NJU26060 Series Hardware Specification

■ General Description

The NJU26060 Series is a high performance 24-bit digital signal processor. The NJU26060 Series provides stereo PWM modulators, one Sampling Rate Convertor(SRC), Digital Interface Transemitor(DIT) and four GPI/O ports.

The NJU26060 Series with the OTP(One Time Programmable) function provides the wide range of applications of sound technologies and fast time to market service.

■ Package

NJU26060V

■ Features

- Hardware

- 24bit Fixed-point Digital Signal Processing
- Maximum Clock Frequency : 24.576MHz (Standard), Embedded PLL Circuit
- PWM modulator : stereo 4ch Outputs
- Sampling rate converter (SRC) : Fs=8kHz～192kHz → 48kHz
- Digital interface transmitter (DIT)
- Digital Audio Interface : 3 Input ports / 3 Output ports
- Digital Audio Format : I^2S 24bit, Left-justified, Right-justified, BCK : 32/64fs
- Master / Slave Mode
  - Sampling Rate Converter: Slave mode
  - In Master Mode: MCKO(256 or 512fs), BCKO(64 or 32fs), BCK (1fs)
- Host Interface
  - I^2C Bus (Fast-mode/400kbps)
- Power Supply : V_{DD} = 3.3V
- Input terminal: : 5V Input tolerant
- Package : SSOP44 (Pb-Free)

■ DSP Block Diagram

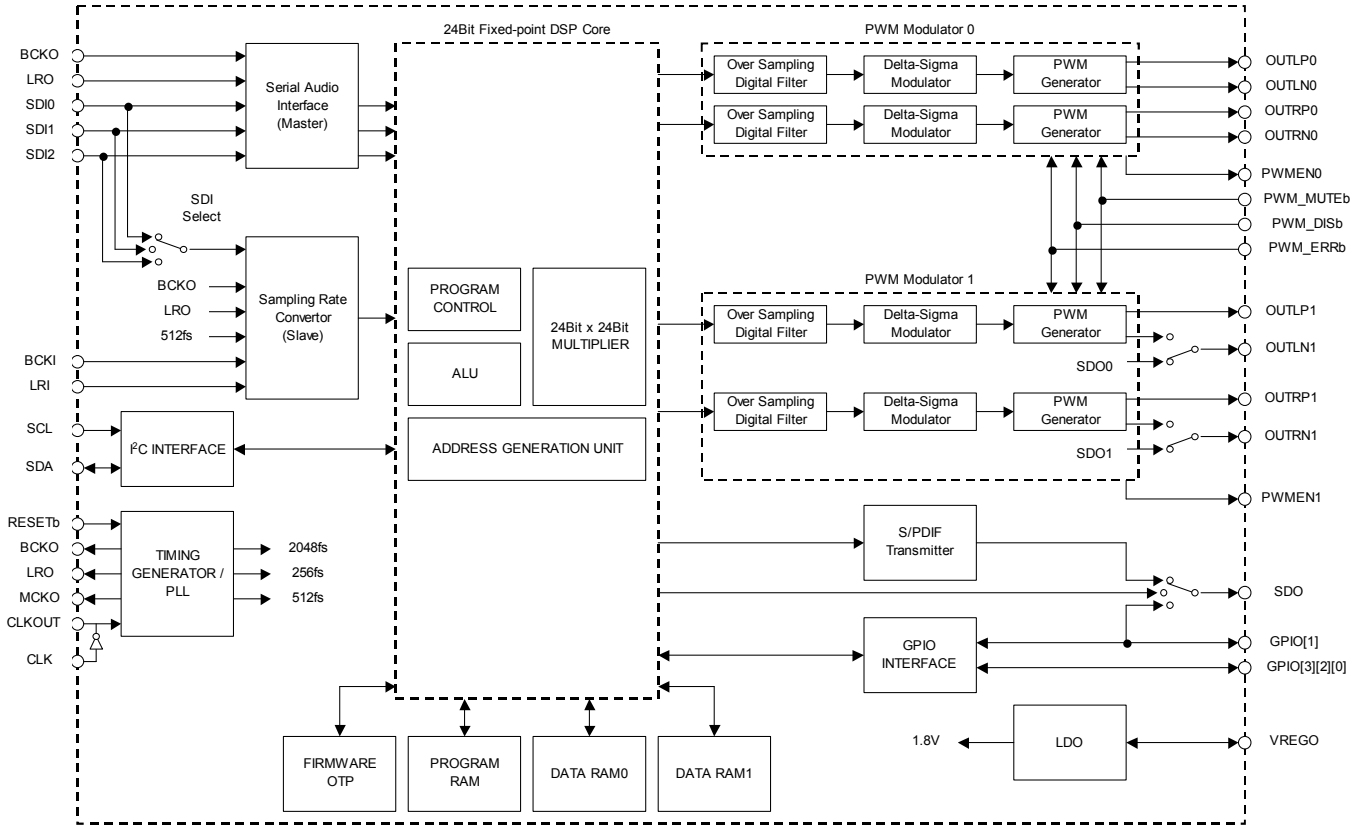


Fig.1 NJU26060 Series Block Diagram

■ Pin Configuration

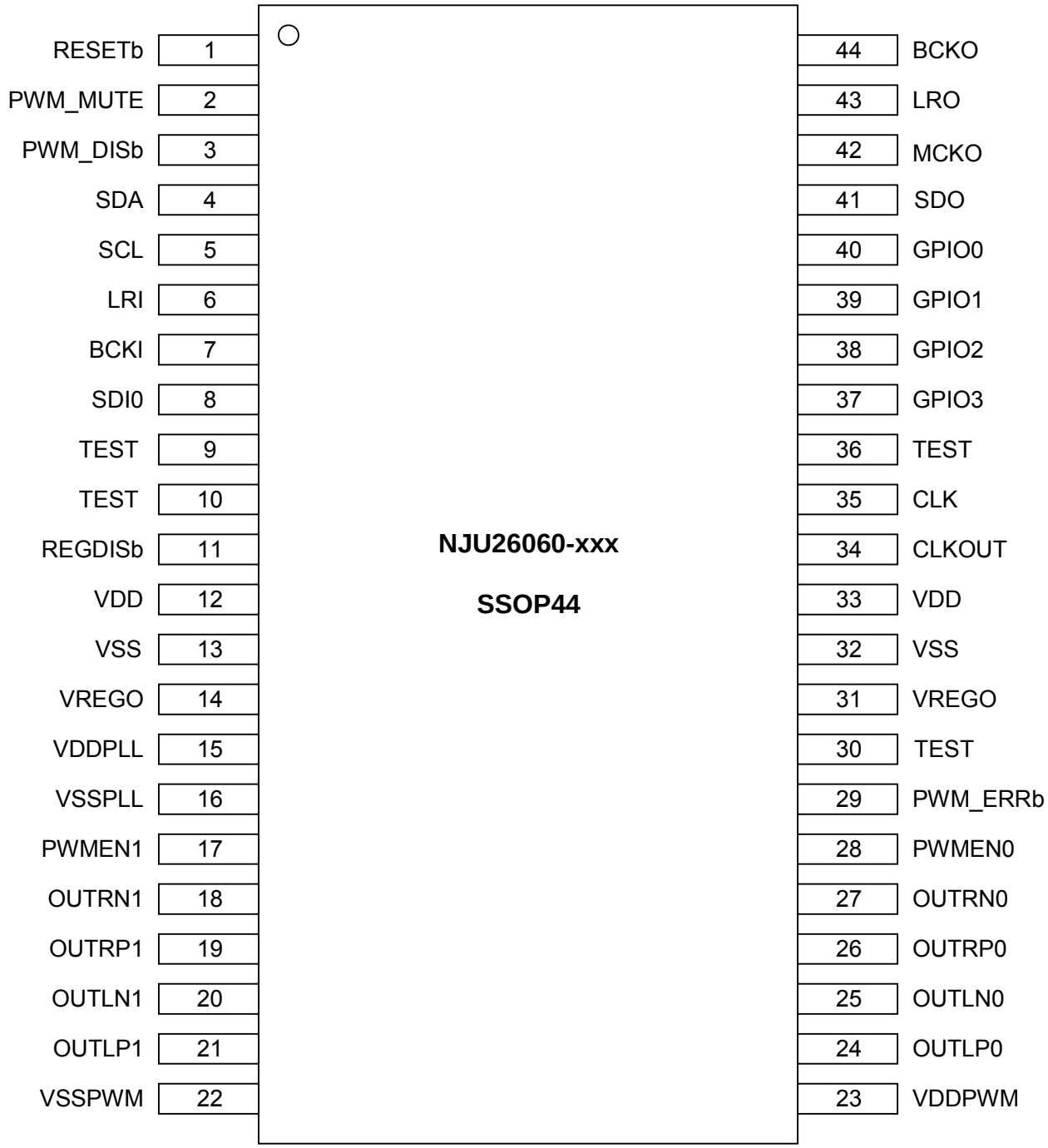


Fig.2 NJU26060 Series Pin Configuration

■ Pin Description

Table 1. Pin Description

Pin No.	Symbol	I/O	Description
1	RESETb	I	Reset (RESETb="Low" : DSP Reset)
2	PWM_MUTEb	I+	PWM Block Mute request input
3	PWM_DISb	I+	PWM Block Standby request input
4	SDA	OD	I^2C I/O
5	SCL	I	I^2C clock
6	LRI	I-	LR Clock Input for Fs conversion side
7	BCKI	I-	Bit Clock Input for Fs conversion side
8	SDI0	I	Audio Data Input 0 (L/R)
9	TEST	I	For Test (connected to VSS)
10	TEST	I	For Test (connected to VSS)
11	REGDISb	I	Built-in Power Supply Enable
12	VDD	-	Power Supply +3.3V
13	VSS	-	GND
14	VREGO	PI	Built-in Power Supply Bypass
15	VDDPLL	-	PLL Power Supply +1.8V
16	VSSPLL	-	PLL Power Supply GND
17	PWMEN1	O	PWM1 enable output (PWMEN1='1': enable)
18	OUTRN1	OP	PWM1 R- output / Audio Data output 1 (setting Firmware)
19	OUTRP1	OP	PWM1 R+ output
20	OUTLN1	OP	PWM1 L- output / Audio Data output 0 (setting Firmware)
21	OUTLP1	OP	PWM1 L+ output
22	VSSPWM	-	PWM Power Supply GND
23	VDDPWM	-	PWM Power Supply +3.3V
24	OUTLP0	OP	PWM0 L+ output
25	OUTLN0	OP	PWM0 L- output
26	OUTRP0	OP	PWM0 R+ output
27	OUTRN0	OP	PWM0 R- output
28	PWMEN0	O	PWM0 enable output (PWMEN0='1': enable)
29	PWM_ERRb	I+	PWM block stop request input (PWM_ERRb='0': PWM stop)
30	TEST	I	for Test (connected to VSS)
31	VREGO	PI	Built-in Power Supply Bypass
32	VSS	-	GND
33	VDD	-	Power Supply +3.3V
34	CLKOUT	O	OSC Output
35	CLK	I	OSC Clock Input
36	TEST	I-	for Test (connected to VSS)
37	GPIO3	I/O	General Purpose IO 3 / for TEST
38	GPIO2	I/O	General Purpose IO 2 / for TEST
39	GPIO1	I/O	General Purpose IO 1 / for TEST
40	GPIO0	I/O	General Purpose IO 0 / for TEST
41	SDO	O	DIT output / Audio Data Output 2 (setting Firmware)
42	MCK	O	Master Clock Output for A/D, D/A
43	LRO	O	LR clock Output
44	BCKO	O	Bit clock Output

Note :
I : Input
O: Output
I+ : Input (Pull-up)
I -: Input (Pull-down)
OD : Bi-directional (Open Drain) This pin requires a pull-up resistance.
I/O : Bi-directional
PI: Built-in Power Supply Bypass
OP : PWM output(supply for VDDPWM)

NOTICE: Does not keep the terminal without the pull-up resistance or the pull-down resistance open.
The functions of SDIO0 to SDIO2, SDO, OUTxxx depend on the IC specifications.

■ Absolute Maximum Ratings

Table2 Absolute Maximum Ratings **(V_{SS}=V_{SSPLL}=V_{SSIO}=0V, Ta=25°C)**

Parameter		Symbol	Rating	Units
Supply Voltage *		V_{DD}, V_{DDPWM}	-0.3 to 4.2	V
Supply Voltage Bypass *		V_{REGO}	-0.3 to 2.3	
Supply Voltage PLL *		V_{DDPLL}	-0.3 to 2.3	
Terminal Voltage *	In	$V_{x(IN)}$	-0.3 to 5.5 (V_{DDIO}≥3.0V) -0.3 to 4.2 (V_{DDIO}<3.0V)	V
	I/O, O/D	$V_{x(I/O)}$, $V_{x(OD)}$		
	Out	$V_{x(OUT)}$	-0.3 to 4.2	
	CLK	$V_{x(CLK)}$	-0.3 to 4.2	
	CLKOUT	$V_{x(CLKOUT)}$	-0.3 to 4.2	
Power Dissipation		P_D	800 It mounts on the board of the EIAJ spec. 76.2 x 114.3 x 1.6mm, 2layer, FR-4	mW
Operating Temperature		T_{OPR}	-40 to 85	°C
Storage Temperature		T_{STR}	-40 to 125	°C

* V_{DD} : 12, 33 pin
* V_{DDPW} : 23 pin
* V_{REGO} : 14, 31 pin
* V_{DDPLL} : 15 pin
* $V_{x(IN)}$: 1~3, 5~11, 29, 30, 36 pin
* $V_{x(OD)}$: 4 pin
* $V_{x(I/O)}$: 37~40 pin
* $V_{x(OUT)}$: 17~21, 24~28, 41~44 pin
* $V_{x(CLK)}$: 35 pin
* $V_{x(CLKOUT)}$: 34 pin

■ Equivalent Circuits

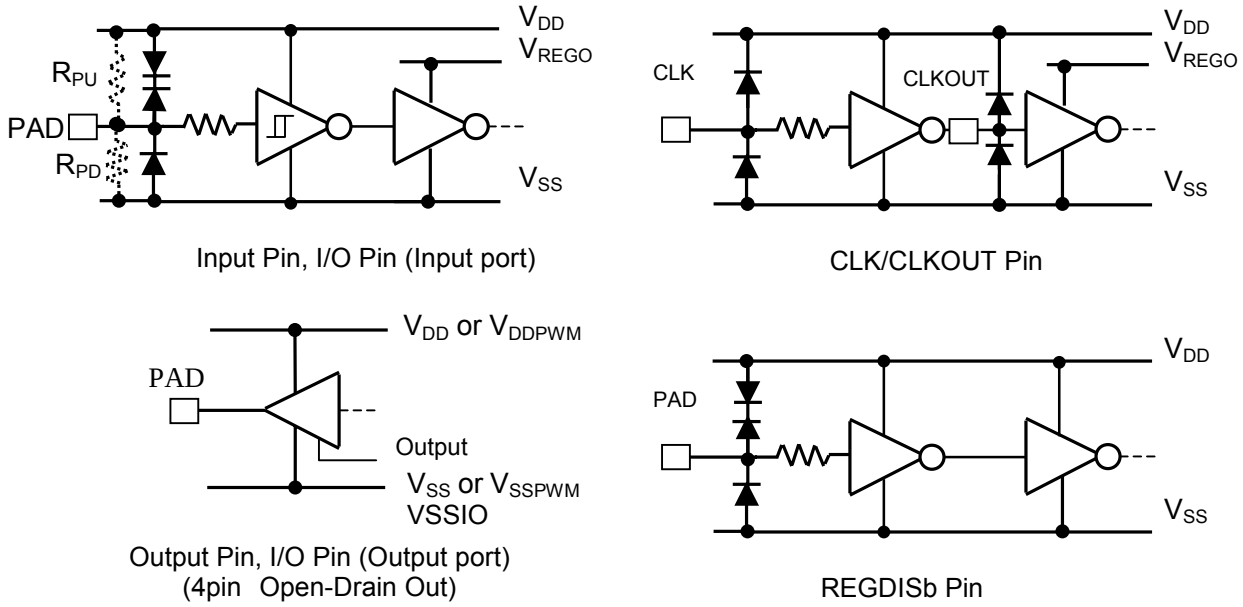


Fig.3 NJU26060 Series Equivalent Circuits

■ Electric Characteristics

Table3 Electric Characteristics **(V_{DD}=V_{DDPWM}=3.3V, f_{OSC}=24.576MHz, Ta=25°C)**

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Units
Operating Voltage *1	V_{DD}	V_{DD}, V_{DDPWM} Pin	3.0	3.3	3.6	V
Operating Current	I_{DD}	AT no Load, V_{DD} + V_{DDPWM}	-	35	50	mA
High Level Input Voltage	V_{IH}		V_{DD} x 0.7	-	V_{DD} *2	V
Low Level Input Voltage	V_{IL}		0	-	V_{DD} x 0.3	
High Level Output Voltage *3	V_{OH}	I_{OH} = -1mA	V_{DD} x 0.8	-	V_{DD}	
Low Level Output Voltage	V_{OL}	I_{OL} = 1mA	0	-	V_{DD} x 0.2	
Terminal Leakage Current *4	I_{IN}	V_{IN} = V_{SS} ~ V_{DD}	-10	-	10	μA
	$I_{IN(PU)}$		-120	-	10	
	$I_{IN(PD)}$		-10	-	120	
Clock Frequency	f_{OSC}	CLK Pin *5	20	22.5792 24.576	25	MHz
Ext. System Clock Duty Cycle	r_{EC}		45	50	55	%

*1 Please use the V_{DD} ,V_{DDpwm} within the electric characteristics. V_{DD} ,V_{DDpwm} is monotonous increase. Don't drop voltage under the electric characteristics after booting V_{DD} ,V_{DDpwm} to regulation voltage. When it turns off DSP and turns on DSP again, it is necessary to drop V_{DD} to GND level. Then it turns on DSP again.
*2 Input pin, Output pin and Open-Drain input/output pin are +5.0V tolerant except CLK input pin.
*3 Except 4pin (Open-Drain I/O) input pin.
*4 $I_{IN(PU)}$: 2,3,29,37,38pin, $I_{IN(PD)}$: 6~10,36,39,40 pin
*5 Please give usually the clock of 24.576MHz using for 48kHz and 22.5792MHz using for 44.1kHz.
An internal sampling frequency is 1/512 of the input clock frequency.

1. Power ,Clock and Reset

1.1 Power Supply

The NJU26060 Series has three power supplies V_{DD}/V_{SS}, V_{DDPLL}/V_{SSPLL} and V_{DDPWM}/V_{SSPWM}. V_{DD}/V_{SS} is used as an internal core supply, V_{DDPLL}/V_{SSPLL} is used as an internal PLL power supply and V_{DDPWM}/V_{SSPWM} is used as PWM output power supply.

The NJU26060 has a power supply V_{DD}/V_{SS}, V_{DDPLL}/V_{SSPLL}. To setup good power supply condition, the decoupling capacitors should be implemented at the all power supply terminals.

Please use the V_{DD}/V_{DDPWM} within the electric characteristics. V_{DD}/V_{DDPWM} is monotonous increase. Don't drop voltage under the electric characteristics after booting V_{DD}/V_{DDPWM} to regulation voltage. When it turns off DSP and turns on DSP again, it is necessary to drop V_{DD}/V_{DDPWM} to GND level. Then it turns on DSP again.

V_{DDPWM}/V_{SSPWM} is used as PWM output :OUTLP0, OUTLN0, OUTRP0, OUTLP1, OUTLN1, OUTRP1power supply. V_{DD}/V_{SS} has a same power supply.

The NJU26060 include a built-in power supply (LDO) for internal logic. A built-in power supply generates 1.8V (-10% to +10%). VREGO (No.14,31) pin is a built-in power supply bypass pin. Connect low-ESR capacitor of 0.01uF in parallel between VSS (No.13,32) pin.

The NJU26060 include PLL for internal logic and PWM modulator. PLL power has $V_{DDPWM}/V_{SSPWM,}$ but an include circuit unconnected straight for each other power. PLL power is supply for VREGO (No.14).
Connect the decoupling capacitor of 0.01uF in parallel between V_{DDPLL} and V_{SSPLL}. V_{SSPLL} is connected $V_{SS.}$

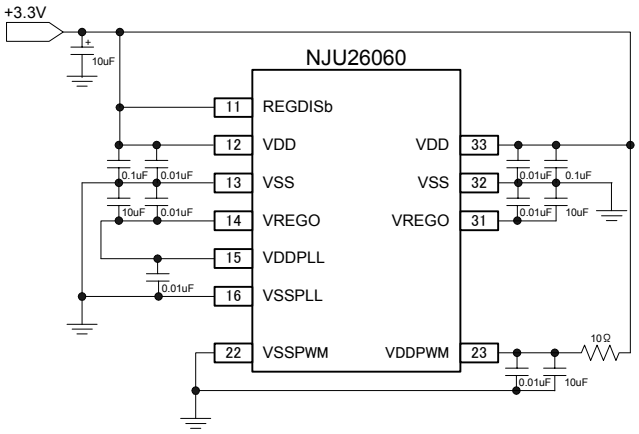


Fig.4 Simple power filter sample

A built-in power supply is used only for NJU26060 operation. Be not short-circuited of this pin. Do not take out the current, and connect other power supplies.

1.2 Input/Output terminal

It restricts, when the input terminals, the input/output terminals and the bi-directional Open-drain terminal of NJU26060, and V_{DD} are supplied on regular voltage (V_{DD}=3.3V), and it becomes +5V Input tolerant.

1.3 Clock

The NJU26060 CLK pin requires the system clock that should be related to the sample frequency 512 Fs using the PWM modulator.
It is possible to be generated the system clock by connecting a crystal oscillator between CLK and CLKOUT. CLK/CLKOUT pins are not 5V tolerant, so check the voltage level of these pins.

Note: When the crystal oscillator supplies the clock, the characteristic of the NJU26060 series is secured. However, when the clock of external generation is supplied, the characteristic of the sampling rate converter and the PWM modulator might be depraved.

1.4 Reset

To initialize the NJU26060, RESETb pin should be set Low level during some period. After some period of Low level, RESETb pin should be High level. This procedure starts the initialization of the NJU26060. After the power supply and the oscillation of the NJU26060 becomes stable, RESETb pin must be kept Low-level more than t_{RESETb} period. (Fig.5)

After RESETb pin level goes to "High" (after reset release), a setup of the internal hardware of a Serial Host Interface completes NJU26060. Then, it will be in the state which can communicate.

Fig. 5 Reset Timing

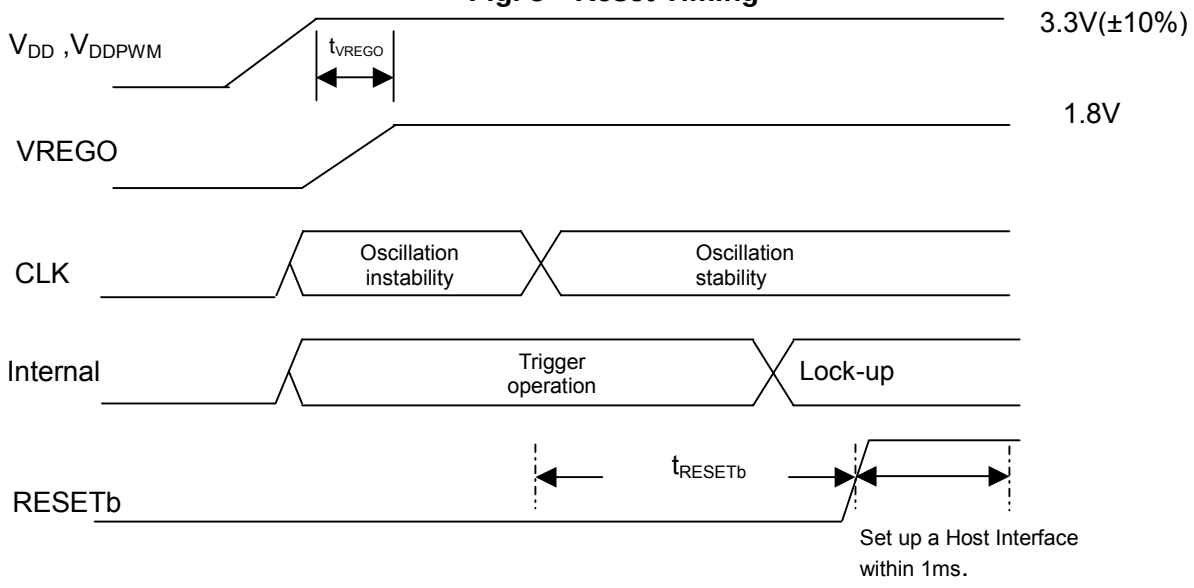


Table 4 Reset time

Symbol	Time
t_{VREGO}	≥10msec
t_{RESETb}	≥10msec

NOTICE: All the output terminals are irregular from turning on the power supply to the internal reset completion. Especially, when the terminal PWMEN0/1 is used by the control signal, the redundant design is needed to protect the system.

Do not stop providing clock during operation. If stopped, the built-in PLL cannot provide a normal clock toward internal NJU26060 series doesn't work correctly.

2. Digital Audio Clock

Digital audio data needs to synchronize and transmit between digital audio systems.
When the sampling rate converter is not used, the NJU26060 series is used as a master mode.
Sampling rate converter is supported for slave mode only.

- In Master mode;
  The clock of MCKO, BCKO, and LRO is used for digital audio data transfer as a clock of other slave devices.
- In Slave mode;
  BCKI and LRI input the clock from other maste devices.

2.1 Audio Clock

Three kinds of clocks are needed for digital audio data transfer.
(1) LR clock (LRI, LRO) is needed by serial-data transmission. It is the same as the sampling frequency of a digital audio signal.
(2) Bit clock (BCKI, BCKO) is needed by serial-data transmission. It becomes the multiple of LR clock.
(3) Master clock (MCKO) needed by A/D, D/A converter, etc. It becomes the multiple of LR clock. It is not related to serial audio data transmission.
The NJU26060 series support serial data format that includes 32(32fs) or 64(64fs) BCK clocks.

The NJU26060 Series supplies the clock necessary for digital audio data transmission to an external device as a master device by each terminal of MCKO, BCKO, and LRO. On the other hand, the sampling rate converter that works as a slave device takes digital audio data with the clock input to BCKI and the terminal LRI, and converts the sampling frequency into the clock system composed of MCKO/BCKO/LRO. After internal reset ends as a master clock, the terminal MCKO sets the buffer output or 2 dividing frequency the output of the input clock to the terminal CLK. The stop is also possible according to the command of the firmware.

The NJU26060 Series is used by 512 times the internal operation sampling frequency (It is 24.576MHz in the sampling frequency 48kHz). In that case, NJU26060 can output 64 times, 32 times the bit clock to of the LR clock one time the sampling frequency and of each, and 512 times and 256 times the master clock as a mastering device. Table 5 shows the relation of each clock.

Table 5 Supply Clock for CLK pin Frequency and BCKO,LRO,MCKO

Clock Signal	Multiple Frequency	Clock Frequency	
		22.5792MHz	24.576MHz
LRO	1Fs	44.1kHz	48kHz
BCKO(32Fs)	32Fs	1.4112MHz	1.536MHz
BCKO(64Fs)*	64Fs	2.8224MHz	3.072MHz
MCKO(256Fs)*	256Fs	11.2896MHz	12.288MHz
MCKO(512Fs)	512Fs	22.5792MHz	24.576MHz

* default for starting up

3. Sampling Rate Converter (SRC)

The NJU26060 Series provide the stereo (two channels) Sampling Rate Converter (SRC). The internal audio sampling frequency (Fs) is 1/512 of the CLK pin.

The SRC can convert an arbitrary sampling frequency (Fs=8kHz to 192kHz) into the internal sampling frequency (Fs=CLK/512). For example, CLK=24.576MHz at Fs=48kHz, CLK=22.5792MHz at Fs=44.1kHz.

3.1 Automatic Sample-frequency Detection

The NJU26060 Series provide the automatic sampling-frequency detection to provide the best converting performance. When the sample frequency changes on a large scale, this automatic detection resets the SRC.

To detect the sampling frequency change, the NJU26060 Series count the length of the LRI clock, every 2,048 LRI clock. In case of CLK=24.576MHz and LRI=48kHz, the count of length is 24,576/48=512. The LRI and CLK are asynchronous, so the negligible error count is about ±1 clock. The detection block compares the previous counts f_{LRI} with the current counts $f_{LRI'}$. When the detection block finds that the count difference exceeds ±4, the detection block resets the SRC.

The detection function operates when the next condition occurs.

$$f_{LRI'} < 1 / \{(4+CLK/ f_{LRI}) / CLK\} \quad or \quad f_{LRI'} > 1 / \{(4-CLK/ f_{LRI}) / CLK\} \quad [Hz]$$

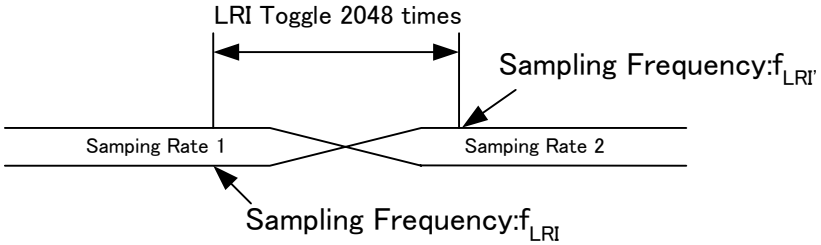


Fig.6 Relation between $f_{LRI'}$ and $f_{LRI'}$

The automatic detection can detect the frequency change as follows:

In case of CLK=24.576MHz and f_{LRI}=8kHz, the next two $f_{LRI'}$ frequency ranges can be detected.

$f_{LRI'}$ < 7.989kHz or $f_{LRI'}$ > 8,010kHz

* 2,048sample=2,048/8,000=256msec, f_{LRI}=1/{(4±24.576M/8k)/24.576M}

In case of CLK=24.576MHz and f_{LRI}=192kHz, the next two $f_{LRI'}$ frequency ranges can be detected.

$f_{LRI'}$ < 186.18kHz or $f_{LRI'}$ > 198.19kHz

* 2,048sample=2,048/192,000=10.7msec, f_{LRI}=1/{(4±24.576M/192k)/24.576M}

The firmware can check if the SRC is reset by the automatic detection. The reset period is fixed at 2,048 X 512(1/CLK) seconds. This function is also effective in the reset period. During the reset this detection happens, the reset period becomes longer.

This function is active in default. When the changing speed of the LRI clock is too slow, the automatic detection could not be detected. When the input audio signal does not meet the above frequency detection requirement with bad-quality LRI and BCKI, the SRC does not convert correctly. In this case, reset the SRC by the firmware. Also reset the SRC by the firmware once when the system powers on.

The detection block cannot detect the complete stopped LRI clock. In case of the stopped LRI clock, the SRC generates the noise depending on the input signal condition. When this kind of noise happens, reset or stop the SRC function by the firmware.

3.2 Sampling Frequency Conversion Ratio and Group Delay

After the automatic detection reset or the firmware reset is done, the SRC generates an effective conversion output within 256 input samples. The NJU26060 Series does not generate digital noise after this kind of reset. The conversion ratio comes to the target specification and fixes conversion ratio within 16,384 input samples after the reset. After the automatic detection reset or the firmware reset, the LRI clock should be stable.

In case of the sampling converter ratio is fixed, the group delay is 256 sampling frequency clocks. To transfer the data to the firmware, it takes five more sampling frequency clocks. The zero data is inputted into the SRC during the group delay period, the output data of the SRC becomes zero.

3.3 Jitter-Tolerated Dose

The SRC can accept the jitter of 0.1UI. The UI is abbreviation of unit interval. The 1UI is one LRI clock time. The UI is defined by single peak.

Ex.1) Fs=8kHz 0.1UI = 0.1/8,000=12.5μsec
Ex.2) Fs=192kHz 0.1UI = 0.1/192,000=521nsec

The jitter-tolerated dose is shown in fig.7. The dotted line (0.1UI) is acceptable limitation to keep the performance of the SRC. The lack of data occurs above the solid line. Above the solid line, audible noise is generated.

This characteristic is measured with the sine wave jitter. Also the SRC can convert the square wave with the jitter very well as far as lower than 0.1U area.

Some kind of product generates high peak jitter instantaneously. For example, some kind of USB audio product. When the signal with more than 0.1U jitter is connected to the SRC, the SRC has possibility to generate audible noise.

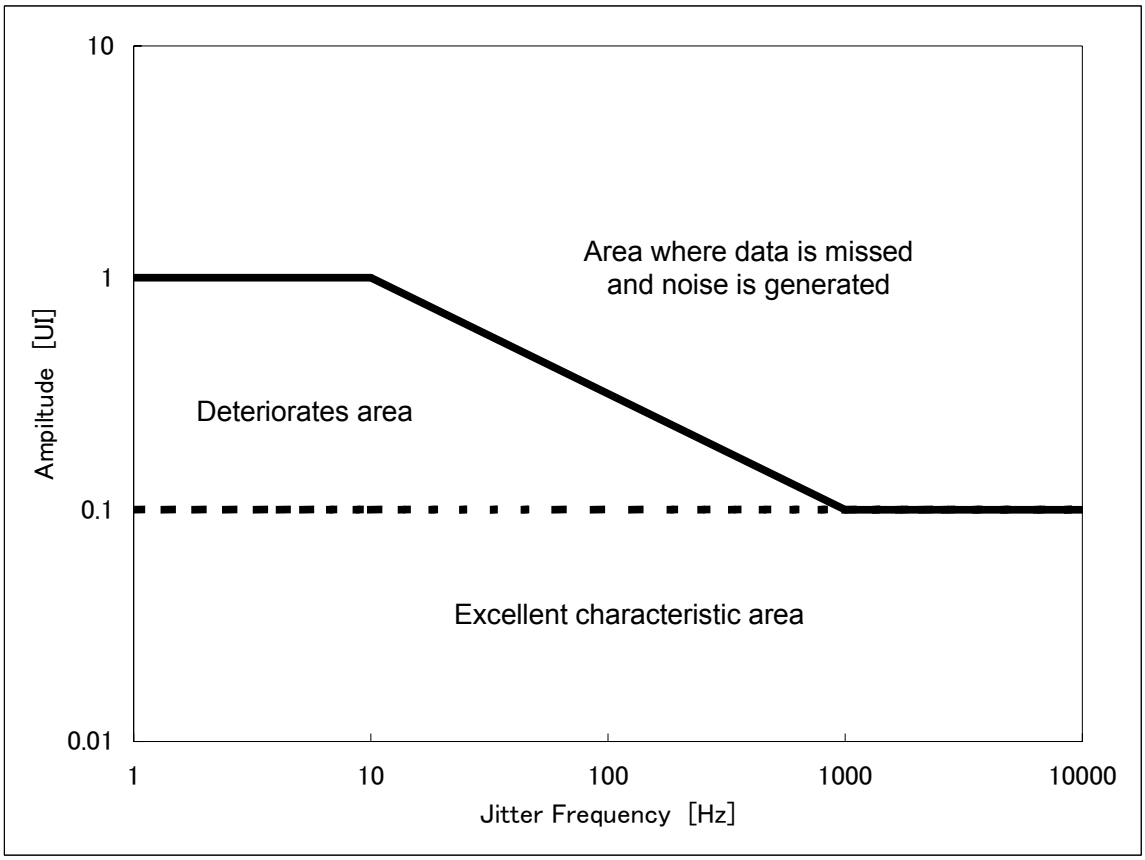


Fig.7 Jitter Tolerated dose

3.4 Sampling Rate Converter Characteristics

This section describes Sampling Rate Converter characteristics. The characteristics are measured through the serial audio I/O interface. The characteristics depend on the PWM modulator when the output is via the PWM modulator.

Table 6 Sampling rate converter: THD+N Characteristics

Parameter	Input Fs(kHz)	CLK pin Frequency		Units
		22.5792MHz (Inside F_{SO}=44.1kHz)	24.576MHz (Inside F_{SO}=48.0kHz)	
THD+N Frequency: 22~F_{SO}/2(Hz) Input: 1kHz, 0dBFS Input bit Width:24bit	8.0	-114	-120	dB
	11.025	-122	-122	
	12.0	-126	-125	
	22.05	-130	-130	
	24.0	-128	-128	
	32.0	-124	-124	
	44.1	-130	-126	
	48.0	-119	-130	
	64.0	-125	-131	
	88.2	-133	-132	
	96.0	-119	-133	
	128.0	-131	-134	
	176.0	-134	-133	
	192.0	-132	-135	

Table7 Sampling rate converter: Dynamic range Characteristics

Parameter	Input Fs(kHz)	CLK pin Frequency		Units
		22.5792MHz (Inside F_{SO}=44.1kHz)	24.576MHz (Inside F_{SO}=48.0kHz)	
Dynamic range Frequency: 22~F_{SO}/2(Hz) INPUT: 1kHz, -60dBFS Input bit Width 24bit A-Weight Filter	8.0	132	132	dB
	11.025	132	132	
	12.0	132	132	
	22.05	133	133	
	24.0	133	133	
	32.0	133	133	
	44.1	133	133	
	48.0	134	134	
	64.0	135	134	
	88.2	136	136	
	96.0	136	136	
	128.0	138	137	
	176.0	139	138	
	192.0	139	139	

4. Digital Audio Interface

4.1 Digital Audio Data Format

The NJU26060 Series can use three kinds of formats hereafter as industry-standard digital audio data format.

(1) I^2S : MSB is put on the 2nd bit of LR clock change rate.(1 bit is delayed to left stuffing)
(2) Left-justified : LR clock -- MSB is placed for changing.
(3) Right-justified : LSB is placed just before LR clock change rate.

The main differences among three kinds of formats are in the position relation between LR clock (LRI, LRO) and an audio data (SDI, SDO).

- In every format: : a left channel is transmitted previously.
- In Right/Left-justified : LR clock ='High' shows a left channel.
- I^2S : LR clock=”Low” shows a left channel.
- The Bit clock BCK (BCKI, BCKO) is used as a shift clock of transmission data. The number of clocks more than the number of sum total transmission bits of a L/R channel is needed at least.
- One cycle of LR clock is one sample of a stereo audio data. The frequency of LR clock becomes equal to a sample rate (fs).

4.2 Serial Audio Data Input/output

The NJU26060 Series audio interface includes 3 data input lines: SDI0, SDI1 and SDI2 (Table 8). 3 data output lines: SDO0, SDO1 and SDO2 (Table 9). Refer to each datasheet.

Table 8 Serial Audio Input Pin Description

Pin No.	Symbol	Description
8	SDI0	Audio Data Input 0
9	SDI1	Audio Data Input 1
10	SDI2	Audio Data Input 2

Table 9 Serial Audio Output Pin Description

Pin No.	Symbol	Description
20	OUTLN1	Audio Data Output 0
18	OUTRN1	Audio Data Output 1
41	SDO	Audio Data Output 2

The serial audio output pin switches the PWM output and the DIT output by the firmware (Table1).

The NJU26060 Series can input and output digital audio data by the following general serial audio interfaces. The default resetting it is set to I²S 64Fs 24bit. The setting can be changed according to the firmware. The NJU26060 Series operates as a mastering device that synchronizes with the clock that consists of MCKO, BCKO, and LRO (Refer to Chapter 2) SDO set to the serial audio interface, OUTRN1, and OUTLN1 are output synchronizing with these clocks. The SDI pin that has been selected with the sampling rate converter can be operated by an independent format by the input of the data of the clock of BCKI and LRI.

The NJU26060 Series can use three kinds of formats hereafter as industry-standard digital audio data format; (1) I²S (2) Left-justified (3) Right-justified and 16 / 24bits data length. (Fig.8-1 to Fig8-6)
An audio interface input and output data format become the same data format.

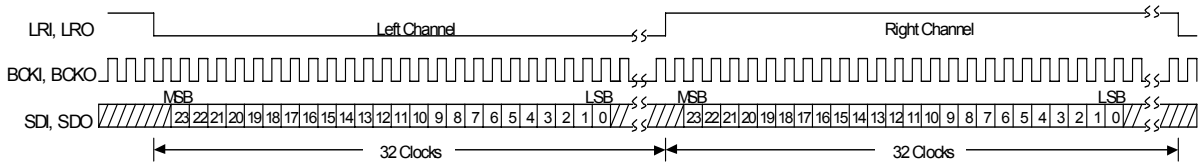


Fig8-1 I²S Data Format 64Fs, 24bit Data

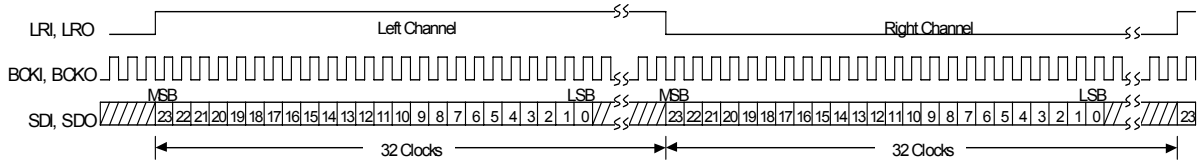


Fig.8-2 Left-Justified Data Format 64Fs, 24bit Data

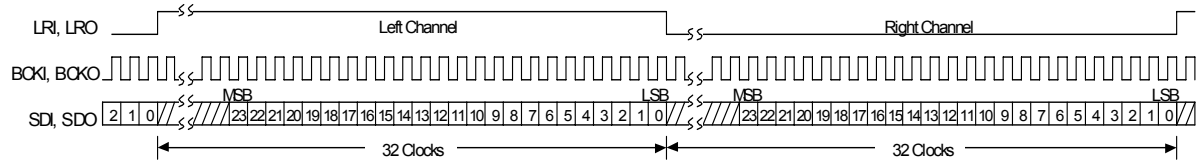


Fig.8-3 Right-Justified Data Format 64Fs, 24bit Data

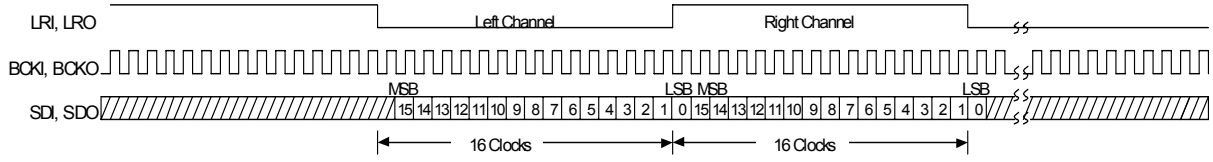


Fig.8-4 I²S Data Format 32Fs, 16bit Data

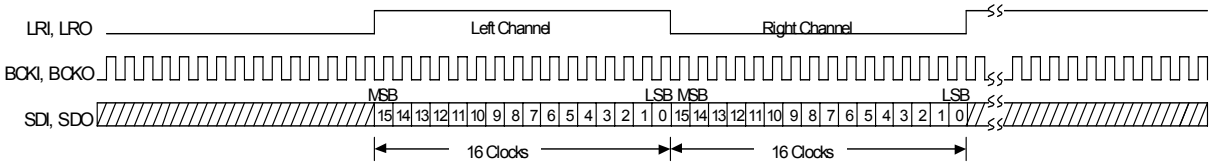


Fig.8-5 Left-Justified Data Format 32Fs, 16bit Data

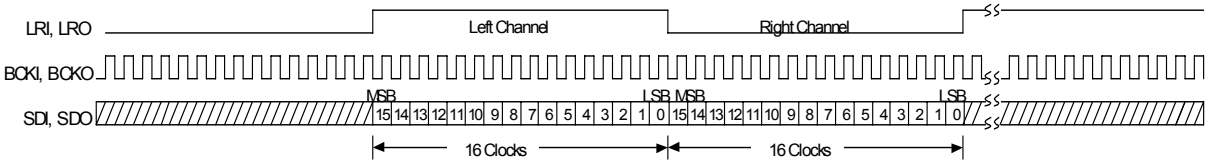


Fig.8-6 Right-Justified Data Format 32Fs, 16bit Data

4.3 Serial Audio Timing

Table 10 Serial Audio Input Timing Parameters **(V_{DD}= V_{DDPWM}=3.3V, Ta=25°C)**

Parameter	Symbol	Test Condition	Min	Typ.	Max	Units
BCK Frequency *	f_{BCK}		-	-	10	MHz
BCK Period *						
Low Pulse Width	t_{SIL}		35	-	-	ns
High Pulse Width	t_{SIH}		35			
BCK to LR Time *	t_{SLI}		15	-	-	ns
LR to BCK Time *	t_{LSI}		15	-	-	ns
Data Setup Time **	t_{DS}		15	-	-	ns
Data Hold Time **	t_{DH}		15	-	-	ns

* It is regulations of the sampling converter interface.
** The terminal SDI selecting the sampling rate converter is regulations to BCKI. Exact to BCKO.

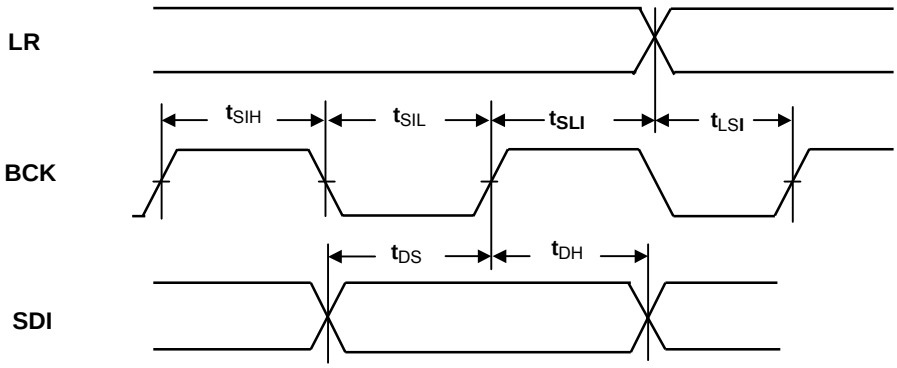


Fig. 9 Serial Audio Input Timing

Table 11 Serial Audio Output Timing Parameters **(V_{DD}= V_{DDPWM}=3.3V, Ta=25°C)**

Parameter	Symbol	Test Condition	Min	Typ.	Max	Units
BCK to LR Time	t_{SLO}	C_L=25pF	-15	-	15	ns
Data Output Delay ***	t_{DOD}		-	-	15	ns

*** It is regulations to SDO, OUTRN1, OUTLN1 set to the serial audio output.

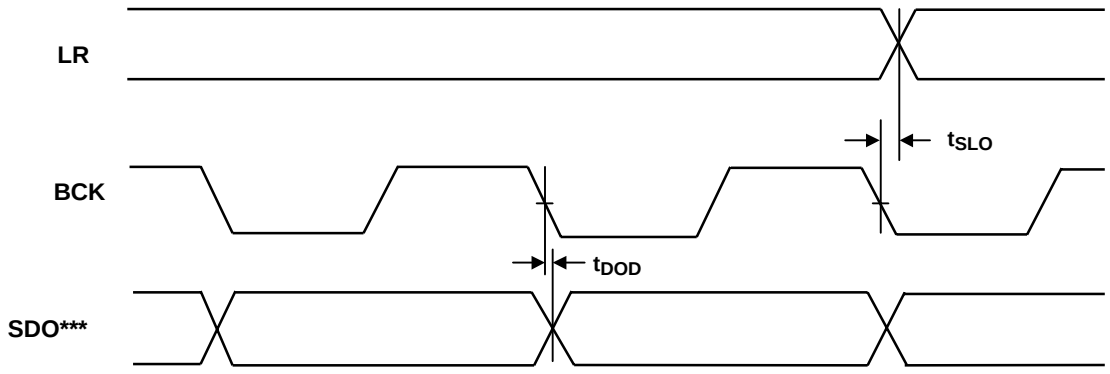


Fig.10 Serial Audio Output Timing

5. PWM Modulator

The NJU26060 Series provide the PWM modulator with two stereo (four channels) outputs.
The PWM modulator employs eight-times over-sampling digital-filters, the fifth order ΔΣ modulators, and the modulation efficiency is 88%. The dynamic range is over 90dB. The PWM modulator provides the function of “noise suppression at silence period” and this function improves the S/N ratio up to 100dB.

The PWM switching frequency is eight times of the sampling frequency. For example, 384kHz at Fs=48kHz, 352.8kHz at Fs=44.1kHz. The NJU26060 Series can directly drive the speakers with the power drivers because of the high modulation efficiency.

After the reset the PWM modulator is standby mode. So the PWM modulator should be initialized by the firmware after the reset.

Table12 PWM Modulator Pin Assignment

Pin No.	Symbol	Attribute	Description
23	VDDPWM	PP	PWM Power Supply +3.3V
22	VSSPWM	GP	PWM Power Supply GND
3	PWM_DISb	I+	PWM Block Standby request input pin (PWM_DISb =‘0’:Stand-BY)
2	PWM_MUTEb	I+	PWM Block Mute request input pin (PWM_MUTEb= ‘0’:Mute)
29	PWM_ERRb	I+	PWM block stop request input pin (PWM_ERRb=’0’: PWM stop)
28	PWMEN0	O	PWM0 enable output pin (PWMEN0=’1’: enable)
17	PWMEN1	O	PWM1 enable output pin (PWMEN1=’1’: enable)
24	OUTLP0	O	PWM0 L channel + output
25	OUTLN0	O	PWM0 L channel - output
26	OUTRP0	O	PWM0 R channel + output
27	OUTRN0	O	PWM0 R channel - output
21	OUTLP1	O	PWM1 L channel + output
20	OUTLN1	O	PWM1 L channel - output
19	OUTRP1	O	PWM1 R channel + output
18	OUTRN1	O	PWM1 R channel - output

Note: I+: Input (Pull-up), O: Output, PP: PWM Power Supply, PG: PWM Power Supply GND

The firmware or the external pins can select the PWM modulator functions in table13.

Table13 PWM Modulator Function

Description (Symbol)	Setting		Default (Reset)
	Pin	Firmware	
PWM Recognition signal (PWMEN0, PWMEN1)	Available	Available	Invalid
PWM Modulator stand by (PWM_DISb)	Available *	Available	Stand-By
Mute Function (PWM_MUTEb)	Available *	Available	Mute
Request PWM Error signal (PWM_ERRb)	Available *	Available	Stop
Extend BPZ Output Function	Not Available	Available	Invalid
The terminal OUTLN1 is switched to selial audio output 0. **	Not Available	Available	OUTLN1
The OUTRN1 is connected to serial audio output 1. **	Not Available	Available	OUTRN1
Noise suppression function at silence period	Not Available	Available	Effective
Short plus limitation	Not Available	Available	Invalid

* The firmware can mask the external input for the each block.
** BPZ is bipolar zero. The BPZ is a clock waveform of duty50%. It changes automatically if 'BPZ output function' is set to the PWM1 block.

5.1 PWM Effective Signal / PWM Modulator Standby

The PWMEN0/1 output shows whether the PWM output is effective or not. The PWM modulator is standby mode after the power-on or the reset and the PWMEN0/1 pin becomes GND level. The firmware can activate the PWM modulator. The PWM_DISb pin and the firmware can make the PWM modulator standby.

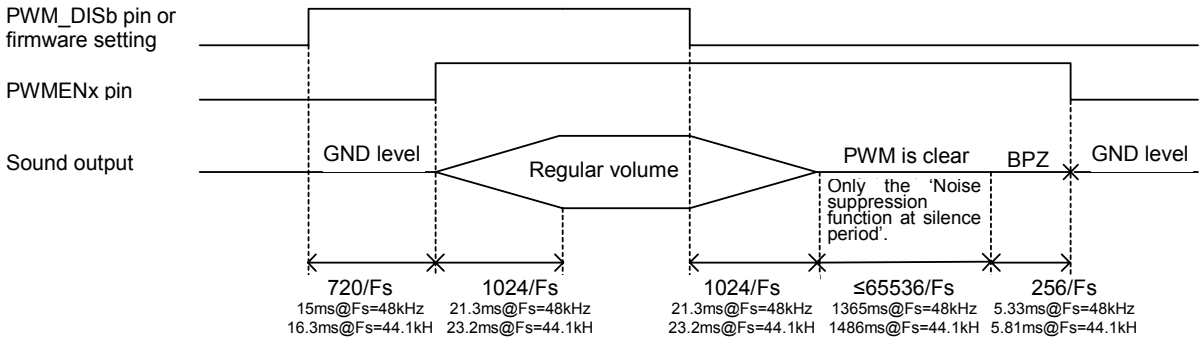


Fig.11 Relation between 'PWM Modulator Standby' and 'PWMEN, PWM output'
(Fs=48kHz: CLK=24.576MHz, Fs=44.1kHz: CLK=22.5792MHz)

After releasing the standby mode, the PWM modulator sets PWMEN0/1 pin High level and outputs the PWM signal. After activating PWM modulator, the mute is released and the signal goes up to the maximum level. This procedure takes 1,024/Fs. This mute release procedure does not provide zero-cross function.

By setting standby mode, the PWM modulator becomes the mute mode within 1,024/Fs.This mute procedure does not provide zero-cross function. If "noise suppression at silence period" mode becomes active, the clearance of the ΔΣ modulator is started. This procedure takes 65,536/Fs maximally. If "noise suppression at silence period" mode is not active, the clearance time is zero.

After that, BPZ signal is outputted during some periods and the PWMEN0/1 signal becomes Low. Also the PWM signal output stops at the same time as PWMEN0/1=Low. The signal level of the PWM output becomes GND level.

5.2 Mute

The NJU26060 Series can mute the PWM modulator by setting PWM_MUTEb low or the firmware. The each L/R channel is muted or unmated respectively. The mute or un-mate is done at zero cross point. The step of the mute or the un-mute is 0.25dB/Fs.

In case of very low input frequency, the mute or un-mute is not finished within 2048/Fs. In the above case, the mute or un-mute is done with 1/Fs step. So the mute or un-mute operates under time-out condition. And the time of the mute or un-mute is not fixed under time-out condition. If this time-out condition is not good for the system, the firmware can be designed to control the time of mute or un-mute.

5.3 Stop Function for the PWM Modulator

In case that the backend IC becomes abnormal condition, the firmware or PWM_EERb=Low can stop the PWM modulator fast. But the pop noise happens.

To stop or release the PWM modulator function takes eight CLK clocks. To release the stop condition of the PWM modulator, PWM_STBYb should be High.

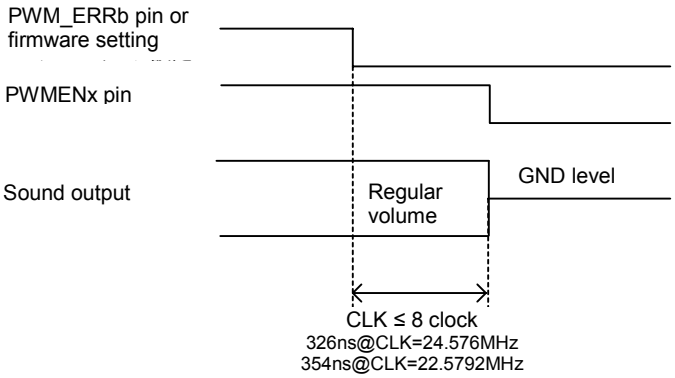


Fig.12 Relation between PWM Reset and PWMEN, PWM Output

5.4 BPZ Output Extension (BPZ : Bipolar Zero)

In case that PWMEN0/1 is GND, the PWM output is GND to prevent the power-on pop noise. The firmware can generate BPZ before and PWMEN0x=High by BPZ Output extension. The fig.13 shows the relation among PWM_DISb, PWMENx, and the sound output. The BPZ is inserted before and after PWMENx=High. The PWM modulation should be active to keep PWM modulator output.

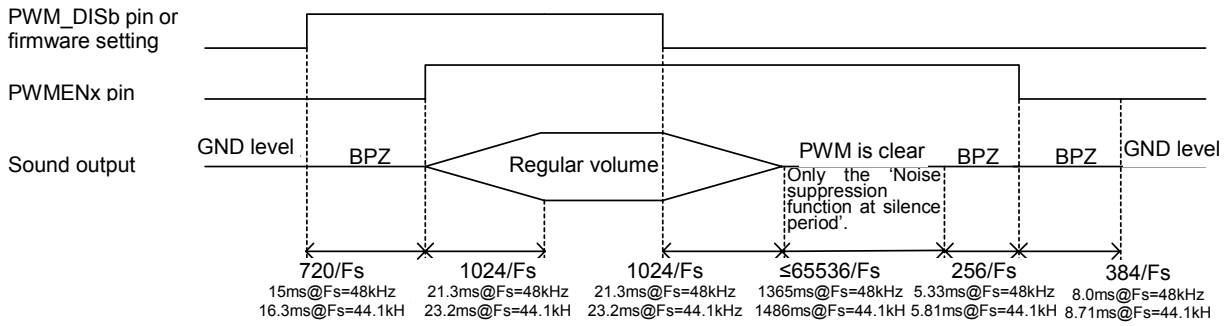


Fig.13 Relation between 'BPZ Output Extension' and 'PWMEN, PWM output'
(Fs=48kHz: CLK=24.576MHz, Fs=44.1kHz: CLK=22.5792MHz)

5.5 Switching from the PWM output to the serial audio output

In case that the BPZ output extension of PWM1 block is activated, the next two pins are assigned as follows:

OUTLN1 : Serial audio output0 that is same as PWM0 signal
OUTRN1: Serial audio output1 that is same as PWM1 signal

These pins are PWM outputs after power-on.

5.6 Noise Suppression at Silence Period

The noise suppression function of the PWM modulator can suppress an internal idle noise of the ΔΣ modulator in no input signal. This noise suppression function is active in default.

After the input of the PWM modulator becomes no signal, this function clear the internal PWM modulator within 65536/Fs and suppresses the internal noise. If the audio signal comes into the PWM modulator, the PWM modulator stops the noise suppression and generates the audio signal without any lack of audio signal.

To activate the noise suppression function, the input signal should be complete no signal. The mute function of the PWM modulator can clear all input signal and the noise suppression becomes active.
In case of the firmware mute, the input signal should be complete zero. Otherwise this function is not activated.

5.7 Short Plus Limitation

The PWM modulator generates the shortest 'Low' level pulse of 20nsec.
The PWM modulator provides the four kinds of pulse width limitation by the firmware in fig.14.
These pulse limitations do not include rising-time and falling-time of the pulse at the PWM output pin.

Set level	The minimum “L” level width restriction value	
	CLK Frequency (Internal processing Fs)	
	22.5792MHz (Fs=44.1kHz)	24.576MHz (Fs=48kHz)
0 (default)	0ns(no limit)	0ns (no limit)
1	22.1ns	20.3ns
2	44.3ns	40.7ns
3	66.4ns	61.0ns

Table14 Shortest Pulse limitation

5.8 PWM Modulator Characteristics

Table15 PWM Modulator characteristics
(CLK=24.576MHz(Fso=48kHz),LRI=48kHz,BCKI=3.072MHz, V_{DD}=V_{DDPWM}=3.3V,Ta=25℃)

Parameter	Min	Typ	Max	Unit
THD+N (1kHz, 0dBFS)	-	-85	-75	dB
S/N ratio (1kHz, Noise decrease function as no-sound On, A-Weight)	90	100	-	dB
Dynamic range (1kHz, -60dBFS, A-Weight)	85	90	-	dB
Channel Separation (1kHz BPF)	90	100	-	dB

The characteristics in table15 are measured with the next circuits in fig.14. This circuit includes the second low-pass filters (cut-off frequency 50kHz). The Audio Precision measures the signal with the AES17 filter (20KHz LPF). The condition of this measurement:

1) The conversion ratio of the SRC is 1:1 (48kHz -> 48kHz).
2) The outputs of the SRC go to the output pins without any DSP processing.

With this measurement condition, the power supply and the internal noise are added to the PWM output. The common mode noise is suppressed with the differential inputs. But the common mode noise is not suppressed with the single-end inputs. These characteristics have possibility to be degraded by the SRC. Because the sample rate converter is asynchronous, so some frequency degrades the characteristics.

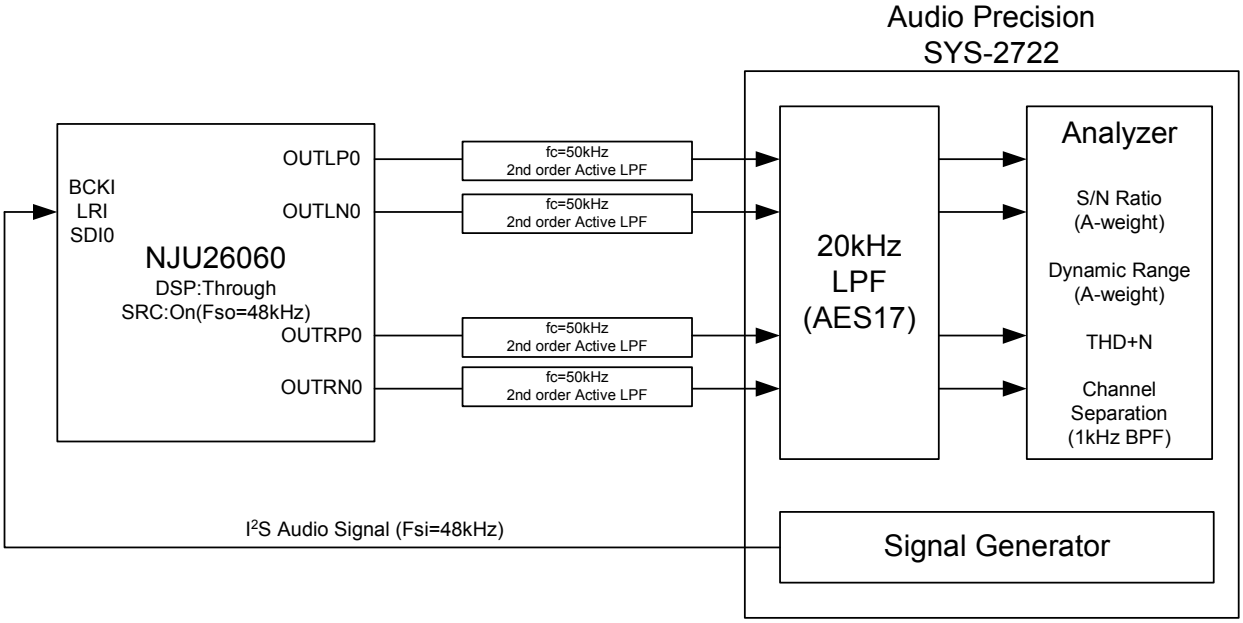


Fig.14 PWM Modulator Measuring circuit
(OUTLP1/LN1/RP1/RN1A are also the same)

6. Digital Interface Transemitor (DIT)

The NJU26060 series provides Digital Interface Transemitor. The DIT is compliant with AES3, IEC60958, S/PDIF and EIAJ CP1201 consumer specification. The DIT generates bi-phase signal that is CLK/512 frequency. The SDO generates bi-phase signal. The SDO is assigned as serial audio output in default. The firmware can change this output setting.

The firmware can connect the GPIO[1] input to the SDO output.
The SDO is hysteresis I/O pin with a pull-down resister, so the input level should be adjusted.

The DIT channel status is shown in table 16. To connect a coaxial cable, the external buffer is recommended.

Table16 Channel Status Parameter

Channel Status Parameter			Fixation/ Variable	Default
CS0	Consumer/ Professional	0: Consumer mode	Fixation	0
CS1	Data type	0: Audio data, 1: Digital data	Variable	0
CS2	Copyright	0: Protection, 1: No-Protection	Variable	0
CS3	Pre-emphasis	[CS3,CS4]=00: OFF [CS3,CS4]=10: ON	Variable	0
CS4			Fixation	0
CS5	Channel	0: 2channel	Fixation	0
CS6~7	Mode	00: mode 0	Fixation	00
CS8	Category code	Prefer to standard book Default [CS8:CS15]=0010000 Application of Japan to digital audio broadcasting reception.	Variable	0
CS9				0
CS10				1
CS11				0
CS12				0
CS13				0
CS14				0
CS15				0
CS16 ~19	Source number	0000: no specification	Fixation	0000
CS20 ~23	Channel number	0000: no specification	Fixation	0000
CS24	Sampling Frequency	[CS24:CS27]=0000 44.1kHz [CS24:CS27]=0100 48kHz [CS24:CS27]=1100 32kHz	Variable	0
CS25				1
CS26				0
CS27				0
CS28	Clock Accuracy	[CS28,CS29]=00 standard mode [CS28,CS29]=10 High precision mode	Variable	0
CS29				0

7. Host Interface

The NJU26060 Series can be controlled via Serial Host Interface (SHI) using I^{2}C bus. Data transfers are in 8 bit packets (1 byte) when using either format.

Refer to Serial Host Interface Pin Description. (Table 4)

Table.17 Serial Host Interface Pin Description

Pin No.	Symbol	I^{2}C bus Format
5	SCL	Serial Clock
4	SDA	Serial Data Input (Open Drain Input/Output)

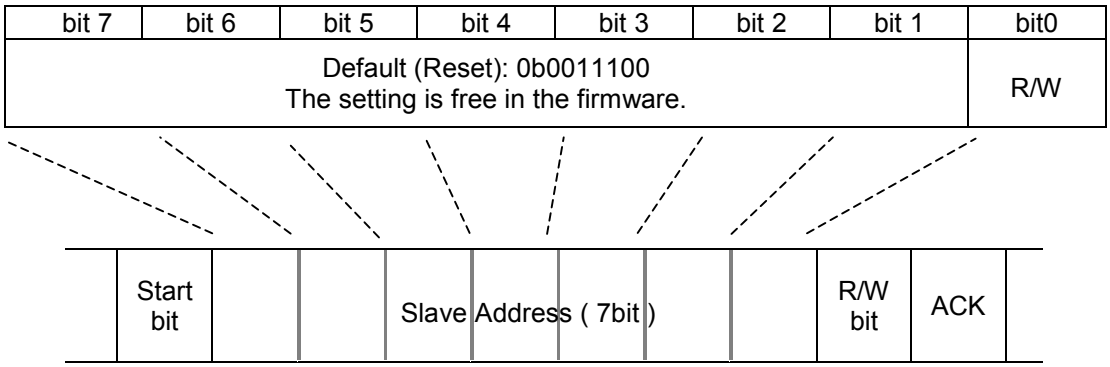
Note : SDA pin (No.4) is a bi-directional open drain terminal. This pin requires a pull-up resister.

7.1 I^{2}C bus Interface

I^{2}C bus interface transfers data to the SDA pin and clocks data to the SCL pin. SDA pin is a bi-directional open drain and requires a pull-up resister.

When the NJU26060 Series is configured for I^{2}C bus communication during the Reset initialization sequence, I^{2}C bus interface transfers data to the SDA pin and clocks data to the SCL pin. An address can be arbitrarily set up by the seven-bit SLAVE address of the serial host interface. (Table 5)

Table.17 Serial Host Interface Pin Description



Note : The serial host interface supports “Standard-Mode (100kbps)” and “Fast-Mode (400kbps)” I^{2}C bus data transfer.

Table 19 I^2C bus Interface Timing Parameters (V_{DD}=3.3V, f_{OSC}=24.576MHz, Ta=25°C)

Parameter	Symbol	Min	Max	Units
SCL Clock Frequency	f_{SCL}	0	400	kHz
Start Condition Hold Time	$t_{HD:STA}$	0.6	-	µs
SCL "Low" Duration	t_{LOW}	1.3	-	µs
SCL "High" Duration	t_{HIGH}	0.6	-	µs
Start Condition Setup Time	$t_{SU:STA}$	0.6	-	µs
Data Hole Time *1	$t_{HD:DAT}$	0	0.9	µs
Data Setup Time	$t_{SU:DAT}$	250	-	ns
Rising Time	t_R	-	1000	ns
Falling Time	t_F	-	300	ns
Stop Condition Setup Time	$t_{SU:STO}$	0.6	-	µs
Bus Release Time *2	t_{BUF}	1.3	-	µs

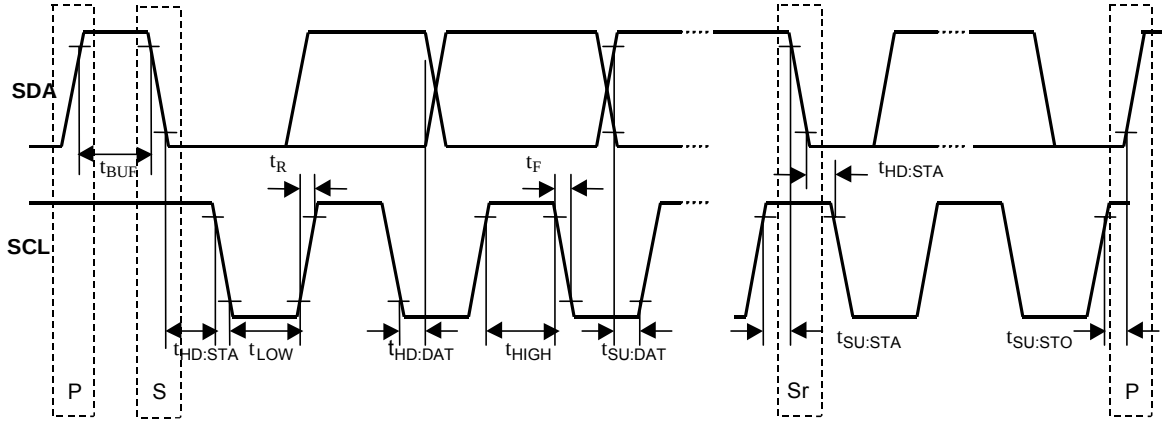


Fig. 15 I^2C bus Timing

Note :

*1 $t_{HD:DAT}$: Keep data 100ns hold time to avoid indefinite state by SCL falling edge.

*2 This item shows the interface specification. The interval of a continuous command is specified separately.

8. General-purpose in/out pin

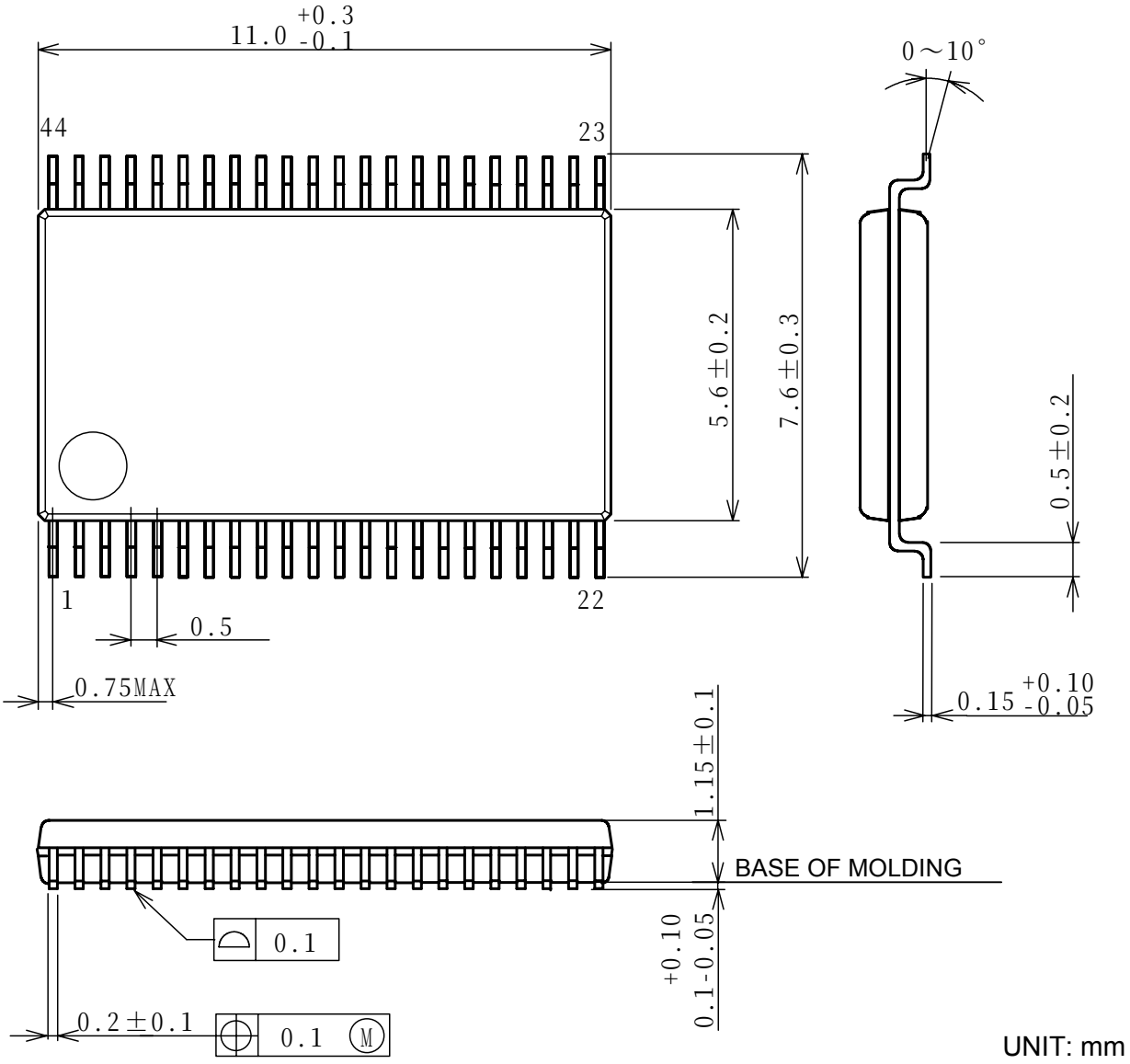
The NJU26060 Series has general-purpose in/out pin. GPIO0 pin includes with TEST mode and limits for starting up.

Table 20 General-purpose in/out pin and pin disposal

Pin No.	Symbol	Description
40	GPIO0 (Pull-down I/O)	Starts with "Low". It depends on the firmware after it starts.
39	GPIO1 (Pull-down I/O)	It depends on the firmware.
38	GPIO2 (Pull-up I/O)	It depends on the firmware.
37	GPIO3 (Pull-up I/O)	It depends on the firmware.

9. Package

SSOP44, Pb-Free



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