Sound Document or How to Make Music with the Sega

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! Caveat : This information has been obtained by careful inspection of, and experimentation on the sound hardware. While the information is fairly complete with respect to the capacity of the sound hardware concerning the use of 'patches' and 'instruments', it is not complete with respect to the full capabilities of the Yamaha sound chip in the Sega. We know of specific capabilities that are not discussed in this document (Revision 0.2 specifically digitized sound output - Dan Thompson and Tim Wilson know how to do this.).

Some Definitions are in order.
Instrument: the basic high level unit of sound output or sound effect.
The sound chip has six instruments.
Voice: see waveform
Patch: the data that characterizes the sound quality of an instrument.
We might have a piano patch, or a phaser patch, or trumpet patch, etc.
Waveform: the lowest level of sound output. In our case each instrument is
capable of combing up to four waveforms.

More Caveats -
This is very much a 'document in progress' and serves mostly to give an over view. Also, this is the document to refer to when trying to figure out patch register function and use. For actually making sounds, the better choice of document is the Z-80 code of the Sound Driver. After all, the final proof of accuracy in documentation is when you have the sounds coming out of the machine, and to do that I highly recommend using the Sound Driver. It's a way of life. Any way, by using the Sound Driver, we can use your feedback to keep the Sound Driver and this document in a current state. So, if you use the Sound Driver and go hacking it to your own obscure purposes, <u>let us know what you have discovered</u> so we can incorporate and share your knowledge.
- thanks,
Andrew

Outline: (not followed rigorously)

I. The Z-80
   A. Communication with the 68000
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      2. Z-80 -> 68000
   B. Communication with the sound chip
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II. The Yamaha Sound Chip
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      3. Activate instrument Release

Sound Chip Register Access

There are two pages of registers that can be accessed in the sound chip. Each page is accessed by a pair of memory locations.

Page A:
SRegA at $4000 (Z-80 relative)
SValA at $4001

Page B:
SRegB at $4002
SValB at $4003

Setting the value of a register is accomplished as follows:

1. LD SVal and loop until bit 7 is clear.
2. LD SReg with the register number you want to access.
3. LD SVal with the data.

(for specific code example see the Sound Driver)

Register Map - stapled to back -

(see THINK C document - because this WP sucks)

The Sound Chip - Over View of Capabilities

The main feature we are concerned with in this document is the ability to generate music and sound effects. The Sound Chip is capable of playing six independent instruments simultaneously. Each of the instruments is identical in format.

Instrument Description: (here instrument and patch are used interchangeably)

An instrument is comprised of four wave forms labeled A, B, C and D.

Each wave form has associated the following variables:
Harmonic multiplier : the multiple of the root frequency.

Detune factor : a small 'delta' to pull the wave frequency away from tune.

Attenuation : control of the wave form amplitude.

Envelope scaler : an overall scaler for attack,decay,sustain and release timing.

Attack rate : control of the attack time of the envelope.

Decay rate : control of the decay time of the envelope.

Sustain Amplitude : control the volume sustain begins at.

Sustain : control of the sustain slope (zero slope is common to other kind of sound chip).

Release rate : control of the rate of envelope once release has been triggered.

Root frequency : control of the frequency that the harmonic multipliers use as a base from which to multiply.

Control A and Control B : control of how the wave forms are shaped, how they are combined and where they are output in terms of left/center/right channel.

The implementation of an instrument i.e. the above components are contained in a 32 byte patch:

	A	B	C	D
0	detune/ harmonic multiplier	...	...	...
1	attenuation	...	...	...
2	scaler/attack	...	...	...
3	decay	...	...	...
4	sustain	...	...	...
5	sustain level/ release	...	...	...
6	unknown function	unknown function	unknown function	unknown function
7	root frequency register L	root frequency register H		
8	Control register 1	Control register 2 — L,R output & Resonance		

Patch registers A0 thru A6, B0 thru B6, C0 thru C6, and D0 thru D6 have the same functional relations corresponding respectively to waveforms A, B, C, and D.

Patch register x0 - detune/harmonic multiplier

$x\ d_2\ d_1\ d_0\ h_3\ h_2\ h_1\ h_0$

h bits 0,1,2,3 choose the factor the root frequency is multiplied by to obtain the waveform frequency. They form a number between 0h and Fh.

h bits	multiplier	*h* bits	multiplier
0h	1	8h	16
1h	2	9h	18
2h	4	Ah	20
3h	6	Bh	22
4h	8	Ch	24
5h	10	Dh	26
6h	12	Eh	28
7h	14	Fh	30

d bits 4,5,6 control the degree to which the waveform frequency is pulled out of tune. They for a 3 bit 'signed' number which we tabulate in an 'unsigned' manner.

d bits	detune factor
%000	0.00%
%001	+0.10%
%010	+0.20%
%011	+0.25%
%100	0.00%
%101	-0.11%
%110	-0.20%
%111	-0.31%

(One use of the detune - by selecting two waves of the same frequency
and pulling one of them off tune, you can achive amplitude modulation
in the form of a 'beat' between the two waves.)

Patch register x1 - attenuation

$x\ v_6\ v_5\ v_4\ v_3\ v_2\ v_1\ v_0$

v bits choose the amount of attenuation applied to the waveform. 0 being no attenuation (full amplitude waveform) thru 0x7F being full attenuation (no waveform).

x bit - always observed to be 0.

v bits	amplitude
00h	100%
01h	91.2%
02h	83.3%
04h	69.8%
08h	49.3%
10h	25.6%
20h	7.9%
40h	2.8%

Patch register x2 - envelope scale and attack rate

$s_1\ s_0\ x\ a_4\ a_3\ a_2\ a_1\ a_0$

s bits control the scale factor applied to attack/decay/sustain/release.
%00 being the slowest factor and %11 being the quickest.
x bit has unknown function.

a bits control attack rate from never (0) to very fast (0x1F). the longest attack can be nearly 150 seconds, the shortest to fast to hear.

Patch register x3 - decay rate

$x\ x\ x\ d_4\ d_3\ d_2\ d_1\ d_0$

d bits control decay rate like the *a* bits in instrument register x2.

Patch register x4 - sustain rate

$x\ x\ x\ s_4\ s_3\ s_2\ s_1\ s_0$

s bits control sustain rate like the *a* bits in instrument register x2.

Patch register x5 - sustain level and release rate

$v_3\ v_2\ v_1\ v_0\ r_3\ r_2\ r_1\ r_0$

v bits control the level at which sustain is initiated - full volume (0)
no sound (0xF).
r bits control the rate at which a note is released once release is activated.
/* make sure to check what happens if 0 - not done yet in version 0.2 */

Patch register x6 - unknown function

~~These registers are almost always 0 in the patches observed~~ except for ~~one case where the are~~ 0x20, but I have not been able to detect any effect that they might produce. ~~(when set to FFh~~ there is no sound out.)
It is likely that their function is selected by some other bits, possibly in the control registers - I have a feeling they affect phase modulation, but I haven't verified this.

Patch registers A7 and B7 - root frequency

A7 - $f_7\ f_6\ f_5\ f_4\ f_3\ f_2\ f_1\ f_0$

least significant bits of the root frequency

B7 - $x\ x\ o_2\ o_1\ o_0\ f_{10}\ f_9\ f_8$

most significant bits of the root frequency, and the octave bits

x bits unknown function

o bits control the octave of the f bits

f bits are the most significant bits of the root frequency

the functional relation has been measured to be:

Frequency(*f*,*o*) = (0.0126990 ± 0.0000005) *f* * 2^*o* [Hz]

(Under some conditions - not specifically clear - the frequency or
at least the octave bits have an affect on the time scale of the envelope i.e. higher frequency makes for shorter envelope.)

Patch register A8 - waveform control 1

x w w w w s s s

~~Qualitatively this controls which waveforms are added to the composite waveform and the waveform shapes e.g. sine, sawtooth, or noise.
So far it appears that waveforms B, C, and D are restricted to being sinewaves and that waveform A can be selected to be sine/sawtooth/noise.
I belive that waveform B can also have a selected form but this is not yet verified.
A bitwise functional description is forthcoming.~~

This has proved to be a bit more difficult to determine than I expected.
Here is what I've found so far:

s bits	A	B	C	D
%000				X
%001				X
%010				X
%011				X
%100			X	X
%101		X	X	X
%110		X	X	X
%111	X	X	X	X

(X indicates wave present)

these bits are a little strange in that there doesn't seem to be a one to one relation between bit and wave (except wave C which seems to be turned on by bit 2). Wave D is always on, and waves A and B are on where there are Xs in the above table. I assume there are subtleties that I have missed so far.

the *w* bits seem to control the shape of wave form A.
When all the *w* bits are 0 wave A is sine shape. When all the bits are 1 wave A is 'noise', and between those values, the wave progresses from sine to sawtooth to noise in a 'linear' fashion.

Patch register B8 - waveform control 2

r l x_5 x_4 x_3 x_2 x_1 x_0

r - if set output to right channel

l - if set output to left channel

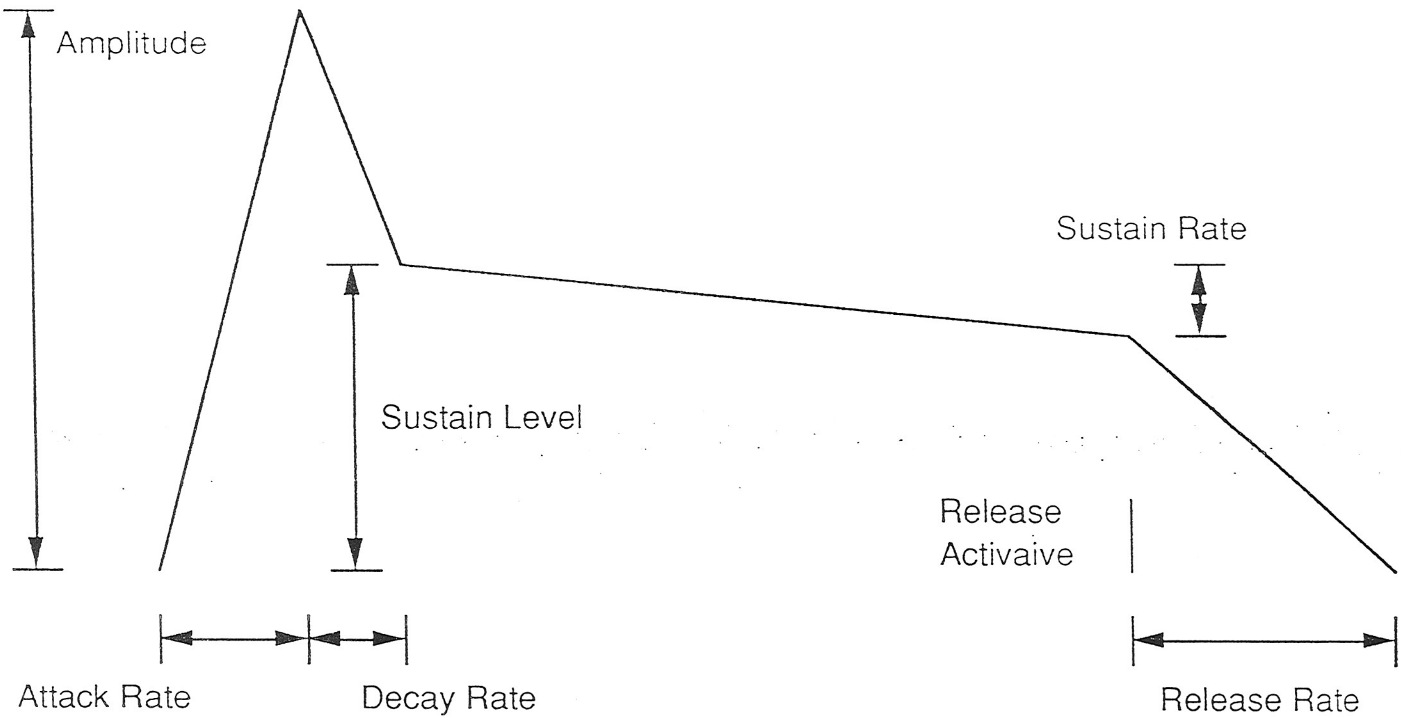
It follows that if neither *r* nor *l* are set there is no output (not strictly true - some leeks thru) and that if both *r* and *l* are set then the output is centered between right and left channels.

x bits - ~~qualitatively - they at least control some phase modulation in waveform D and possibly all the wave-forms. A bitwise functional description is forthcoming.~~

resonance

Note - qualitative functional descriptions of envelope timing is pending better measurement instruments to get exact timing.

Qualitative Envelope Diagram



Register Maps for the Sega Sound Chip:

How to read these maps :
the first digit corresponds to instrument number
the second two digits correspond to the patch register for that particular instur

special: RegA 0Fh is initialized to 27h
RegA 22h is initialized to 0Fh
RegA 28h is constantly being accessed to activate and release voices, see the Sound Driver code for how this is done.

Note: there doesn't seem to be any special requirments for order of accsess with the exception of the frequency registers (patch registers A7 and B7) : see the Sound Dri code for how this is done.

Register Page A

n	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0n	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	27h
1n	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2n	...	...	0Fh	...	...	...	...	...	xxx	...	...	...	...	...	...	...
3n	0A0	1A0	2A0	...	0B0	1B0	2B0	...	0C0	1C0	2C0	...	0D0	1D0	2D0	...
4n	0A1	1A1	2A1	...	0B1	1B1	2B1	...	0C1	1C1	2C1	...	0D1	1D1	2D1	...
5n	0A2	1A2	2A2	...	0B2	1B2	2B2	...	0C2	1C2	2C2	...	0D2	1D2	2D2	...
6n	0A3	1A3	2A3	...	0B3	1B3	2B3	...	0C3	1C3	2C3	...	0D3	1D3	2D3	...
7n	0A4	1A4	2A4	...	0B4	1B4	2B4	...	0C4	1C4	2C4	...	0D4	1D4	2D4	...
8n	0A5	1A5	2A5	...	0B5	1B5	2B5	...	0C5	1C5	2C5	...	0D5	1D5	2D5	...
9n	0A6	1A6	2A6	...	0B6	1B6	2B6	...	0C6	1C6	2C6	...	0D6	1D6	2D6	...
An	0A7	1A7	2A7	...	0B7	1B7	2B7	...	...	...	...	...	...	...	...	...
Bn	0A8	1A8	2A8	...	0B8	1B8	2B8	...	...	...	...	...	...	...	...	...
Cn	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Dn	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
En	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Fn	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Register Page B

n	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0n	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1n	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2n	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3n	3A0	4A0	5A0	...	3B0	4B0	5B0	...	3C0	4C0	5C0	...	3D0	4D0	5D0	...
4n	3A1	4A1	5A1	...	3B1	4B1	5B1	...	3C1	4C1	5C1	...	3D1	4D1	5D1	...
5n	3A2	4A2	5A2	...	3B2	4B2	5B2	...	3C2	4C2	5C2	...	3D2	4D2	5D2	...
6n	3A3	4A3	5A3	...	3B3	4B3	5B3	...	3C3	4C3	5C3	...	3D3	4D3	5D3	...
7n	3A4	4A4	5A4	...	3B4	4B4	5B4	...	3C4	4C4	5C4	...	3D4	4D4	5D4	...
8n	3A5	4A5	5A5	...	3B5	4B5	5B5	...	3C5	4C5	5C5	...	3D5	4D5	5D5	...
9n	3A6	4A6	5A6	...	3B6	4B6	5B6	...	3C6	4C6	5C6	...	3D6	4D6	5D6	...
An	3A7	4A7	5A7	...	3B7	4B7	5B7	...	...	...	...	...	...	...	...	...
Bn	3A8	4A8	5A8	...	3B8	4B8	5B8	...	...	...	...	...	...	...	...	...
Cn	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Dn	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
En	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Fn	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...