

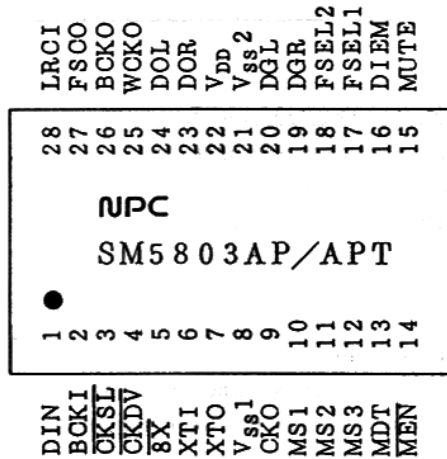
## ■ OVERVIEW

The SM5803AP/APT is a multi-function digital filter for digital audio fabricated using NPC's original molybdenum-gate CMOS technology. This LSI uses a variety of functions including 4-times/8-times oversampling, digital de-emphasis, digital attenuator, jitter-free mechanism and soft mute. The I/O interface allows 16- or 18-bit input data and 16-, 18- or 20-bit output data, so a wide range of system configurations can be realized.

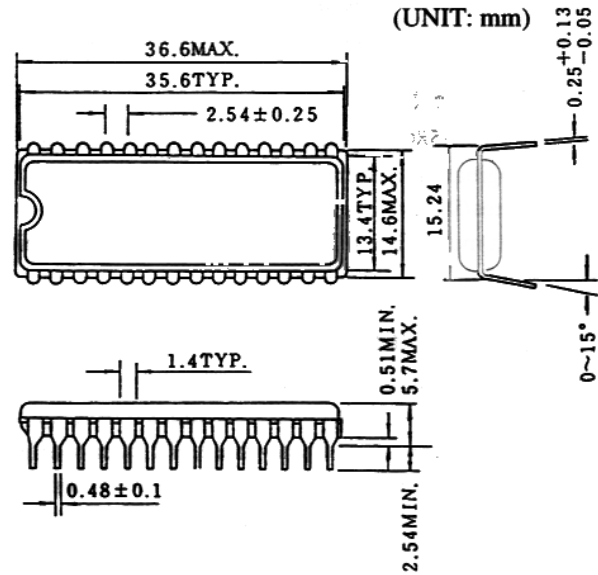
## ■ FEATURES

- Filter configuration
  - Two-channel 4-times/8-times oversampling
  - Three-stage linear-phase FIR filter configuration (153th order + 29th order + 17th order)
  - 22-bit filter coefficient to reduce round-off error
  - $20 \times 22$ -bit parallel multiplier
  - High-precision operation by 25-bit accumulator
  - Digital attenuation
  - Built-in overflow limiter
  - Built-in quartz oscillator circuitry
- Filter characteristics (fs: sampling frequency)
  - Passband ripple 0 to 0.4535 fs
    - ..... Within 0.00005 dB
  - Stopband attenuation
    - 0.5465 to 7.4535 fs (8 fs mode)
    - 0.5465 to 3.4535 fs (4 fs mode)
    - ..... 110 dB or more
  - Linear phase (group delay distortion: zero)
- Input/output
  - 16/18-bit serial data input (2's complement, MSB first)
  - 16/18/20-bit serial data output (2's complement or COB, MSB first)
- Clock
  - System clock: 512 fs, 256 fs, 384 fs and 192 fs
- Supply voltage 5 V  $\pm$  0.25 V
- Package 28-pin plastic DIP
- Molybdenum-gate CMOS construction
- Filter functions
  - Noise shaper (can be turned on or off)
    - Reduction of re-quantization noise component in the audio band
  - Soft mute
    - Smooth changes of attenuation level
  - Digital attenuation
    - 0.188-dB step attenuation in the 0 to -96 dB range
    - Floating output prevents reduction of dynamic range.
    - Floating output (0/1/2/3/4/5/6-bit selection)
    - Control possible with external analog attenuator control output digital attenuator setting
  - Jitter-free mode
    - Operation unaffected by input clock jitters
  - Digital de-emphasis
- Free running mode (Jitter-free)
- INPUT/OUTPUT
  - 16 bit serial data input (2's complement code, MSB first)
  - 16/18/20bit serial data output (2's complement/Complemented offset binary, MSB first)
- SYSTEM CLOCK (512fs/256fs/384fs/192fs)
- PACKAGE 28-pin plastic DIP

## ■ PINOUT (TOP VIEW)



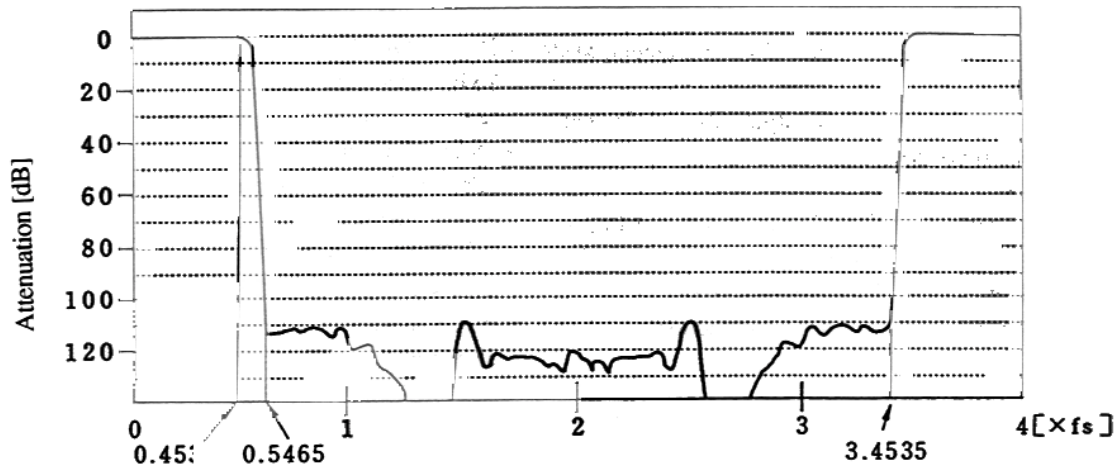
## ■ PACKAGE DIMENSION



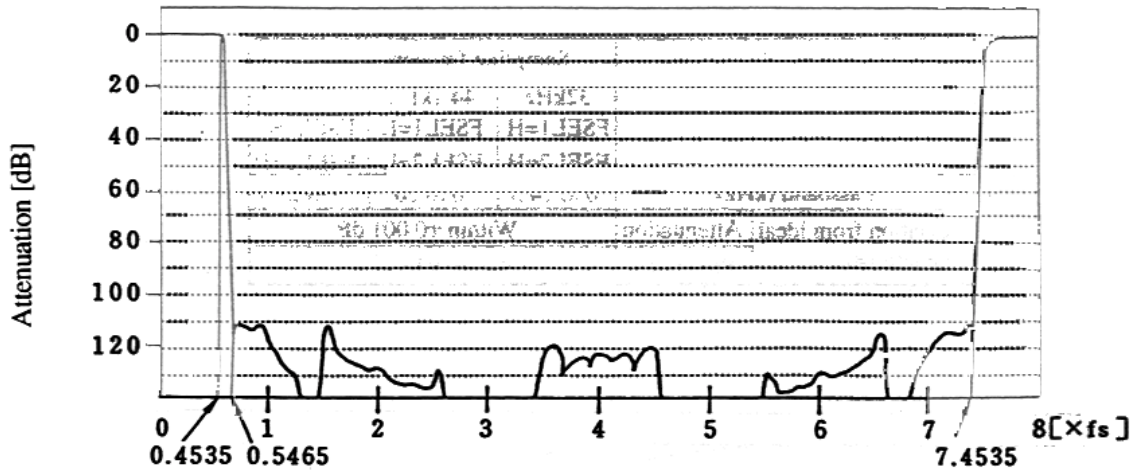
## ■ FILTER CHARACTERISTICS

## 1. Oversampling filter

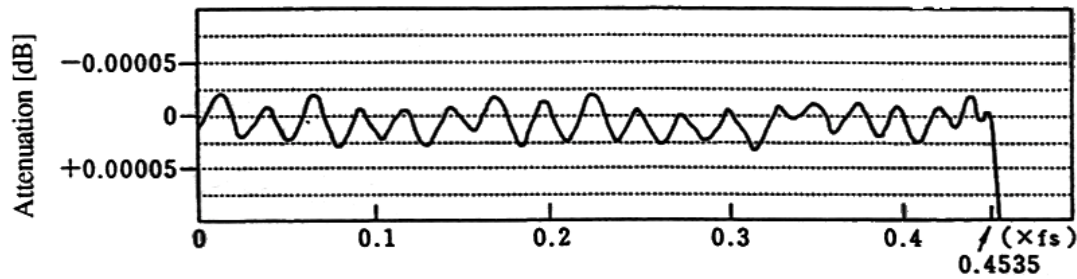
| Parameter            | 8fs mode                | 4fs mode           |
|----------------------|-------------------------|--------------------|
| Passband             | 0 to 0.4535fs           |                    |
| Stopband             | 0.5465 to 7.4535fs      | 0.5465 to 3.4535fs |
| Passband ripple      | Within $\pm 0.00005$ dB |                    |
| Stopband attenuation | 110 dB minimum          |                    |
| Group delay time     | Constant                |                    |



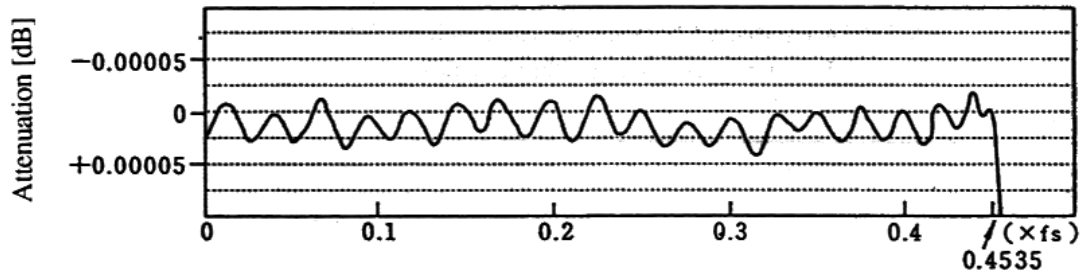
SM5803A Frequency Characteristic (4fs mode, de-emphasis OFF)



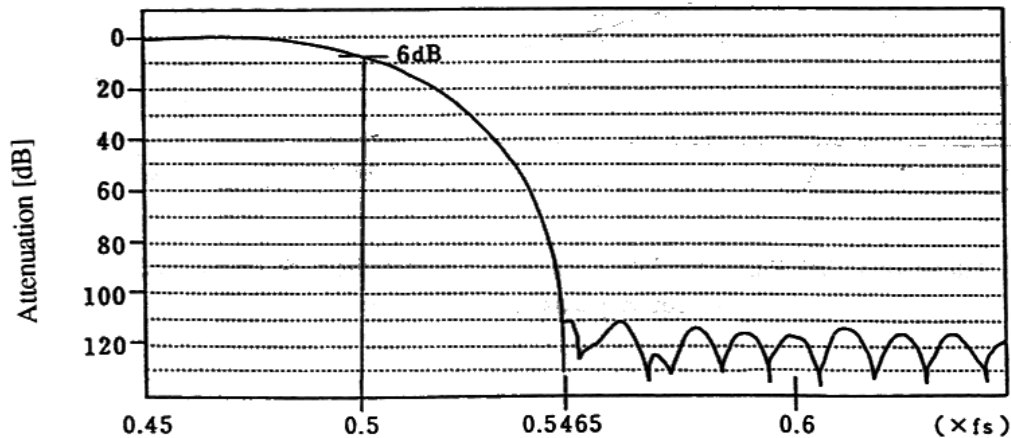
SM5803A Frequency Characteristic (8fs mode, de-emphasis OFF)



SM5803A Passband Characteristic (4fs mode, de-emphasis OFF)



SM5803A Passband Characteristic (8fs mode, de-emphasis OFF)



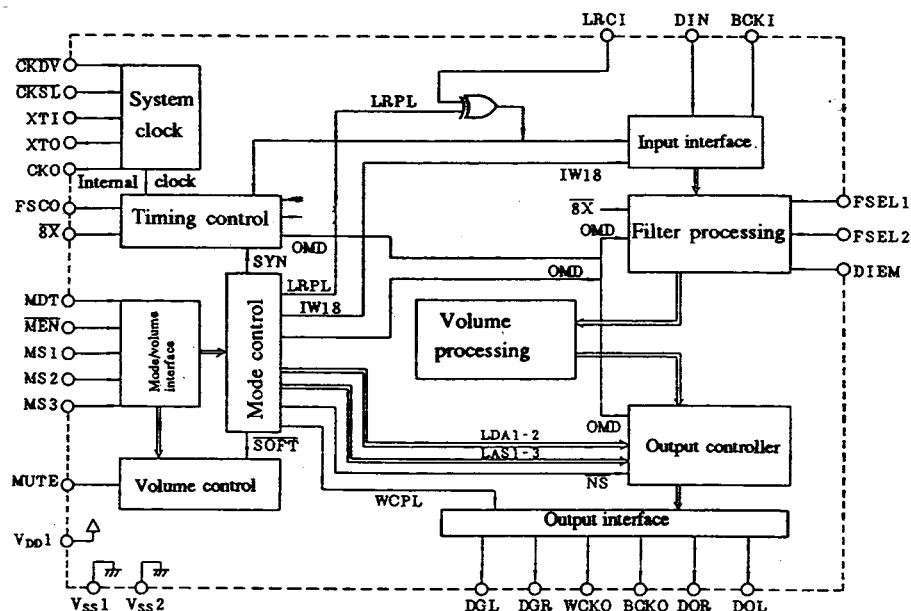
SM5803A Transition-band Characteristics (4fs/8fs mode, de-emphasis OFF)

## ■ PIN DESCRIPTION

| No.   | NAME     | DESCRIPTION                                                                                                                                                                                      |          |  |          |            |          |       |   |   |   |       |   |   |   |
|-------|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|--|----------|------------|----------|-------|---|---|---|-------|---|---|---|
| 1     | DIN      | Input data                                                                                                                                                                                       |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 2     | BCKI     | Input data bit clock (data input on the rising edge)                                                                                                                                             |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 3     | CKSL     | XTI pin input frequency selection (See 6: XTI pin.)                                                                                                                                              |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 4     | CKDV     |                                                                                                                                                                                                  |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 5     | 8X       | Output sampling rate selection<br>H: 4fs mode, L: 8fs mode                                                                                                                                       |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 6     | XTI      | Oscillator input (192fs: CKSL = H, CKDV = H)<br>(384fs: CKSL = H, CKDV = L)<br>(256fs: CKSL = L, CKDV = H)<br>(512fs: CKSL = L, CKDV = L)                                                        |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 7     | XTO      | Oscillator output                                                                                                                                                                                |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 8     | Vss1     | GND 1                                                                                                                                                                                            |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 9     | CKO      | Oscillator output clock (same frequency as XTI)                                                                                                                                                  |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 10    | MS1      | Mode set control 1                                                                                                                                                                               |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 11    | MS2      | Mode set control 2                                                                                                                                                                               |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 12    | MS3      | Mode set control 3                                                                                                                                                                               |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 13    | MDT      | Mode set data                                                                                                                                                                                    |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 14    | MEN      | Mode set enable                                                                                                                                                                                  |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 15    | MUTE     | Mute ON/OFF selection H: no sound output, L: normal output                                                                                                                                       |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 16    | DIEM     | De-emphasis ON/OFF selection<br>H: de-emphasis ON, L: de-emphasis OFF                                                                                                                            |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 17    | FSEL1    | De-emphasis filter type (fs)                                                                                                                                                                     |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 18    | FSEL2    | selection                                                                                                                                                                                        |          |  |          |            |          |       |   |   |   |       |   |   |   |
|       |          | <table><tr><td></td><td>fs=32kHz</td><td>fs=44.1kHz</td><td>fs=48kHz</td></tr><tr><td>FSEL1</td><td>H</td><td>L</td><td>L</td></tr><tr><td>FSEL2</td><td>H</td><td>L</td><td>H</td></tr></table> |          |  | fs=32kHz | fs=44.1kHz | fs=48kHz | FSEL1 | H | L | L | FSEL2 | H | L | H |
|       | fs=32kHz | fs=44.1kHz                                                                                                                                                                                       | fs=48kHz |  |          |            |          |       |   |   |   |       |   |   |   |
| FSEL1 | H        | L                                                                                                                                                                                                | L        |  |          |            |          |       |   |   |   |       |   |   |   |
| FSEL2 | H        | L                                                                                                                                                                                                | H        |  |          |            |          |       |   |   |   |       |   |   |   |
| 19    | DGR      | 8fs LR parallel output mode: de-glitched negative output<br>4fs LR alternate output mode: Rch de-glitched output<br>4fs LR parallel output mode: de-glitched negative output                     |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 20    | DGL      | 8fs LR parallel output mode: de-glitched positive output<br>4fs LR alternate output mode: Lch de-glitched output<br>4fs LR parallel output mode: de-glitched positive output                     |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 21    | Vss2     | GND pin 2                                                                                                                                                                                        |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 22    | VDD      | Power supply (5 V)                                                                                                                                                                               |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 23    | DOR      | 8fs LR parallel output mode: Rch data output<br>4fs LR alternate output mode: LR clock output<br>4fs LR parallel output mode: Rch data output                                                    |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 24    | DOL      | 8fs LR parallel output mode: Lch data output<br>4fs LR alternate output mode: Lch/Rch data output<br>4fs LR parallel output mode: Lch data output                                                |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 25    | WCKO     | Output word clock                                                                                                                                                                                |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 26    | BCKO     | Output bit clock                                                                                                                                                                                 |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 27    | FSCO     | fs-period internal operation and output timing clock                                                                                                                                             |          |  |          |            |          |       |   |   |   |       |   |   |   |
| 28    | LRCI     | Input data sampling rate (fs) clock                                                                                                                                                              |          |  |          |            |          |       |   |   |   |       |   |   |   |

(fs stands for the input data sampling frequency.)

## ■ BLOCK DIAGRAM



## ■ ABSOLUTE MAXIMUM RATINGS

(V<sub>SS</sub>=0V)

| Item                      | Symbol           | Rating                       | Unit |
|---------------------------|------------------|------------------------------|------|
| Supply voltage            | V <sub>DD</sub>  | -0.3 ~ 7.0                   | V    |
| Input voltage             | V <sub>IN</sub>  | -0.3 ~ V <sub>DD</sub> + 0.3 | V    |
| Storage temperature range | T <sub>STG</sub> | -40 ~ 125                    | °C   |
| Power dissipation         | P <sub>W</sub>   | 250 (AP)<br>300 (APT)        | mW   |
| Soldering temperature     | T <sub>SLD</sub> | 255 (APT)                    | °C   |
| Soldering time            | T <sub>SLD</sub> | 10                           | Sec  |

## ■ RECOMMENDATORY OPERATING CONDITIONS

(V<sub>SS</sub>=0V)

| Item                  | Symbol           | Rating      | Unit |
|-----------------------|------------------|-------------|------|
| Supply voltage        | V <sub>DD</sub>  | 4.75 ~ 5.25 | V    |
| Operating temperature | T <sub>OPR</sub> | -20 ~ 70    | °C   |

## ■ DC ELECTRIC CHARACTERISTICS

V<sub>DD</sub>=4.75 to 5.25V, T<sub>a</sub>=-20 to 70°C, V<sub>SS</sub>=0V unless otherwise specified.

| Item                | Pin             | Symbol           | Condition                                                                                                  | Rating             |     |                           |      |
|---------------------|-----------------|------------------|------------------------------------------------------------------------------------------------------------|--------------------|-----|---------------------------|------|
|                     |                 |                  |                                                                                                            | MIN                | TYP | MAX                       | UNIT |
| Current consumption | V <sub>DD</sub> | I <sub>DD</sub>  | V <sub>DD</sub> =5V, f <sub>sys</sub> *3<br>= 10MHz<br>V <sub>DD</sub> =5V, f <sub>sys</sub> *3<br>= 13MHz |                    |     | 45<br>(AP)<br>50<br>(APT) | mA   |
| Input voltage       | XTI             | V <sub>IH</sub>  |                                                                                                            | 0.7V <sub>DD</sub> |     |                           | V    |
|                     |                 | V <sub>IL1</sub> |                                                                                                            |                    |     | 0.3V <sub>DD</sub>        |      |
|                     |                 | V <sub>IL2</sub> |                                                                                                            | 2.4                |     | 0.5                       |      |
| Output voltage      | (*2)            | V <sub>OH</sub>  | I <sub>OH</sub> =-0.4mA                                                                                    | 2.5                |     |                           | V    |
|                     |                 | V <sub>OL</sub>  | I <sub>OL</sub> =1.6mA                                                                                     |                    |     | 0.4                       |      |
| Input leak current  | XTI             | I <sub>LH</sub>  | V <sub>IN</sub> =V <sub>DD</sub>                                                                           | 10                 | 20  |                           | μA   |
|                     |                 | I <sub>LL</sub>  | V <sub>IN</sub> =0V                                                                                        | 10                 | 20  |                           |      |
| Input current       | (*1)            | I <sub>LH</sub>  | V <sub>IN</sub> =V <sub>DD</sub>                                                                           |                    |     | 1.0                       | μA   |
|                     |                 | I <sub>IN</sub>  | V <sub>IN</sub> =0V                                                                                        | 10                 | 20  |                           |      |

&lt; Pin type &gt;

|    |                                                                                        |
|----|----------------------------------------------------------------------------------------|
| *1 | LRCI, DIN, BCKI, CKSL, CKDV<br>MS1, MS2, MS3, MDT, MEN<br>MUTE, DIEM, FSEL1, FSEL2, 8X |
| *2 | CKO, DGR, DGL, DOR, DOL,<br>WCKO, BCKO, FSCO                                           |

Internal pull-up resistors are attached to all input pins (\*1) except XTI.

(\*3) f<sub>sys</sub>: system clock frequency  
 CKDV = L : f<sub>XTI</sub>/2  
 CKDV = H : f<sub>XTI</sub>  
 (f<sub>XTI</sub> is the XTI input clock frequency.)

## SM5803AP

## • AC CHARACTERISTICS

(Ta = -20 ~ 70°C, V<sub>DD</sub> = 4.75 ~ 5.25V, V<sub>SS</sub> = 0V)

## 1. XTI TERMINAL

## a. Quartz oscillation

| ITEM                  | SYM-BOL          | RATING |     |      | UNIT | CONDITION |      | NOTE  |
|-----------------------|------------------|--------|-----|------|------|-----------|------|-------|
|                       |                  | MIN    | TYP | MAX  |      | CKSL      | CKDV |       |
| Oscillating frequency | f <sub>MAX</sub> | 1.0    |     | 9.5  | MHz  | H         | H    | 192fs |
|                       |                  | 2.0    |     | 19.0 |      | H         | L    | 384fs |
|                       |                  | 1.0    |     | 9.5  |      | L         | H    | 256fs |
|                       |                  | 2.0    |     | 19.0 |      | L         | L    | 512fs |

## b. External clock input

| ITEM                           | SYM-BOL          | RATING |     |      | UNIT | CONDITION |      | NOTE  |
|--------------------------------|------------------|--------|-----|------|------|-----------|------|-------|
|                                |                  | MIN    | TYP | MAX  |      | CKSL      | CKDV |       |
| Width of clock pulse (H level) | t <sub>CWH</sub> | 38     |     | 500  | nSec | H         | H    | 192fs |
|                                |                  | 24     |     | 250  |      | H         | L    | 384fs |
|                                |                  | 38     |     | 500  |      | L         | H    | 256fs |
|                                |                  | 24     |     | 250  |      | L         | L    | 512fs |
| Width of clock pulse (L level) | t <sub>CWL</sub> | 48     |     | 500  | nSec | H         | H    | 192fs |
|                                |                  | 24     |     | 250  |      | H         | L    | 384fs |
|                                |                  | 48     |     | 500  |      | L         | H    | 256fs |
|                                |                  | 24     |     | 250  |      | L         | L    | 512fs |
| Cycle time of clock pulse      | t <sub>CI</sub>  | 105    |     | 1000 | nSec | H         | H    | 192fs |
|                                |                  | 52     |     | 500  |      | H         | L    | 384fs |
|                                |                  | 105    |     | 1000 |      | L         | H    | 256fs |
|                                |                  | 52     |     | 500  |      | L         | L    | 512fs |

## 2. SERIAL INPUT TIMING

## a. BCKI, DIN, LRCI terminal

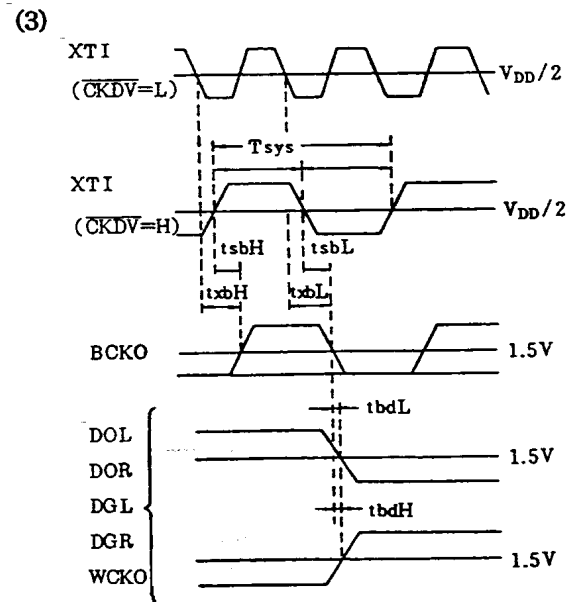
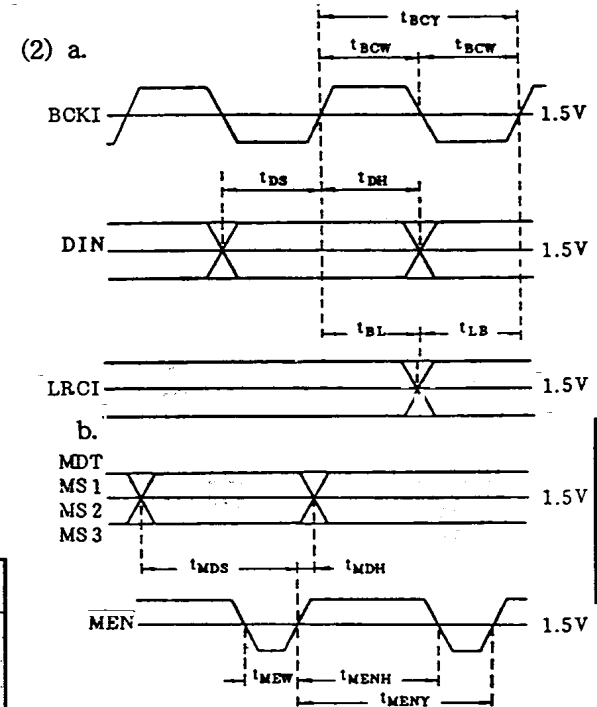
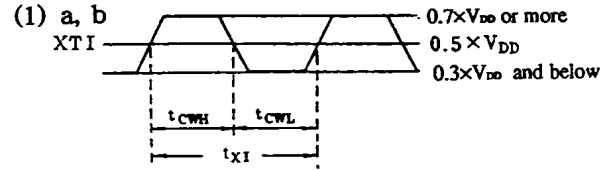
| ITEM                                      | SYMBOL           | RATING |     |     | UNIT |
|-------------------------------------------|------------------|--------|-----|-----|------|
|                                           |                  | MIN    | TYP | MAX |      |
| BCKI, Pulse width                         | t <sub>BCW</sub> | 100    |     |     | nSec |
| BCKI, Cycle time                          | t <sub>BCY</sub> | 200    |     |     | nSec |
| DIN, Set up time                          | t <sub>DS</sub>  | 75     |     |     | nSec |
| DIN, Hold time                            | t <sub>DH</sub>  | 75     |     |     | nSec |
| Rising edge of last BCKI to Edge of LRCI  | t <sub>BL</sub>  | 75     |     |     | nSec |
| Edge of LRCI to Rising edge of first BCKI | t <sub>LB</sub>  | 75     |     |     | nSec |

## b. MS1, MS2, MS3, MDT, MEN terminal

| ITEM                                               | SYMBOL            | RATING                   |     |     | UNIT                 |
|----------------------------------------------------|-------------------|--------------------------|-----|-----|----------------------|
|                                                    |                   | MIN                      | TYP | MAX |                      |
| MDT, MS1, MS2, MS3 setup time                      | t <sub>MDS</sub>  | 20                       |     |     | nSec                 |
| MDT, MS1, MS2, MS3 hold time                       | t <sub>MDH</sub>  | 20                       |     |     | nSec                 |
| MEN L-level period                                 | t <sub>MEW</sub>  | 20                       |     |     |                      |
|                                                    | t <sub>MENH</sub> | 5T <sub>sys</sub> + 20nS |     |     |                      |
|                                                    | t <sub>MENY</sub> | 6                        |     |     | T <sub>sys</sub> (*) |
| Interval with next pulse (MC0, MC3-MC7) (MC1, MC2) |                   | 34                       |     |     |                      |

## 3. OUPUT TIMING

| ITEM                     | SYMBOL | RATING           |     |     | UNIT | NOTE      |
|--------------------------|--------|------------------|-----|-----|------|-----------|
|                          |        | MIN              | TYP | MAX |      |           |
| BCKO delay time from XTI | CKDV   | t <sub>xbH</sub> | 35  | 95  | nSec |           |
|                          | =L     | t <sub>xbL</sub> | 35  | 95  |      |           |
|                          | CLDV   | t <sub>xbH</sub> | 35  | 95  |      |           |
|                          | =H     | t <sub>xbL</sub> | 35  | 95  |      |           |
| Output delay time        |        | t <sub>bdL</sub> | -10 | 0   | nSec | 15pF Load |
|                          |        | t <sub>bdH</sub> | -10 | 0   |      |           |



(\*) T<sub>sys</sub>: System clock period CKDV = L: t<sub>CI</sub> × 2  
 CKDV = H: t<sub>CI</sub>  
 where t<sub>CI</sub> is the period of the clock input on XTI.

## SM5803APT

## • AC CHARACTERISTICS

(Ta = -20 ~ 70°C, V<sub>DD</sub> = 4.75 ~ 5.25V, V<sub>SS</sub> = 0V)

## 1. XTI TERMINAL

## a. Quartz oscillation

| ITEM                  | SYM-BOL          | RATING |     |     | UNIT | CONDITION |      | NOTE  |
|-----------------------|------------------|--------|-----|-----|------|-----------|------|-------|
|                       |                  | MIN    | TYP | MAX |      | CKSL      | CKDV |       |
| Oscillating frequency | f <sub>MAX</sub> | 1.0    |     | 130 | MHz  | H         | H    | 192fs |
|                       |                  | 2.0    |     | 260 |      | H         | L    | 384fs |
|                       |                  | 1.0    |     | 130 |      | L         | H    | 256fs |
|                       |                  | 2.0    |     | 260 |      | L         | L    | 512fs |

## b. External clock input

| ITEM                           | SYM-BOL          | RATING |     |      | UNIT | CONDITION |      | NOTE  |
|--------------------------------|------------------|--------|-----|------|------|-----------|------|-------|
|                                |                  | MIN    | TYP | MAX  |      | CKSL      | CKDV |       |
| Width of clock pulse (H level) | t <sub>CWH</sub> | 35*    |     | 500  | nSec | H         | H    | 192fs |
|                                |                  | 15     |     | 250  |      | H         | L    | 384fs |
|                                |                  | 35*    |     | 500  |      | L         | H    | 256fs |
|                                |                  | 15     |     | 250  |      | L         | L    | 512fs |
| Width of clock pulse (L level) | t <sub>CWL</sub> | 35*    |     | 500  | nSec | H         | H    | 192fs |
|                                |                  | 15     |     | 250  |      | H         | L    | 384fs |
|                                |                  | 35*    |     | 500  |      | L         | H    | 256fs |
|                                |                  | 15     |     | 250  |      | L         | L    | 512fs |
| Cycle time of clock pulse      | t <sub>CL</sub>  | 76     |     | 1000 | nSec | H         | H    | 192fs |
|                                |                  | 38     |     | 500  |      | H         | L    | 384fs |
|                                |                  | 76     |     | 1000 |      | L         | H    | 256fs |
|                                |                  | 38     |     | 500  |      | L         | L    | 512fs |

## 2. SERIAL INPUT TIMING

## a. BCKI, DIN, LRCI terminal

| ITEM                                                                        | SYMBOL           | RATING |     |     | UNIT |
|-----------------------------------------------------------------------------|------------------|--------|-----|-----|------|
|                                                                             |                  | MIN    | TYP | MAX |      |
| BCKI, Pulse width                                                           | t <sub>BCW</sub> | 100    |     |     | nSec |
| BCKI, Cycle time                                                            | t <sub>BCY</sub> | 200    |     |     | nSec |
| DIN, Set up time                                                            | t <sub>DS</sub>  | 75     |     |     | nSec |
| DIN, Hold time                                                              | t <sub>DH</sub>  | 75     |     |     | nSec |
| Rising edge of last BCKI to Edge of LRCI                                    | t <sub>BL</sub>  | 75     |     |     | nSec |
| Edge of LRCI to Rising edge of first BCKI                                   | t <sub>LB</sub>  | 75     |     |     | nSec |
| XTI rising edge to Start edge of LRCI (*) (only in forced synchronous mode) | t <sub>XL</sub>  | 20     |     |     | nSec |
| Start edge of LRCI (*) to XTI rising edge (only in forced synchronous mode) | t <sub>LX</sub>  | 0      |     |     | nSec |

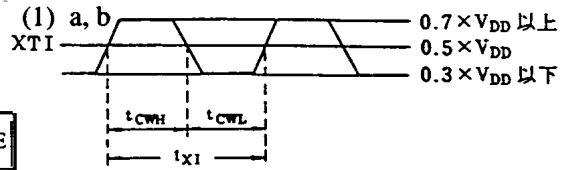
## b. MS1, MS2, MS3, MDT, MEN terminal

| ITEM                                               | SYMBOL            | RATING            |     |     | UNIT                 |
|----------------------------------------------------|-------------------|-------------------|-----|-----|----------------------|
|                                                    |                   | MIN               | TYP | MAX |                      |
| MDT, MS1, MS2, MS3 setup time                      | t <sub>MDS</sub>  | 20                |     |     | nSec                 |
| MDT, MS1, MS2, MS3 hold time                       | t <sub>MDH</sub>  | 20                |     |     | nSec                 |
| MEN L-level period                                 | t <sub>MEW</sub>  | 20                |     |     |                      |
| MEN H-level period                                 | t <sub>MEMH</sub> | 5T <sub>SYS</sub> |     |     |                      |
| Interval with next pulse (MC0, MC3-MC7) (MC1, MC2) | t <sub>MENY</sub> | 6                 |     |     | T <sub>SYS</sub> (*) |
|                                                    |                   | 34                |     |     |                      |

(Note) See the table on p.12 for MC0-MC7.

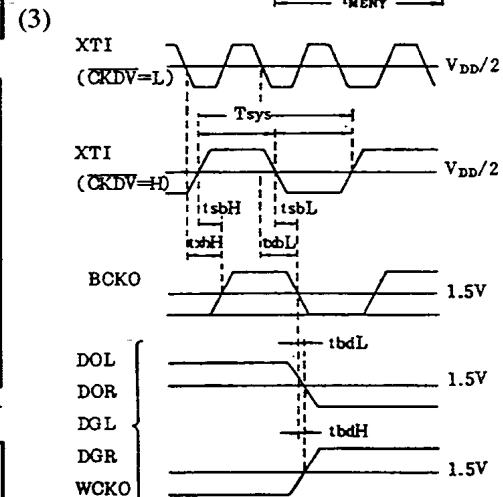
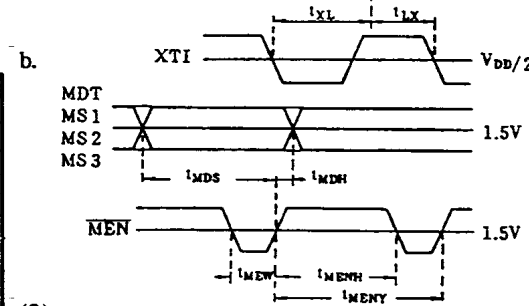
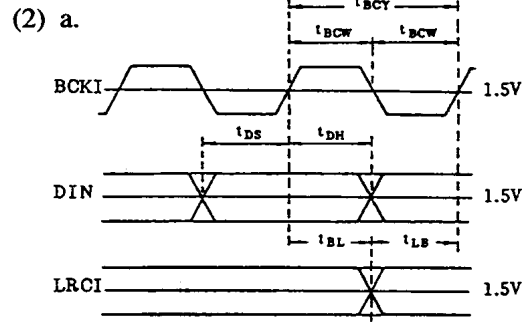
## 3. OUTPUT TIMING

| ITEM                     | SYMBOL           | RATING |     |     | UNIT | NOTE      |
|--------------------------|------------------|--------|-----|-----|------|-----------|
|                          |                  | MIN    | TYP | MAX |      |           |
| BCKO delay time from XTI | CKDV=L           | txbH   | 35  | 95  | nSec |           |
|                          |                  | txbL   | 35  | 95  |      |           |
|                          | CKDV=H           | tsbH   | 35  | 95  |      |           |
|                          |                  | tsbL   | 35  | 95  |      |           |
| Output delay time        | t <sub>bdL</sub> | -10    | 0   | +10 | nSec | 15pF Load |
|                          | t <sub>bdH</sub> | -10    | 0   | +10 |      |           |



\*1 The clock duty ratios on t<sub>CWH</sub> and t<sub>CWL</sub> (i.e., t<sub>CWH</sub>/t<sub>XI</sub> × 100) are as follows:

| XTI clock frequency     | Duty ratio     |
|-------------------------|----------------|
| 13MHz                   | 45.5% to 54.5% |
| 12.288MHz (48kHz × 256) | 43% to 57%     |



(\*) Start edge of LRCI:

LRPL flag = L Rising edge

LRPL flag = H Falling edge

(\*)1 T<sub>SYS</sub>: system clock period CKDV = L: t<sub>CL</sub> × 2, CKDV = H: t<sub>CL</sub>t<sub>CL</sub> is the period of the clock input on XTI.

## FUNCTION DESCRIPTION

### 1. Output mode selection ( $\overline{8X}$ input, OMD flag)

| $\overline{8X}$ input | OMD flag | Output mode      |
|-----------------------|----------|------------------|
| L                     | L        | 8fs LR parallel  |
| H                     | L        | 4fs LR alternate |
| H                     | H        | 4fs LR parallel  |
| L                     | H        | Test mode (*1)   |

(\*1) The test mode is the same as [8fs LR parallel output mode] except that the attenuation change operation is accelerated in the soft mute mode.

### 2. Oversampling filter function

#### • 8fs oversampling

Signal input at the sample rate  $f_s$  is output as data at the oversampling rate  $8f_s$ . This filter eliminates sampling noise of  $0.5465f_s$  to  $7.4535f_s$ .

#### • 4fs oversampling

Signal input at the sample rate  $f_s$  is output as data at the oversampling rate  $4f_s$ . This filter eliminates sampling noise of  $0.5465f_s$  to  $3.4535f_s$ .

### 3. Digital de-emphasis filter

An IIR filter is used to revive the gain and phase characteristics of the de-emphasis filter.

#### • De-emphasis mode selection (DIEM input)

De-emphasis ON (DIEM input = H or open)

De-emphasis OFF (DIEM input = L)

#### • Filter coefficient selection (FSEL1 input, FSEL2 input)

|       | fs coefficient selection |         |       |
|-------|--------------------------|---------|-------|
|       | fs=32kHz                 | 44.1kHz | 48kHz |
| FSEL1 | H                        | L       | L     |
| FSEL2 | H                        | L       | H     |

#### • Features of the digital de-emphasis filter

The IIR achieves almost ideal gain and phase characteristics, so there is no distortion and variation due to component parameters. The primary objective of de-emphasis is to reduce quantization noise in the high-frequency band and widen the dynamic range. However, de-emphasis in the digital stage narrows the dynamic range. This digital filter ensures a sufficiently wide dynamic range by minimizing the level of requantization noise by the following measures:

- 1) 8fs or 4fs oversampling output
- 2) Noise shaper
- 3) 18-bit or longer output word length

### 4. Digital attenuator

Attenuation is possible in 0.188 dB steps from 0 to -96 dB. Lch and Rch outputs can be attenuated independently. The attenuation level is given by the fol-

lowing equations:

Attenuation (L) = attenuation setting (L)  $\times$  0.188 dB; Lch

Attenuation (R) = attenuation setting (R)  $\times$  0.188 dB; Rch

#### • Relation with soft mute mode

When the soft mute mode is ON ( $\overline{\text{SOFT}}$  flag = L):

When an attenuation value is set, attenuation changes gradually in 0.188 dB steps until it reaches the level given by the above equation. (See Figure 1.)

When the soft mute mode is OFF ( $\overline{\text{SOFT}}$  flag = H):

When an attenuation value is set, attenuation immediately changes to the level given by the above equation.

### 5. Mute

The maximum attenuation value (511) is set in the mute mode (i.e., attenuation of 95.9 dB). When the mute mode is reset, attenuation returns to the previous setting. (When the setting is changed externally while in the mute mode, attenuation changes to the new value.)

#### • Mute mode selection (MUTE input)

Mute mode ON (MUTE input = H or open)

Mute mode OFF (MUTE input = L)

#### • Relation with soft mute mode

When the soft mute mode is ON ( $\overline{\text{SOFT}}$  flag = L):

Gradual attenuation in 0.188 dB steps (See Figure 2.)

When the soft mute mode is OFF ( $\overline{\text{SOFT}}$  flag = H):

Direct attenuation to the specified level

### 6. Soft mute

When the soft mute mode is ON, noise generated by the attenuator setting (MC4, MC5, MC6) or mute ON/OFF is prevented by gradual attenuation.

#### • Soft mute mode selection ( $\overline{\text{SOFT}}$ flag)

Soft mute mode ON ( $\overline{\text{SOFT}}$  flag = L)

Soft mute mode OFF ( $\overline{\text{SOFT}}$  flag = H)

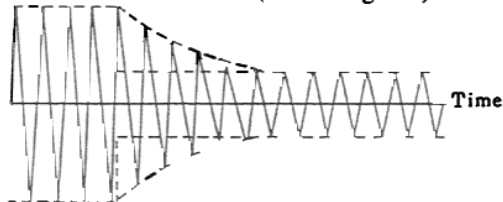


Figure 1 When the attenuator setting is changed

flag)

- Output data format

MSB first

Switching between 2's complement and COB (complemented offset binary) (COB flag)

2's complement format (COB flag = L)

COB format (COB flag = H)

- Floating output system

In the floating output system, a 6 dB-step analog attenuator is provided after D/A conversion and controlled (switched) according to the digital attenuator setting. Ordinary digital attenuators use only the low-order bits of the DA converter when a large attenuation value is set, which narrows the dynamic range.

The floating output system does not suffer this problem. The 6-dB step attenuator is switched statically according to the digital attenuator setting, so errors in the analog attenuator stage do not adversely affect sound quality.

In floating output, a word is configured from the DA data and analog shift words. (See Figure 5.)

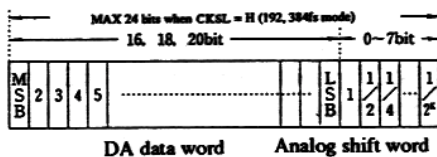


Figure 5 Configuration of Output Word

- DA data word

This data word is input to the DA converter for analog conversion. Data value  $N_{da}$  is expressed as follows:

$$N_{da} = N_{real}/N_{as}$$

where  $N_{real}$  is the true data value, and  $N_{as}$  is the value (1, 1/2, 1/4, ...) of the analog shift part.

- DA data word bit selection (LDA1 flag, LDA2 flag)

Selection can be made from 16, 18 and 20 bits.

| DA output part, No. of bits | LDA1 flag | LDA2 flag |
|-----------------------------|-----------|-----------|
| 16                          | L         | L         |
| 18                          | H         | L         |
| 20                          | L         | H         |

- Analog shift word

Word for controlling the analog attenuator stage following the DA converter

- Maximum shift bit (Las) selection

(LAS1, LAS2, LAS3 flag)

When the configuration of the analog attenuator is 1, 1/2, 1/4 ... 1/2<sup>K</sup> (K ≤ 6), set the following:

$$Las = K$$

When  $Las$  is set from 1 to 6, bits 2 to 7 are output as the analog shift word. Each bit is output MSB first and weighed with 1, 1/2, 1/4 ... 1/2<sup>K</sup>. Only 1 bit corresponding to the digital attenuator value is active (H) while the rest are set to 0 (L).

Note:

When the CKSL input is H (192fs/384fs clock mode), the sum of DA word bits and analog shift word bits must not exceed 24 ( $L_{da} + Las \leq 23$ ).

| Las setting flag |      |      |     | Analog shift bit | Digital attenuator value |           |            |            |             |             |             |         | DA data word length that can be used when CKSL = H (*1) |
|------------------|------|------|-----|------------------|--------------------------|-----------|------------|------------|-------------|-------------|-------------|---------|---------------------------------------------------------|
| LAS3             | LAS2 | LAS1 | LAS |                  | 0 - -0dB                 | 32 - -6dB | 64 - -12dB | 96 - -18dB | 128 - -24dB | 160 - -30dB | 192 - -36dB |         |                                                         |
| L                | L    | L    | 0   |                  | No analog shift part     |           |            |            |             |             |             |         |                                                         |
| L                | L    | H    | 1   | 1                | 1/2                      | 1/2       | 1/2        | 1/2        | 1/2         | 1/2         | 1/2         | 20 bits |                                                         |
| L                | H    | L    | 2   | 1                | 1/2                      | 1/4       | 1/4        | 1/8        | 1/8         | 1/8         | 1/8         | 18 bits |                                                         |
| L                | H    | H    | 3   | 1                | 1/2                      | 1/4       | 1/8        | 1/8        | 1/8         | 1/8         | 1/8         | 16      |                                                         |
| H                | L    | L    | 4   | 1                | 1/2                      | 1/4       | 1/8        | 1/8        | 1/16        | 1/16        | 1/16        | 18 bits |                                                         |
| H                | L    | H    | 5   | 1                | 1/2                      | 1/4       | 1/8        | 1/16       | 1/16        | 1/32        | 1/32        | 16      |                                                         |
| H                | H    | L    | 6   | 1                | 1/2                      | 1/4       | 1/8        | 1/16       | 1/16        | 1/32        | 1/64        | 16 bits |                                                         |

(\*1) The DA data length is not limited when CKSL = L, so any combinations of 16, 18 and 20 bits are possible.

- Output timing

| Item             | Symbol | Output mode         |                     |                     |
|------------------|--------|---------------------|---------------------|---------------------|
|                  |        | 8fs LR parallel     | 4fs LR alternate    | 4fs LR parallel     |
| Bit clock period | $T_b$  | $T_{sys}$           | $T_{sys}$           | $2 \times T_{sys}$  |
| Data word length | $T_w$  | $24 \times T_{sys}$ | $24 \times T_{sys}$ | $48 \times T_{sys}$ |
| CKSL = H         |        |                     |                     |                     |
| CKSL = L         |        | $32 \times T_{sys}$ | $32 \times T_{sys}$ | $64 \times T_{sys}$ |

$T_{sys}$ : Internal system clock period (See 8. System clock.)

$T_b$ ,  $T_w$ : See the figure below.

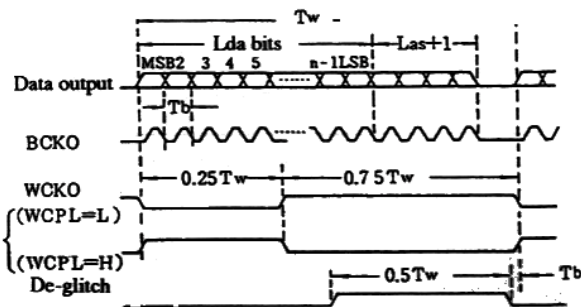


Figure 6 Output word

When the floating system is not in use ( $Las = 0$ : LAS1, LAS2, LAS3 flags = L)

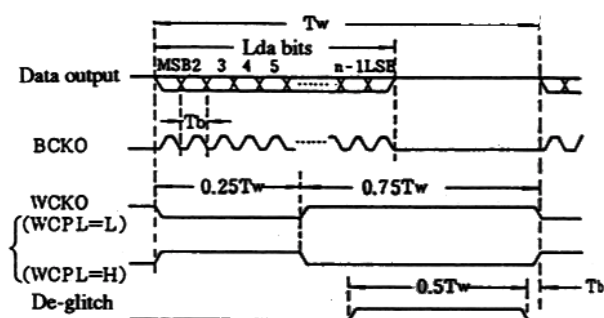


Figure 7 Output word

When the floating system is in use ( $L_{as} \geq 1$ )

12. Attenuation register (RattL, RattR) and mode flag register (Rmod) setting  
(MS1 to MS3 input, MDT input,  $\overline{MEN}$  input)

| Mode set control input |     |     |     |                  | Operation                                                                                                                                                            |
|------------------------|-----|-----|-----|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Mode                   | MS1 | MS2 | MS3 | $\overline{MEN}$ |                                                                                                                                                                      |
| MC0                    | L   | L   | L   |                  | Read MDT input to MSIPO and simultaneously shift MSIPO by 1 bit (READ).                                                                                              |
| MC1                    | H   | L   | L   |                  | Increment the attenuation register (L, R) by 1 (INC RattL, RattR).                                                                                                   |
| MC2                    | L   | H   | L   |                  | Decrement the attenuation register (L, R) by 1 (DEC, RattL, RattR).                                                                                                  |
| MC3                    | H   | H   | L   |                  | Set the attenuation register (L, R) to 0 (Reset RattL, RattR).                                                                                                       |
| MC4                    | L   | L   | H   |                  | Transfer the MSIPO contents to the attenuation register (L) (MSIPO to RattL).                                                                                        |
| MC5                    | H   | L   | H   |                  | Transfer the MSIPO contents to the attenuation register (R) (MSIPO to RattR).                                                                                        |
| MC6                    | L   | H   | H   |                  | Transfer the MSIPO contents to the mode flag register (Rmod) (MSIPO to Rmod).                                                                                        |
| MC7                    | H   | H   | H   |                  | Reset the mode flag register Rmod (set all flags to L).<br>Reset the attenuation register (L, R) (Reset RattL, RattR).<br>Reset the operation output timing counter. |

MSIPO; serial → parallel conversion register  
; rising edge

- Attenuation register (Ratt(L) and Ratt(R)) setting  
Of all the functions listed in the table above, 6 functions have an effect on the attenuation registers.

- (MC1) Increment the attenuation register by 1 (this increases the attenuation by 0.188 dB).

$Ratt(L) + 1 \rightarrow Ratt(L)$

$Ratt(R) + 1 \rightarrow Ratt(R)$

The register value will not change when it is the maximum value (511).

- (MC2) Decrement the attenuation register by 1 (this decreases the attenuation by 0.188 dB).

$Ratt(L) - 1 \rightarrow Ratt(L)$

$Ratt(R) - 1 \rightarrow Ratt(R)$

The register value will not change when it is the minimum value (0).

- (MC3) Reset the attenuation register (attenuation 0 dB).

$0 \rightarrow Ratt(L)$

$0 \rightarrow Ratt(R)$

Figure 8 and Figure 9 show examples of the attenuation register settings using MC1 to MC3.

- (MC4) (MC5) Transfer MSIPO register contents to the attenuation register.

$MSIPO \rightarrow Ratt(L)$  (with MC4)

$MSIPO \rightarrow Ratt(R)$  (with MC5)

The MSIPO register must be set with [MC0] prior to using MC4 or MC5.

See Figure 10 and Figure 11.

- (MC7) Reset the attenuation register.

$0 \rightarrow Ratt(L)$

$0 \rightarrow Ratt(R)$

This function also resets the mode flag register (Rmod) and the operation output timing counter at the same time.

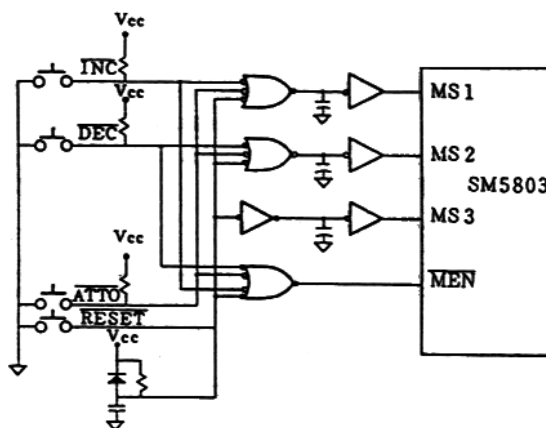


Figure 8 Example of attenuation register setting circuit using MC1, MC2 and MC3

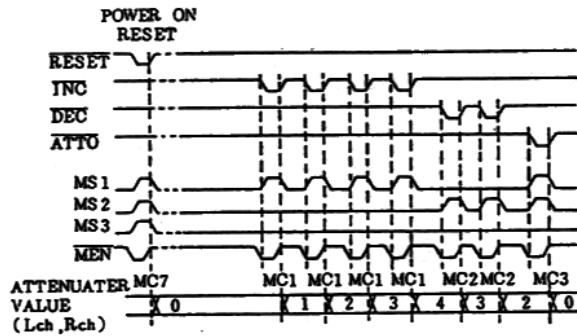


Figure 9 (Figure 8) Operation timing

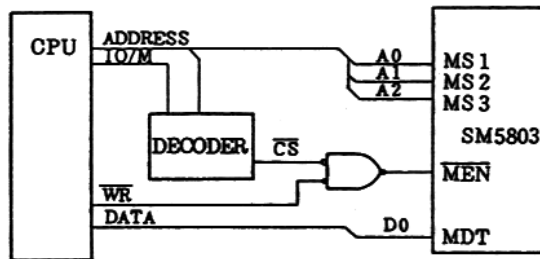


Figure 10 Example of attenuation register setting circuit using MC0, MC4 and MC5

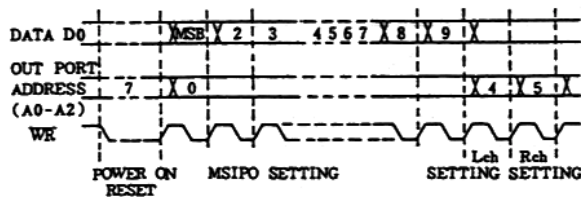


Figure 11 Operation timing of (Figure 10)

- Mode flag register (Rmod) setting  
Of all the functions listed in the above table, 2 functions have an effect on the mode flag register.

(MC6) Transfer MSIPO register contents to the mode flag register (Rmod).

MSIPO → Rmod

The MSIPO register must be set with (MC0) prior to using this function.

See Figure 12 and Figure 13.

(MC7) Reset the MSIPO register (Rmod) (i.e. set all flags to L). This function also resets the attenuation register and operation output timing at the same time.

See the table below on the right.

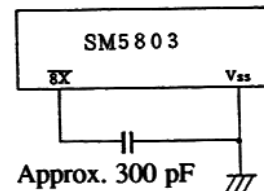
- Internal operation timing reset

(MC7) When this function is input, the internal operation and output timing counter is synchronously reset with the start edge of LRCI. This is useful for synchronizing the external input clock (LRCI) with the internal operation/output timing at the start of the jitter-free mode (SYN flag = L).

This function also resets the mode flag register and the attenuation register at the same time.

#### Notes:

1. This IC must be reset entirely in the (MC7) mode after power-on.
2. To perform 4-times oversampling, the IC must operate once in the 8-times mode at power-up or thereafter. The circuit shown below activates 8-times oversampling at power-up.



The time required for taking 8X L must be at least half (1/2) the LRCI clock period when the XTI clock is ON.

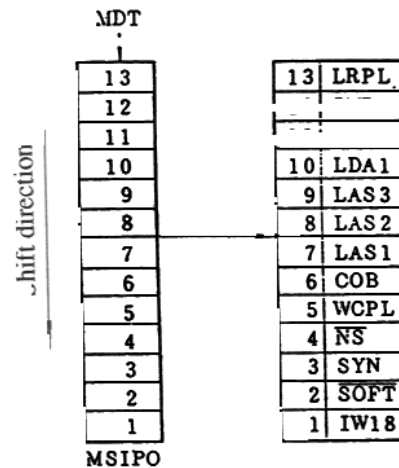


Figure 12 Mode flag register contents

List of mode flag settings (\*Note 1)

| Mode flag                         | Value      | State                                              |
|-----------------------------------|------------|----------------------------------------------------|
| LRPL                              | L          | Start on the rising edge of LRCI                   |
|                                   | H          | Start on the falling edge of LRCI                  |
| OMD                               | L          | 8fs LR parallel output operation (when 8X = L)     |
|                                   |            | 4fs LR alternate output operation (when 8X = H)    |
|                                   | H          | Test mode (when 8X = L)                            |
| LDA1<br>LDA2<br>(*Note 2)         |            | Lda = DA data length (bit)                         |
|                                   |            | 16 18 20                                           |
|                                   | LDA1 L H L |                                                    |
|                                   | LDA2 L L H |                                                    |
| LAS1<br>LAS2<br>LAS3<br>(*Note 2) |            | Maximum analog shift setting                       |
|                                   |            | Las = LAS1<br>+2 × LAS2<br>+4 × LAS3               |
| COB                               | L          | Output data in 2's complement format               |
|                                   | H          | Output data in COB format                          |
| WCPL                              | L          | Word delimit on the falling edge of the WCKO clock |
|                                   | H          | Word delimit on the rising edge of the WCKO clock  |
| NS                                | L          | Noise shaper ON                                    |
|                                   | H          | Noise shaper OFF                                   |
| SYN                               | L          | Jitter-free mode                                   |
|                                   | H          | Forced synchronization mode                        |
| SOFT                              | L          | Soft mute ON                                       |
|                                   | H          | Soft mute OFF                                      |
| IW18                              | L          | Input data word length, 16 bits                    |
|                                   | H          | Input data word length, 18 bits                    |

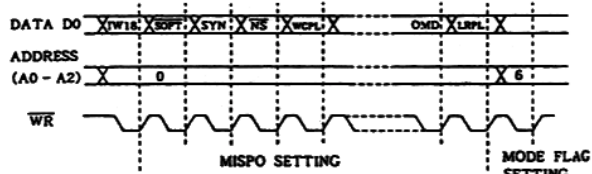


Figure 13 Mode flag setting using MC0 and MC6 (circuit of Figure 10 is in use)

## ■ TIMING CHART

## 1. INPUT TIMING (DIN, BCKI, LRCI)

(\*Note 1) All flags are reset to "L" upon reset.

(\*Note 2) The sum of Lda and Las values must be 23 or less when CKSL = H (192fs/384fs mode).

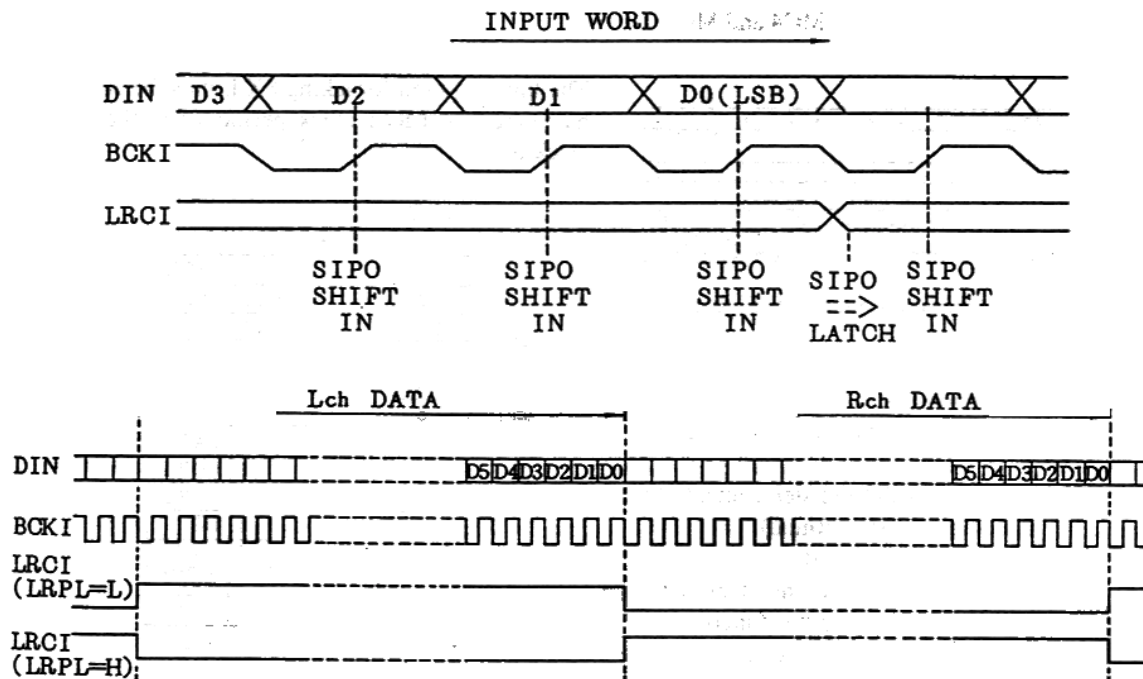
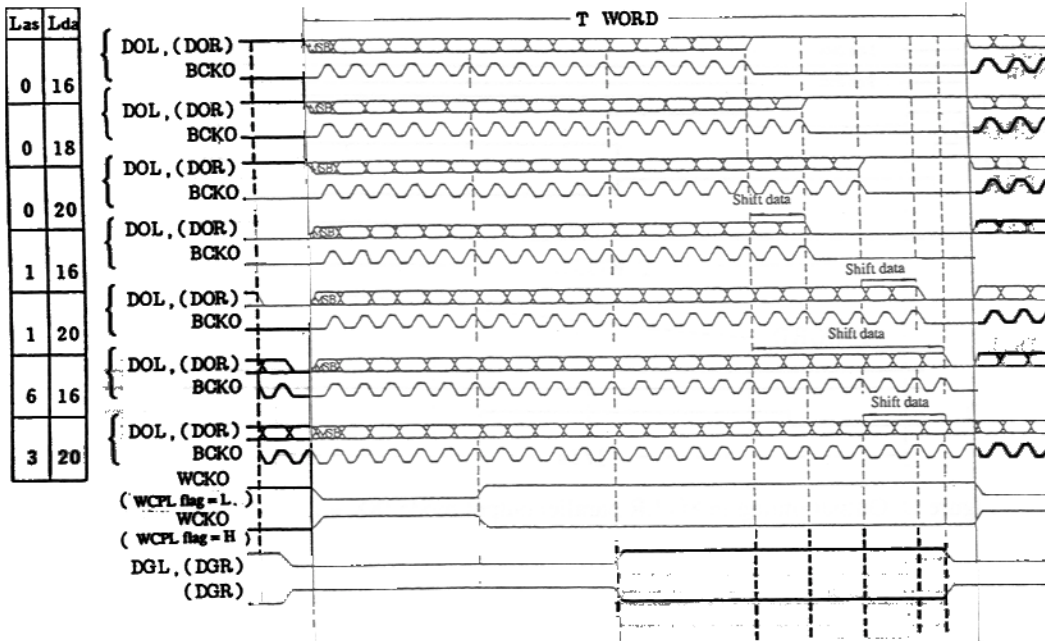


Figure A Audio data input timing

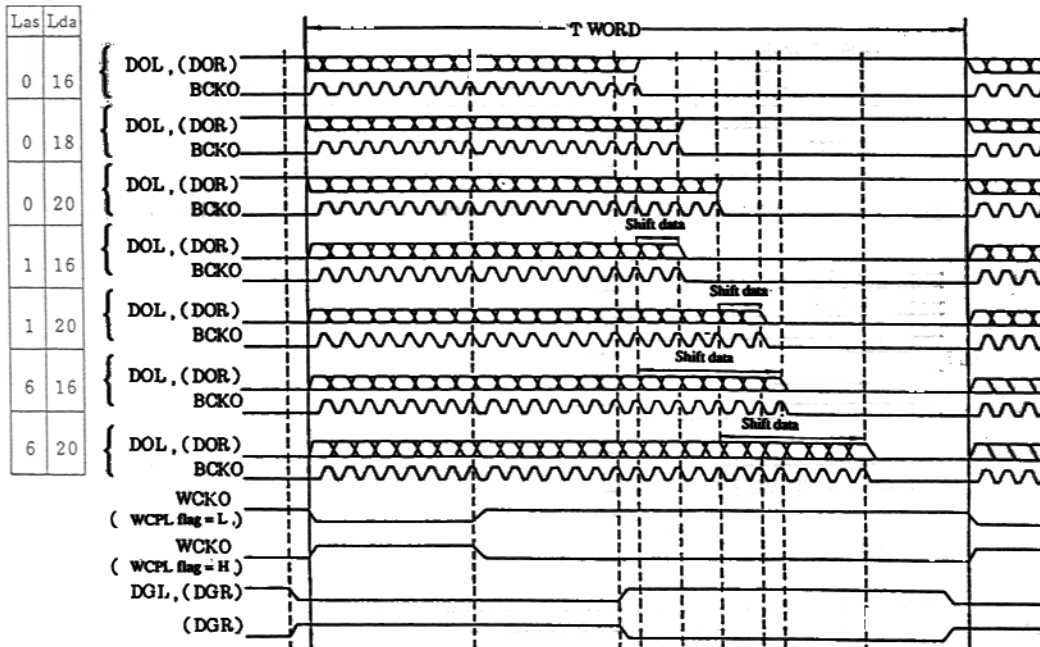
The 16 bits (when IW18 flag = L) or 18 bits (IW18 flag = H) immediately preceding the changing edge of the LRCI input clock are latched as input data.

## Output timing (DOL, DOR, BCKO, WCKO, DGL, DGR)

Figure B Unit output word timing (when  $\overline{\text{CKSL}} = \text{H}$ )

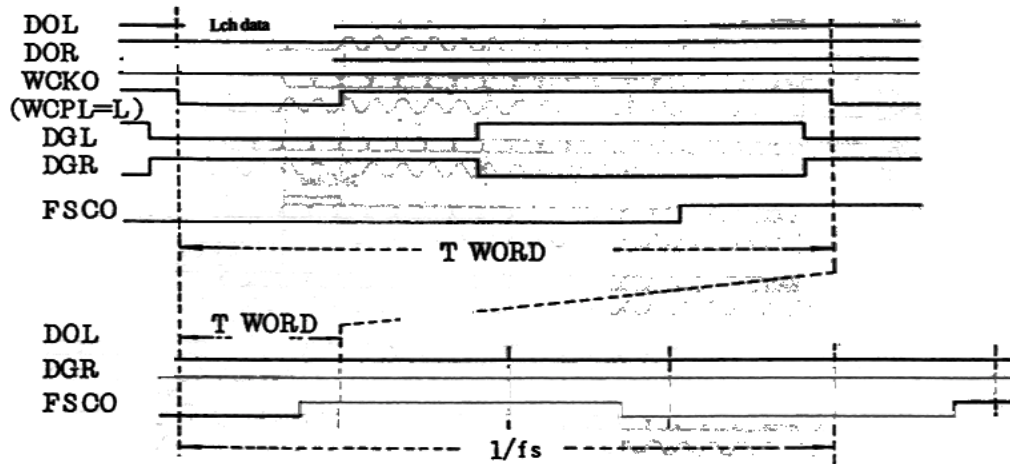
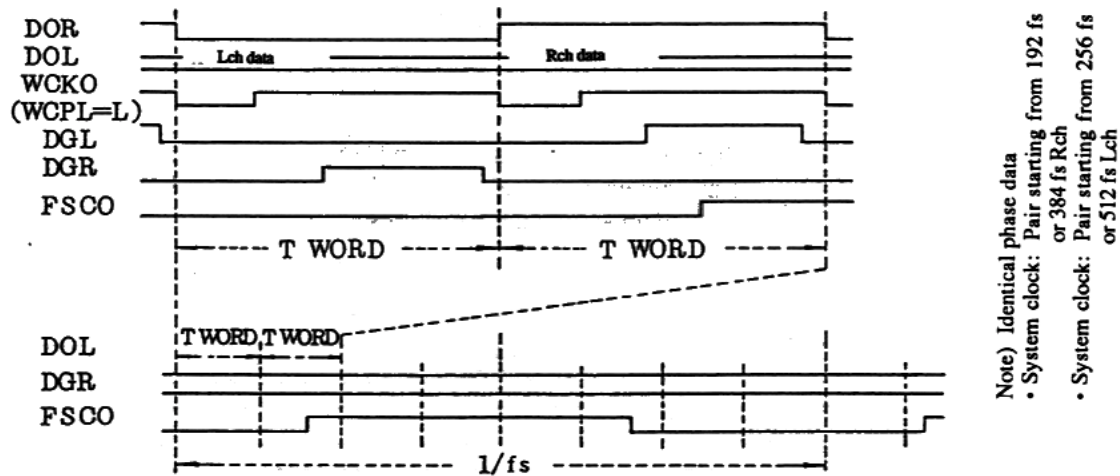
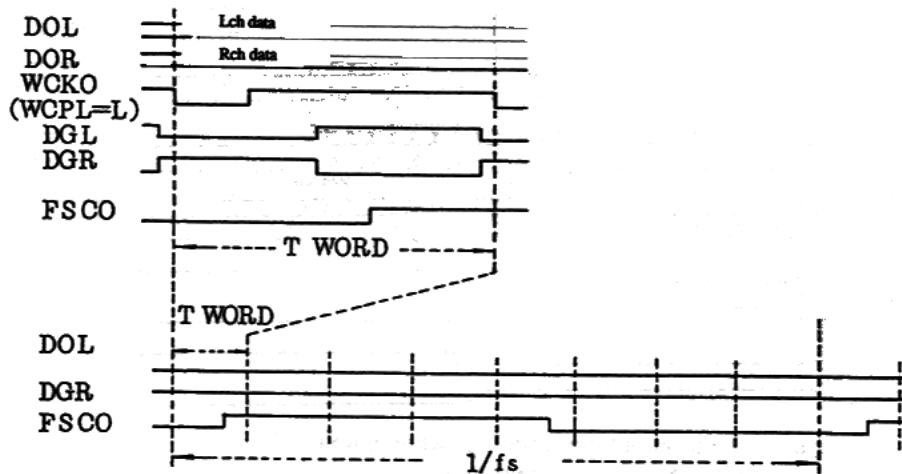
Lda: Number of DAC bits

Las: Number of analog shift bits

Figure C Unit output word timing (when  $\overline{\text{CKSL}} = \text{L}$ )

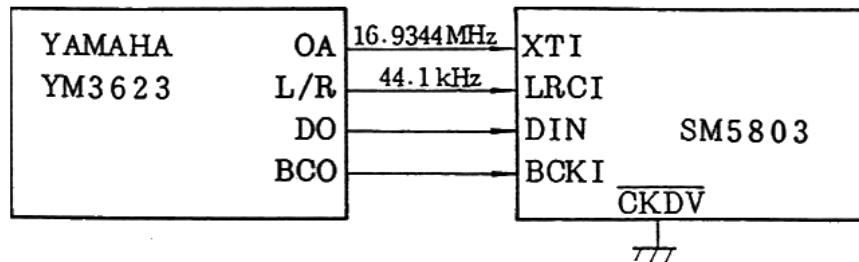
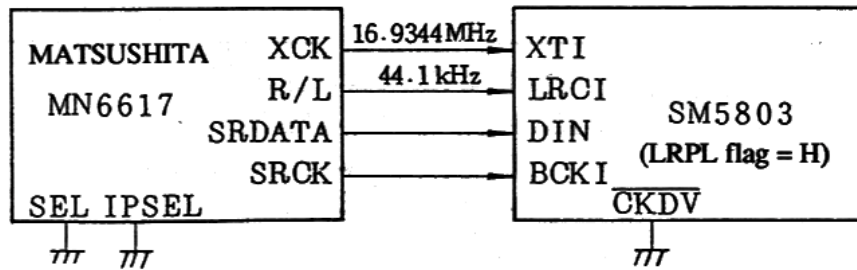
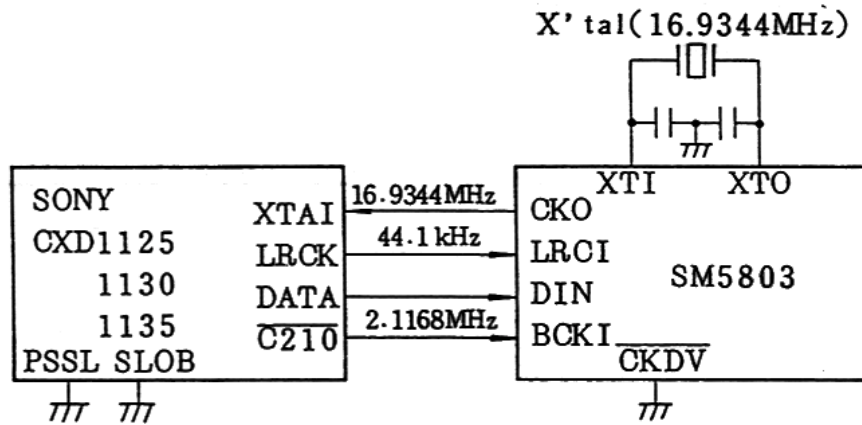
Lda: Number of DAC bits

Las: Number of analog shift bits

Figure D Output timing in 8fs LR parallel output mode ( $\overline{8X} = L$ , OMD flag = L or H)Figure F Output timing in 4fs LR alternate output mode ( $\overline{8X} = H$ , OMD flag = L)Figure G Output timing in 4fs LR parallel output mode ( $\overline{8X} = H$ , OMD flag = H)

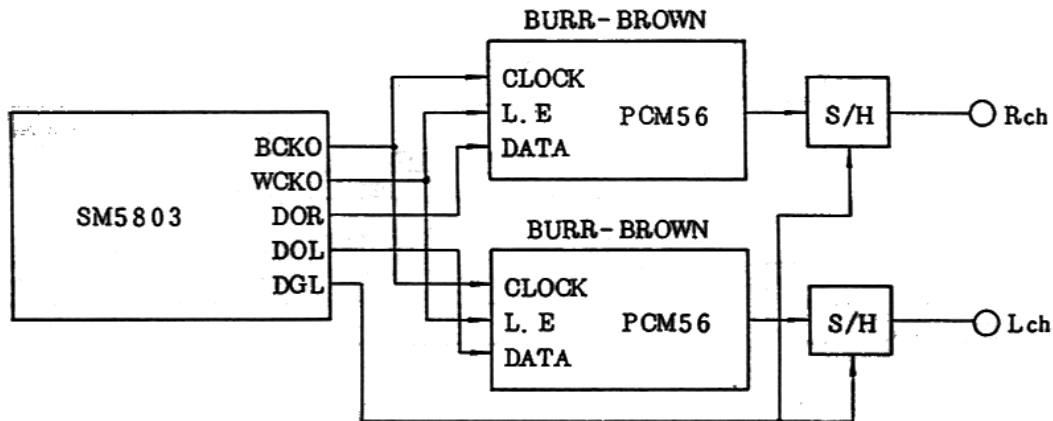
# TYPICAL APPLICATION

## 1. Input connection examples



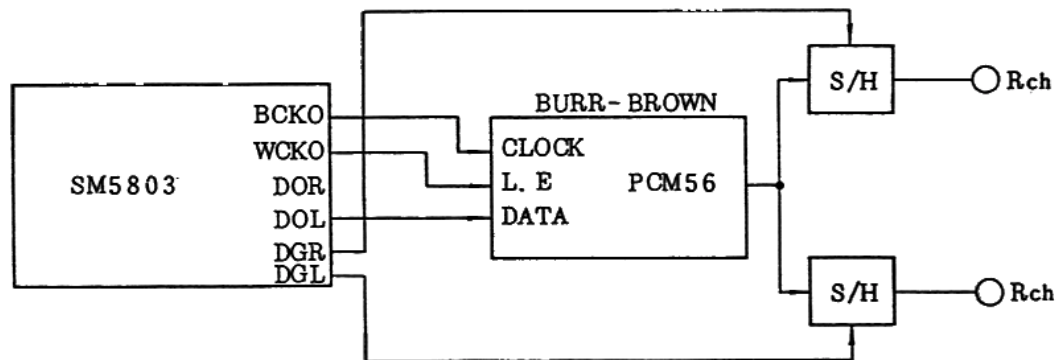
## Output connection examples

## (1) Example of using 16-bit 2DAC (8fs, 4fs LR parallel output mode)



- 8fs LR parallel output  $\overline{8X}$  input = L, OMD flag = L
- 4fs LR parallel output  $\overline{8X}$  input = H, OMD flag = H

## (2) Example of using 16-bit 1DAC (4fs LR alternate output mode)



- 4fs LR parallel output  $\overline{8X}$  output = H, OMD flag = L