Programmer's Guide to Yamaha YMF 262/OPL3 FM Music Synthesizer

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Version 1.00 Nov-24-1994

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on your own.

INTRODUCTION

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The chip I am going to describe is getting more and more common, but

programming information is still scarce, so I have decided to fill in this

gap. All information contained in this file is a result of my experience in

Adlib programming, research (read: reverse engineering) and finally of my

effort to write down everything necessary to understand and use this piece

of hardware. No official sources (i.e. development kits, books about this

topic, etc.) were available to me except:

Adlib Programming Guide - by Tero Tîttî, and

The PC Games Programmers Encyclopedia V1.0

The information below is a combination of known features of Adlib (alias

Yamaha YM 3812/OPL2) and my own uncountable experiments and failures, which

brought out a lot of important details you have to know about the chip.

As far as I know, there are four major sound cards based on OPL3 chip:

\* Sound Blaster Pro II (not Sound Blaster Pro I)

\* Sound Blaster 16

\* Adlib Gold

\* Pro Audio Spectrum Plus/16

I currently have a Sound Blaster Pro II-compatible card only, so all the

programming info I provide will be based on this card. (The other cards

are quite similar, however. They are just wired at different I/O-port

addresses.)

Note: I assume some knowledge of FM music programming (mainly Adlib FM

synthesizer) in this manual. If you are new to this topic I recommend

you try Adlib first before going higher. Anyway, OPL3 is a direct

descendant of OPL2 (what a surprise), so most features of OPL2 are

also present on OPL3.

DESCRIPTION OF THE SYNTHESIZER

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My card's user manual says: "[this card contains] ... a stereo music

FM synthesizer with 20 channels consisting of four (4) operators each ... "

I thought: "Wow -- that's together eighty operators. This must be a GOOD

sound-card." I was wrong. Just another advertising lie.

So let's clear some facts. First, OPL3 has only thirty-six (36) operators

which can be combined in several ways:

\* 18 FM channels (36 operators), or

\* 15 FM channels (30 ops) and 5 percussion instruments (6 ops), giving

us 20 channels altogether, or

\* up to 6 four-operator FM channels (max 24 ops), the rest again being

divided into two-operator FM channels and drums.

From the table above you can see that not all channels can be used in four-

operator (4-OP) mode -- only a part of the synthesizer is really capable of

making 4-OP sounds -- the rest uses traditional two-operator (2-OP) mode.

Second, the manual states this card is capable of "stereo" music. Yes, the

quotes are necessary, because the stereo capabilities are very limited.

You are given ability to control output going to left or right channel by

turning it on and off. That's all. So the sound can flow from very left side,

center and very right side. No sound panning, no special stereo effects. :-(

Well, flaming apart, back to the main topic.

The OPL3 chip is capable of making sounds in several ways:

1. Two-operator Additive Synthesis

Output of both operators is simply added. It is the simplest way to

make any sound, and it works on both OPL2 and OPL3. The diagram

should make it clear.

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2. Two-operator Frequency Modulation (FM) Synthesis

Output from the first operator (Modulator) is sent to the input of the

second one (Carrier) and is used to modulate (alter) frequency of the

second operator. Only the second operator produces sound. Most of

interesting sounds are made this way. This also works on OPL2.

Hope the picture helps.

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≥ Operator 1 √ƒƒƒƒƒƒƒƒ>≥ Operator 2 √ƒƒƒƒƒƒƒƒ> Output

≥(Modulator) ≥ ≥ (Carrier) ≥

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3. Four-operator "Mess" Modulation Synthesis

All of OPL3's 4-OP configurations are combinations of the above two modes

of synthesis. OPL3 combines these two modes in four ways. I have no words

to describe these four ways. Only the pictures can show their principle.

a) FM-FM Mode

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b) AM-FM Mode

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c) FM-AM Mode

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d) AM-AM Mode

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Nice, aren't they?

The only way I think this can be written is a math formula.

Symbol + (plus) means additive synthesis, and \* (asterisk) means

frequency modulation (Op1 \* Op2 means operator 1 modulates operator 2,

not vice versa). Here they are:

a) FM-FM Mode: (Op1 \* Op2 \* Op3 \* Op4) ƒƒƒƒ> Output

b) AM-FM Mode: Op1 + (Op2 \* Op3 \* Op4) ƒƒƒ> Output

c) FM-AM Mode: (Op1 \* Op2) + (Op3 \* Op4) ƒƒ> Output

d) AM-AM Mode: Op1 + (Op2 \* Op3) + Op4 ƒƒƒ> Output

4. Percussion Mode

In this mode 6 operators are used to produce five different percussion

instruments:

\* Bass Drum (2 operators)

\* Snare Drum (1 operator)

\* Tom-Tom (1 operator)

\* Cymbal (1 operator)

\* Hi-Hat (1 operator)

Because these instruments occupy only three melodic channels, only

Bass Drum, Snare Drum and Tom-Tom frequencies can be set. Cymbal and

Hi-Hat frequencies are fixed.

This mode is identical with that of OPL2. For more details see ADLIB.DOC.

PROGRAMMING THE SYNTHESIZER

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OPL3 may be found at the following addresses:

Sound Blaster Pro II 220h or 240h (selectable), also 388h

Adlib Gold 388h

Pro Audio Spectrum Plus/16 ? (if you have a PAS you should know it)

The base address of the synthesizer will be called "base".

The chip occupies four I/O addresses:

base+0 Primary index register (write), Status register (read)

base+1 Primary data register (write-only)

base+2 Secondary index register (write)

base+3 Secondary data register (write-only)

The index registers are used to select internal registers and data registers

are used to write to them. Status register returns the state of two timers

built in the chip.

OPL3 contains two sets of registers. The Primary set maps to channels 0-8

(operators 0-17) and the secondary maps to channels 9-17 (operators 18-35).

The reason for this is simple: all these registers wouldn't fit into single

register set.

Unlike Adlib (OPL2), OPL3 doesn't need delay between register writes.

With OPL2 you had to wait 3.3 Ês after index register write and another

23 Ês after data register write. On the contrary OPL3 doesn't need

(almost) any delay after index register write and only 0.28 Ês after data

register write. This means you can neglect the delays and slightly speed up

your music driver. But using reasonable delays will certainly do no harm.

The data registers can't be read (they are write-only) on both OPL2 and OPL3.

REGISTER MAP

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The registers are grouped in the same manner as in the OPL2 chip. Programs

using both OPL2 and OPL3 chips may use the same code provided that their

direct I/O interface is well written. The only thing you have to change is

operator-to-register mapping, which must accomodate the fact that registers

are spread between two register sets.

(The register map is nearly the same so I dared to copy it from ADLIB.DOC.)

Status Register (base+0):

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≥ D7 D6 D5 D4 D3 D2 D1 D0 ≥

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≥IRQFlag ≥ T1Flag ≥ T2Flag ≥ ≥

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Data Registers (base+1, base+3):

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≥ 01 ≥ ≥WSEnable≥ Test Register ≥

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≥ 02 ≥ Timer 1 Count (80 Êsec resolution) ≥

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≥ 03 ≥ Timer 2 Count (320 Êsec resolution) ≥

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≥ 04\* ≥IRQReset≥ T1Mask ≥ T2Mask ≥ ≥T2 Start≥T1 Start≥

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≥ 04\*\*≥ ≥4-OP B-E≥4-OP A-D≥4-OP 9-C≥4-OP 2-5≥4-OP 1-4≥4-OP 0-3≥

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≥ 05\*\*≥ ≥ OPL3 ≥

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≥ 08 ≥ CSW ≥NOTE-SEL≥ ≥

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≥20-35≥Tremolo ≥Vibrato ≥Sustain ≥ KSR ≥ Frequency Multiplication Factor ≥

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≥40-55≥ Key Scale Level ≥ Output Level ≥

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≥60-75≥ Attack Rate ≥ Decay Rate ≥

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≥80-95≥ Sustain Level ≥ Release Rate ≥

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≥A0-A8≥ Frequency Number ( Lower 8 bits ) ≥

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≥B0-B8≥ ≥ KEY-ON ≥ Block Number ≥ F-Num (hi bits) ≥

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≥ BD ≥Trem Dep≥Vibr Dep≥PercMode≥ BD On ≥ SD On ≥ TT On ≥ CY On ≥ HH On ≥

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≥C0-C8≥ ≥ Right ≥ Left ≥FeedBack Modulation Factor≥SynthTyp≥

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≥E0-F5≥ ≥ Waveform Select ≥

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Notes:

\* This applies only to port base+1

\*\* This applies only to port base+3

For register bases A0, B0 and C0 there is one register per output channel.

The primary register set holds the first nine channels (0-8) and the secondary

holds last nine channels (9-17).

For bases 20, 40, 60, 80 and E0 there are two registers per channel. Each

register maps to one operator. Unfortunately the operator's register numbers

are not continuous. The following table shows which operator maps to which

register set and offset (in hex).

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≥ Op. Set/Offset ≥ Op. Set/Offset ≥

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≥ 0 0/00 ≥ 18 1/00 ≥

≥ 1 0/01 ≥ 19 1/01 ≥

≥ 2 0/02 ≥ 20 1/02 ≥

≥ 3 0/03 ≥ 21 1/03 ≥

≥ 4 0/04 ≥ 22 1/04 ≥

≥ 5 0/05 ≥ 23 1/05 ≥

≥ 6 0/08 ≥ 24 1/08 ≥

≥ 7 0/09 ≥ 25 1/09 ≥

≥ 8 0/0A ≥ 26 1/0A ≥

≥ 9 0/0B ≥ 27 1/0B ≥

≥ 10 0/0C ≥ 28 1/0C ≥

≥ 11 0/0D ≥ 29 1/0D ≥

≥ 12 0/10 ≥ 30 1/10 ≥

≥ 13 0/11 ≥ 31 1/11 ≥

≥ 14 0/12 ≥ 32 1/12 ≥

≥ 15 0/13 ≥ 33 1/13 ≥

≥ 16 0/14 ≥ 34 1/14 ≥

≥ 17 0/15 ≥ 35 1/15 ≥

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The following tables summarize which operators form a channel in various

modes:

1. Two-operator Melodic Mode

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≥ Channel ≥ 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 ≥

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≥ Operator 1 ≥ 0 1 2 6 7 8 12 13 14 18 19 20 24 25 26 30 31 32 ≥

≥ Operator 2 ≥ 3 4 5 9 10 11 15 16 17 21 22 23 27 28 29 33 34 35 ≥

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2. Two-operator Melodic and Percussion Mode

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≥ Channel ≥ 0 1 2 3 4 5 BD SD TT CY HH 9 10 11 12 13 14 15 16 17 ≥

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≥ Operator 1 ≥ 0 1 2 6 7 8 12 16 14 17 13 18 19 20 24 25 26 30 31 32 ≥

≥ Operator 2 ≥ 3 4 5 9 10 11 15 21 22 23 27 28 29 33 34 35 ≥

¿ƒƒƒƒƒƒƒƒƒƒƒƒ¡ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒŸ

3. Four-operator Melodic Mode

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≥ Channel ≥ 0 1 2 6 7 8 9 10 11 15 16 17 ≥

√ƒƒƒƒƒƒƒƒƒƒƒƒ≈ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ¥

≥ Operator 1 ≥ 0 1 2 12 13 14 18 19 20 30 31 32 ≥

≥ Operator 2 ≥ 3 4 5 15 16 17 21 22 23 33 34 35 ≥

≥ Operator 3 ≥ 6 7 8 24 25 26 ≥

≥ Operator 4 ≥ 9 10 11 27 28 29 ≥

¿ƒƒƒƒƒƒƒƒƒƒƒƒ¡ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒŸ

Channels 3, 4, 5 and 12, 13, 14 can't be used separately because their

operators became part of channels 0, 1, 2 and 9, 10, 11 respectively.

For instance a four-operator channel 1 consists of two two-operator

channels number 1 and 4. (The second 2-OP channel number is always the

first 2-OP channel number plus three.)

OPL3 allows you to enable/disable 4-OP mode separately for any of

channels 0, 1, 2, 9, 10 and 11 (see register 104h in the reference below).

This means for instance when you switch only channel 2 into 4-OP mode,

channels number 0, 1, 3, 4, 6, 7, 8, 9, etc. will be still independent

2-OP channels.

Channels 6, 7, 8 and 15, 16, 17 are always two-operator ones. They can't

be grouped to form four-operator channels.

4. Four-operator Melodic and Percussion Mode

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≥ Channel ≥ 0 1 2 BD SD TT CY HH 9 10 11 15 16 17 ≥

√ƒƒƒƒƒƒƒƒƒƒƒƒ≈ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ¥

≥ Operator 1 ≥ 0 1 2 12 16 14 17 13 18 19 20 30 31 32 ≥

≥ Operator 2 ≥ 3 4 5 15 21 22 23 33 34 35 ≥

≥ Operator 3 ≥ 6 7 8 24 25 26 ≥

≥ Operator 4 ≥ 9 10 11 27 28 29 ≥

¿ƒƒƒƒƒƒƒƒƒƒƒƒ¡ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒŸ

Examples:

\* Two-operator channel #14 consists of operators 26 and 29 which occupy

these registers (all are in the secondary register set):

12A - Operator 1 - Tremolo/Vibrato/Sustain/KSR/Multiplication

12D - Operator 2 - Tremolo/Vibrato/Sustain/KSR/Multiplication

14A - Operator 1 - Key Scale Level/Output Level

14D - Operator 2 - Key Scale Level/Output Level

16A - Operator 1 - Attack Rate/Decay Rate

16D - Operator 2 - Attack Rate/Decay Rate

18A - Operator 1 - Sustain Level/Release Rate

18D - Operator 2 - Sustain Level/Release Rate

1A5 - Frequency Number (low)

1B5 - Key On/Block Number/Frequency Number (high)

1C5 - FeedBack/Synthesis Type

1EA - Operator 1 - Waveform Select

1ED - Operator 2 - Waveform Select

\* Four-operator channel #1 consists of operators 1, 4, 7 and 10. All

registers except register 104h are in the primary set:

104 - bit 1 = 1 - Enable Four-Operator Synthesis in channel #1

21 - Operator 1 - Tremolo/Vibrato/Sustain/KSR/Multiplication

24 - Operator 2 - Tremolo/Vibrato/Sustain/KSR/Multiplication

29 - Operator 3 - Tremolo/Vibrato/Sustain/KSR/Multiplication

2C - Operator 4 - Tremolo/Vibrato/Sustain/KSR/Multiplication

41 - Operator 1 - Key Scale Level/Output Level

44 - Operator 2 - Key Scale Level/Output Level

49 - Operator 3 - Key Scale Level/Output Level

4C - Operator 4 - Key Scale Level/Output Level

61 - Operator 1 - Attack Rate/Decay Rate

64 - Operator 2 - Attack Rate/Decay Rate

69 - Operator 3 - Attack Rate/Decay Rate

6C - Operator 4 - Attack Rate/Decay Rate

81 - Operator 1 - Sustain Level/Release Rate

84 - Operator 2 - Sustain Level/Release Rate

89 - Operator 3 - Sustain Level/Release Rate

8C - Operator 4 - Sustain Level/Release Rate

A1 - Frequency Number (low)

A4 - Unused

B1 - Key On/Block Number/Frequency Number (high)

B4 - Unused

C1 - FeedBack/Synthesis Type (part 1)

C4 - Synthesis Type (part 2)

E1 - Operator 1 - Waveform Select

E4 - Operator 2 - Waveform Select

E9 - Operator 3 - Waveform Select

EC - Operator 4 - Waveform Select

NOTE: If a register number is greater than 100h, then it belongs into the

secondary register set. (I use this numbering to emphasize the fact

that the particular register MUST be written to the secondary set.)

See Appendix A.

OPL3 REGISTER REFERENCE

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Because the registers of OPL3 are almost the same as of OPL2, I have copied

their descriptions from file ADLIB.DOC.

\* Status Register:

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫IRQ≥T1 ≥T2 ≥ Not used ∫

”ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒΩ

bit 7: IRQ Flag. Set whenever any timer has elapsed.

bit 6: Timer 1 Flag. Set every time the preset time in Timer 1 has elapsed.

bit 5: Timer 2 Flag. Set every time the preset time in Timer 2 has elapsed.

Timer interrupts are not wired to any IRQ (why??). The timers can be used

to detect the OPL2/OPL3 chip (see Appendix B).

\* Data Registers:

01: Test Register / Waveform Select Enable:

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫ ≥WSE≥ Test Register ∫

”ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒΩ

bit 5: Waveform Select Enable. If clear, all channels will use normal

sine wave. If set, register E0-F5 (Waveform Select) contents

will be used.

bits 0-4: Test Register. Must be reset to zero before any operation.

02: Timer 1 Count:

Upward 8 bit counter with a resolution of 80 Êsec. If an overflow occurs,

the status register bit is set, and the preset value is loaded into the

timer again.

03: Timer 2 Count:

Same as Timer 1, but with a resolution of 320 Êsec.

004 (port: base+1): IRQ-Reset / Mask / Start:

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫Rst≥T1M≥T2M≥ ≥T2S≥T1S∫

”ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒΩ

bit 7: IRQ-Reset. Resets timer and IRQ flags in status register.

All other bits are ignored when this bit is set.

bit 6: Timer 1 Mask. If 1, status register is not affected in overflow.

bit 5: Timer 2 Mask. Same as above.

bit 1: Timer 2 Start. Timer on/off.

bit 0: Timer 1 Start. Same as above.

104 (port: base+3): Four-Operator Enable:

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫ ≥ChB≥ChA≥Ch9≥Ch2≥Ch1≥Ch0∫

”ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒΩ

bit 5: Enable four-operator synthesis for channel pair 11 - 14 (decimal).

bit 4: Same as above for channel pair 10 - 13.

bit 3: Same as above for channel pair 9 - 12.

bit 2: Same as above for channel pair 2 - 5.

bit 1: Same as above for channel pair 1 - 4.

bit 0: Same as above for channel pair 0 - 3.

If reset to zero, OPL3 can produce 18 two-operator sounds at a time.

If nonzero, OPL3 produces four-operator sound in appropriate channel pair.

105 (port: base+3): OPL3 Mode Enable:

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫ ≥OPL∫

”ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒΩ

bit 0: OPL3 Mode Enable. When set, OPL3 extensions (36 operators, 4-OP

synthesis, 8 waveforms, stereo output) can be used. When reset,

the chip behaves as an ordinary OPL2. This bit is zero by default

for compatibility with OPL2.

08: CSW / NOTE-SEL:

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫CSW≥N-S≥ ∫

”ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒΩ

bit 7: Composite sine wave mode on/off. All KEY-ON bits must be clear

in order to use this mode. The card is unable to create any other

sound when in CSW mode. (Unfortunately, I have no info how to

use this mode :-< ).

bit 6: NOTE-SEL. Controls the split point of the keyboard. When 0, the

keyboard split is the second bit from the bit 8 of the F-Number.

When 1, the MSb of the F-Number is used. (???)

20-35: Tremolo / Vibrato / Sustain / KSR / Frequency Multiplication Factor:

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫Tre≥Vib≥Sus≥KSR≥ Multiplication∫

”ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒΩ

bit 7: Tremolo (Amplitude vibrato) on/off.

bit 6: Frequency vibrato on/off.

bit 5: Sound Sustaining. When 1, operator's output level will be held at

its sustain level until a KEY-OFF is done.

bit 4: Envelope scaling (KSR) on/off. When 1, higher notes are shorter

than lower notes.

bits 0-3: Frequency Multiplication Factor (MULTI). Operator's frequency

is set to (see registers A0, B0) F-Number \* Factor.

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≥ MULTI ≥ Factor ≥

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≥ 0 ≥ ´ ≥

≥ 1 ≥ 1 ≥

≥ 2 ≥ 2 ≥

≥ 3 ≥ 3 ≥

≥ 4 ≥ 4 ≥

≥ 5 ≥ 5 ≥

≥ 6 ≥ 6 ≥

≥ 7 ≥ 7 ≥

≥ 8 ≥ 8 ≥

≥ 9 ≥ 9 ≥

≥ 10 ≥ 10 ≥

≥ 11 ≥ 10 ≥

≥ 12 ≥ 12 ≥

≥ 13 ≥ 12 ≥

≥ 14 ≥ 15 ≥

≥ 15 ≥ 15 ≥

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40-55: Key Scale Level / Output Level:

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫ KSL ≥ Output Level ∫

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bits 6-7: Key Scale Level. Attenuates output level towards higher pitch:

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≥ KSL ≥ Attenuation ≥

√ƒƒƒƒƒ≈ƒƒƒƒƒƒƒƒƒƒƒƒƒ¥

≥ 0 ≥ - ≥

≥ 1 ≥ 1.5 dB/oct ≥

≥ 2 ≥ 3.0 dB/oct ≥

≥ 3 ≥ 6.0 dB/oct ≥

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bits 0-5: Output Level. Attenuates the operator output level. 0 is the

loudest, 3F is the softest. In additive synthesis, varying

the output level of any operator varies the volume of its

corresponding channel. In FM synthesis, varying the output level

of the carrier varies the volume of the channel. Varying the

output of the modulator will change the frequency spectrum

produced by the carrier.

The following table summarizes which operators' output levels

should be updated when trying to change channel output level.

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≥ Mode ≥ Op 1 ≥ Op 2 ≥ Op 3 ≥ Op 4 ≥

√ƒƒƒƒƒƒƒ≈ƒƒƒƒƒƒ≈ƒƒƒƒƒƒ≈ƒƒƒƒƒƒ≈ƒƒƒƒƒƒ¥

≥ AM ≥ ˚ ≥ ˚ ≥ N/A ≥ N/A ≥

≥ FM ≥ - ≥ ˚ ≥ N/A ≥ N/A ≥

≥ FM-FM ≥ - ≥ - ≥ - ≥ ˚ ≥

≥ AM-FM ≥ ˚ ≥ - ≥ - ≥ ˚ ≥

≥ FM-AM ≥ - ≥ ˚ ≥ - ≥ ˚ ≥

≥ AM-AM ≥ ˚ ≥ - ≥ ˚ ≥ ˚ ≥

¿ƒƒƒƒƒƒƒ¡ƒƒƒƒƒƒ¡ƒƒƒƒƒƒ¡ƒƒƒƒƒƒ¡ƒƒƒƒƒƒŸ

60-75: Attack Rate / Decay Rate:

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫ Attack Rate ≥ Decay Rate ∫

”ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒΩ

bits 4-7: Attack Rate. Determines the rising time for the sound.

The higher the value, the faster the attack.

bits 0-3: Decay Rate. Determines the diminishing time for the sound.

The higher the value, the shorter the decay.

80-95: Sustain Level / Release Rate:

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫ Sustain Level ≥ Release Rate ∫

”ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒΩ

bits 4-7: Sustain Level. Determines the point at which the sound ceases

to decay and chages to a sound having a constant level. The

sustain level is expressed as a fraction of the maximum level.

0 is the softest and F is the loudest sustain level.

Note that the Sustain-bit in the register 20-35 must be set for

this to have an effect.

bits 0-3: Release Rate. Determines the rate at which the sound disappears

after KEY-OFF. The higher the value, the shorter the release.

A0-A8: Frequency Number:

Determines the pitch of the note. Highest bits of F-Number are stored

in the register below.

B0-B8: Key On / Block Number / F-Number(hi bits):

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫ ≥KEY≥ Block Num.≥ Freq ∫

”ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒΩ

bit 5: KEY-ON. When 1, channel output is enabled.

bits 2-4: Block Number. Roughly determines the octave.

bits 0-1: Frequency Number. 2 highest bits of the above register.

The following formula is used to determine F-Number and Block:

F-Number = Music Frequency \* 2^(20-Block) / 49716 Hz

NOTE: In four-operator mode only the register value of Operators 1 and 2

is used, value of Operators 3 and 4 in this register is ignored.

In other words: one channel uses only one frequency, block and KEY-ON

value at a time, regardless whether it is a two- or four-operator

channel.

BD: Tremolo Depth / Vibrato Depth / Percussion Mode / BD/SD/TT/CY/HH On:

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫Tre≥Vib≥Per≥BD ≥SD ≥TT ≥CY ≥HH ∫

”ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒΩ

bit 7: Tremolo (Amplitude Vibrato) Depth. 0 = 1.0dB, 1 = 4.8dB.

bit 6: Frequency Vibrato Depth. 0 = 7 cents, 1 = 14 cents.

A "cent" is 1/100 of a semi-tone.

bit 5: Percussion Mode. 0 = Melodic Mode, 1 = Percussion Mode.

bit 4: BD On. KEY-ON of the Bass Drum channel.

bit 3: SD On. KEY-ON of the Snare Drum channel.

bit 2: TT On. KEY-ON of the Tom-Tom channel.

bit 1: CY On. KEY-ON of the Cymbal channel.

bit 0: HH On. KEY-ON of the Hi-Hat channel.

NOTE: KEY-ON bits of channels 6, 7 and 8 must be clear and their

F-Nums, Attack/Decay/Release rates, etc. must be set properly

to use percussion mode.

C0-C8: FeedBack Modulation Factor / Synthesis Type:

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫ ≥ R ≥ L ≥ FeedBack ≥Syn∫

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bit 5: Right Speaker Enable. When set, channel output goes to right

speaker.

bit 4: Left Speaker Enable. When set, channel output goes to left

speaker. At least one of these bits must be set to hear

the channel.

These two bits can be used to realize sound "panning", but this

method offers only three pan positions (left/center/right).

These bits apply only to operators producing sound (Carriers).

Modulators are not affected by their setting.

bits 1-3: FeedBack Modulation Factor. If 0, no feedback is present. If 1-7,

operator 1 will send a portion of its output back into itself.

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≥ FeedBack ≥ Factor ≥

√ƒƒƒƒƒƒƒƒƒƒ≈ƒƒƒƒƒƒƒƒ¥

≥ 0 ≥ 0 ≥

≥ 1 ≥ „/16 ≥

≥ 2 ≥ „/8 ≥

≥ 3 ≥ „/4 ≥

≥ 4 ≥ „/2 ≥

≥ 5 ≥ „ ≥

≥ 6 ≥ 2˘„ ≥

≥ 7 ≥ 4˘„ ≥

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When in four-operator mode, the FeedBack value is used only by

Operator 1, value of Operators 2, 3 and 4 is ignored.

bit 0: Synthesis Type. 1 = Additive synthesis, 0 = Frequency Modulation

In four-operator mode, there are two bits controlling the

synthesis type. Both are the bit 0 of register C0, one of

Operators 1 and 2 and the second of Operators 3 and 4.

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≥ Op 1&2 ≥ Op 3&4 ≥ Type ≥

√ƒƒƒƒƒƒƒƒ≈ƒƒƒƒƒƒƒƒ≈ƒƒƒƒƒƒƒƒ¥

≥ 0 ≥ NONE ≥ FM ≥

≥ 1 ≥ NONE ≥ AM ≥

≥ 0 ≥ 0 ≥ FM-FM ≥

≥ 1 ≥ 0 ≥ AM-FM ≥

≥ 0 ≥ 1 ≥ FM-AM ≥

≥ 1 ≥ 1 ≥ AM-AM ≥

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E0-F5: Waveform Select:

÷ƒ7ƒ¬ƒ6ƒ¬ƒ5ƒ¬ƒ4ƒ¬ƒ3ƒ¬ƒ2ƒ¬ƒ1ƒ¬ƒ0ƒ∑

∫ ≥ WaveForm ∫

”ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒ¡ƒƒƒΩ

bits 0-2: WaveForm Select (WS):

WaveForm 0: Sine WaveForm 1: Half-Sine

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WaveForm 2: Abs-Sine WaveForm 3: Pulse-Sine

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WaveForm 4: Sine - even periods only

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WaveForm 5: Abs-Sine - even periods only

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WaveForm 6: Square

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WaveForm 7: Derived Square

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NOTE: Bit 5 of register 01 must be set to use waveforms other than sine.

Waveforms 4-7 are available only on OPL3.

See files WAVEn.GIF for real waveforms, where n is a number between

0 and 7.

APPENDIX A - EXAMPLES

---------------------

These examples show a few working routines used in my MUS Player.

They are written in Borland C++ 3.1 but should be easy to translate to any

other language.

--------------------------------- cut here ---------------------------------

// I prefer using these Assembler-like types

typedef unsigned int WORD;

typedef unsigned char BYTE;

/\*

\* FM Synthesizer base port. SB Pro II - 0x220, Adlib 0x388

\*/

WORD FMport = 0x220;

/\*

\* Enables OPL3 extensions.

\*/

WORD OPL3 = 1;

/\*

\* Direct write to any Adlib/SB Pro II FM synthetiser register.

\* reg - register number (range 0x001-0x0F5 and 0x101-0x1F5). When high byte

\* of reg is zero, data go to port FMport, otherwise to FMport+2

\* data - register value to be written

\*/

BYTE FMwriteReg(WORD reg, BYTE data)

{

asm {

mov dx,FMport

mov ax,reg

or ah,ah // high byte is nonzero -- write to port base+2

jz out1

inc dx

inc dx

}

out1: asm {

out dx,al

mov cx,6

}

loop1:asm { // delay between writes

in al,dx

loop loop1

inc dx

mov al,data

out dx,al

dec dx

mov cx,36

}

loop2:asm { // delay after data write

in al,dx

loop loop2

}

return \_AL;

}

/\*

\* Write to an operator pair. To be used for register bases of 0x20, 0x40,

\* 0x60, 0x80 and 0xE0.

\*/

void FMwriteChannel(BYTE regbase, BYTE channel, BYTE data1, BYTE data2)

{

static BYTE adlib\_op[] = {0, 1, 2, 8, 9, 10, 16, 17, 18};

static BYTE sbpro\_op[] = { 0, 1, 2, 6, 7, 8, 12, 13, 14,

18, 19, 20, 24, 25, 26, 30, 31, 32};

static WORD rg[] = {0x000,0x001,0x002,0x003,0x004,0x005,

0x008,0x009,0x00A,0x00B,0x00C,0x00D,

0x010,0x011,0x012,0x013,0x014,0x015,

0x100,0x101,0x102,0x103,0x104,0x105,

0x108,0x109,0x10A,0x10B,0x10C,0x10D,

0x110,0x111,0x112,0x113,0x114,0x115};

if (OPL3)

{

register WORD reg = sbpro\_op[channel];

FMwriteReg(rg[reg]+regbase, data1);

FMwriteReg(rg[reg+3]+regbase, data2);

} else {

register WORD reg = regbase+adlib\_op[channel];

FMwriteReg(reg, data1);

FMwriteReg(reg+3, data2);

}

}

/\*

\* Write to channel a single value. To be used for register bases of

\* 0xA0, 0xB0 and 0xC0.

\*/

void FMwriteValue(BYTE regbase, BYTE channel, BYTE value)

{

static WORD ch[] = {0x000,0x001,0x002,0x003,0x004,0x005,0x006,0x007,0x008,

0x100,0x101,0x102,0x103,0x104,0x105,0x106,0x107,0x108};

register WORD chan;

if (OPL3)

chan = ch[channel];

else

chan = channel;

FMwriteReg(regbase + chan, value);

}

--------------------------------- cut here ---------------------------------

APPENDIX B - DETECTION METHODS

------------------------------

An official method of Adlib (OPL2) detection is:

1. Reset Timer 1 and Timer 2: write 60h to register 4.

2. Reset the IRQ: write 80h to register 4.

NOTE: Steps 1 and 2 can't be combined together.

3. Read status register: read port base+0 (388h). Save the result.

4. Set Timer 1 to FFh: write FFh to register 2.

5. Unmask and start Timer 1: write 21h to register 4.

6. Wait in a delay loop for at least 80 Êsec.

7. Read status register: read port base+0 (388h). Save the result.

8. Reset Timer 1, Timer 2 and IRQ as in steps 1 and 2.

9. Test the results of the two reads: the first should be 0,

the second should be C0h.

If either is incorrect, then the OPL2 is not present.

NOTE1: You should AND the result bytes with E0h because the unused bits

are undefined.

NOTE2: This testing method doesn't work in some SoundBlaster compatible cards.

OPL3 DETECTION

--------------

0. Detect OPL2. If present, continue.

1. Read status register: read port base+0.

2. AND the result with 06h.

3. If the result is zero, you have OPL3, otherwise OPL2.

NOTE: This is NOT an official method. I have dug it out of a sound driver.

I haven't tested it, because I haven't an OPL2 card (Adlib, SB Pro I).

Nevertheless it "detects" my SB Pro II properly. ;-)

Another possible detection method for distinguishing between SB Pro I and

SB Pro II would be to try to detect OPL2 at I/O port base+0 and then at port

base+2. The first test should succeed and the second should fail if OPL3 is

present. (Remember: SB Pro I contains twin OPL2 chips at addresses base+0 and

base+2, while SB Pro II contains one OPL3 chip at I/O address base+0 thru

base+3).

BLASTER ENVIRONMENT VARIABLE

----------------------------

Perhaps the most recommended "detection" method. Reading this variable avoids

blindfold I/O port scanning and possible device conflicts. The user is

responsible for its proper setting.

The variable has this format:

BLASTER=Aaddr Iirq Ddma Ttype

A: Base I/O address given in hex. For most Sound Blasters the default is 220.

I: IRQ Number (decimal). Default 7.

D: DMA Number (decimal). Default 1.

T: Card Type (decimal):

1 - Sound Blaster 1.5

2 - Sound Blaster Pro I

3 - Sound Blaster 2.0

4 - Sound Blaster Pro II

Example:

BLASTER=A220 I7 D1 T4

REFERENCES

----------

Title: The PC Games Programmers Encyclopedia

Authors: Mark Feldman and many others on Usenet and Internet

FTP: teeri.oulu.fi

/pub/msdos/programming/gpe

... you can find (almost) everything you need there

Title: Sound Blaster - The Official Book

Authors: Richard Heimlich, David M. Golden, Ivan Luk, Peter M. Ridge

Publishers: Osborne/McGraw Hill

ISBN: 0-07-881907-5

... this is a number-one in my book-wishlist. If anyone wanted to get rid of

the book, I wouldn't scorn it ... :-)

Title: The SoundBlaster Developer Kit

Publishers: Creative Labs Inc

Creative Technology PTE LTD

... I wonder if you can find something comprehensible in that.