CHAPTER 3: SOUND FUNCTIONS

1. OVERVIEW OF SOUND FUNCTIONS

The sound circuitry consists of circuits that generate 4 types of sounds (Sounds 1-4). It can also synthesize external audio input waveforms and output sounds. (External audio input is a function available only in CGB).

Sound 1: Generates a rectangle waveform with sweep and envelope functions.
Sound 2: Generates a rectangle waveform with an envelope function.
Sound 3: Outputs any waveform from waveform RAM.
Sound 4: Generates white noise with an envelope function.

Each sound has two modes, ON and OFF.

- ON Mode
  Sounds are output according to data in the mode register for each sound.
  The mode register data can be specified as needed while outputting sound.

  - Initialization Flag
    When the default envelope values are set and the length counter is restarted, the initialization flag is set to 1 and the data is initialized.

  - Mute
    In the following instances, the synthesizer will enter mute status. No sound will be output regardless of the ON flag setting.

    Sounds 1, 2, and 4:
    - When the output level is 0 with the default envelope value set to a value other than 0000 and in DOWN mode
    - When the step is 0 with the default envelope value set to a value of 0000 and in UP mode (NR12, NR22, and NR42 set to 0x08 and the initialization flag set)

    Sound 3:
    With the output level set to mute
    (bits 5 and 6 of NR32 set to 0)

  - Stop Status
    In the following cases, the ON flag is reset and sound output is halted.
    -Sound output is halted by the length counter.
    -With Sound 1, during a sweep operation, an overflow occurs in addition mode.

- OFF Mode
  Stops operation of the frequency counter and D/A converter and halts sound output.

  - Sounds 1, 2, and 4:
    -When the default level is set to 0000 with the envelope in DOWN mode (initialization not required)

  - Sound 3:
    -When the Sound OFF flag (bit 7 of NR30) is set to 0.
    Setting the Sound OFF flag to 1 cancels OFF mode.

Sound 3 is started by re-initialization.

- All Sounds OFF mode
  -Setting the All Sounds ON/OFF flag (bit 7 of NR52) to 0 resets all of the mode registers (for sounds 1, 2, 3, and 4) and halts sound output. Setting the All Sounds ON/OFF flag to 1 cancels All Sounds OFF mode.

Note	***The sound mode registers should always be set after All Sound OFF mode is canceled. The sound mode registers cannot be set in All Sound OFF mode.***

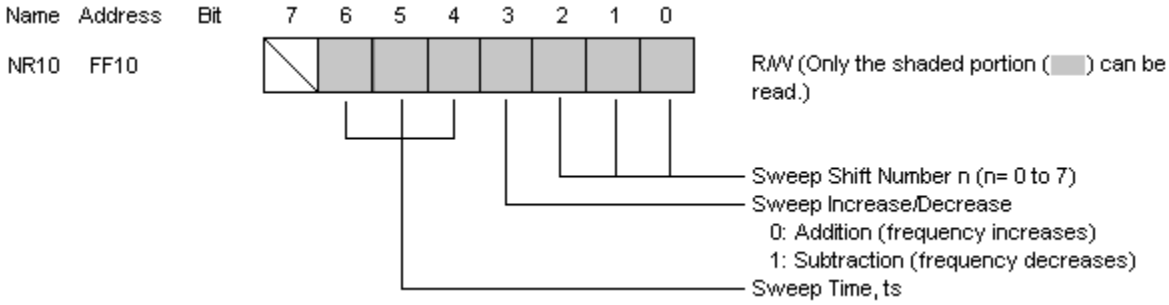
- Sound Usage Notes
  Use one of the following methods to halt sounds 1, 2, or 4.

  1) Use NR51.
  2) Set NR12, NR22, and NR42 to 0x08.
  3) Set NR14, NR24, and NR44 to 0x80.

2. SOUND CONTROL REGISTERS

2.1 Sound 1 Mode Registers

Sound 1 is a circuit that generates a rectangle waveform with sweep and envelope functions. It is set by registers NR10, NR11, NR12, NR13, and NR14.



♦ Sweep Shift Number

The frequency with one shift (NR13 and NR14) is determined by the following formula.

$X(t) = X(t-1) \pm X(t-1) / 2^n$ n = 0 to 7

X (0) = default data X (t-1) is the previous output frequency

If the result of this formula is a value consisting of more than 11 bits, sound output is stopped and the Sound 1 ON flag of NR52 (bit 0) is reset.

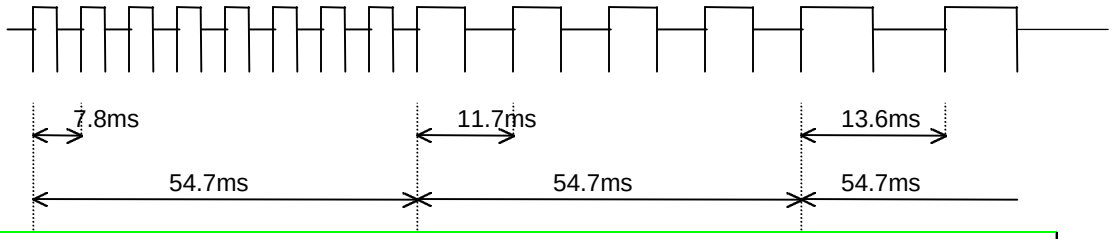
In a subtraction operation, if the subtrahend is less than 0, the result is the pre-calculation value X (t) = X (t - 1). However, if n = 0, shifting does not occur and the frequency is unchanged.

♦ Sweep time (ts)

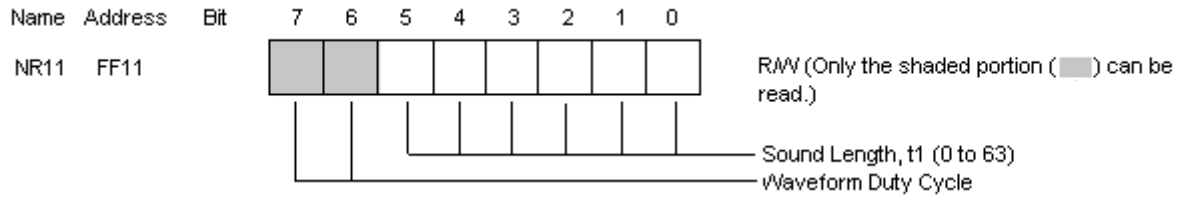
Frequency varies with each value of ts.

000: Sweep OFF
001: ts=1/f128 (7.8ms)
010: ts=2/f128 (15.6ms)
011: ts=3/f128 (23.4ms)
100: ts=4/f128 (31.3ms)
101: ts=5/f128 (39.1ms)
110: ts=6/f128 (46.9ms)
111: ts=7/f128 (54.7ms) f128=128Hz

Example: When NR10 = 0x79 and the default frequency = 0x400, the sweep waveform appears as follows.



Note ***When the sweep function is not used, the increase/decrease flag should be set to 1 (subtraction mode).***



Sound length = (64 - t1) x (1/256) sec

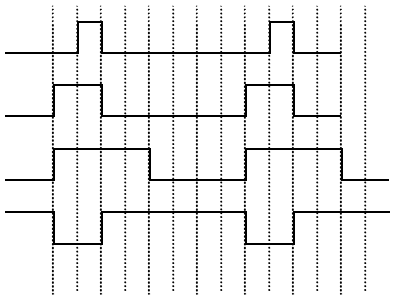
Waveform Duty Cycles

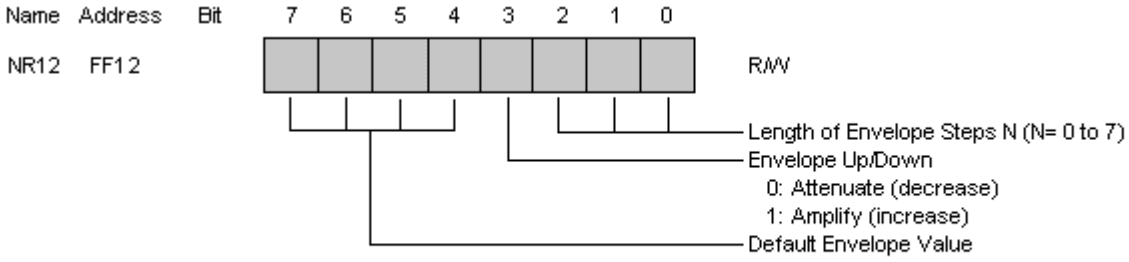
00 : 12.5%

01 : 25%

10 : 50%

11 : 75%

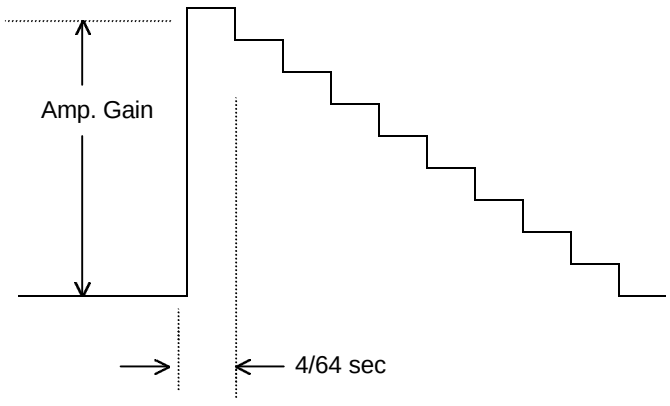


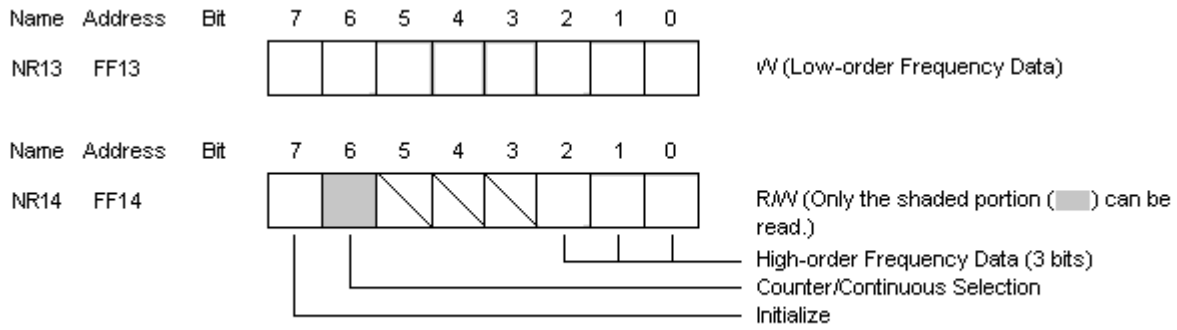


Length of Envelope Steps:
Sets the length of each step of envelope amplification or attenuation.
Length of 1 step = N x (1/64) sec
When N = 0, the envelope function is stopped.

Default Envelope Value (0000 to 1111_B):
16 step levels can be specified using the 4-bit D/A circuit.
Maximum is 1111_B, and 0000 is the mute setting.

Example: When NR12 = 0x94, the Amp Gain is as follows.





Counter/Continous Selection
0: Outputs continuous sound regardless of length data in register NR11.
1: Outputs sound for the duration specified by the length data in register NR11.
When sound output is finished, bit 0 of register NR52, the Sound 1 ON flag, is reset.

Initialize
Setting this bit to 1 restarts Sound 1.

With the 11-bit frequency data specified in NR13 and NR14 represented by x, the frequency, f, is determined by the following formula.
$f = 4194304 / (4 \times 2^5 \times (2048 - X))$ Hz
Thus, the minimum frequency is 64 Hz and the maximum is 131.1 KHz.

♦ Sound 1 Usage Notes

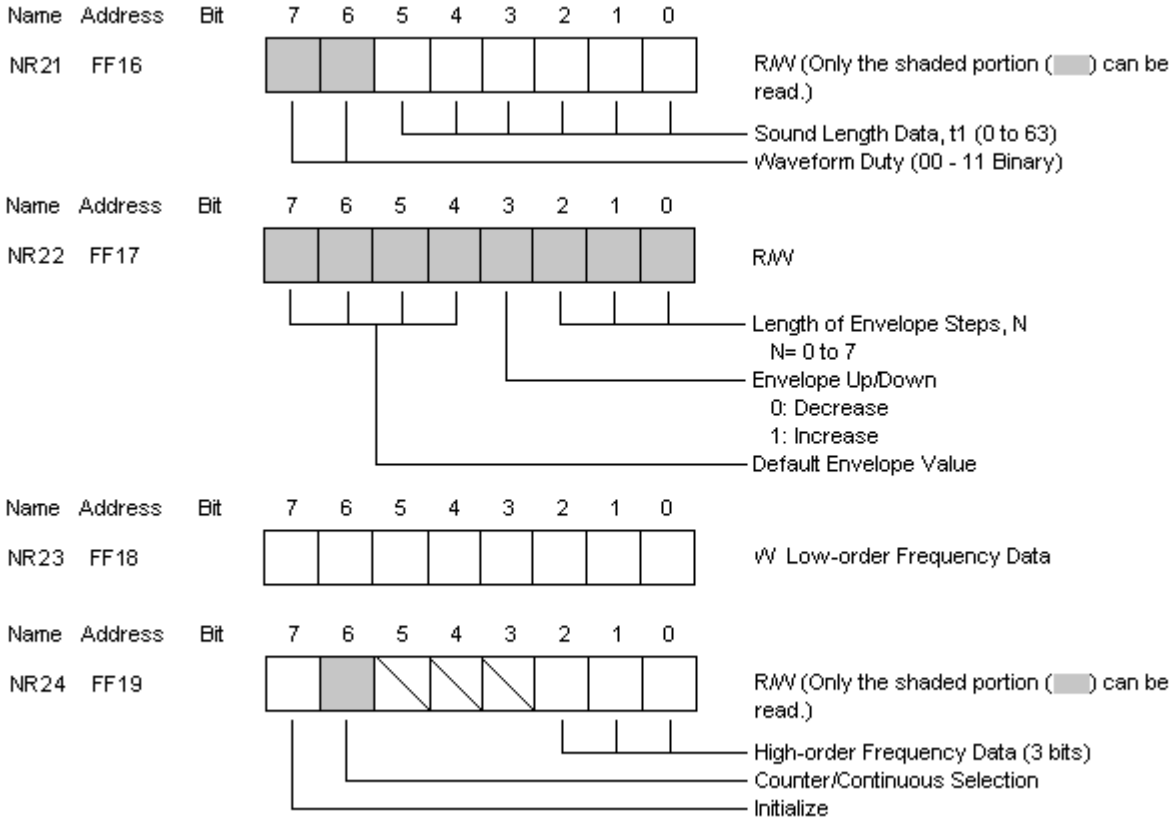
When no sweep function is used with Sound 1, the sweep time should be set to 0 (sweep OFF). In addition, either the sweep increase/decrease flag should be set to 1 or the sweep shift number set to 0 (set to 0x08-0x0F or 0x00 in NR10).

Sound may not be produced if the sweep increase/decrease flag of NR10 is set to 0 (addition mode), the sweep shift number set to a value other than 0, and the mode set to sweep OFF (e.g. NR10 = 0x01)

If the contents of the envelope register (NR12) needs to be changed during sound operation (ON flag set to 1), the initialize flag should be set after the value in the envelope register is set.

2.2 Sound 2 Mode Registers

Sound 2 is a circuit that generates a rectangle waveform with an envelope function. It is set by registers NR21, NR22, NR23, and NR24.



Counter/Continous Selection
0: Outputs continuous sound regardless of length data in register NR21.
1: Outputs sound for the duration specified by the length data in register NR21.
When sound output is finished, bit 1 of register NR52, the Sound 2 ON flag, is reset.

Initialize
Setting this bit to 1 restarts Sound 2.

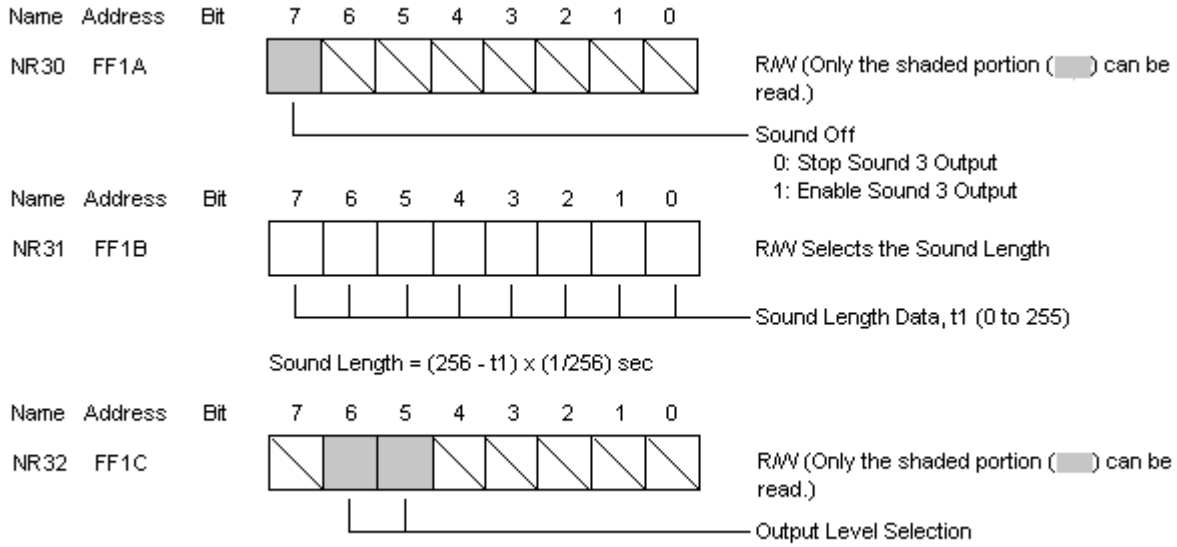
♦ Sound 2 Usage Notes

If the contents of the envelope register (NR22) needs to be changed during sound operation (ON flag set to 1), the initialize flag should be set after the value in the envelope register is set.

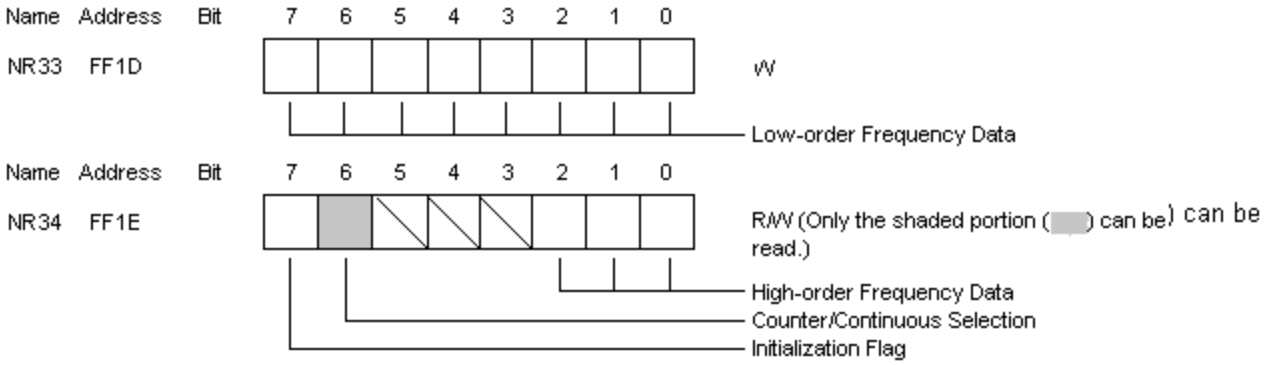
2.3 Sound 3 Mode Registers

Sound 3 is a circuit that generates user-defined waveforms. It automatically reads a waveform pattern (1 cycle) written to waveform RAM at 0xFF30-0xFF3F, and it can output a sound while changing its length, frequency, and level by registers NR30, NR31, NR32, NR33, and NR34.

The settings of the sound length and frequency functions and data are the same as for the Sound 1 circuit.



Output Level:
00: Mute
01: Output waveform RAM data (4-bit length) unmodified.
10: Output waveform RAM data (4-bit length) shifted 1 bit to the right (1/2).
11: Output waveform RAM data (4-bit length) shifted 2 bits to the right (1/4).



Counter/Continous Selection
0: Outputs continuous sound regardless of length data in register NR31.
1: Outputs sound for the duration specified by the length data in register NR31.
When sound output is finished, bit 2 of register NR52, the Sound 3 ON flag, is reset.

Initialization Flag
When the Sound OFF flag (bit 7, NR30) is set to 1, setting this bit to 1 restarts Sound 3.

♦ Sound 3 Usage Notes

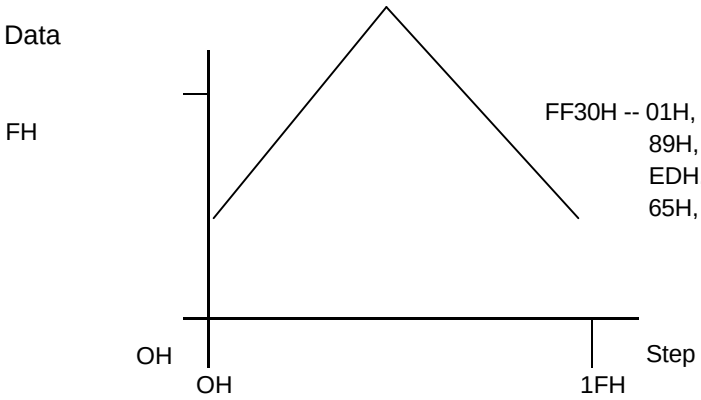
- The initialization flag should not be set when the frequency is changed during Sound 3 output.
- Setting the initialization flag during Sound 3 operation (Sound 3 ON flag = 1) may destroy the contents of waveform RAM.
- Setting the initialization flags for Sound 1, Sound 2, or Sound 4 does not cause a problem.

♦ Waveform RAM Composition

Waveform RAM consists of waveform patterns of 4 bits x 32 steps.

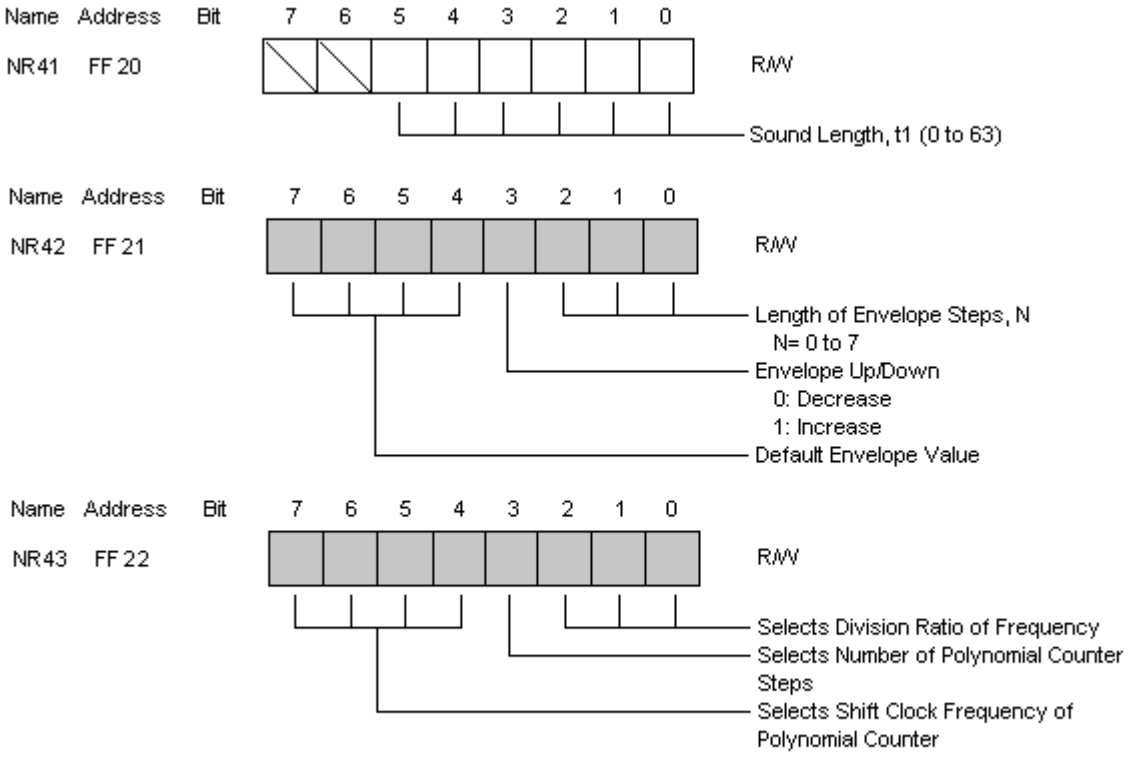
Address	D7	D6	D5	D4	D3	D2	D1	D0
FF30		Step 0				Step 1		
FF31		Step 2				Step 3		
FF32		Step 4				Step 5		
⋮								
FF3F		Step 30				Step 31		

Example: Triangular Wave



2.4 Sound 4 Mode Registers

Sound 4 is a white-noise generating circuit. It can output sound while switching the number of steps of the polynomial counter for random number generation and changing the frequency dividing ratio and envelope data by registers NR41, NR42, NR43, and NR44.

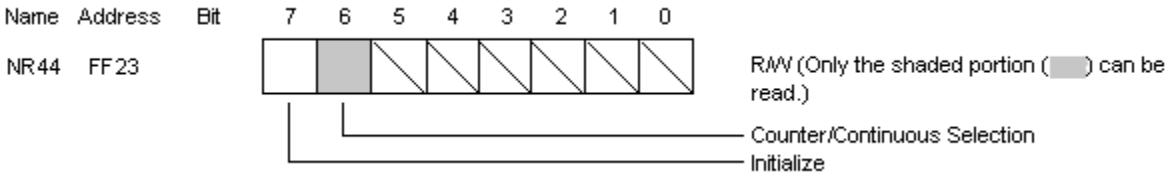


Selecting the dividing ratio of the frequency:
Selects a 14-step prescalar input clock to produce the shift clock for the polynomial counter.

000 : $fx1/2^3x2$
001 : $fx1/2^3x1$
010 : $fx1/2^3x1/2$
011 : $fx1/2^3x1/3$
100 : $fx1/2^3x1/4$
101 : $fx1/2^3x1/5$
110 : $fx1/2^3x1/6$
111 : $fx1/2^3x1/7$ f=4/19430MHz

Selecting the number of steps for the polynomial counter:
0: 15 steps
1: 7 steps

Selecting the shift clock frequency of the polynomial counter:
0000: Dividing ratio frequency x 1/2
0001: Dividing ratio frequency x $1/2^2$
0010: Dividing ratio frequency x $1/2^3$
0011: Dividing ratio frequency x $1/2^4$
: :
1101: Dividing ratio frequency x $1/2^{14}$
1110: Prohibited code
1111: Prohibited code



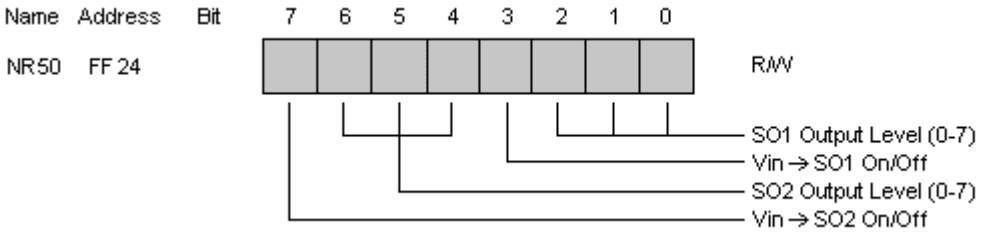
Counter/Continuous Selection:
0: Outputs continuous sound regardless of length data in register NR41.
1: Outputs sound for the duration specified by the length data in register NR41.
When sound output is finished, bit 3 of register NR52, the Sound 4 ON flag, is reset.

Initialize:
Setting this bit to 1 restarts Sound 4.

- Sound 4 Usage Notes

  If the contents of the envelope register (NR22) needs to be changed during sound operation (ON flag set to 1), the initialize flag should be set after the value in the envelope register is set.

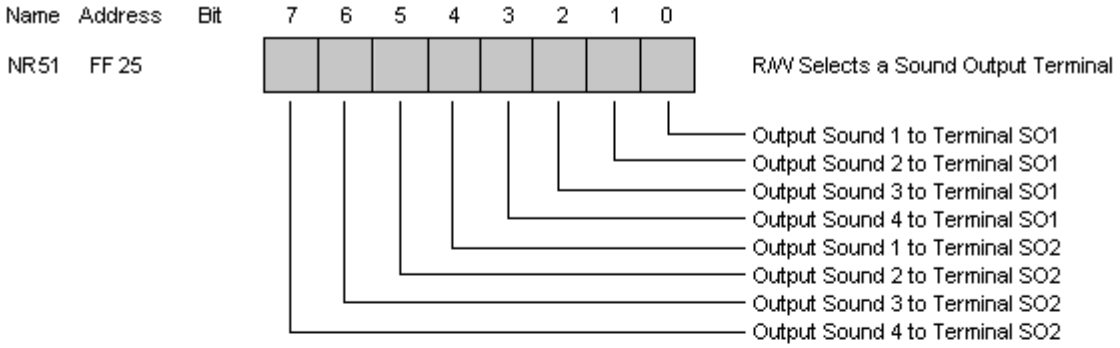
2.5 Sound Control Registers



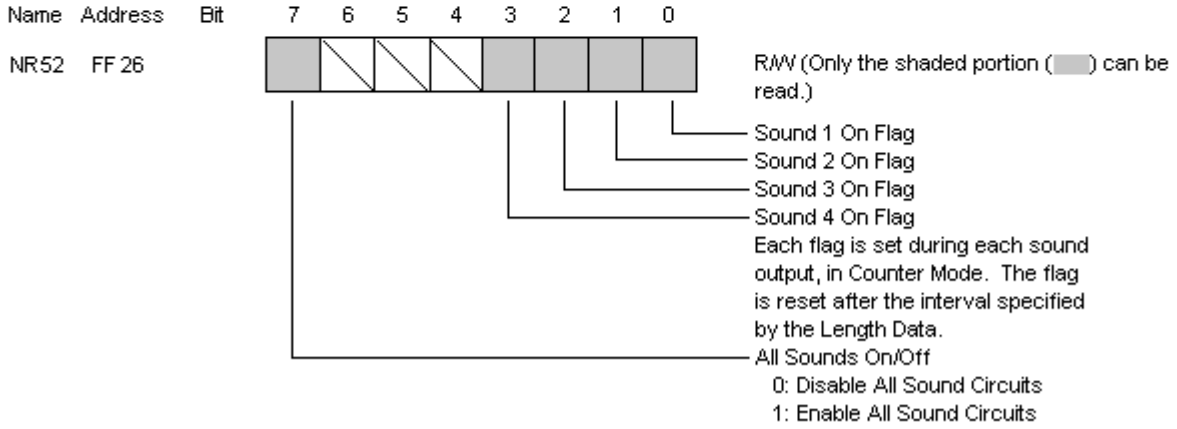
Output Level:
000: Minimum level (Maximum level ÷ 8)
111: Maximum level

V i n → SO1 ON/OFF (V i n → SO2 ON/OFF)
Synthesizes audio input from Vin terminal with sounds 1-4 and ouputs the result.

0: No output
1: Output



0: No Output
1: Output



3. VIN TERMINAL USAGE NOTES

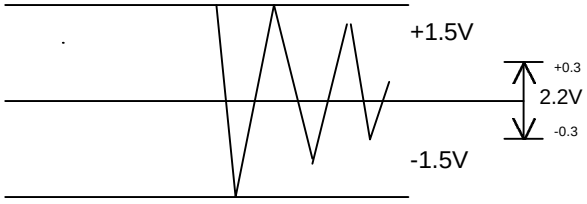
- The VIN terminal can be used normally only in CGB. (Since the signal from the VIN terminal is too low to be used, the VIN terminal cannot be used in DMG.)
- The maximum amplitude of the synthesized output is 3V.
- The design prevents the maximum amplitude from exceeding 3V when only sounds 1-4 are used, even when the output level for each sound is set to the maximum.

  When the output level is set to 0x0F, each sound is output at 0.75V.

  0.75V x 4 = 3V
- The maximum amplitude of the synthesized sound output also must be limited to 3V or less when the VIN terminal is used to input external sound.

Example: Using Sounds 1-4 and the VIN terminal

Use software to adjust the output levels of sounds 1-4 so that they do not exceed 0.6V (3V ÷).
Also limit the output level of the VIN terminal to 0.6V or less (input range of 1.9 - 2.5V).



- The input voltage from the VIN terminal also can be increased if the levels of the internal sounds are low or if not all 4 sounds are used (total output level of 3V or less).

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