OKI Semiconductor

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ML2213

Speech Synthesizer & Melody LSI with On-Chip 1.5-Mbit Mask ROM

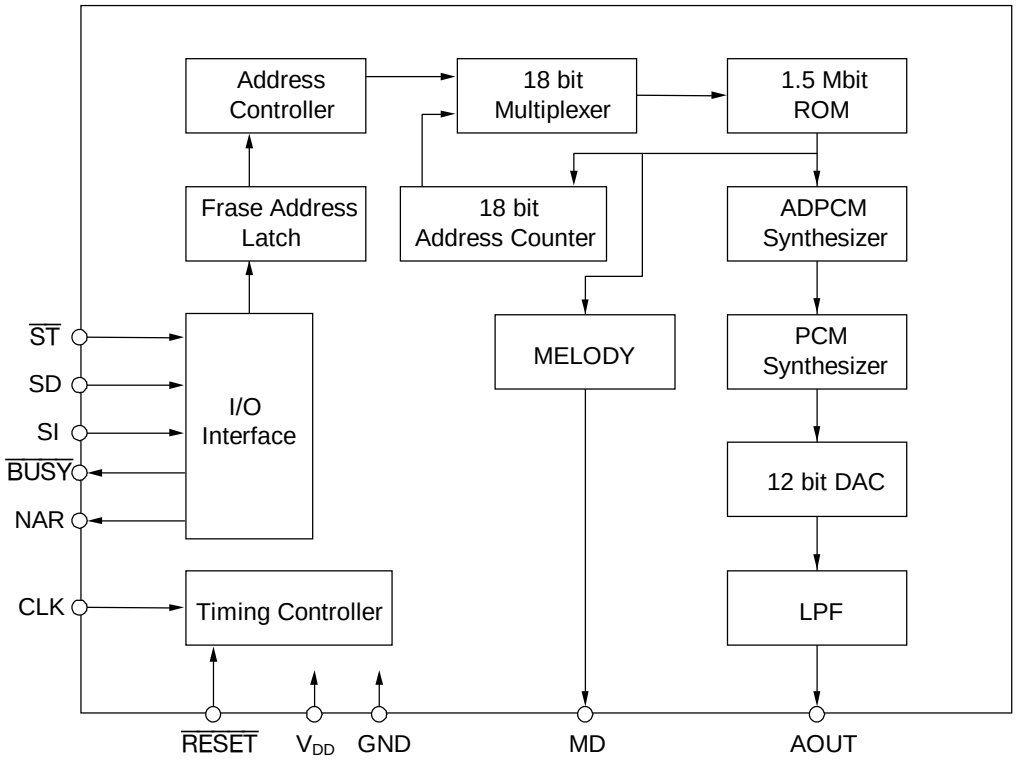
GENERAL DESCRIPTION

The ML2213 is an ADPCM-based Speech Synthesizer LSI with on-chip 1.5-Mbit Mask ROM for storing multiple speech data. In addition, the LSI has a built-in Melody Generator circuit that can generate melodies by automatically acquiring user-defined musical notes data from the ROM. The ML2213 has a 12-bit D/A Converter and Low Pass Filter, and enables a user to readily build a message and music playback sub-system by simply adding an external speaker and driving amplifier.

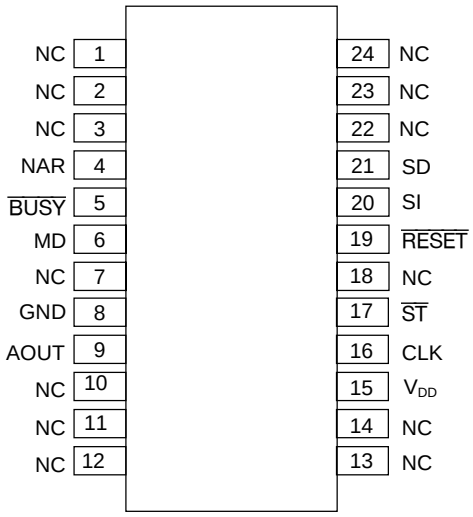
FEATURES

- On-Chip 1.5-Mbit Mask ROM
- Serial Interface: User-selectable Mask options for 2-pin or 3-pin interfacing
- 3 Speech Synthesis Algorithms for user selection
  4-bit ADPCM/8-bit OKI Non-Linear PCM/8-bit PCM/Melody
- Sampling Frequency (At 4.096 MHz External Clock)
  4.0 kHz, 5.3 kHz, 6.4 kHz, 8.0 kHz, 10.7 kHz, 12.8 kHz, 16.0 kHz
- Built-in Melody Generator function
  User-definable 31 musical scales, 60 musical notes, and 30 tempos
- User-defined Phrases up to 247 phrases, including melodies.
- Built-in 12-bit D/A Converter
- Built-in Low Pass Filter
- Driver for piezo-speaker (MD pin)
- External Clock: Frequency can be selected as Mask option
  4.096 MHz, 8.192 MHz, 16.384 MHz
- Power Supply Voltage: 2.4 to 5.5 V
- Package: 24-pin plastic SOP (SOP24-P-430-1.27-K) (Product name: ML2213-xxxMA)
  14-pin plastic SSOP (SSOP14-P-44-0.65-K) (Product name: ML2213-xxxMB)

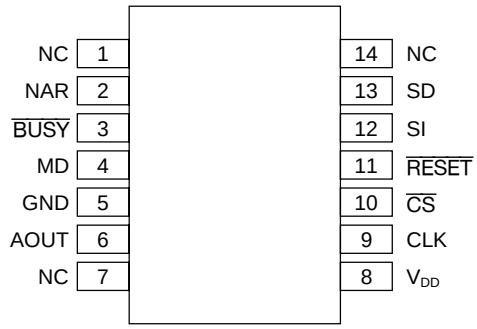
BLOCK DIAGRAM



PIN CONFIGURATION (TOP VIEW)



24-Pin Plastic SOP



14-Pin Plastic SSOP

NC: No connection

Leave the NC pins open.

Note : If the 14-Pin Plastic SSOP is used, contact your nearest Oki sales office for availability and specifications.

PIN DESCRIPTIONS

Pin	Symbol	Type	Description
11 (19)	$\overline{\text{RESET}}$	I	"L" input to this pin turns the LSI into standby mode. At this point, output from the AOUT pin rises up to V_{DD} level, having the LSI initialized internally. By "H" input to the pin the AOUT output returns to 1/2 V_{DD} level.
2 (4)	NAR	O	This pin outputs a signal showing empty/full status of the Phase Address Latch Register. "H" level indicates the register is empty, and thus the LSI is ready to accept serial data input. At powering up, the pin outputs "H level".
3 (5)	$\overline{\text{BUSY}}$	O	Outputs "L" level while output signal is present either at the AOUT or MD pin. At powering up, the pin outputs "H" level.
4 (6)	MD	O	Melody output pin. Leave this pin open when not using melody output.
6 (9)	AOUT	O	Analog output pin. V_{DD} is output from this pin while the $\overline{\text{RESET}}$ pin is at "L" (during standby mode). 1/2 V_{DD} is output except during playback after this LSI is activated.
5 (8)	GND	—	Ground pin
9 (16)	CLK	I	External clock input pin
12 (20)	SI	I	Serial clock input pin
13 (21)	SD	I	Serial data input pin. Input a phrase code corresponding to a phrase address through this pin.
10 (17)	$\overline{\text{ST}}$	I	Chip select signal pin. Mask option allows a user to choose either 2-pin (SD and SI) interfacing or 3-pin (SD, SI and $\overline{\text{ST}}$) interfacing. When 3-pin inter-facing is selected, input to the SD and SI pins is valid while the $\overline{\text{ST}}$ pin being held "L". When 2-pin interfacing is selected, pull this pin down to the GND.
8 (15)	V_{DD}	—	Power supply pin. Insert 0.1 µF or larger bypass capacitor between this pin and the GND pin.

* 14-pin plastic SSOP (24-pin plastic SOP)

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Condition	Rating	Unit
Power Supply Voltage	V_{DD}	Ta = 25°C	–0.3 to +7.0	V
Input Voltage	V_{IN}		–0.3 to V_{DD}+0.3	V
Storage Temperature	T_{STG}	—	–55 to +150	°C

RECOMMENDED OPERATING CONDITIONS

Parameter	Symbol	Condition	Range			Unit
Power Supply Voltage	V_{DD}	—	2.4 to 5.5			V
Operating Temperature	T_{OP}	—	–40 to +85			°C
External Clock Frequency	f_{EXTCK}	Selected as Mask options	Min	Typ.	Max	MHz
			3.5	4.096	4.5	
			7.5	8.192	9.0	
			14.5	16.384	18.0	

ELECTRICAL CHARACTERISTICS

DC Characteristics (3 V Version)

(V_{DD} = 2.4 to 3.6 V, GND = 0 V, Ta = –40 to +85°C)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
"H" Input Voltage	V_{IH}	—	0.87 × V_{DD}	—	—	V
"L" Input Voltage	V_{IL}	—	—	—	0.13 × V_{DD}	V
"H" Output Voltage	V_{OH}	I_{OH} = –500 µA	V_{DD}–0.3	—	—	V
"L" Output Voltage	V_{OL}	I_{OL} = 1 mA	—	—	0.4	V
"H" Input Current	I_{IH}	V_{IH} = V_{DD}	—	—	10	µA
"L" Input Current	I_{IL}	V_{IL} = GND	–10	—	—	µA
Operating Supply Current	I_{DD}	—	—	1	4	mA
Standby Supply Current	I_{DS}	Ta = –40 to +85°C	—	—	10	µA
DA Output Relative Error	$\|V_{DAE}\|$	—	—	—	40	mV

DC Characteristics (5 V Version)

(V_{DD} = 3.7 to 5.5 V, GND = 0 V, Ta = –40 to +85°C)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
"H" Input Voltage	V_{IH}	—	0.85 × V_{DD}	—	—	V
"L" Input Voltage	V_{IL}	—	—	—	0.15 × V_{DD}	V
"H" Output Voltage	V_{OH}	I_{OH} = –500 µA	V_{DD}–0.3	—	—	V
"L" Output Voltage	V_{OL}	I_{OL} = 1 mA	—	—	0.4	V
"H" Input Current	I_{IH}	V_{IH} = V_{DD}	—	—	10	µA
"L" Input Current	I_{IL}	V_{IL} = GND	–10	—	—	µA
Operating Power Consumption	I_{DD}	—	—	2	4	mA
Standby Power Consumption	I_{DS}	Ta = –40 to +85°C	—	—	10	µA
DA Output Relative Error	$\|V_{DAE}\|$	—	—	—	40	mV

AC Characteristics

(V_{DD} = 2.4 to 5.5 V, GND = 0 V, Ta = –40 to +85°C)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
CLK Duty Cycle	f_{duty}	—	40	50	60	%
$\overline{\text{RESET}}$ Input Pulse Width	$t_{W(\overline{RST})}$	—	10	—	—	µs
$\overline{\text{RESET}}$ Input Time after Powering Up	$t_{D(\overline{RST})}$	—	0	—	—	µs
Serial Clock Pulse Width	$t_{W(SI)}$	—	350	—	—	ns
Start Pulse Width	t_{SDST}	With 2-pin interfacing	1	—	—	µs
Serial Data Setup Time	t_{SDS}	—	1	—	—	µs
Serial Data Hold Time	t_{SSD}	—	1	—	—	µs
Serial Clock Setup Time	t_{SIS}	With 3-pin interfacing	1	—	—	µs
Serial Clock Hold Time	t_{SSI}	With 3-pin interfacing	1	—	—	µs
*Silent time after Playback	t_{SIL}	—	6	—	—	ms

*Varies depending on the setting value for the ROM data.

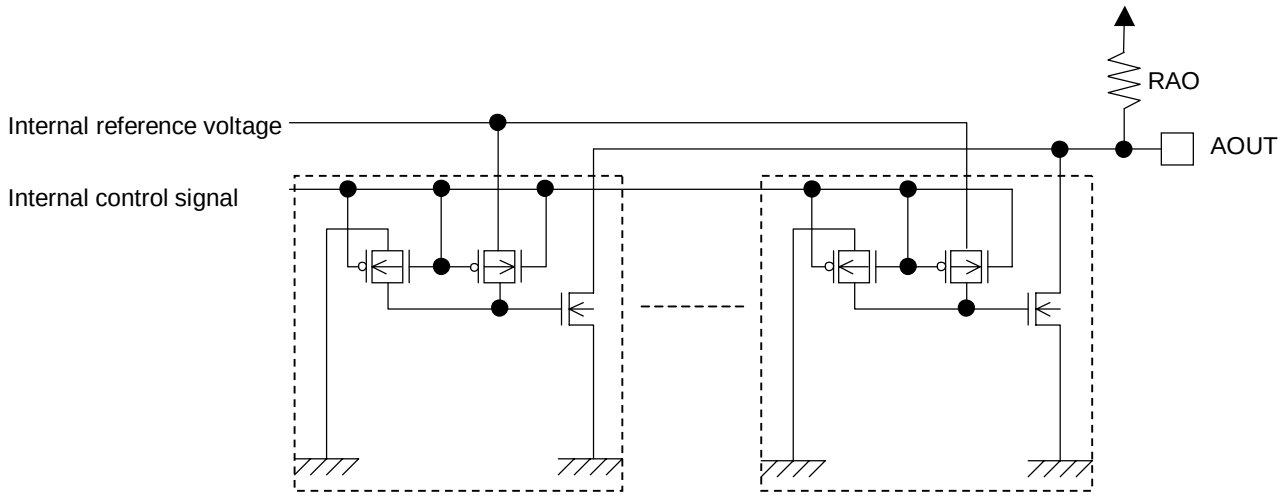
Analog Characteristics

(V_{DD} = 2.4 to 5.5 V, GND = 0 V, Ta = –40 to +85°C)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
AOUT Output Voltage	V_{AO}	—	V_{DD}/4	—	V_{DD}	V
AOUT Pull-up Resistor Value	R_{AO}	—	1.5	2.5	4.5	kΩ

Note that the maximum amplitude voltage output from the AOUT pin is about 80% of V_{DD}.

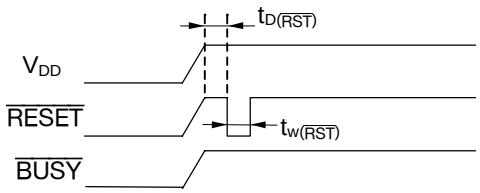
AOUT Equivalent Circuit



As shown above, the ML2213 uses current type DACs.

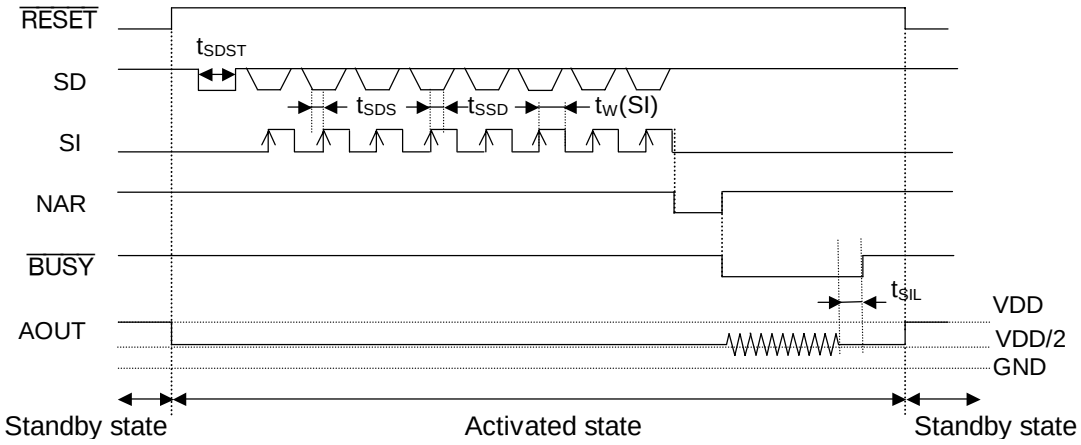
TIMING DIAGRAM

1. At powering up

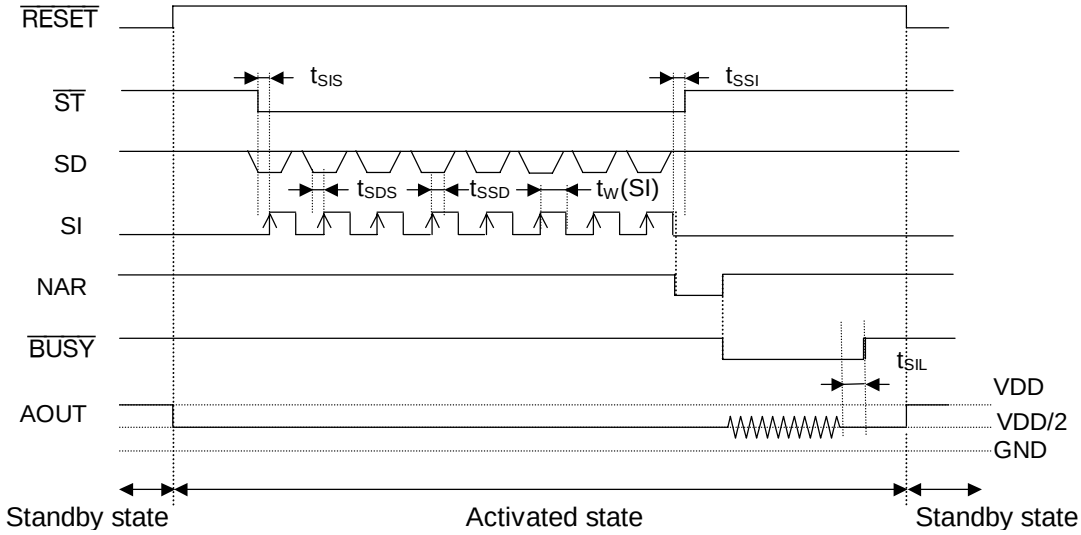


2. At LSI activation and standby state

2.1 When 2-pin interfacing selected as Mask option



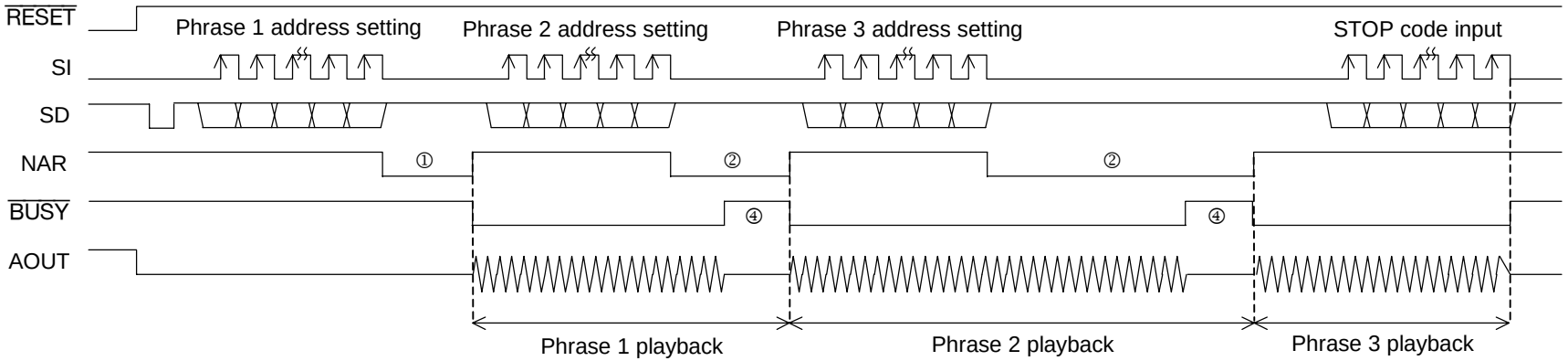
2.2 When 3-pin interfacing selected as Mask option



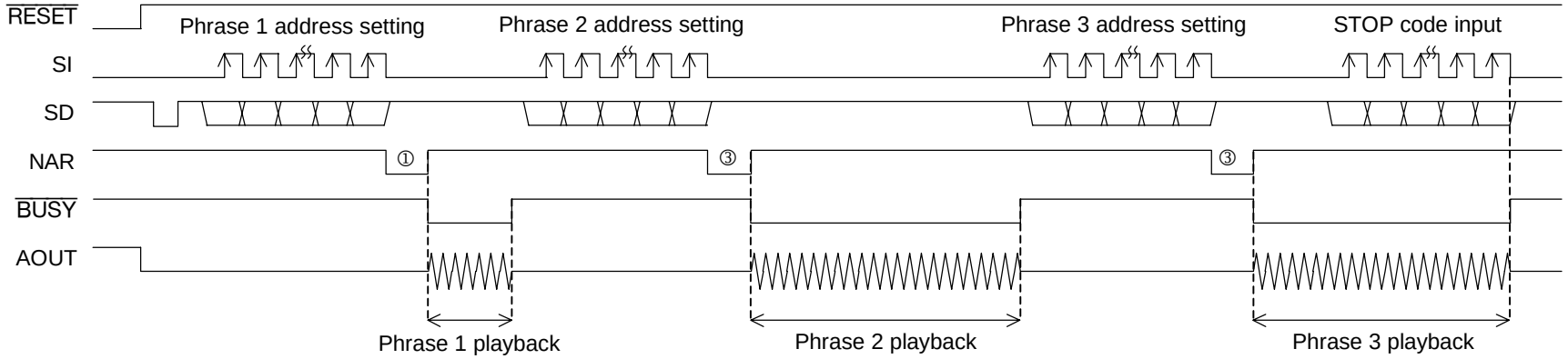
3. Continuous Playback Timing

3.1 When 2-pin interfacing selected as Mask option

1) Continuous playback by NAR

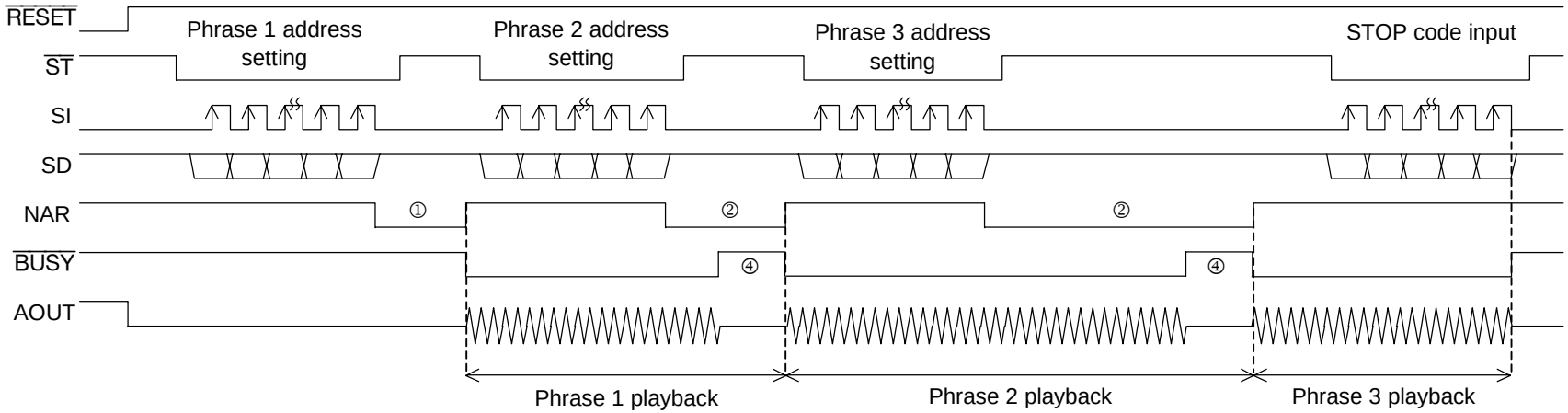


2) Continuous playback by $\overline{\text{BUSY}}$

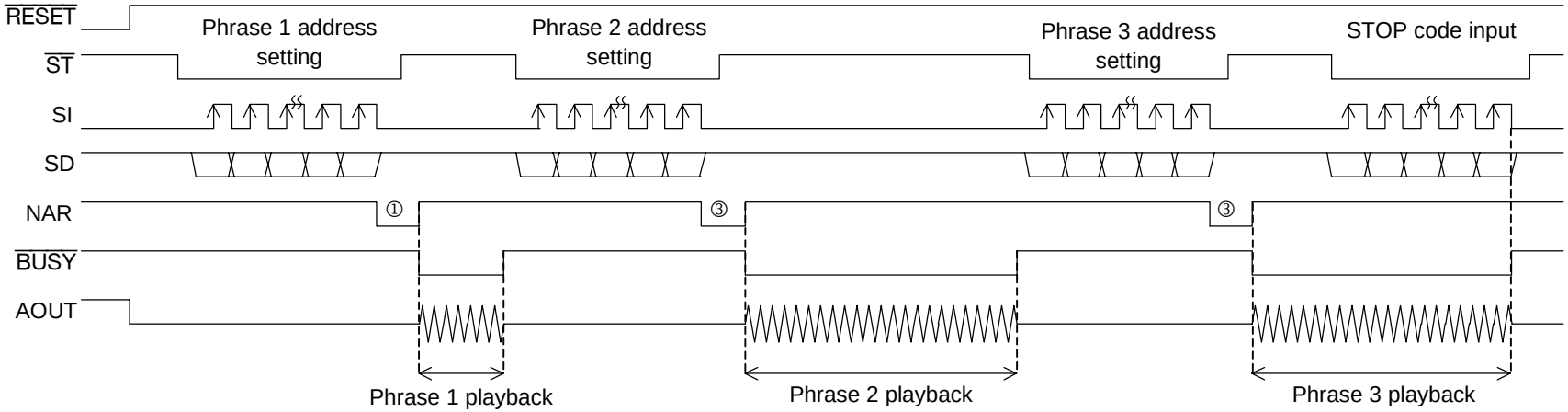


3.2 When 3-pin interfacing selected as Mask option

1) Continuous playback by NAR



2) Continuous playback by $\overline{\text{BUSY}}$



3.3 "L" duration at NAR pin and "H" duration at $\overline{\text{BUSY}}$ pin

(1) The "L" duration at the NAR pin when the first phrase is designated after power is turned on:
250 μs + playback phrase sampling period ×7

(2) The "L" duration at the NAR pin when the next playback phrase is designated when the $\overline{\text{BUSY}}$ pin is at "L":
Remaining playback time of the phrase being played + playback phrase sampling period ×2 + sampling period of the next playback phase ×7

(3) The "L" duration at the NAR pin during continuous playback by the $\overline{\text{BUSY}}$ pin:
Sampling period of the previous playback phase ×2 + Sampling period of the next playback phase ×7

(4) The "H" duration at the $\overline{\text{BUSY}}$ pin during continuous playback by the NAR pin:
Sampling period of the previous playback phase ×2 + Sampling period of the next playback phase ×7

Note: The maximum durations are shown above.

FUNCTIONAL DESCRIPTION

1. Specifying a user-defined phrase code for playback

The LSI allows a user to define up to 247 phrases. To playback a user-defined phrase, input a phrase code (phrase address) in serial order, starting with the MSB, through the SD pin.

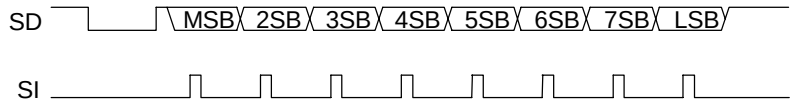


Figure 1.1 Timing for Phrase Code Input

When more than 8 SI clocks are input, the first 8-clock data is taken as valid data. Table 1.1 shows phrase codes for user-defined phrases.

Table 1.1 Phrase Code for User-Defined Phrase

MSB to LSB	Code Description
00000000	Stop Code
00000001 • • 11110111	User-defined Phrase Codes
11111000 • • 11111111	Test Codes*

Note: * No test codes could be used to represent a user-defined phrase.

2. Use-Prohibited Area in on-chip Mask ROM

As shown in the Table 2.1, the last 3 bytes of on-chip Mask ROM are use-prohibited. Be sure not to use the last 3 bytes when you prepare ROM data using an analyzing tool.
Table 2.1 shows addresses that are prohibited to use, and Figure 2.1 shows the address map of on-chip Mask ROM.

Table 2.1 User's Data Area and Use-Prohibited Area in On-Chip Mask ROM

User's Data Area	Use-Prohibited Area
007C8 to 2FFFC	2FFFD, 2FFFE, 2FFFF

00000H 007C7H	Phrase Control Table Area
007C8H 2FFFCH	User's Date Area
2FFFDH 2FFFFH	Test Date Area

Figure 2.1 Mask ROM Address Map

3. Mask Options

The following mask options are available to choose an interfacing type and an external clock frequency, as shown in Table 3.1.

Table 3.1 Mask Options

Option	Interfacing Type	External Clock Frequency
A	3-pin Interfacing	4.096 MHz
B	3-pin Interfacing	8.192 MHz
C	3-pin Interfacing	16.384 MHz
D	2-pin Interfacing	4.096 MHz
E	2-pin Interfacing	8.192 MHz
F	2-pin Interfacing	16.384 MHz

4. Interfacing Types

Mask option allows a user to select a interfacing type and a frequency of external clock input. Available options are listed in Table 3.1 below.

4.1 2-pin Controlled Serial Input Interface

2-pin interfacing uses the SD and SI pins to control interfacing. Pull the $\overline{ST}$ pin down to "L".

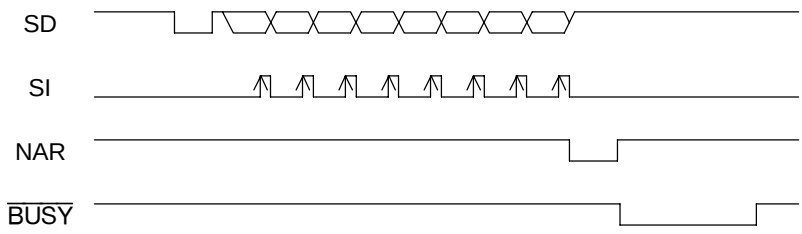


Figure 4.1 Timing Chart of Serial Input

As shown in Figure 4.1, serial data input is enabled by entering 1 μsec or longer "L" input (the Start-bit input) to the SD pin. Serial data input to the SD pin is fetched to the internal register in synchronization with the falling edge of the SI's 8th clock as a phrase code for a user-defined phrase.
You must input the external clock to the CLK pin. Otherwise, serial data input cannot be acquired internally, regardless $t_{SDST} \geq 1$ μs or $t_{SDST} < 1$ μs.

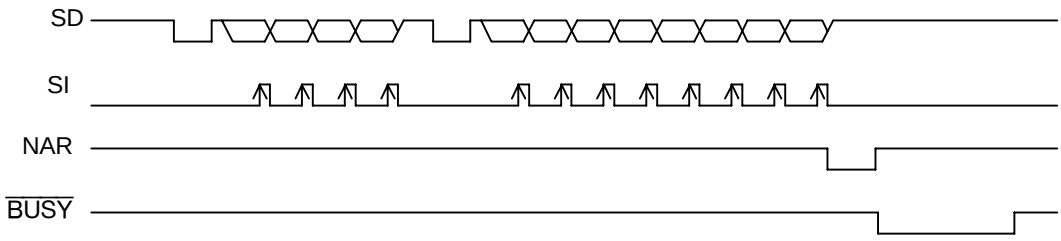


Figure 4.2 Timing Chart of Serial Input

As shown in Figure 4.2, re-inputting the Start-bit before the SI's 8th clock cancels the preceding serial data entry, and 8-clock data following the Start-bit is taken as valid data.

4.2 3-pin Controlled Serial Input Interface
3-pin interfacing uses the SD, SI and $\overline{ST}$ pins to control interfacing.

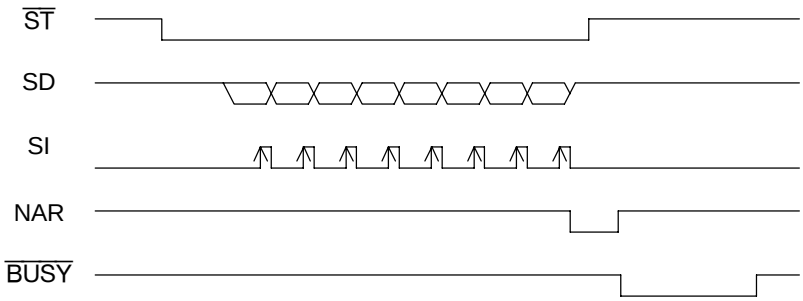


Figure 4.3 Timing Chart of Serial Input

When 3-pin interfacing is selected, input to the SD and SI pins is enabled while the $\overline{ST}$ pin being held "L". Serial data input to the SD pin is acquired to the internal register in synchronization with the falling edge of the SI's 8th clock as an 8-bit phrase code for a user-defined phrase. If the $\overline{ST}$ pin is brought back to "H" before the SI's 8th clock, the preceding entry is cancelled, and 8-clock data after the $\overline{ST}$ pin being brought back to "L" again is taken as valid data.

5. External Clock Input

Mask option allows a user to choose an external clock frequency, as shown in Table 5.1.

Table 5.1 External Clock Frequency and Sampling Frequency

External Clock Frequency	Internal Sampling Frequency
4.096 MHz	4.0 kHz, 5.3 kHz, 6.4 kHz, 8.0 kHz, 10.7 kHz, 12.8 kHz, 16.0 kHz
8.192 MHz	4.0 kHz, 5.3 kHz, 6.4 kHz, 8.0 kHz, 10.7 kHz, 12.8 kHz, 16.0 kHz
16.384 MHz	4.0 kHz, 5.3 kHz, 6.4 kHz, 8.0 kHz, 10.7 kHz, 12.8 kHz, 16.0 kHz

When an external clock frequency were chosen as Mask option and a different frequency input were made, the sampling frequency changes in proportion to the actual input frequency. For example, while 4.096 MHz external clock frequency option was selected as Mask option, and when 6.144 MHz external clock is actually input, then the sampling frequency changes accordingly, e.g. sampling frequency at 1.5 times of those shown in Table 5.1.

6. Stop Code

The Stop code (Table 1.1) input to the SD pin during playback makes the LSI stop playback on the SI's falling edge following to the LSB input, and the AOUT falls down to 1/2 V_{DD} level. If the LSI plays a melody, melody output stops in the same way.
Timings for the Stop code input are shown below, for 2-pin interfacing in Figure 6.1 and for 3-pin interfacing in Figure 6.2 respectively.

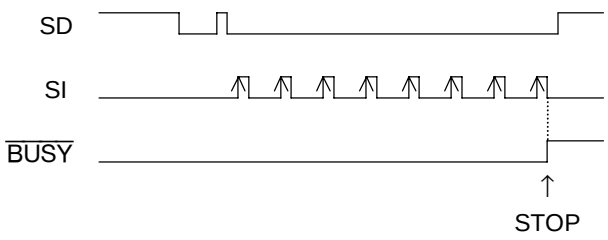


Figure 6.1 Timing for Stop Code Input – 2-pin Interfacing

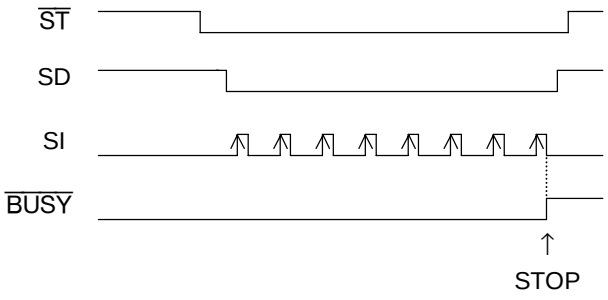


Figure 6.2 Timing for Stop Code Input – 3-pin Interfacing

7. Melody Generator

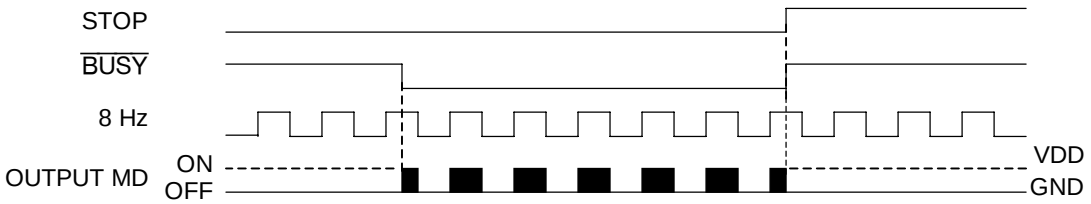
Melodies are generated using the Oki's Voice Analysis Tool, where music scales, tempos, start addresses, and so on can be set. The melody output is initiated from the MD pin by activating a melody phrase that has been set externally.

The Voice Analysis Tool can create melodies in the following ranges:

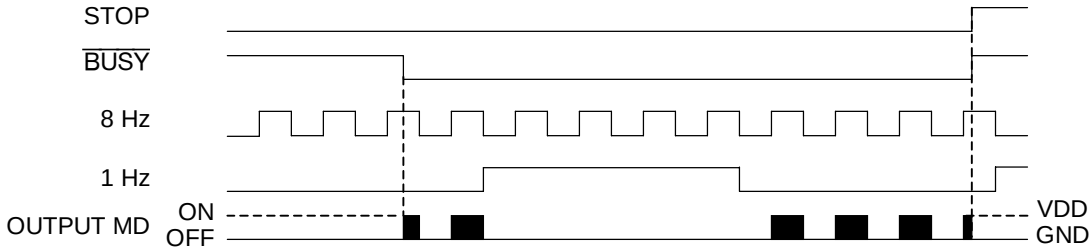
- 31 musical scales (C1 to Fis3)
- 60 music notes and rests
- 30 tempos (♩ = 625 to 39.1)
- Monotones (chords cannot be created)
- Sampling Frequency: Fixed 8 kHz

8. Buzzer

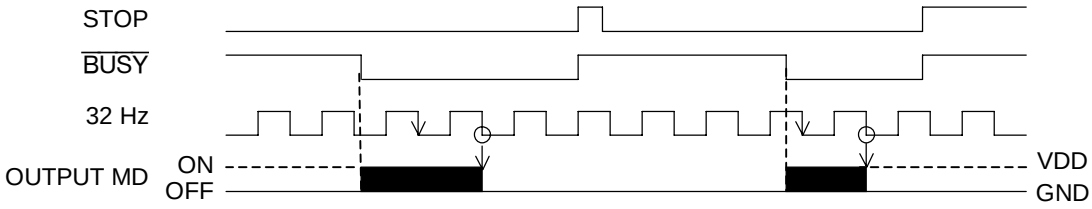
A buzzer output is generated using an Oki's Voice Analysis Tool. By setting a frequency and sound type with the Voice Analysis Tool and activating a buzzer phrase that has been set, the buzzer output is started via the MD pin. Four buzzing sound types, intermittent 1, intermittent 2, single and continuous, and three 50%-duty frequencies, at 0.5 kHz, 1.0 kHz and 2.0 kHz, can be selected using the Analyzing Tool. Sampling Frequency is fixed 8 kHz. Figure 8.1 shows output wave-form in each output mode. The waveforms shown as solid blank indicate buzz output signals at 0.5/1.0/2.0 kHz.



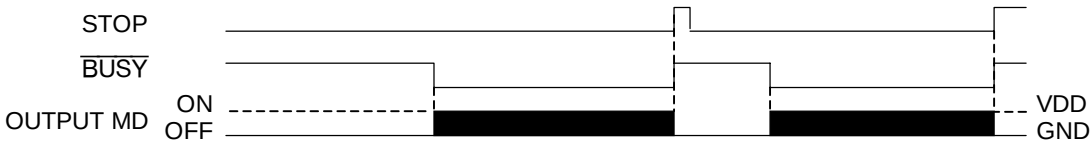
(a) TP1 = 0, TP0 = 0 (intermittent tone 1)



(b) TP1 = 0, TP0 = 1 (intermittent tone 2)



(c) TP1 = 1, TP0 = 0 (single tone)



(d) TP1 = 1, TP0 = 1 (continuous tone)

Figure 8.1 Output Wave-form from the Buzzer Driver in Each Output Mode

9. Low Pass Filter

ML2213's analog output goes through the built-in Low Pass Filter. The Figure 9.1 below shows Frequency Characteristics and Table 9.1 shows Cut-off Frequency of the LPF.
No analog output passing through the LPF is available on this chip.

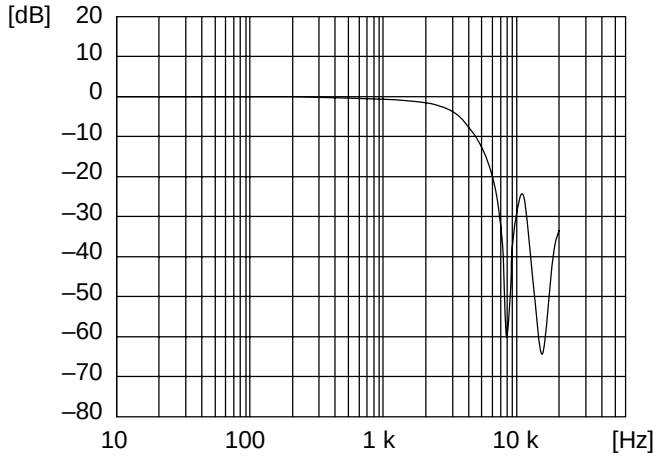


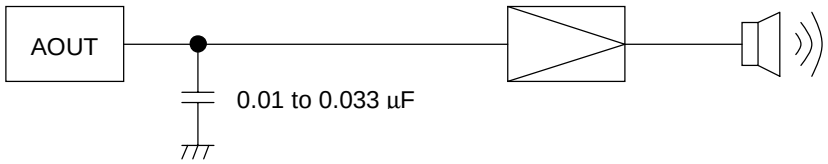
Figure 9.1 LPF Frequency Characteristics (f_{SAM} = 8 kHz)

Table 9.1 LPF Cut-off Frequency

Sampling Frequency (kHz) (f_{SAM})	Cut-off Frequency (kHz) (f_{CUT})
4.0	1.2
5.3	1.6
6.4	2.0
8.0	2.5
10.6	3.2
12.8	4.0
16.0	5.0

10. AOUT Connecting Circuit

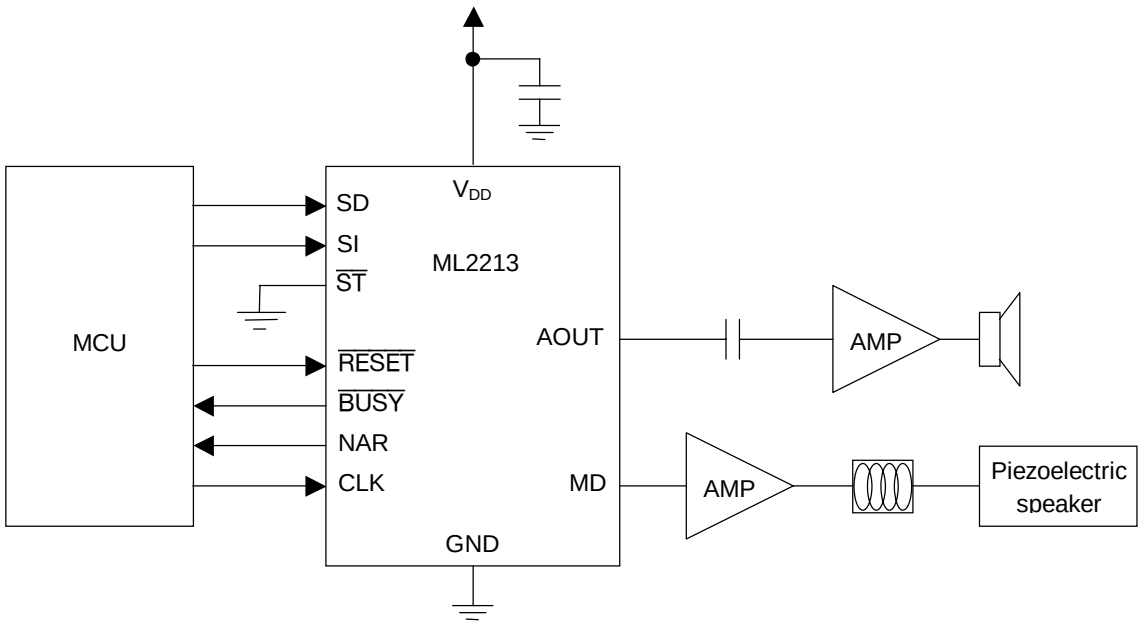
It is recommended to connect a capacitor of 0.01 to 0.033 µF to the AOUT pin.
The circuit diagram is as shown below.



The capacitor is used for improving a voice quality. Check the voice quality before determining the capacitor value. If the voice quality is excellent without connecting a capacitor, no capacitor is required.

APPLICATION CIRCUITS

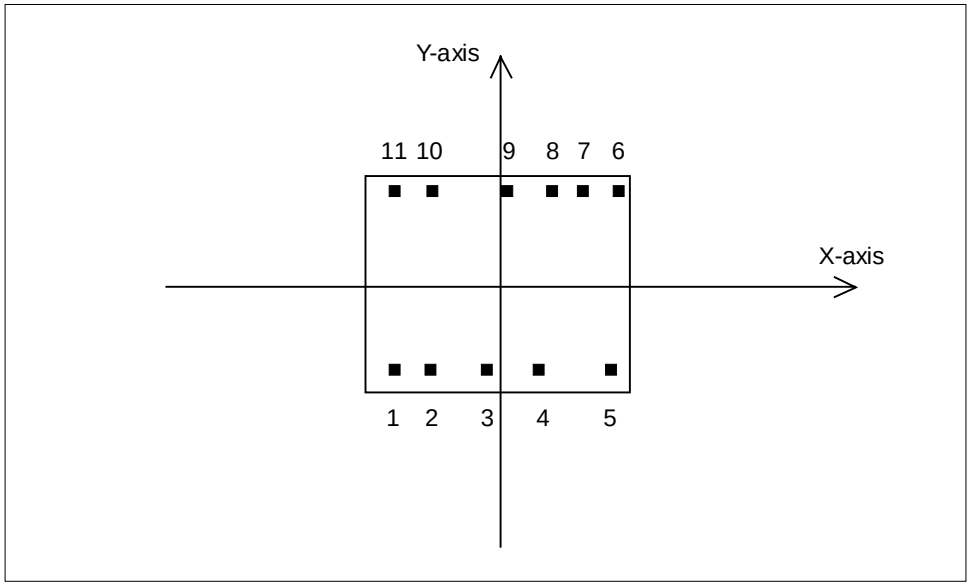
When 2-pin interfacing is selected
(Fix the $\overline{ST}$ pin to GND.)



PAD CONFIGURATION

Chip size X = 2.808 mm Y = 2.496 mm

1. Chip and Pad Numbers



2. Pad Coordinates
(Chip center is located at X = 0 and Y = 0)

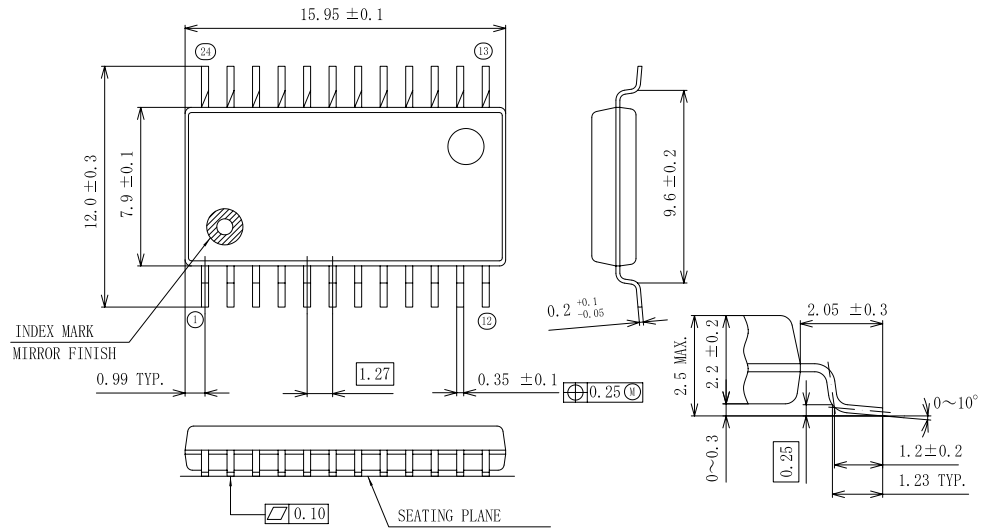
(Unit: µm)

PAD No.	PAD Name	X-axis	Y-axis
1	NAR	–1066	–1098.5
2	$\overline{\text{BUSY}}$	–689	–1098.5
3	MD	–182	–1098.5
4	GND	247	–1098.5
5	AOUT	1105	–1098.5
6	VDD	1248	1098.5
7	CLK	819	1098.5
8	$\overline{\text{ST}}$	390	1098.5
9	$\overline{\text{RESET}}$	13	1098.5
10	SI	–689	1098.5
11	SD	–1066	1098.5

PACKAGE DIMENSIONS

(Unit : mm)

SOP24-P-430-1.27-K



Package material	Epoxy resin
Lead frame material	42 alloy
Lead finish	Sn/Pb=70/30 to 95/5
Pin treatment	Solder plating (≥5μm)
Package weight (g)	0.58 TYP.
Rev. No./Last Revised	7/Jul. 30, 2004

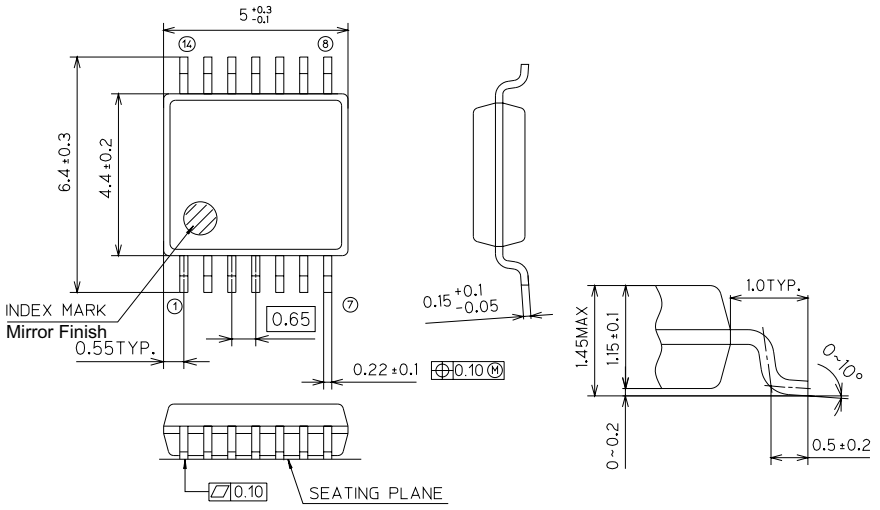
Oki Electric Industry Co., Ltd.

Notes for Mounting the Surface Mount Type Package

The surface mount type packages are very susceptible to heat in reflow mounting and humidity absorbed in storage.
Therefore, before you perform reflow mounting, contact Oki's responsible sales person for the product name, package name, pin number, package code and desired mounting conditions (reflow method, temperature and times).

(Unit: mm)

SSOP14-P-44-0.65-K



Package material	Epoxy resin
Lead frame material	42 alloy
Pin treatment	Solder plating (≥5µm)
Package weight (g)	0.066 TYP.
Rev. No./Last Revised	1/Sept. 18, 1998

Oki Electric Industry Co., Ltd.

Notes for Mounting the Surface Mount Type Package

The surface mount type packages are very susceptible to heat in reflow mounting and humidity absorbed in storage.
Therefore, before you perform reflow mounting, contact Oki's responsible sales person for the product name, package name, pin number, package code and desired mounting conditions (reflow method, temperature and times).

September 10, 2004

To Oki Electric Industry Co., Ltd.

Phrase Address Corresponding List

Type: ML2215-999
Company: Oki Electric Industry Co., Ltd.

Source oscillation frequency: 4,096 [MHz]

Phrase address	Voice word	Playback method	Sampling frequency [kHz]	Phrase address	Voice word	Playback method	Sampling frequency [kHz]
00	[Stop code]	ADPCM	8.0				
01	[A]	ADPCM	8.0				
02	[B]	ADPCM	8.0				
03	[C]	ADPCM	8.0				
04	[Push] + silence (199.5 ms)	ADPCM	8.0				
05	[the button]	ADPCM	8.0				
06	♩ Melody	Melody	-				
07	Intermittent tone 1 (f = 1.0 kHz)	Buzzer	-				
08	Intermittent tone 2 (f = 1.0 kHz)	Buzzer	-				
09	Single tone (f = 0.5 kHz)	Buzzer	-				
0A	Continuous tone (f = 2.0 kHz)	Buzzer	-				

* In the case of the ML2213/2215, the minimum silent time of 6.0 [ms] is automatically added at the end of a phrase. Specify the silent time according to 1.5 [ms]×(m + 1)×(n + 1), where 1≤m≤31 and 1≤n≤63. Specify the silence after a phrase according to "+ silence (- - -)".

* Since address "00"h is the stop code, the address cannot be used. Usable addresses are "01"h to "FF"h.

* Select the playback method from 4-bit ADPCM, 8-bit straight PCM, nonlinear PCM, Melody, or Buzzer.

REVISION HISTORY

Document No.	Date	Page		Description
		Previous Edition	Current Edition	
FEDL2213-01	–	–	–	Final edition 1
FEDL2213-02	Aug. 2001	–	–	Final edition 2
FEDL2213-03	Aug. 21, 2003	–	–	Final edition 3
		–	23	The "Phrase Address Corresponding List" has been added.
FEDL2213-04	Jan. 17, 2005	–	–	Final edition 4
		4	4	Descriptions of the MD and AOUT pins have been partially modified.
		5	5	The Min., Typ., and Max. values of "External Clock Frequency" have been added.
		6	6	- Parameter "Silent Time after Playback" and the statement below the table in the "AC Characteristics" Section have been added. - Values of parameter "AOUT Pull-up Resistor Value" in the "Analog Characteristics" Section have been changed.
		8	8	Time "t_{SIL}" has been added in the timing diagrams in Sections 2.1 and 2.2.
		8 to 10	8 to 10	Statements in the timing diagrams in Sections 2 and 3 have been partially added.
		–	11	Section 3.3, "L" during at NAR pin and "H" duration at NAR pin has been added.
		15 to 20	16	Contents in Section 7 have been changed.
		–	20	The "PAD CONFIGURATION" Section has been added.
		23	23	Statements below the "Phrase Address Corresponding List" table have been partially modified.
FEDL2213-05	Jun. 26, 2006	–	–	Final edition 5
		8 to 10	8 to 10	Statements in the timing diagrams in Sections 2 and 3 have been partially modified.
		–	–	- Word music has been changed to word melody throughout. - Words "analog output" has been changed to words "voice output" throughout.

NOTICE

1. The information contained herein can change without notice owing to product and/or technical improvements. Before using the product, please make sure that the information being referred to is up-to-date.

2. The outline of action and examples for application circuits described herein have been chosen as an explanation for the standard action and performance of the product. When planning to use the product, please ensure that the external conditions are reflected in the actual circuit, assembly, and program designs.

3. When designing your product, please use our product below the specified maximum ratings and within the specified operating ranges including, but not limited to, operating voltage, power dissipation, and operating temperature.

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