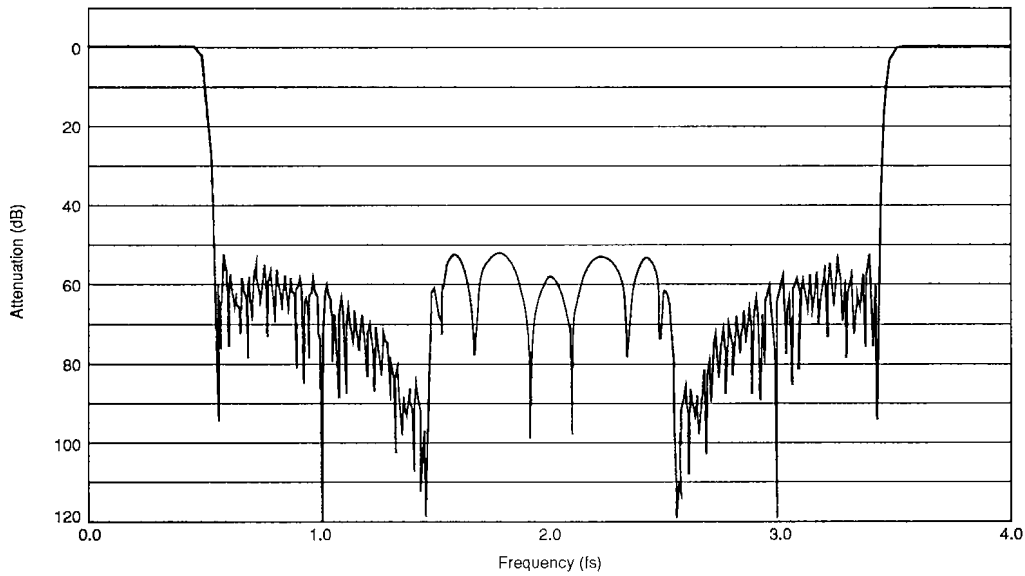
8fs filter band-transition characteristic (Deemphasis OFF)



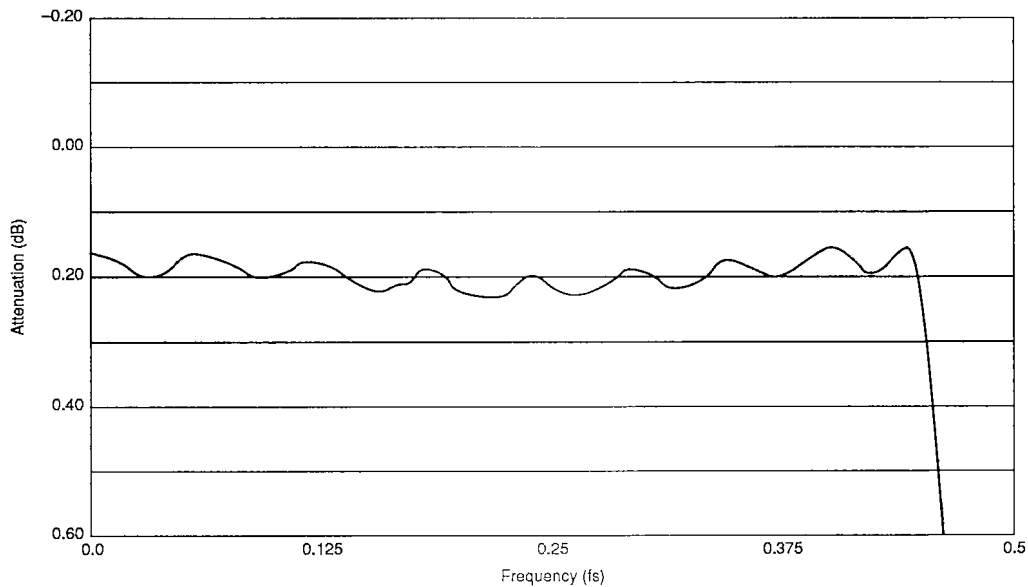
**SM5841B 4-times interpolation filter**

Parameter	Frequency		Rating (dB)		
	f	@fs = 44.1 kHz	min	typ	max
Passband attenuation	0 to 0.4535fs	0 to 20 kHz	-	0.20	-
Passband ripple			-0.03	-	0.03
Stopband attenuation	0.5465fs to 3.4535fs	24.1 to 152 kHz	53	-	-

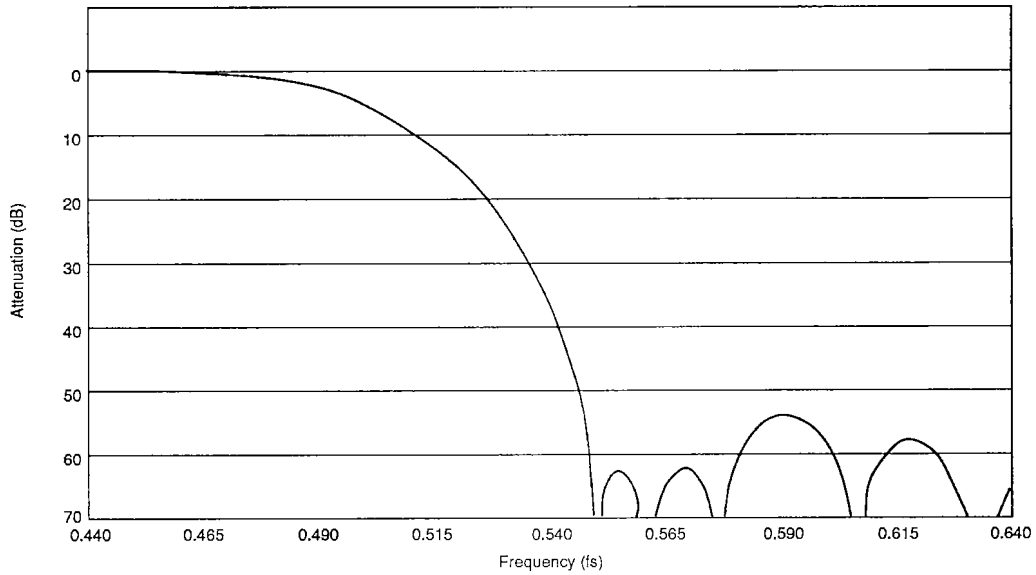
**4fs filter frequency characteristic (Deemphasis OFF)**



**4fs filter passband characteristic (Deemphasis OFF)**



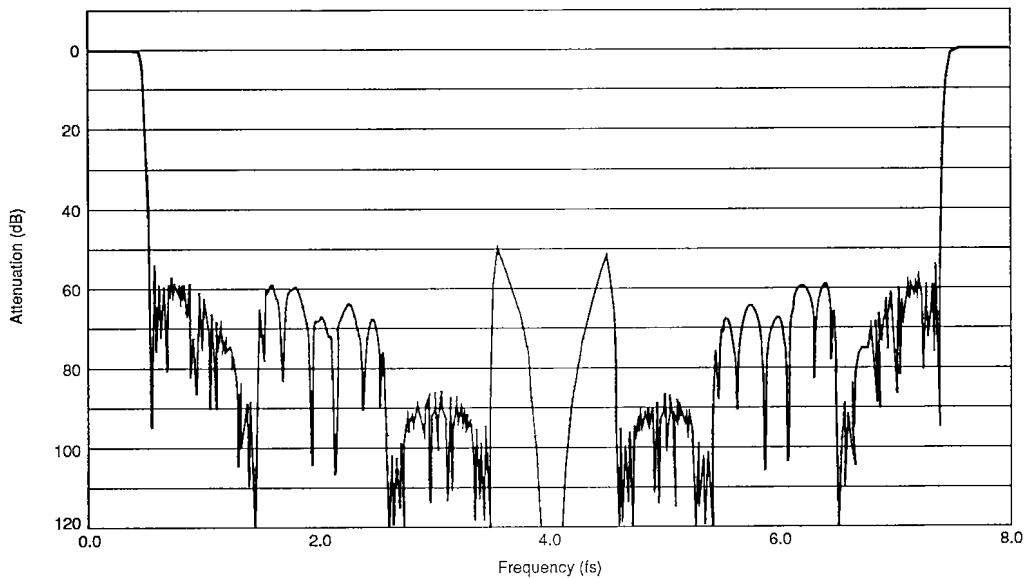
4fs filter band-transition characteristic (Deemphasis OFF)



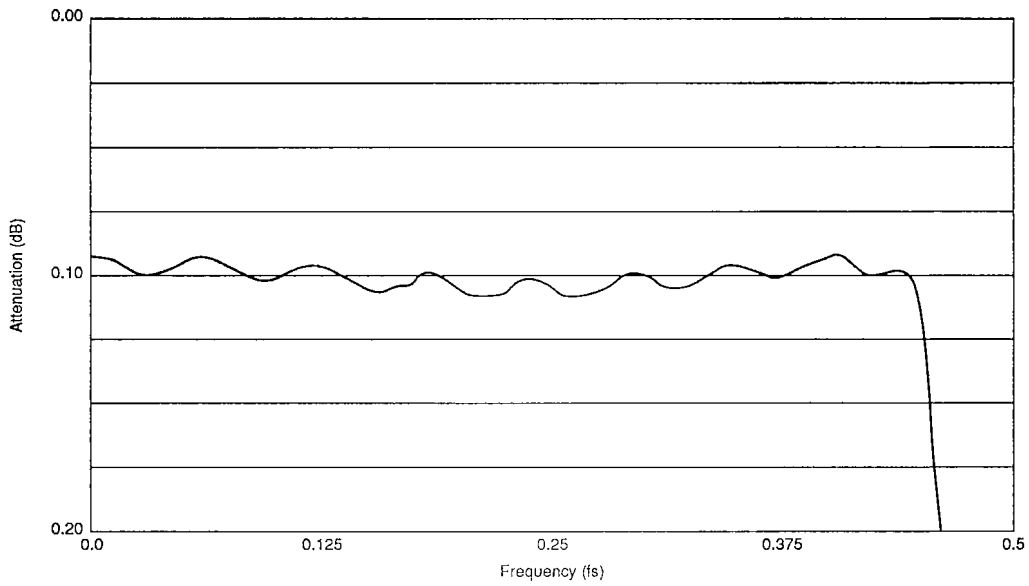
SM5841B 8-times interpolation filter

Parameter	Frequency		Rating (dB)		
	f	@fs = 44.1 kHz	min	typ	max
Passband attenuation	0 to 0.4535fs	0 to 20 kHz	-	0.20	-
Passband ripple			-0.03	-	0.03
Stopband attenuation	0.5465fs to 3.4535fs	24.1 to 152 kHz	53	-	-
	3.4535fs to 4.5465fs	152 to 201 kHz	50	-	-
	4.5465fs to 7.4535fs	201 to 328 kHz	53	-	-

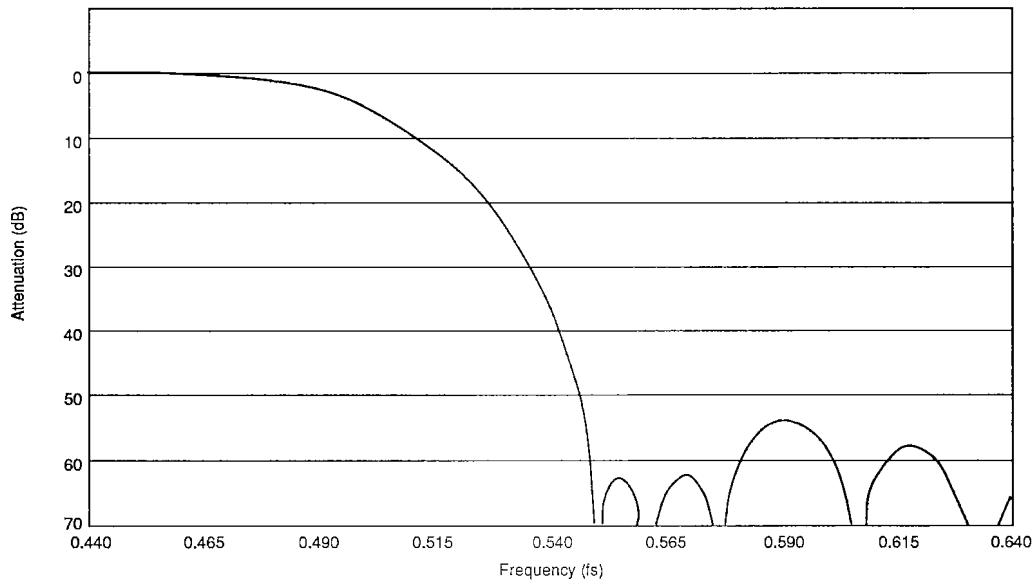
8fs filter frequency characteristic (Deemphasis OFF)



8fs filter passband characteristic (Deemphasis OFF)



8fs filter band-transition characteristic (Deemphasis OFF)

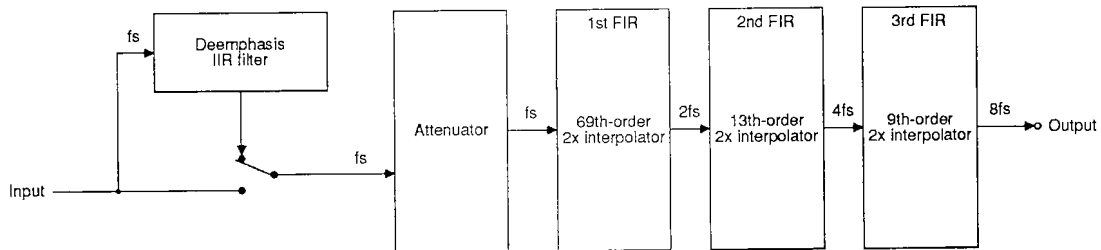


Deemphasis filter

Parameter		Sampling frequency (fs)		
		32 kHz	44.1 kHz	48 kHz
Passband bandwidth (kHz)		0 to 14.5	0 to 20.0	0 to 21.7
Deviation from ideal characteristics	Attenuation (dB)	-0.40 to 0.35	-0.05 to 0.15	-0.30 to 0.05
	Phase, $\theta$ ( $^{\circ}$ )	-2 to 19	-1 to 15	-1 to 14

## FUNCTIONAL DESCRIPTION

### SM5841A/B Arithmetic Block



### Oversampling (Interpolation)

The SM5841A/B performs oversampling using a three-stage FIR interpolation filter. Each filter stage interpolates the signal by a factor of two, giving an overall interpolation factor of eight. Sampling noise components are attenuated by the interpolation filter to greater than 53 dB in the 0.5465fs to 7.4535fs (8fs mode) and 0.5465fs to 3.4535fs (4fs mode) stopband.

### Digital Deemphasis

The deemphasis filter is in cascade with the oversampling filters. It is implemented using an IIR filter, and reproduces the deemphasis gain and phase characteristics more faithfully than conventional analog deemphasis filters. Deemphasis is

enabled when DEEM is HIGH, and disabled when DEEM is LOW. After initialization (system reset), deemphasis is OFF.

The filter coefficients change according to the selected sampling frequency, fs.

FSEL1	FSEL2	Sampling frequency
LOW	LOW	44.1 kHz
LOW	HIGH	48 kHz
HIGH	LOW	44.1 kHz
HIGH	HIGH	32 kHz

After initialization (system reset), 44.1 kHz sampling frequency is selected.

## Digital Attenuator (MDT, MCK, $\overline{\text{MLE}}$ )

The digital attenuator is used for the attenuation and mute functions. An external attenuation coefficient is loaded into an attenuation register using MDT, MCK and  $\overline{\text{MLE}}$ , as shown in figure 1.

The 7-bit attenuation level set data is input on MDT (MSB = LOW), MSB-first and clocked on the falling edge of MCK.

Both the left and right channels are attenuated simultaneously by an amount

$$\text{Attenuation} = 20 \times \log_{10}(1 - \text{DATT}/127) \text{ dB}$$

where DATT is the contents of the attenuation register. When DATT = 127, the attenuation is infinite (mute function). The register is reset to 0 at system reset.

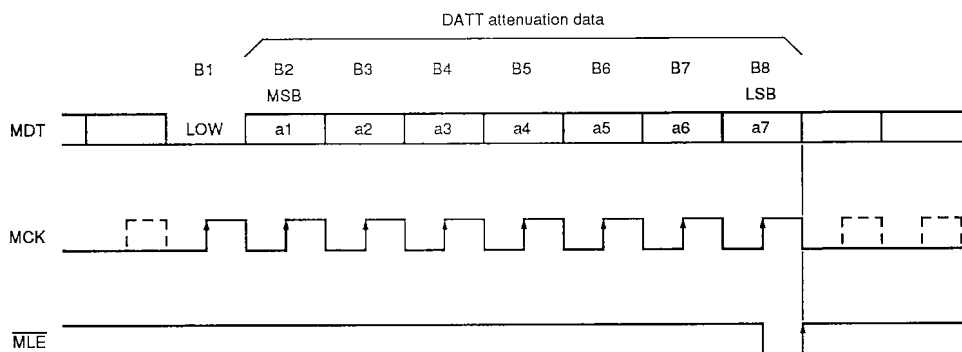


Figure 1. Attenuation data

When a new DATT attenuation coefficient is loaded, the attenuation ramps up or down to the level set by the new coefficient as shown in figure 2. If another attenuation coefficient is loaded

before this new level is reached, the gain ramps in the direction of the latest set level. This occurs because coefficients are temporarily stored in a different register.

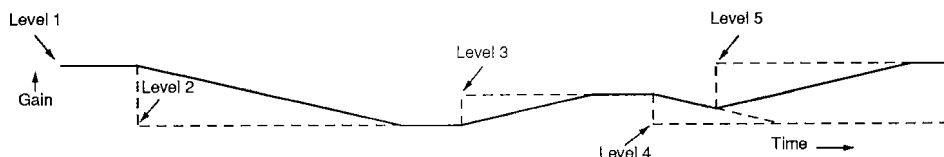


Figure 2. Attenuation level changes

## Soft Mute

The oversampled output can be muted using the MUTE flag. Muting is ON when MUTE is HIGH, and OFF when MUTE is LOW.

When MUTE is HIGH, the maximum attenuation coefficient 127 is loaded into the temporary-storage register and the attenuation slowly changes to  $\infty$  dB.

When MUTE is LOW, the value in the temporary-storage register is the value just before MUTE went LOW. If the external attenuation coefficient changes, the attenuation slowly changes to that new value.

The time taken to increase the attenuation from 0 (DATT = 1) to  $\infty$  dB (DATT = 127) is approximately  $1024/f_s$ , which is approximately 23.2 ms at  $f_s = 44.1$  kHz.

Muting is set to OFF at system reset.

## System Clock (XTI, XTO, CKO, $\overline{\text{CKSL}}$ )

The system clock has 256fs and 384fs selectable frequencies. The clock can be generated either externally (input on XTI) or internally (crystal oscillator between XTI and XTO).

The clock is output on CKO, where the frequency is set by the level on  $\overline{\text{CKSL}}$  as shown in table 1.

Table 1. System clock select

$\overline{\text{CKSL}}$	Clock frequency	Clock input
LOW	256fs	External clock on XTI
HIGH	384fs	Crystal oscillator between XTI and XTO



**Mode Flags (MDT, MCK,  $\overline{\text{MLE}}$ )**

The mode flags are set by data on the serial data interface pins (MDT, MCK and  $\overline{\text{MLE}}$ ).

Mode flag data on MDT is clocked on the falling edge of MCK, and then shifted in a shift register on the rising edge of MCK. Data should, therefore, change on the falling edge of MCK.

The input data in the internal SIPO (serial-in, parallel-out register) is latched into the mode register on the rising edge of the  $\overline{\text{MLE}}$  latch enable. Therefore, data preceding the 8-bit input should be set to 1 (HIGH).

The mode flags set are selected by the state of B1 and B2.

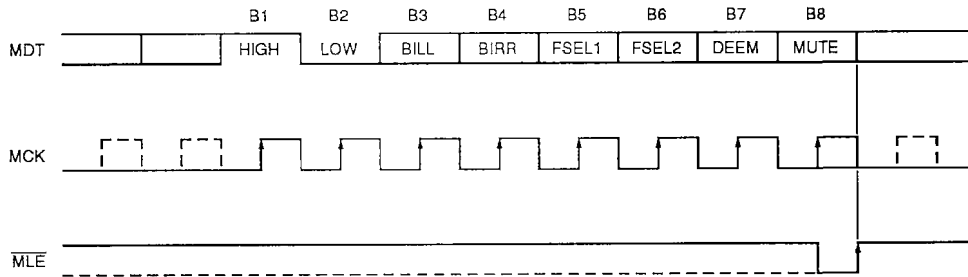


Figure 3. Mode flag setting 1

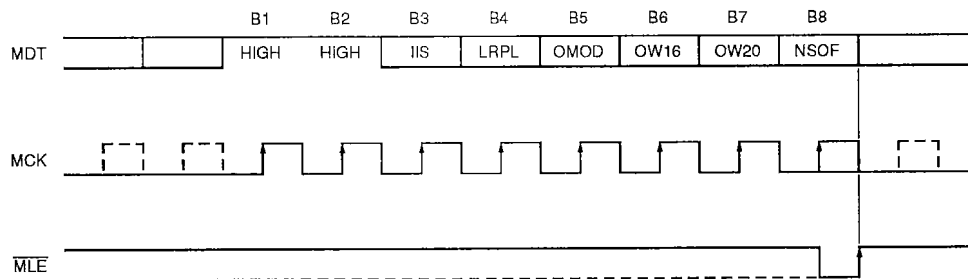


Figure 4. Mode flag setting 2

SM5841A/B

Table 2. Mode flag description

B1	B2	Bit	Mode flag	Mode function select			Default at reset		
				Description	H/L	Function			
HIGH	LOW	3	BILL	Bilingual output select		BILL	BIRR	Output	Stereo
						LOW	LOW	Stereo	
		LOW	HIGH			RR			
		HIGH	LOW			LL			
		HIGH	HIGH			Stereo			
		5	FSEL1	Deemphasis filter sampling frequency		FSEL1	FSEL2	Frequency	44.1 kHz
						LOW	LOW	44.1 kHz	
		LOW	HIGH			48.0 kHz			
HIGH	LOW	44.1 kHz							
HIGH	HIGH	32.0 kHz							
7	DEEM	Deemphasis select	LOW	Deemphasis OFF		OFF			
				Deemphasis ON					
8	MUTE	Mute select	LOW	Mute OFF		OFF			
				Mute ON					
LOW	HIGH	3	IIS	Serial input format select	LOW	Normal serial input		Normal	
						HIGH			IIS serial input
		4	LRPL	LRCI polarity	LOW	Left/right = HIGH/LOW		HIGH/LOW	
						HIGH			Left/right = LOW/HIGH
		5	OMOD	Output mode	LOW	8fs L/R simultaneous		8fs L/R simultaneous	
						HIGH			4fs L/R alternating
		6	OW16	Output bit word length select		OW16	OW20	Output length	18-bit
						LOW	LOW	18-bit	
		LOW	HIGH			20-bit			
		HIGH	LOW			16-bit			
HIGH	HIGH	18-bit							
8	NSOF	Noise shaper select	LOW	Noise shaper ON		ON			
				HIGH			Noise shaper OFF		

## Audio Data Input (DIN, BCKI, LRCI, LRPL flags)

The input is in 16-bit, 2s-complement, MSB-first, serial data format.

The IIS flag selects the IIS serial input format. The SM5841A/B supports IIS-format data at frequencies above 32fs, including 64fs. Normal format is selected at system reset.

### Input timing

Serial input data on DIN is clocked into an SIPO register on the rising edge of the BCKI bit clock, and then converted into parallel data.

The SIPO output data for each channel is latched into either the left-channel or right-channel input register on the rising/falling edge of LRCI.

The timing of the arithmetic and output circuits is independent of the input timing. Accordingly, phase differences between LRCI, BCKI and XTI do not cause incorrect operation, and data input clock jitter does not generate jitter in the output clock.

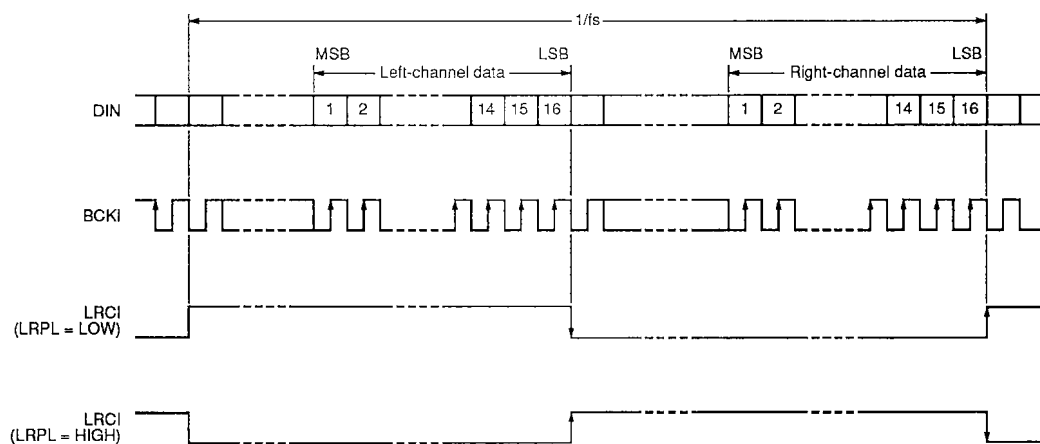


Figure 5. Normal data format (IIS = LOW)

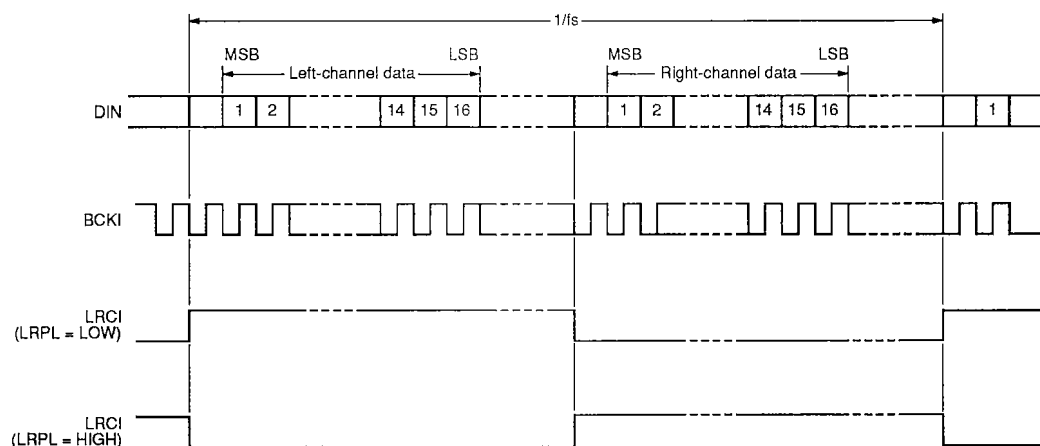


Figure 6. IIS data format (IIS = HIGH)

**Data Output (DOL, DOR, BCKO, WCKO, DG, OMOD flag, OW16 flag, OW20 flag)**

The output is in 2s-complement, MSB-first serial format. The output word length is 16-, 18- or 20-bit selectable using the OW16 and OW20 mode flags. 18-bit format is selected at system reset.

Filter arithmetic data has DC offset compensation added (SM5841B only) to reduce D/A converter zero-crossing distortion for very-small input signals. The offset correction added is approximately 0.8%.

- 512 LSB for 16-bit output
- 2048 LSB for 18-bit output
- 8192 LSB for 20-bit output

The BILL and BIRR flags select the output mode—LL, RR or stereo. LL (and RR) are mono modes where both channels output the left-channel (right-channel) signal. Stereo is selected at reset.

The output timing mode is selected by the OMOD flag. 8fs simultaneous left/right output and 4fs alternating left/right output are supported. 8fs simultaneous is selected at system reset.

Left- and right-channel data is output serially on either two pins (simultaneous or parallel channels) or one pin (alternating or serial channels), selected as shown in table 3.

Table 3. Output timing

Parameter	Symbol	System clock select	Output mode	
			8fs L/R simultaneous	4fs L/R alternating
Bit clock rate	$t_B$	$\overline{CKSL} = \text{HIGH}$	1/192fs	1/192fs
		$\overline{CKSL} = \text{LOW}$	1/256fs	1/256fs
Data word length	$t_{DW}$	$\overline{CKSL} = \text{HIGH}$	24 $t_B$	24 $t_B$
		$\overline{CKSL} = \text{LOW}$	32 $t_B$	32 $t_B$

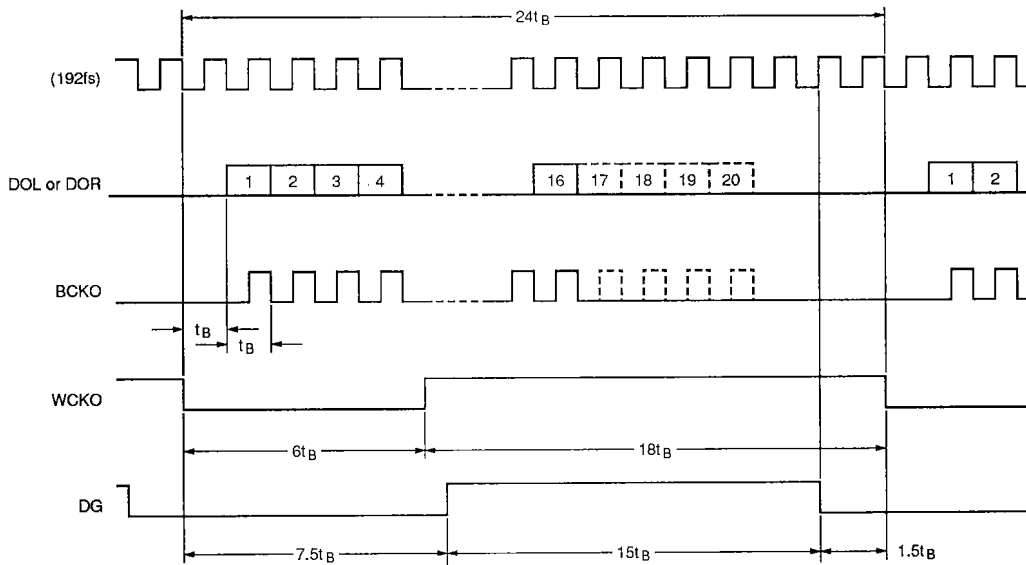


Figure 7. 8fs data output timing (OMOD = LOW,  $\overline{CKSL} = \text{HIGH}$ )

**Note**

In 18-bit mode, pulses 17 and 18 are output, and in 20-bit mode, pulses 17 to 20 are output.

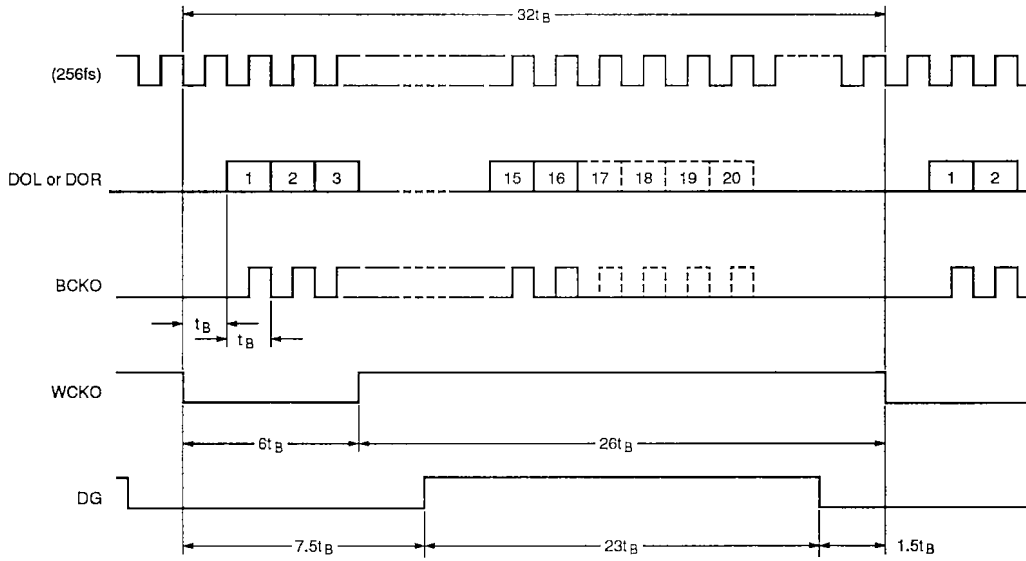


Figure 8. 8fs data output timing (OMOD = LOW,  $\overline{CKSL}$  = LOW)

**Note**

In 18-bit mode, pulses 17 and 18 are output, and in 20-bit mode, pulses 17 to 20 are output.

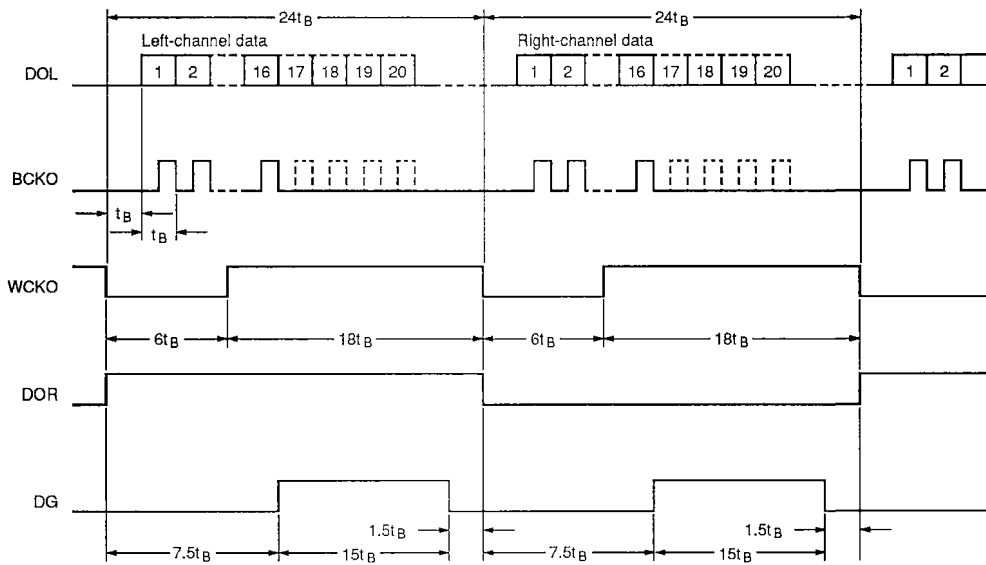


Figure 9. 4fs data output timing (OMOD = HIGH,  $\overline{CKSL}$  = HIGH)

**Note**

In 18-bit mode, pulses 17 and 18 are output, and in 20-bit mode, pulses 17 to 20 are output.

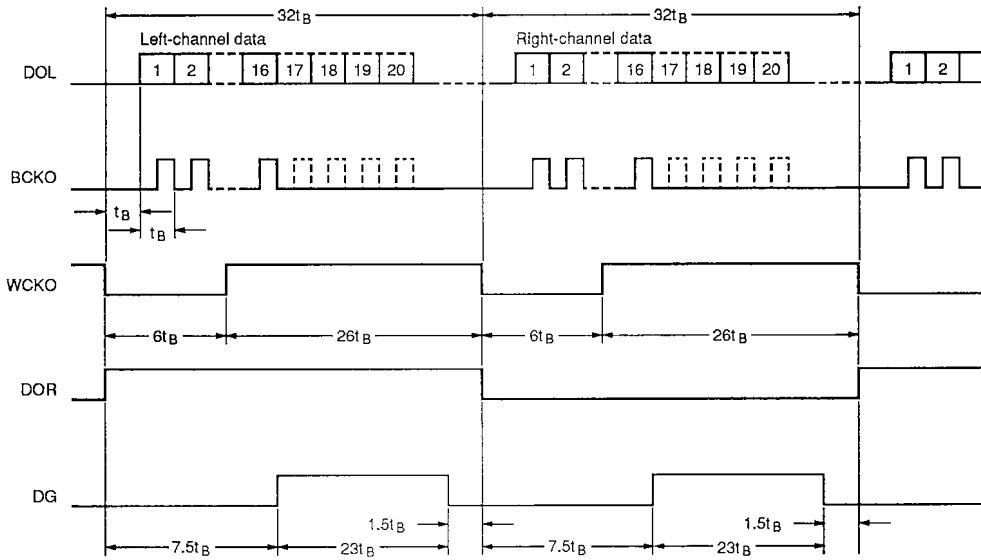


Figure 10. 4fs data output timing (OMOD = high,  $\overline{\text{CKSL}} = \text{LOW}$ )

**Note**

In 18-bit mode, pulses 17 and 18 are output, and in 20-bit mode, pulses 17 to 20 are output.

**System Reset**

The SM5841A/B must be reset at power-ON by applying a LOW-level pulse on  $\overline{\text{RST}}$ .

The following conditions occur at system reset.

1. The arithmetic and output timing counters are reset on the next LRCI start edge after XTI has stabilized.
2. All data flags are reset to LOW when  $\overline{\text{RST}}$  goes HIGH.
3. Mute attenuation is reset to OFF when  $\overline{\text{RST}}$  goes HIGH.

A power-ON reset pulse can be applied from a controlling microprocessor, or by connecting a

300 pF capacitor between  $\overline{\text{RST}}$  and VSS for systems where XTI and LRCI stabilize simultaneously. For other systems that do not use a microcontroller, XTI and LRCI must stabilize before  $\overline{\text{RST}}$  goes HIGH. A larger capacitor can be used to ensure that this occurs.

If the system clock becomes corrupted or develops jitter such that the timing increases above  $\pm 3/8 \times$  (LRCI clock frequency), then the internal timing will automatically reset on the next LRCI start edge. This timing re-synchronization can generate an output click noise.

### Output Muting

When  $\overline{RST}$  goes LOW, DOL and DOR go LOW, immediately muting the output words. Muting is released and timing re-synchronized on the third LRCI rising edge after  $\overline{RST}$  goes HIGH. The BCKO and WCKO clock outputs do not stop.

Furthermore, when  $\overline{CKSL}$  changes state, LRPL changes state or the internal timing re-synchronizes, as shown in figure 11, and output muting and release occurs just as when  $\overline{RST}$  goes LOW.

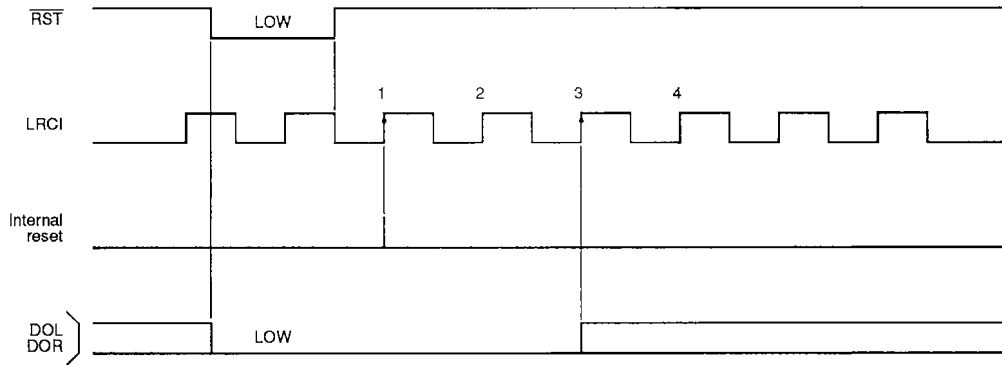


Figure 11. System reset timing and output muting

### TIMING DIAGRAMS

#### Input Timing (DIN, BCKI, LRCI)

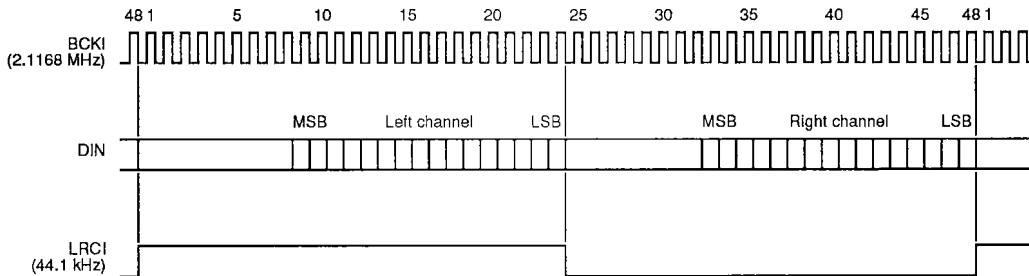


Figure 12. Input timing 1 (IIS = LOW, LRPL = LOW)

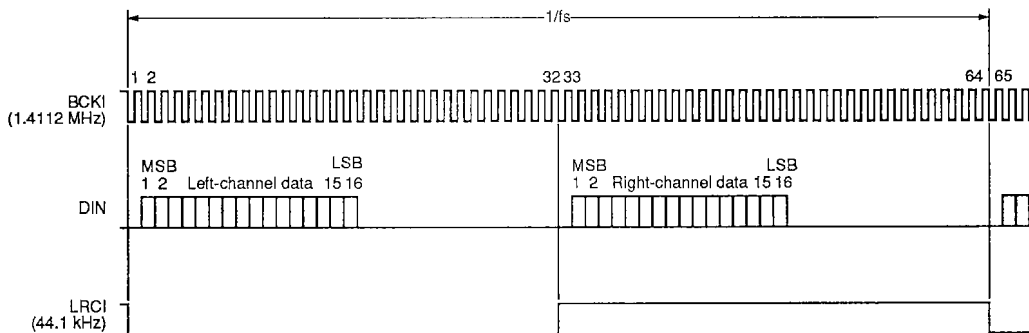


Figure 13. Input timing 2 (IIS = HIGH, LRPL = HIGH)

Output Timing (DOL, DOR, BCKO, WCKO, DG)

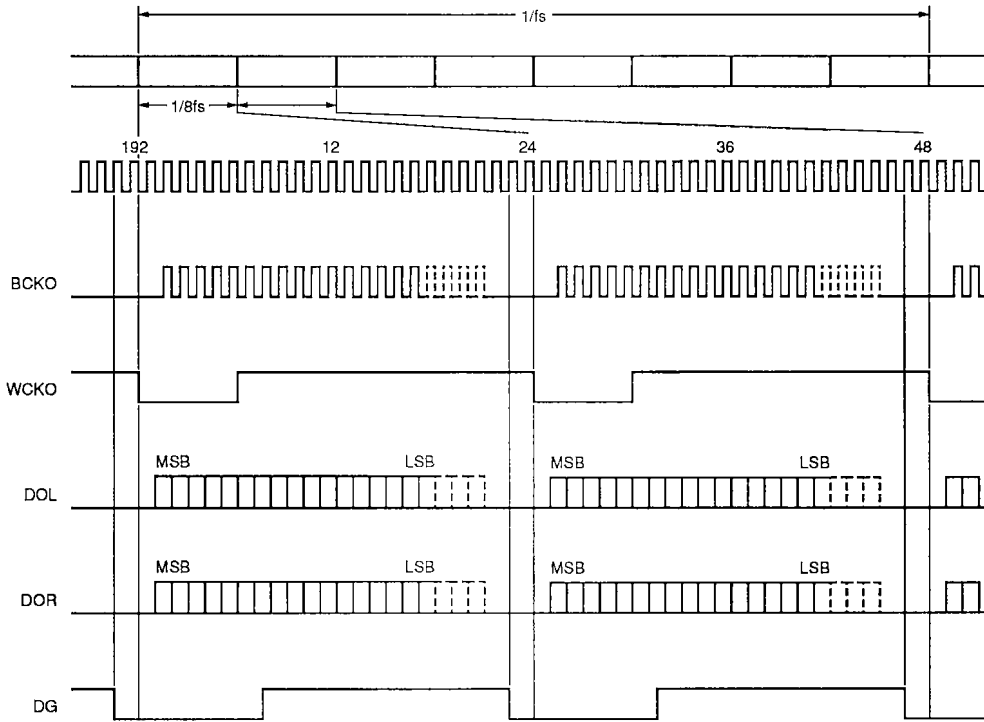


Figure 14. 8fs output timing 1 ( $\overline{CKSL} = \text{HIGH}$ ,  $OMOD = \text{LOW}$ )

Note

In 18-bit mode, pulses 17 and 18 are output, and in 20-bit mode, pulses 17 to 20 are output.

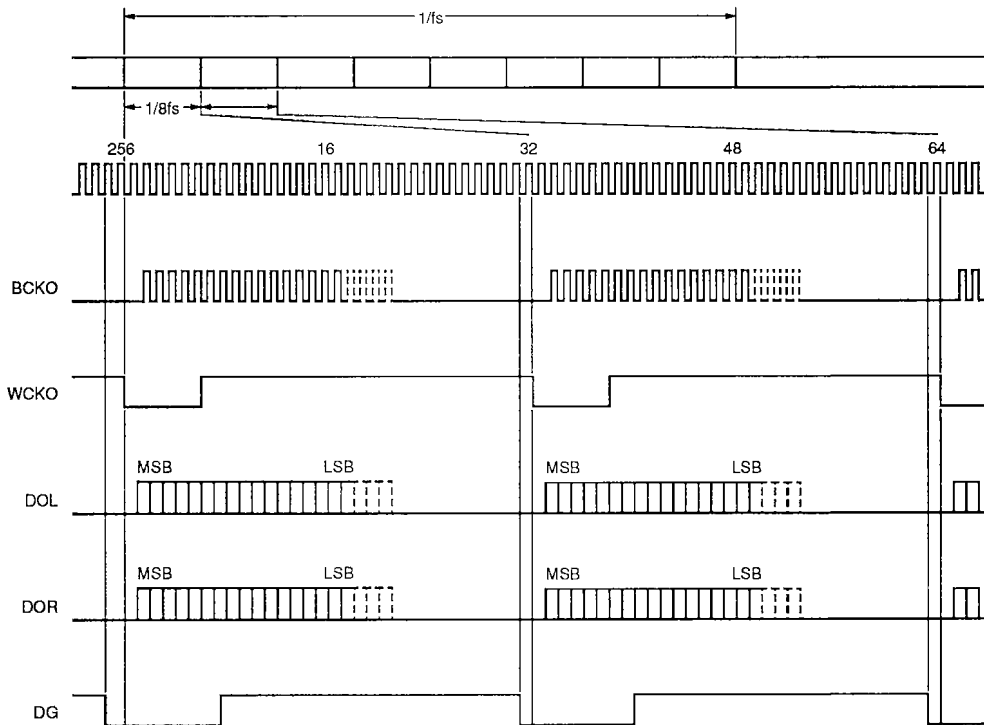


Figure 15. 8fs output timing 2 ( $\overline{CKSL} = \text{LOW}$ ,  $OMOD = \text{LOW}$ )

Note

In 18-bit mode, pulses 17 and 18 are output, and in 20-bit mode, pulses 17 to 20 are output.



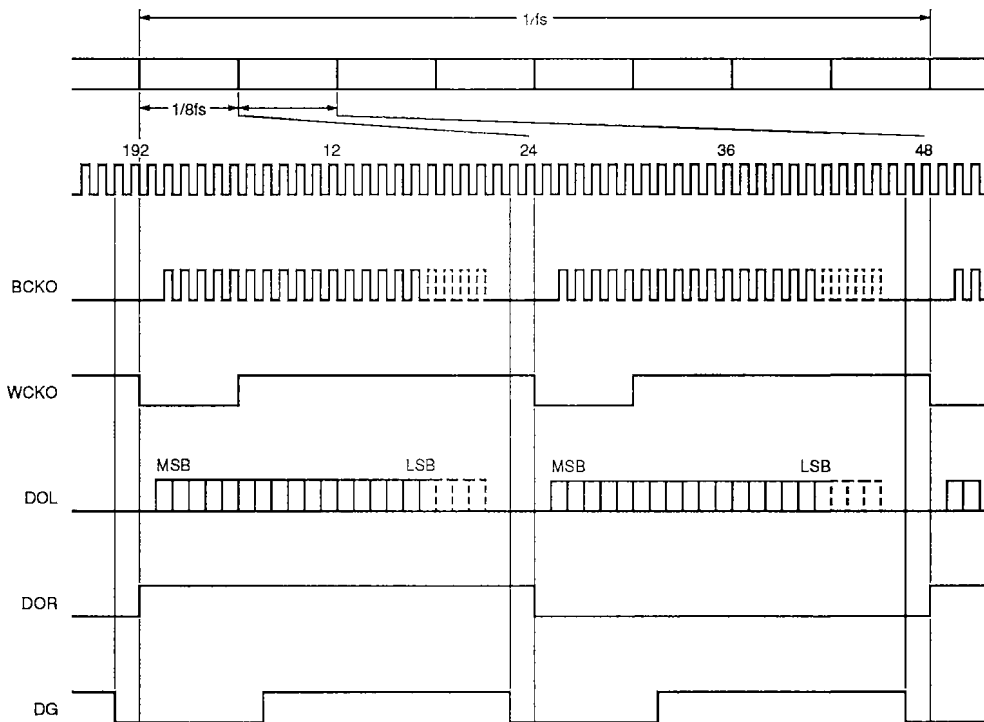


Figure 16. 4fs output timing 1 ( $\overline{\text{CKSL}} = \text{HIGH}$ ,  $\text{OMOD} = \text{HIGH}$ )

**Note**

In 18-bit mode, pulses 17 and 18 are output, and in 20-bit mode, pulses 17 to 20 are output.

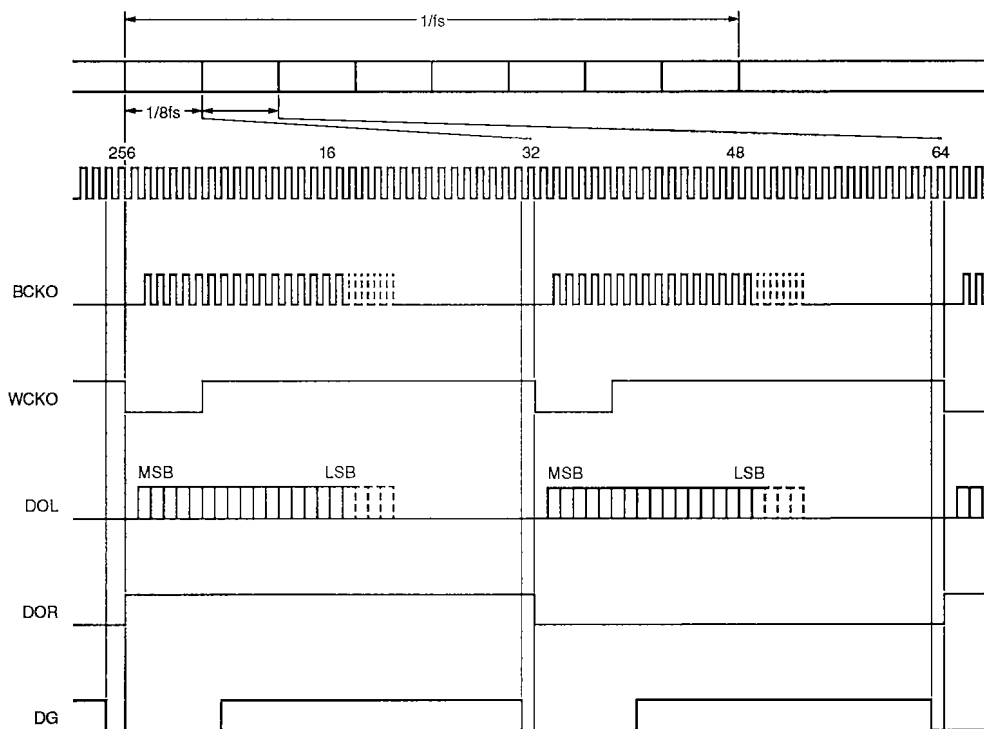


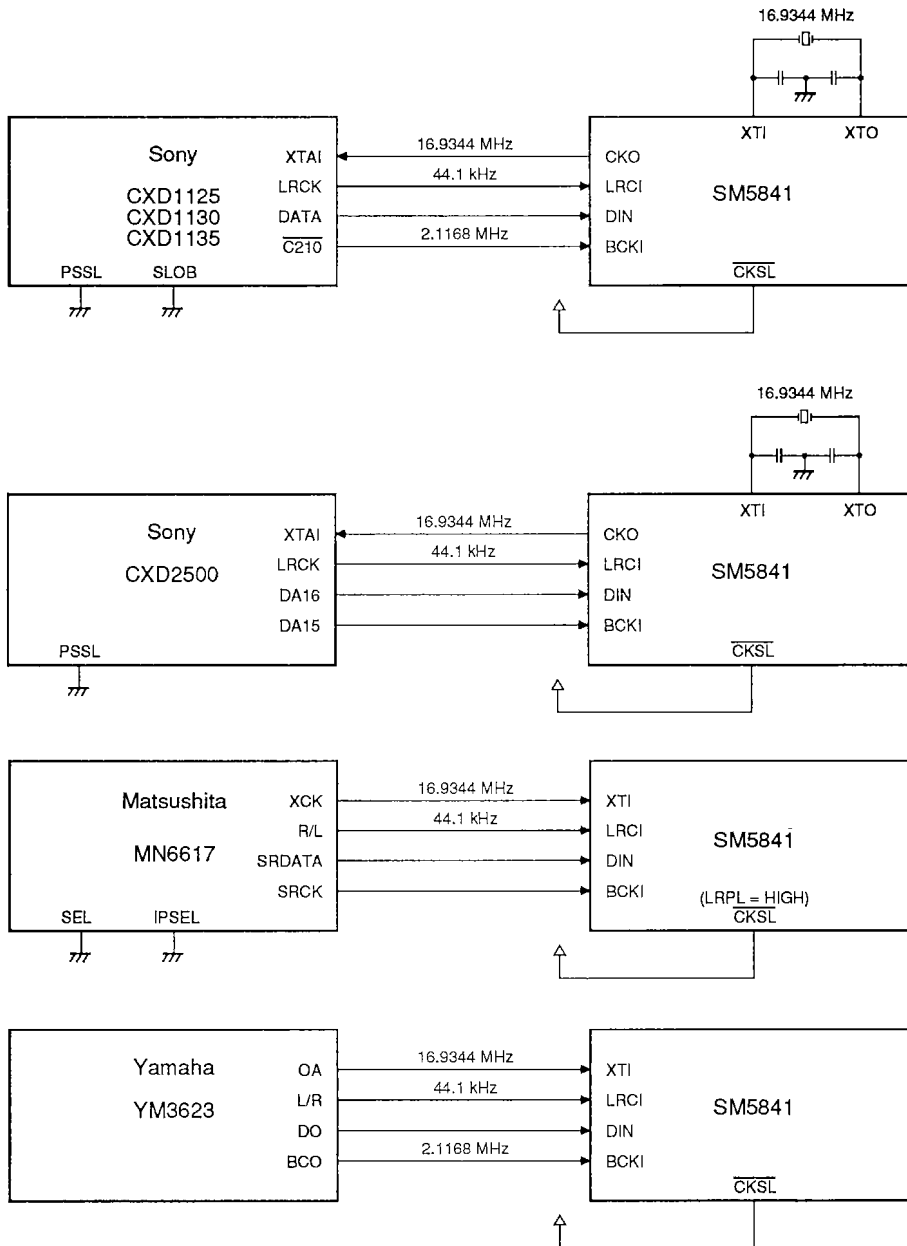
Figure 17. 4fs output timing 2 ( $\overline{\text{CKSL}} = \text{LOW}$ ,  $\text{OMOD} = \text{HIGH}$ )

**Note**

In 18-bit mode, pulses 17 and 18 are output, and in 20-bit mode, pulses 17 to 20 are output.

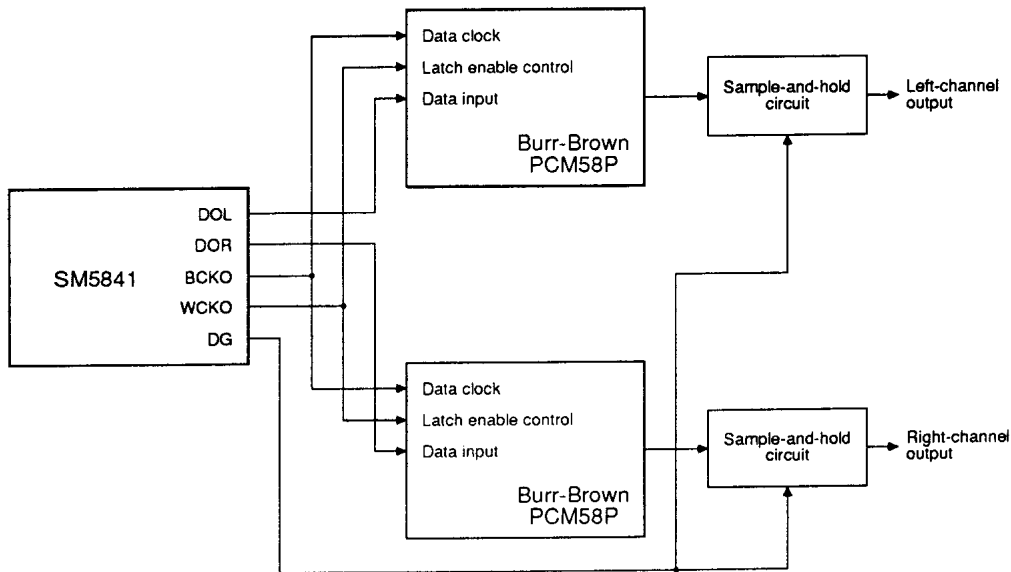
APPLICATION CIRCUITS

Input Interface Circuits

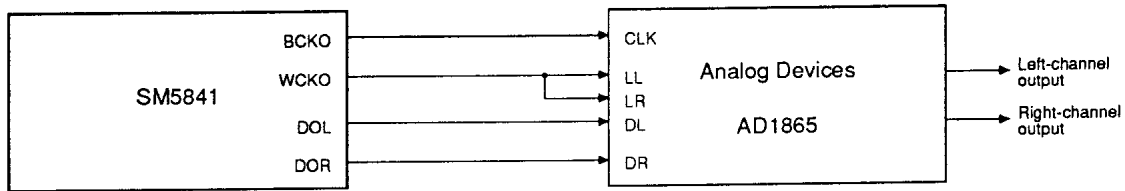


Output Interface Circuits

18-bit dual D/A converter (8fs L/R simultaneous output mode)



18-bit D/A converter



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