NIPPON PRECISION CIRCUITS INC.

SM1350 series

High Tone Quality Melody LSI

OVERVIEW

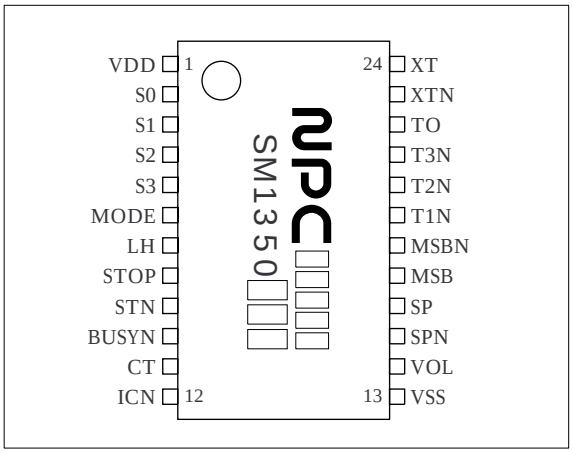
The SM1350 series are single-chip high tone quality melody ICs, fabricated using NPC's Molybdenum-gate CMOS process. Melodies are selected in serial or binary (parallel) mode, up to a maximum of 16 melody blocks. There are 4 sound generators incorporated to produce 4 kinds of output tone controlled by 16-tone data, making these ICs ideal for mechanical clocks and similar applications where high tone quality output is demanded.

FEATURES

- Basic Functions
  - 4.0 MHz oscillator frequency
  - Power-save function
    - Oscillator stopped when no output
    - S0 to S3, MODE, LH pull-up resistors open
  - BTL or A-class outputs
  - Chattering prevention circuit (STN, STOP, S0 to S3)
  - 10-bit D/A converter
- Sound Generator Functions
  - DWS (dual wave synthesis) sound generators
  - 4 simultaneous sounds for 4 tones
  - G2 to F#7 note range
  - 16-tone programmable
- Melody Functions
  - Up to 16 programmable melodies (singly or in medleys)
  - 1024-step length (notes, rests, jumps, end codes)
  - Level hold/one-shot melody modes
  - Serial/binary (parallel) select modes
  - 4.8 to 605.6 tempo range in 127 steps
  - 12 rhythm values

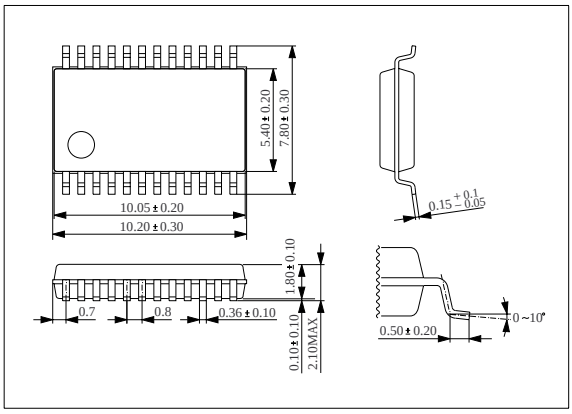
  - Ties and slurs programmable
- Control Signal Outputs
  - BUSYN signal LOW during melody output
  - CT signal output for external control
- 2.4 to 5.5 V supply voltage
- Package
  - 24-pin SSOP (SM1350×××)
- Molybdenum-gate CMOS

PINOUT(TOP VIEW)



PACKAGE DIMENSIONS

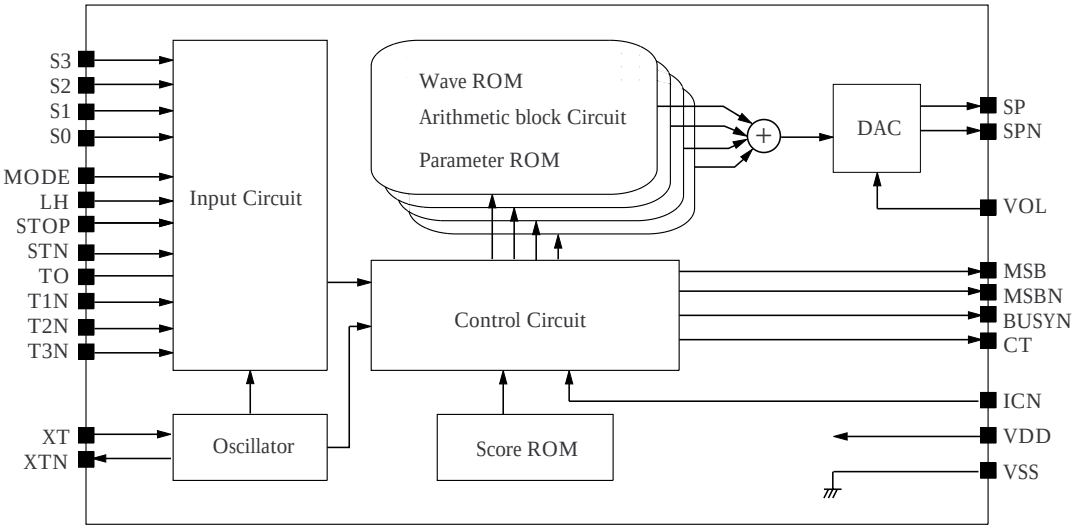
24-pin SSOP (Unit: mm)



ORDERING INFOMATION

Device	Package
SM1350 ×××M	24pin SSOP

BLOCK DIAGRAM



PIN DESCRIPTION

Number	Name	I/O	State[1]	Description[2]
1	VDD	–	–	Supply pin
2	S0	I	SU	Binary select mode: Phrase select pins. Serial select mode: S0 and S1 control melody output.
3	S1	I	SU	
4	S2	I	SU	
5	S3	I	SU	
6	MODE	I	SU	Melody select mode control. Binary mode when LOW, and serial mode when HIGH.
7	LH	I	SU	Melody output mode control. One-shot when LOW, and level hold when HIGH.
8	STOP	I	U or O	One-shot melody mode: Melody output stop control. Level hold melody mode: Invalid input.
9	STN	I	U or O	Melody start control
10	BUSYN	O	C	Busy output signal. LOW when a melody is output.
11	CT	O	C	External control pulse output
12	ICN	I	U	Initialization clear input
13	VSS	–	–	Ground pin
14	VOL	I	–	Volume adjust control. Volume adjusted using an external resistor.
15	SPN	O	P	9-bit D/A converter output in BTL output mode. VOL current output in A-class output mode.
16	SP	O	P	BTL output mode: 9-bit D/A converter output. A-class output mode: 10-bit D/A converter output.
17	MSB	O	C	BTL output mode: Signed-bit output. HIGH when no melody is output.
		I	U	A-class output mode: BUSYIN input
18	MSBN	O	C	BTL output mode: Signed-bit output. HIGH when no melody is output. A-class output mode: ENDN output. HIGH when no melody is output.
19	T1N	I	U	Test signal inputs
20	T2N	I	U	
21	T3N	I	U	
22	TO	O	C	Test signal output. 62.5 kHz output when not in test mode.
23	XTN	O	–	Oscillator output
24	XT	I	–	Oscillator input

1. U = pull-up resistor connection, SU : pull-up resistor connection only when melody output starts,
   P = p-channel open drain, C = complementary output.
   U or O = pull-up resistance or open drain (master slice)
2. BTL/A-class output mode is selected by mask option.

SPECIFICATIONS

Absolute Maximum Ratings

V_{SS} = 0 V

Parameter	Symbol	Condition	Rating	Unit
Supply voltage	V_{DD}		–0.3 to 7.0	V
Input voltage	V_{IN}		V_{SS} – 0.3 to V_{DD} + 0.3	V
Storage temperature	T_{stg}		–40 to 125	°C
Power dissipation	P_D		650	mW
Soldering temperature	T_{sld}		255	°C
Soldering time	t_{sld}		10	s

Recommended Operating Conditions

V_{SS} = 0 V

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Supply voltage	V_{DD}		2.4	–	5.5	V
Operating temperature	T_{opr}		–20	–	80	°C

Master slice

Specifications		Function Selected condition
Serial-mode melody selections		1 to 16
Melody output circuit		BTL / A-class
Level-hold melody select change retrigger		Yes / No
Pull-up/pull-down resistance	STN	U / O
	STOP	U / O

Underlined entries are the default standard options. Throughout this datasheet, the standard options are assumed unless otherwise specified.
U: pull-up resistance O: open input

DC Characteristics

V_{DD} = 3 V, T_a = 25 °C, V_{SS} = 0 V, f_O = 4.0 MHz

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Minimum operating supply voltage[1]	V_{MIN}		–	–	2.4	V
Maximum operating supply voltage[1]	V_{MAX}		5.5	–	–	V
Standby current consumption	I_{STBY}	No melody output	–	–	1.0	µA
Operating current consumption	I_{DD}	BUSYN, CT, TO, SP, SPN, MSB, MSBN all open	–	–	3.5	mA
XT external capacitance	C_G		–	30	–	pF
XTN external capacitance	C_D		–	30	–	pF
Clock frequency[2]	f_{XTI}		3.8	4.0	4.2	MHz
Clock duty cycle[2]	R_{XTI}		40	50	60	%
S0 to S3, MODE, LH, STOP, STN, ICN HIGH-level input voltage	V_{IH}		V_{DD} – 0.3	–	V_{DD}	V
S0 to S3, MODE, LH, STOP, STN, ICN LOW-level input voltage	V_{IL}		V_{SS}	–	V_{SS} + 0.3	V
S0 to S3, MODE, LH, STOP, STN, ICN HIGH-level input current	I_{IH}	$V_{IH} = V_{DD}$	–	10	20	µA
S0 to S3, MODE, LH, STOP, STN, ICN LOW-level input current	I_{IL}	$V_{IL} = V_{SS}$	–	10	20	µA
BUSYN, CT, TO HIGH-level output current	I_{OH1}	$V_{OH1} = V_{DD} - 0.7$	2.0	–	–	mA
BUSYN, CT, TO LOW-level output current	I_{OL1}	$V_{OL1} = V_{SS} + 0.7$	2.0	–	–	mA
MSB, MSBN HIGH-level output current	I_{OH2}	$V_{OH2} = V_{DD} - 0.7$	3.0	–	–	mA
MSB, MSBN LOW-level output current	I_{OL2}	$V_{OL2} = V_{SS} + 0.7$	3.0	–	–	mA
SP, SPN output current[3]	I_{OH3}	$V_{OH3} = V_{SS} + 0.7$	–	–	4.0	mA

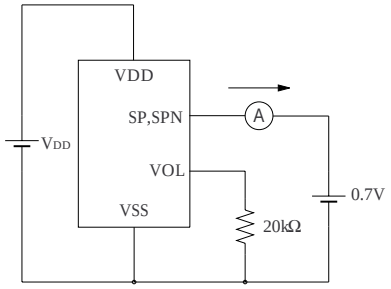
1.Supply voltage ratings shown are with oscillator running and all functions operating normally.
2.Clock frequency and duty cycle are ratings for the clock input on pin XT.
3.Output current when 20 kΩ volume control resistor is connected to VOL, and all D/A converter bits ON, measured using the circuit of the next page.

V_{DD} = 5 V, T_a = 25 °C, V_{SS} = 0 V, f_O = 4.0 MHz

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Minimum operating supply voltage[1]	V_{MIN}		–	–	2.4	V
Maximum operating supply voltage[1]	V_{MAX}		5.5	–	–	V
Standby current consumption	I_{STBY}	No melody output	–	–	1.0	µA
Operating current consumption	I_{DD}	BUSYN, CT, TO, SP, SPN, MSB, MSBN all open	–	–	9.5	mA
XT external capacitance	C_G		–	30	–	pF
XTN external capacitance	C_D		–	30	–	pF
Clock frequency[2]	f_{XTI}		3.8	4.0	4.2	MHz
Clock duty cycle[2]	R_{XTI}		40	50	60	%
S0 to S3, MODE, LH, STOP, STN, ICN HIGH-level input voltage	V_{IH}		V_{DD} – 0.3	–	V_{DD}	V
S0 to S3, MODE, LH, STOP, STN, ICN LOW-level input voltage	V_{IL}		V_{SS}	–	V_{SS} + 0.3	V
S0 to S3, MODE, LH, STOP, STN, ICN HIGH-level input current	I_{IH}	$V_{IH} = V_{DD}$	–	30	50	µA

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
S0 to S3, MODE, LH, STOP, STN, ICN LOW-level input current	I_{IL}	$V_{IL} = V_{SS}$	–	30	50	µA
BUSYN, CT, TO HIGH-level output current	I_{OH1}	$V_{OH1} = V_{DD} - 0.7$	2.0	–	–	mA
BUSYN, CT, TO LOW-level output current	I_{OL1}	$V_{OL1} = V_{SS} + 0.7$	2.0	–	–	mA
MSB, MSBN HIGH-level output current	I_{OH2}	$V_{OH2} = V_{DD} - 0.7$	3.0	–	–	mA
MSB, MSBN LOW-level output current	I_{OL2}	$V_{OL2} = V_{SS} + 0.7$	3.0	–	–	mA
SP, SPN output current[3]	I_{OH3}	$V_{OH3} = V_{SS} + 0.7$	–	–	7.7	mA

1. Supply voltage ratings shown are with oscillator running and all functions operating normally.
2. Clock frequency and duty cycle are ratings for the clock input on pin XT.
3. Output current when 20 kΩ volume control resistor is connected to VOL, and all D/A converter bits ON, measured using the following circuit.



AC Characteristics

V_{DD} = 3 or 5 V, T_a = 25 °C, V_{SS} = 0 V

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Initialization clear time	t_{ICW}		1.0	–	–	µsec
STN pulsewidth	t_{STW}	Pre-input option selected	81.9	–	–	msec
Oscillator start-up time[1]	t_{XST}		–	–	500	µsec
Oscillator stop time	t_{XEN}		180.2	–	196.7	msec
D/A converter rise delay time	t_{DAST}		–	81.9	–	msec
D/A converter fall delay time	t_{DAEN}		180.2	–	196.7	msec
STN, STOP standby chattering time	t_{CH1}		–	81.9	–	msec
STN, STOP oscillator chattering time	t_{CH2}	Oscillator running	65.5	–	82.0	msec
S0 to S3 melody select chattering time	t_{CH3}		65.5	–	131.1	msec
MODE, LH read timing	t_{MR}		–	15.9	–	µsec
S0 to S3 read timing	t_{SR}		–	31.9	–	µsec
BUSYN fall delay time	t_{BYST}		–	8.2	–	msec
BUSYN rise delay time[2]	t_{BYEN}		–	–	8.2	msec
Melody start delay time	t_{PYST}		–	16.4	–	msec
STOP pulsewidth	t_{STPW1}	Pre-input option selected	81.9	–	–	msec
ENDN delay time	t_{EDST}	A-class output option	–	–	8.2	msec
ENDN pulsewidth	t_{EDW}	A-class output option	–	16.0	–	µsec

1.Oscillator start - up time = [time from when STN goes LOW to when TO goes HIGH] - 25.0 µs.
2.The time taken for fast damping to reduce the envelope to 0 level.

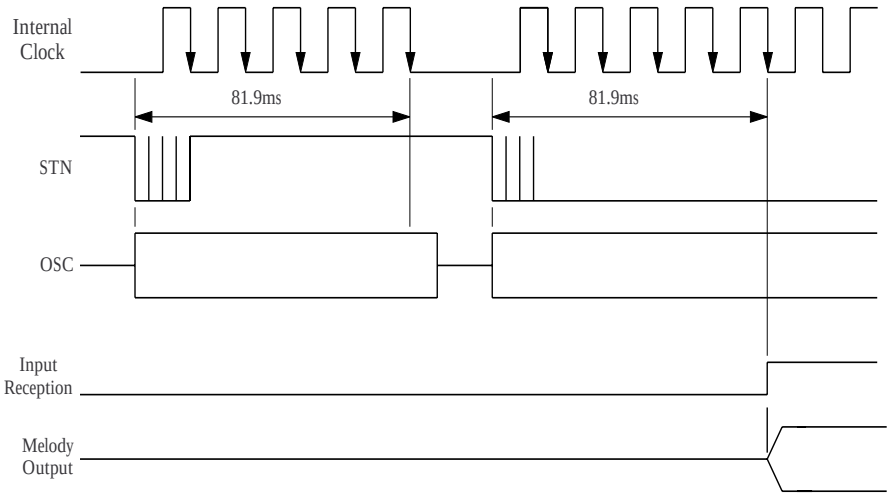
FUNCTIONAL DESCRIPTION

Chattering Prevention

STN, STOP chattering prevention function

Standby Mode

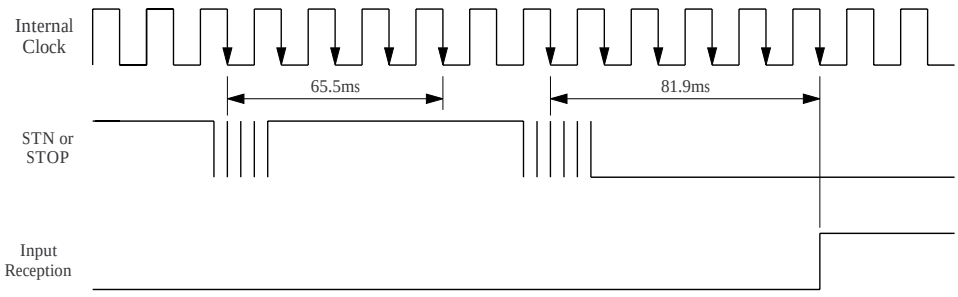
The oscillator starts when STN goes from HIGH to LOW in standby mode. Input data is received and melody data output starts 81.9 ms after the oscillator starts if STN is LOW.



Note: Refer to the "TIMING DIAGRAMS" section to confirm melody timing specifics.
Figure 1. STN, STOP chattering prevention timing (standby mode)

Oscillator starts running

After the oscillator starts running, input data is considered valid 81.9 ms after STN and STOP have last changed state. Input data is considered invalid for intervals less than 65.5 ms.

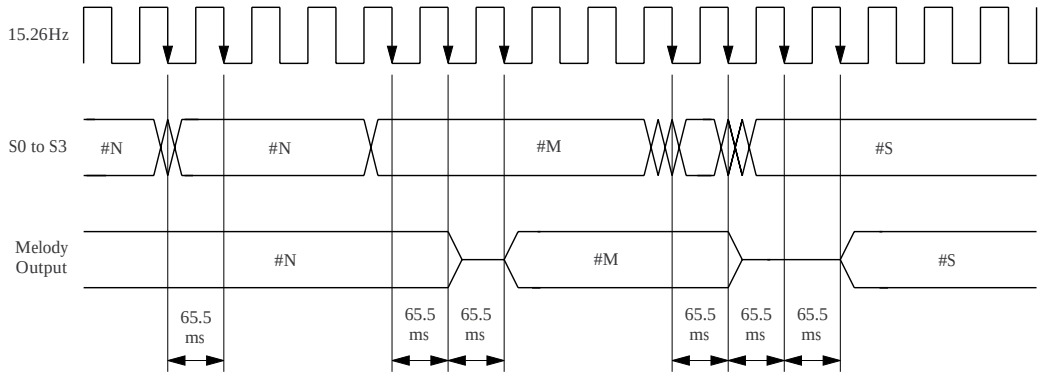


Note: Refer to the "TIMING DIAGRAMS" section to confirm melody timing specifics.
Figure 2. STN, STOP chattering prevention timing (oscillator running)

S0 to S3 chattering prevention function

In binary select mode, S0 to S3 are sampled in sync with the 15.26 Hz clock during level-hold melody output. The chatter prevention function compares the data sampled 65.5 ms after a data transition on S0 to S3 with the data sampled 65.5 ms before the data transition. If the 2 data samples are the same, then the data transition is considered invalid. However, if they are the not the same indicating a true transition has occurred, melody output stops and only restarts again after 2 consecutive identical melody select data samples occur.

Note that except for the “Select change retrigger [No]” master slice option and binary select mode with level hold output, the S0 to S3 chattering prevention circuit is disabled.



Note: Refer to the "TIMING DIAGRAMS" section to confirm melody timing specifics.
Figure 3. S0 to S3 chattering prevention timing

Initialization

When power on and ICN goes LOW, all pins and internal states are initialized to the states shown below. ICN initialization has priority over all other inputs.

- Output pins
  - SP, SPN Open
  - MSB, MSBN V_{DD}
  - CT V_{SS}
  - BUSYN V_{DD}
- Serial melody counter
  Reset to first melody (S0 to S3 all 1)
- Oscillator circuit
  Stopped

Melody Output Circuit

The volume control circuit comprises a P-channel current-summing D/A converter, a built-in constant-current source and an external variable resistor. The circuit is set for either BTL output or A-class output by master-slice option.

BTLoutput

The BTL output comprises a pair of 9-bit D/A converters and 4 external transistors (2 × NPN + 2 × PNP) to drive a speaker.

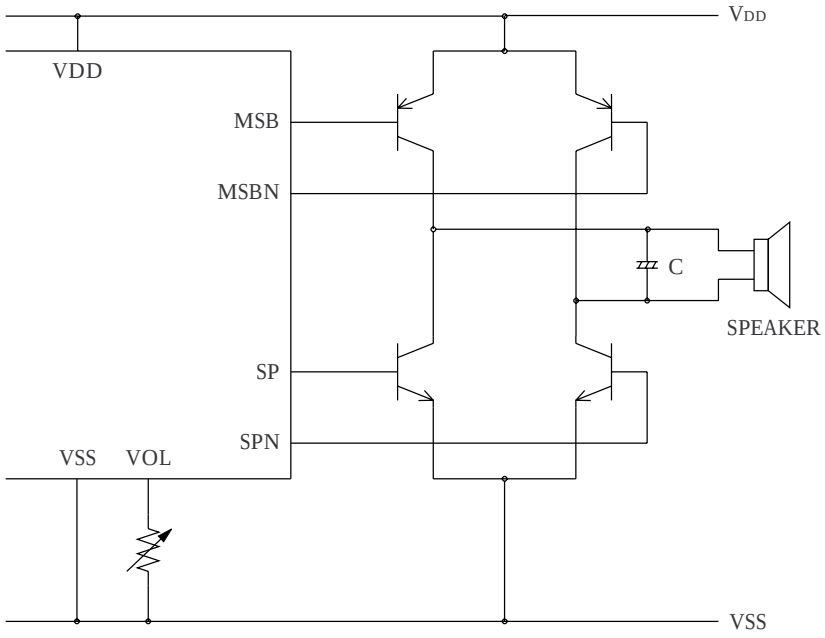
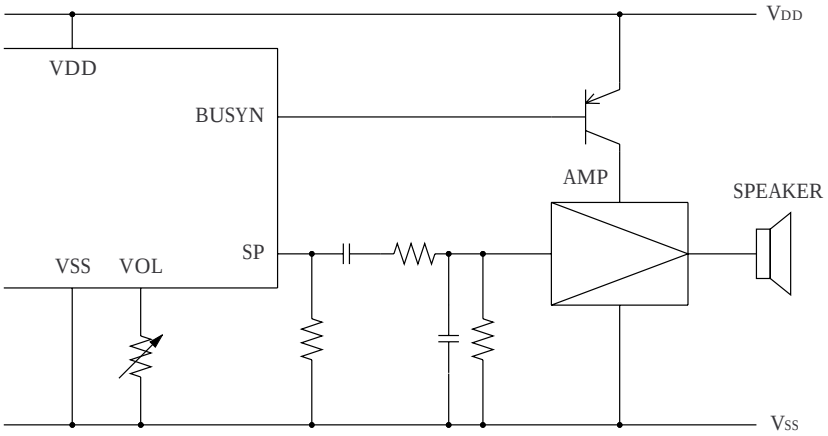


Figure 4. BTL output circuit

A-class output circuit

The A-class output circuit comprises a single 10-bit D/A converter with current output on SP. The D/A converter MSB is set ON immediately after the oscillator starts, and the current output that results is the center point above and below which the converter current output varies in response to the waveform amplitude. The SP output is current-to-voltage converted for connection to audio equipment or amplifiers. In A-class output mode, the 4 sound generator waveforms are time multiplexed, so an integrating circuit must be connected between SP and the amplifier to recover the signal.



Note: Refer to the "TIMING DIAGRAMS" section to confirm melody timing specifics.

Figure 5. A-class output circuit

Pin Functions

Binary select mode (MODE = LOW)

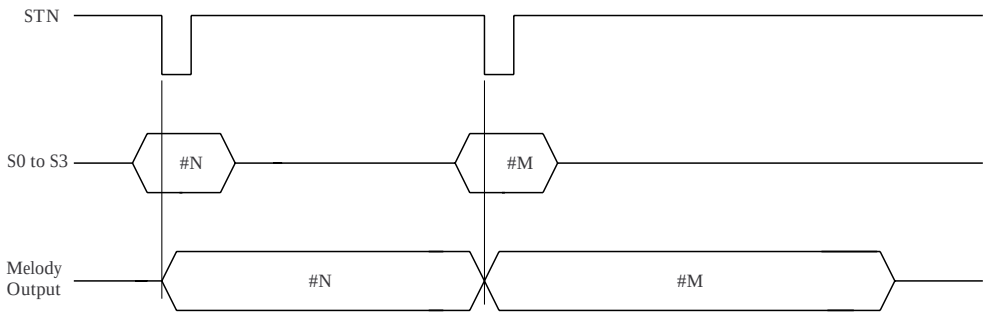
A melody (1 to 16) is selected according to the condition (H or L) of each 4 terminals (S0 to S3).

S3	S2	S1	S0	ST	Melody	S3	S2	S1	S0	ST	Melody
H	H	H	H	↓	1st melody	L	H	H	H	↓	9th melody
H	H	H	L	↓	2nd melody	L	H	H	L	↓	10th melody
H	H	L	H	↓	3rd melody	L	H	L	H	↓	11th melody
H	H	L	L	↓	4th melody	L	H	L	L	↓	12th melody
H	L	H	H	↓	5th melody	L	L	H	H	↓	13th melody
H	L	H	L	↓	6th melody	L	L	H	L	↓	14th melody
H	L	L	H	↓	7th melody	L	L	L	H	↓	15th melody
H	L	L	L	↓	8th melody	L	L	L	L	↓	16th melody

H : V_{DD} level, L : V_{SS} level

Note:Don't select any address with no melody recorded.

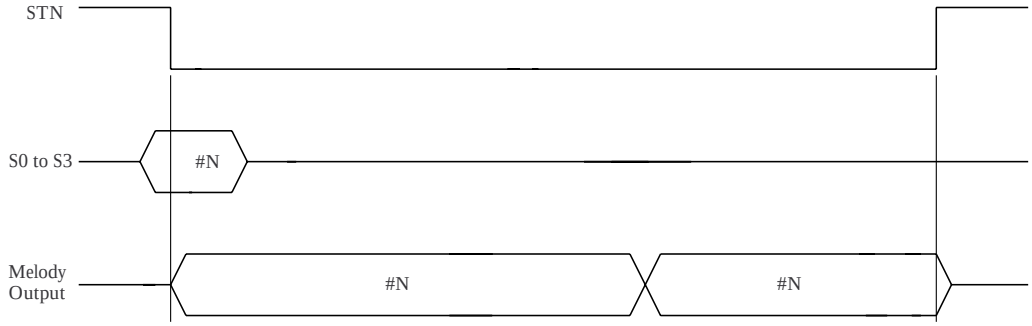
One-shot melody output (LH = LOW)



Note: Refer to the "TIMING DIAGRAMS" section to confirm melody timing specifics

Figure 6. One-shot mode (binary select)

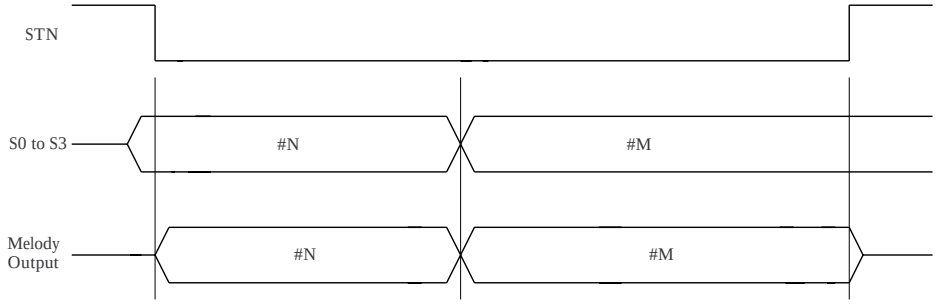
Level hold melody output (LH = HIGH)



Note: Refer to the "TIMING DIAGRAMS" section to confirm melody timing specifics

Figure 7. Level hold mode (binary select) with “Select change retrigger [No]” mask option

If the “Select change retrigger [Yes]” mask option is selected, a new melody starts playing from the leading note when any of the S0 to S3 inputs changes state.



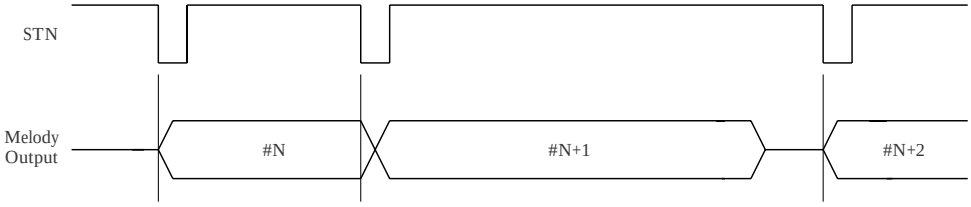
Note: Refer to the "TIMING DIAGRAMS" section to confirm melody timing specifics

Figure 8. Level hold mode (binary select) with “Select change retrigger [Yes]” mask option

Serial select mode (MODE = HIGH)

In serial select mode, the next melody is selected by cycling through the melodies in the order #N → #N+1 … #N−1 → #N when the STN input goes LOW. The number of melodies in the cycle is set by master-slice option. Note that when melody output is stopped using the STOP input, the melody-select counter increments.

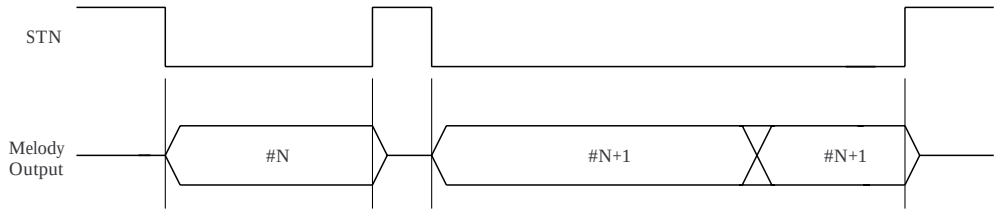
One-shot melody output (LH = LOW)



Note: Refer to the "TIMING DIAGRAMS" section to confirm melody timing specifics

Figure 9. One-shot mode (serial select)

Level hold melody output (LH = HIGH)



Note: Refer to the "TIMING DIAGRAMS" section to confirm melody timing specifics

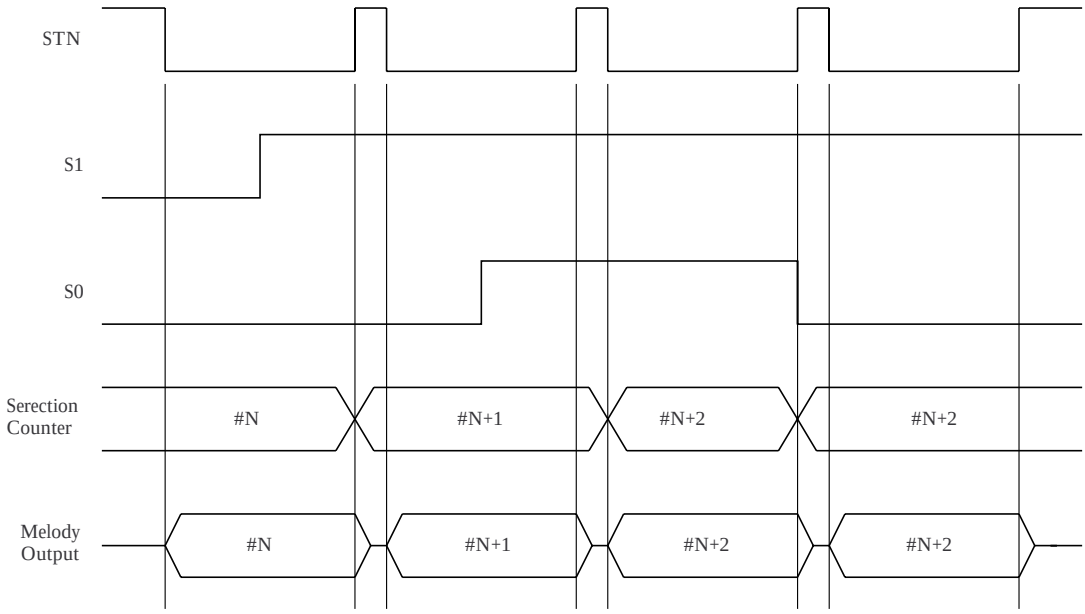
Figure 10. Level hold mode (serial select)

S0, S1 melody output control

The melody selection in serial mode is controlled by S0 and S1 as shown in the following table. When S1 is HIGH, S0 switches to a pull-up input configuration. The states of S0 and S1 are read in immediately after start-up and does not change during melody output.

Table 1. S0, S1 resistor and melody counter

S0	S1	Melody counter
LOW	×	Increments when melody output stops
HIGH	LOW	No increment
HIGH	HIGH	Increments when melody output starts

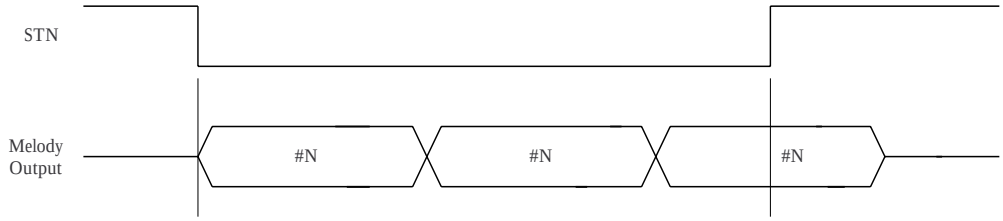


Note: Refer to the "TIMING DIAGRAMS" section to confirm melody timing specifics

Figure 11. S0, S1 melody output control timing

One-shot mode repeat function

In one-shot melody mode, the output repeats the same melody while STN is LOW. When STN goes HIGH, the output continues until the end of the currently playing melody and then stops.



Note: Refer to the "TIMING DIAGRAMS" section to confirm melody timing specifics

Figure 12. One-shot melody repeat timing

One-shot mode perpetual repeat function

If the score ROM end code is set to the jump code, the melody will continue to play continuously once one-shot mode starts.

STOP pin

One-shot output mode stops when STOP goes from HIGH to LOW. The STOP input is ignored in level hold output mode and is also ignored in one-shot mode when STN is LOW. Note that even when STOP is LOW, STN has higher priority.

CT pin

A pulse in sync with selected notes or rests is output on CT. There are 2 modes for the output pulses—pulse mode and hold mode.

In pulse mode, a 16.4 ms pulse is output when a note or rest occurs for which the corresponding CT data in score ROM is set to 1.

Pulse mode

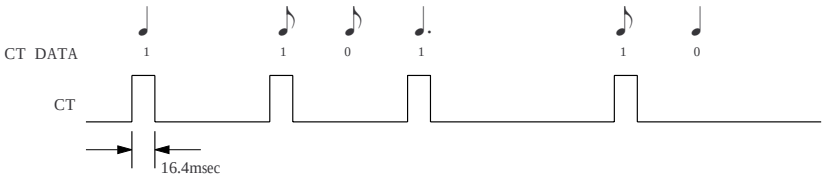


Figure 13. CT pulse mode output

Hold mode

In hold mode, the output pulse inverts when a note or rest occurs for which the corresponding CT data in score ROM is set to 1. The output goes LOW after the start of a melody and when jumping to the leading note of a melody.

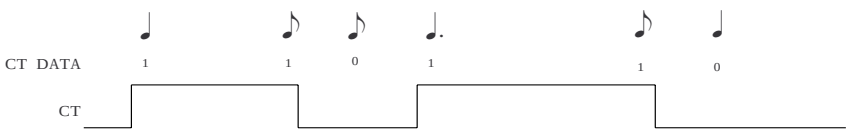
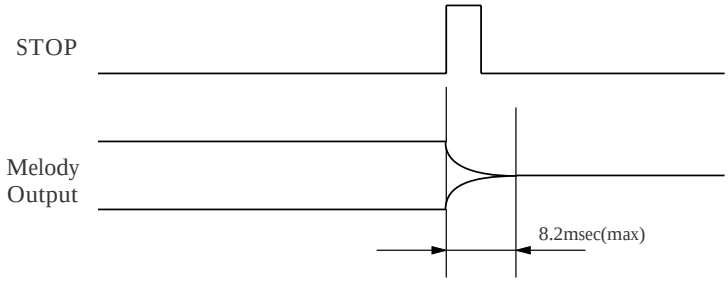


Figure 14. CT hold mode output

Fast Damping

When melody output stops, the D/A converter output amplitude does not fall to zero instantaneously, instead the output converges to zero within a maximum of 8.2 ms to prevent noise being generated. Also, when one-shot melody output mode is retriggered, melody output restarts after the fast damping interval.



Note: Refer to the "TIMING DIAGRAMS" section to confirm melody timing specifics

Figure 15. Fast damping timing

Sound Generator

Synthesis mthod

The sound generators use the dual wave synthesis (DWS) method. The DWS method uses the envelope of 2 waveforms (main waveform and sub waveform) to synthesize the generated tone. Using this method makes possible high tone quality output that faithfully reproduces the tones of real musical instruments.

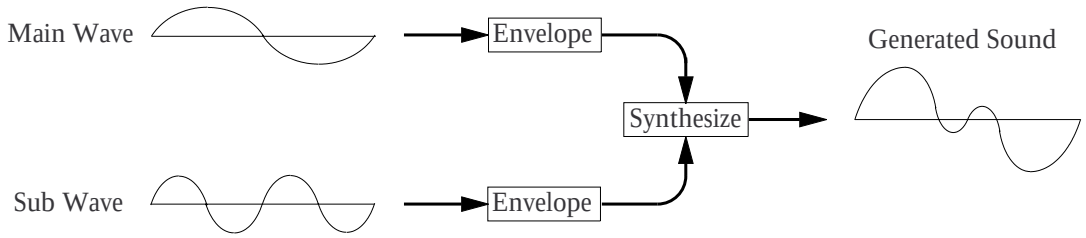


Figure 16.

Number of simultaneous sounds

The maximum number of tones that can be generated simultaneously is 4, making 4-part harmony

harmony

Generation possible (where each tone is derived from corresponding main and sub waveforms).

Sound range

The range of sounds covers 5 octaves from note G2 to F#7.

Waveform ROM

Waveforms are stored in a 10-bit × 128-word × 8-waveform capacity waveform ROM.

Number of programmable tones

The maximum number of programmable tones is 16. Note that 2 similar tones which have different envelope settings are considered to be separate tones.

Built-in ROMs

The built-in ROMs comprise 3 types of ROM—waveform ROM containing waveform data, score ROM containing musical score data, and parameter ROM containing envelope and jump data.

Melodies

Number of melodies

The maximum number of program melodies is 16. Note that is the jump function is used to change the tone or tempo during melody output, then the maximum number of melodies reduces by the number of times the jump function was invoked.

Number of program steps

The maximum number of program steps that can be stored in score ROM (notes, rests, jump codes and end codes) is 1024.

Tempo

The basic quarter note tempo can be set in the range 4.8 to 605.6 in multiples of 4.8.

Note (rest) rhythm values

There are 12 note rhythm values and 13 rest rhythm values that can be used to construct a melody. Also, 2 or more notes can be combined using ties or slurs.

Table 2. Rhythm values Symbol Note Rest

		0	1	2	3	4	5	6	7	8	9	A	B	C
Symbol	Note	𝅝	𝅘𝅥𝅯	𝅘𝅥𝅯	𝅘𝅥𝅮	𝅘𝅥𝅮	𝅘𝅥	𝅘𝅥.	𝅘𝅥	𝅗𝅥	𝅗𝅥	𝅗𝅥	𝅗𝅥	𝅝
	Rest	𝄽	𝄽	𝄽	𝄾	𝄾	𝄽	𝄾	𝄽	𝄻	𝄽	𝄻	𝄻	𝄻

TIMING DIAGRAMS(Refer to AC CHARACTERISTICS)

One-shot Melody Mode

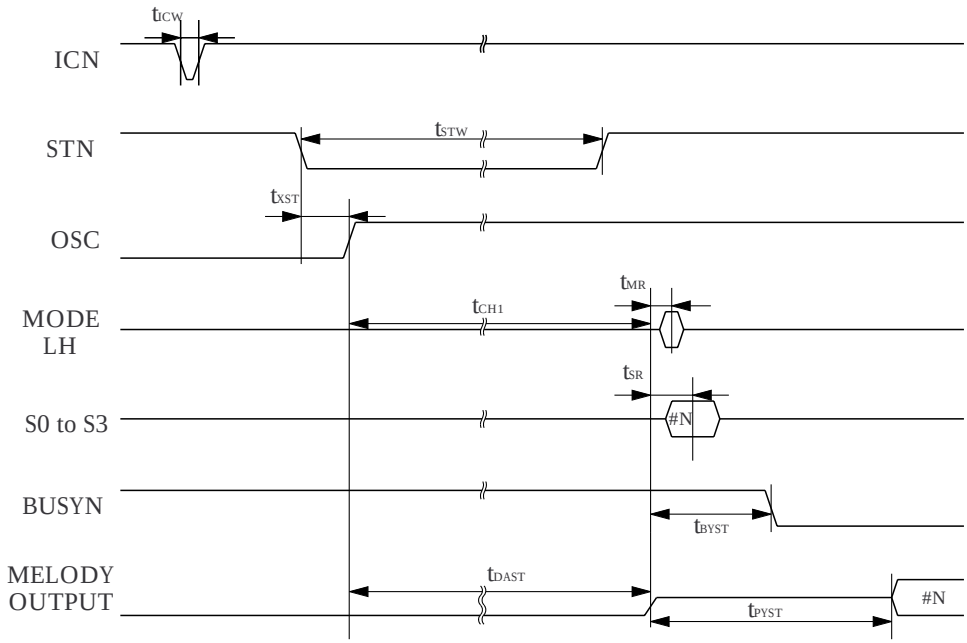


Figure 17. One-shot mode (standby to melody start)

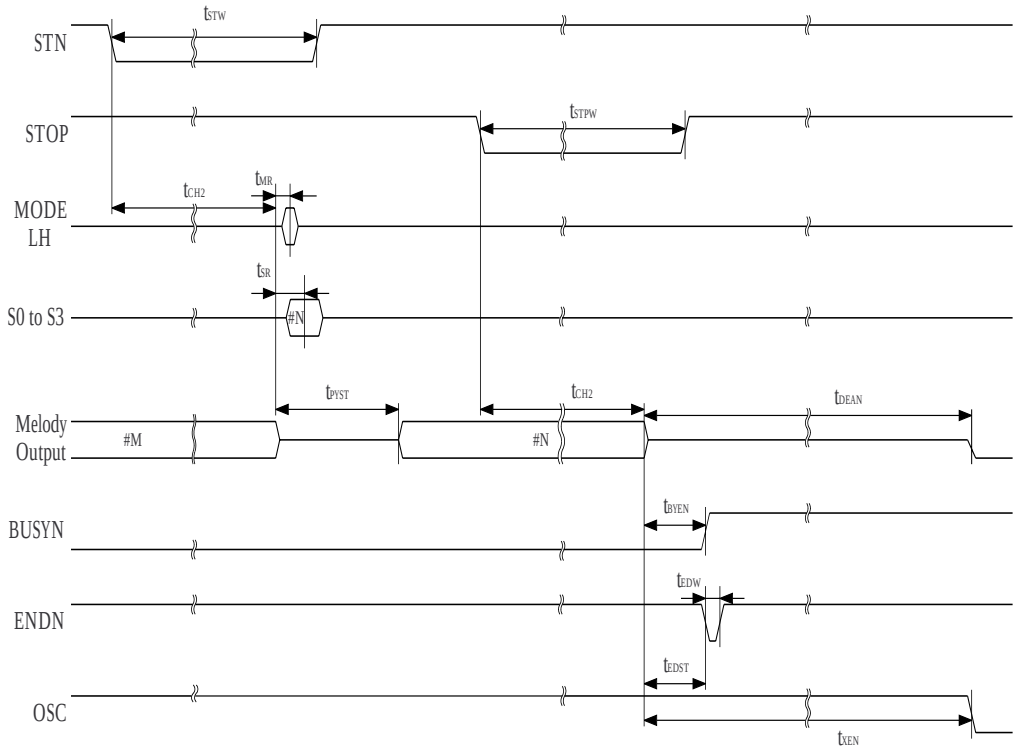


Figure 18. One-shot mode (retrigger to melody stop)

Level Hold Melody Mode 1 (master slice option: “Change select retrigger [Yes]”)

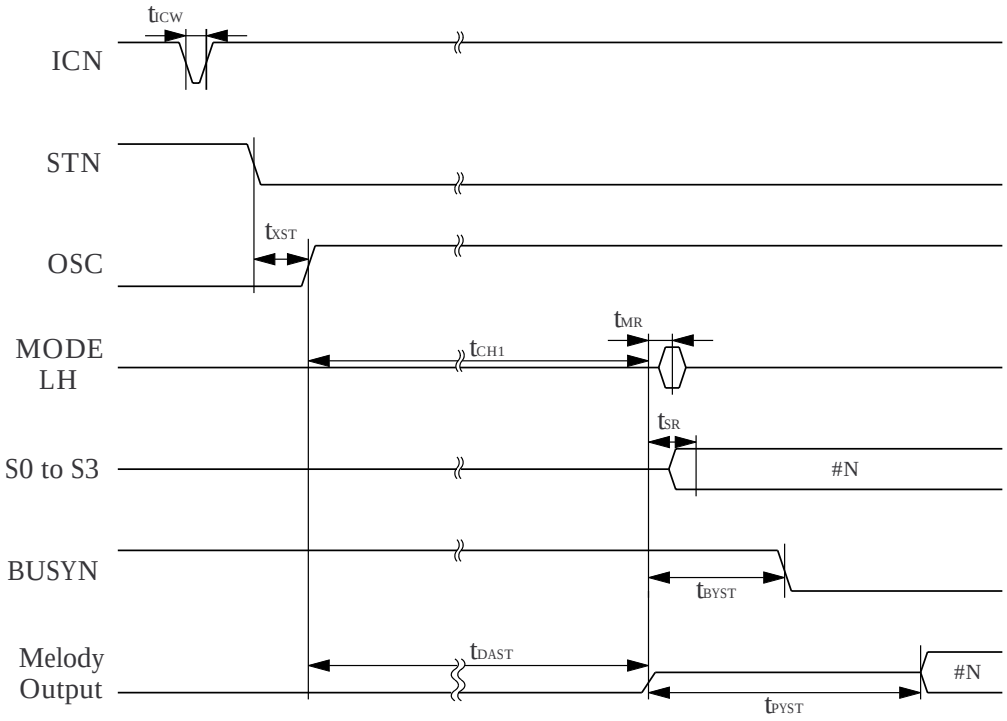


Figure 19. Level hold mode (standby to melody start)

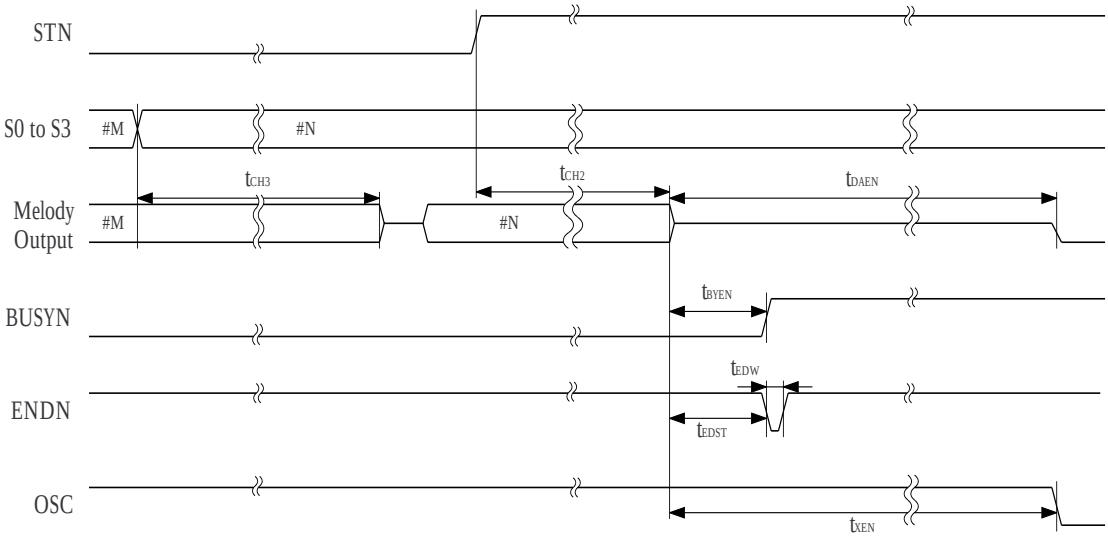


Figure 20. Level hold mode (retrigger to melody stop)

Level Hold Melody Mode 2 (master slice option: “Change select retrigger [No]”)

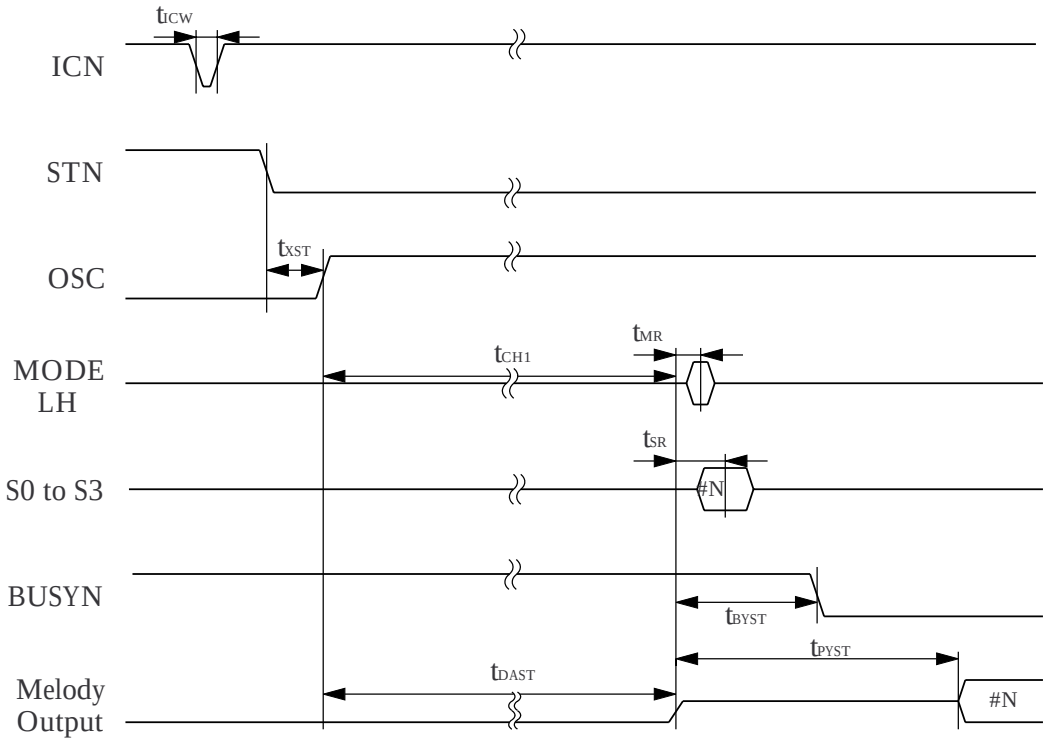


Figure 21. Level hold mode (standby to melody start)

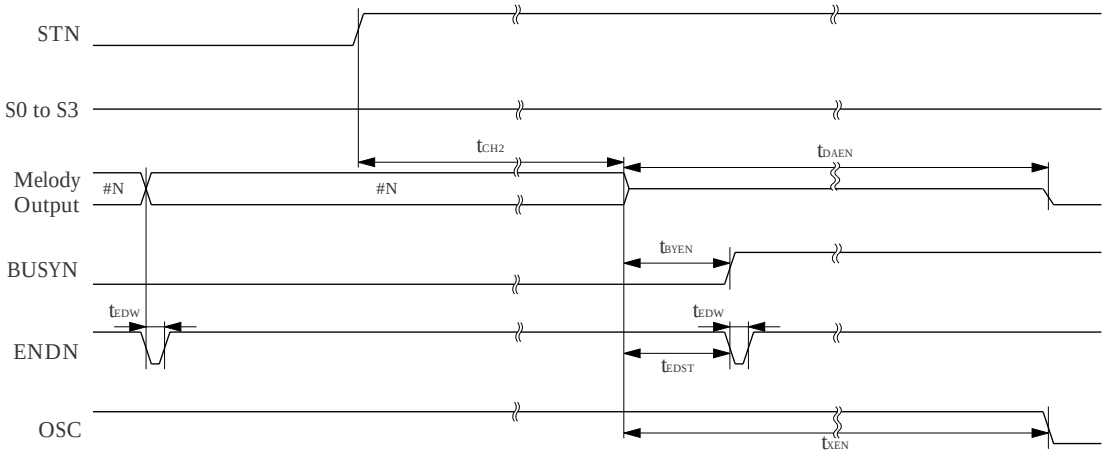
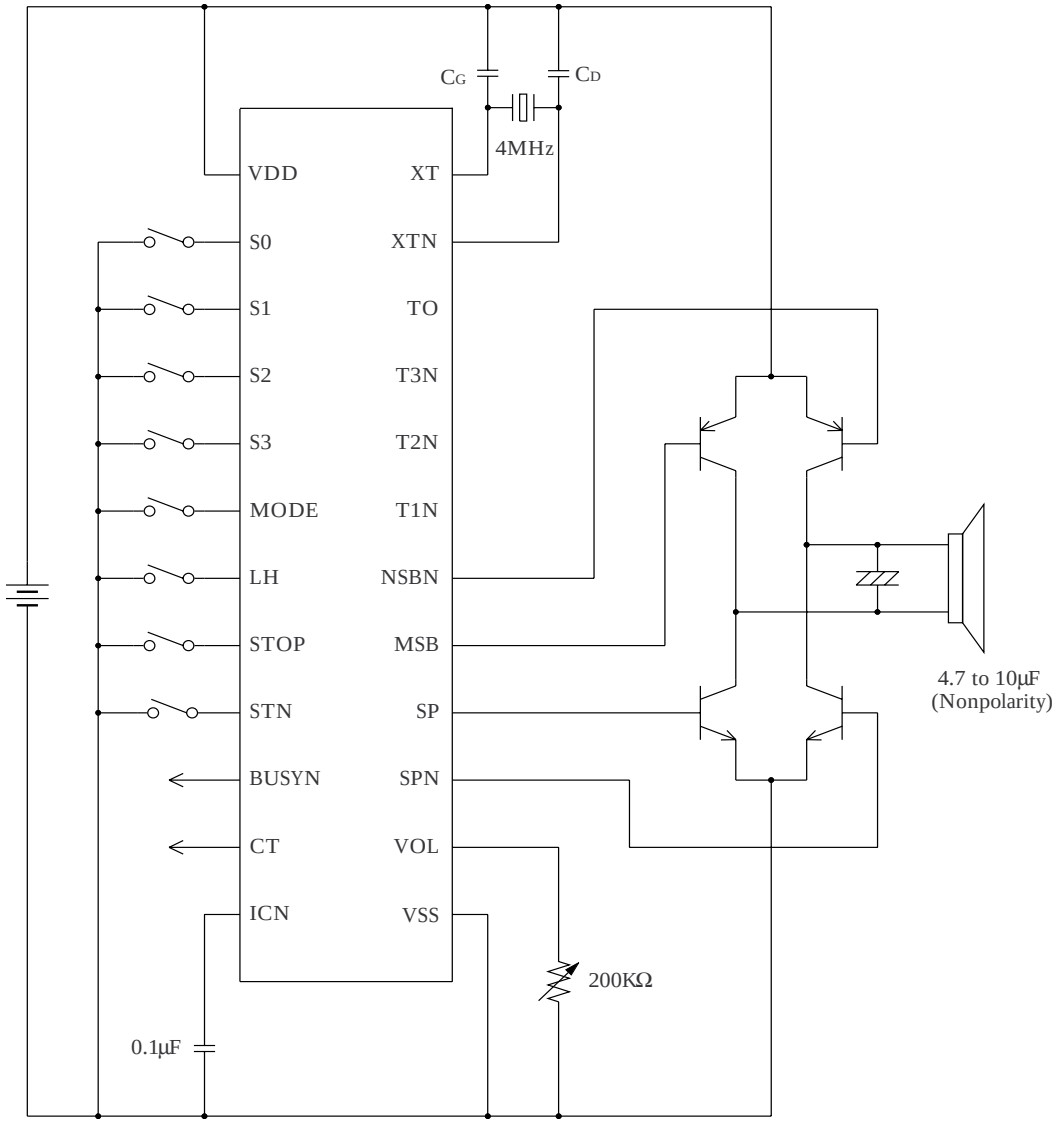


Figure 22. Level hold mode (repeating melody to melody stop)

MEASUREMENT CIRCUIT



Note that circuit constants are reference values.

Parameter	Pin name	Measurement state
1	Melody output circuit	BTL
2	STN	Pull-up
3	STOP	Pull-up
4	ICN	Pull-up
5	LH	Pull-up
6	MODE	Pull-up
7	S0 to S3	Pull-up

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NC9611BE 1998.10