# Programming the AdLib/Sound Blaster FM Music Chips

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## Warranty and Copyright Policy



## Overview

Two of the most popular sound cards for the IBM-PC, the AdLib and the Sound Blaster, suffer from a real dearth of clear documentation for programmers. AdLib Inc. and Creative Labs, Inc. both sell developers' kits for their sound cards, but these are expensive, and (in the case of the Sound Blaster developers' kit) can be extremely cryptic.

This document is intended to provide programmers with a FREE source of information about the programming of these sound cards.

The information contained in this document is a combination of information found in the Sound Blaster Software Developer's Kit, and that learned by painful experience. Some of the information may not be valid for AdLib cards; if this is so, I apologize in advance.

Please note that numbers will be given in hexadecimal, unless otherwise indicated. If a number is written out longhand (sixteen instead of 16) it is in decimal.

## Chapter One - Sound Card I/O

The sound card is programmed by sending data to its internal registers via its two I/O ports:

```
0388 (hex) - Address/Status port (R/W)
0389 (hex) - Data port (W/O)
```

The Sound Blaster Pro is capable of stereo FM music, which is accessed in exactly the same manner. Ports 0220 and 0221 (hex) are the address/ data ports for the left speaker, and ports 0222 and 0223 (hex) are the ports for the right speaker. Ports 0388 and 0389 (hex) will cause both speakers to output sound.

The sound card possesses an array of two hundred forty-four registers; to write to a particular register, send the register number (01-F5) to the address port, and the desired value to the data port.

After writing to the register port, you must wait twelve cycles before sending the data; after writing the data, eighty-four cycles must elapse before any other sound card operation may be performed.

The AdLib manual gives the wait times in microseconds: three point three (3.3) microseconds for the address, and twenty-three (23) microseconds for the data.

AdLib suggested that the delays be produced by reading the register port six times after writing to the register port, and reading the register port thirty-five times after writing to the data port. With the advent of much faster machines, however, this method is not necessarily reliable.

The sound card registers are write-only.

The address port also functions as a sound card status byte. To retrieve the sound card's status, simply read port 388. The status byte has the following structure:

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| both timers | timer 1 | timer 2 | unused | | | | |

Bit 7 - set if either timer has expired.
6 - set if timer 1 has expired.
5 - set if timer 2 has expired.

## Chapter Two - The Registers

The following table shows the function of each register in the sound card. Registers will be explained in detail after the table. Registers not listed are unused.

| Address | Function |
|---|---|

| | |
|---|---|
| 01 | Test LSI / Enable waveform control |
| 02 | Timer 1 data |
| 03 | Timer 2 data |
| 04 | Timer control flags |
| 08 | Speech synthesis mode / Keyboard split note select |
| 20..35 | Amp Mod / Vibrato / EG type / Key Scaling / Multiple |
| 40..55 | Key scaling level / Operator output level |
| 60..75 | Attack Rate / Decay Rate |
| 80..95 | Sustain Level / Release Rate |
| A0..A8 | Frequency (low 8 bits) |
| B0..B8 | Key On / Octave / Frequency (high 2 bits) |
| BD | AM depth / Vibrato depth / Rhythm control |
| C0..C8 | Feedback strength / Connection type |
| E0..F5 | Wave Select |

The groupings of twenty-two registers (20-35, 40-55, etc.) have an odd order due to the use of two operators for each FM voice. The following table shows the offsets within each group of registers for each operator.

| **Channel** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
|---|---|---|---|---|---|---|---|---|---|
| Operator 1 | 00 | 01 | 02 | 08 | 09 | 0A | 10 | 11 | 12 |
| Operator 2 | 03 | 04 | 05 | 0B | 0C | 0D | 13 | 14 | 15 |

Thus, the addresses of the attack/decay bytes for channel 3 are 62 for the first operator, and 65 for the second. (The address of the second operator is always the address of the first operator plus three).

To further illustrate the relationship, the addresses needed to control channel 5 are:

| | | |
|---|---|---|
| **29** | Operator 1 | AM/VIB/EG/KSR/Multiplier |
| **2C** | Operator 2 | AM/VIB/EG/KSR/Multiplier |
| **49** | Operator 1 | KSL/Output Level |
| **4C** | Operator 2 | KSL/Output Level |
| **69** | Operator 1 | Attack/Decay |
| **6C** | Operator 2 | Attack/Decay |
| **89** | Operator 1 | Sustain/Release |

| | | |
|---|---|---|
| **8C** | Operator 2 | Sustain/Release |
| **A4** | | Frequency (low 8 bits) |
| **B4** | | Key On/Octave/Frequency (high 2 bits) |
| **C4** | | Feedback/Connection Type |
| **E9** | Operator 1 | Waveform |
| **EC** | Operator 2 | Waveform |

## Explanations of Registers

**Byte 01** This byte is normally used to test the LSI device. All bits should normally be zero. Bit 5, if enabled, allows the FM chips to control the waveform of each operator.

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| unused | | WS | unused | | | | |

**Byte 02** Timer 1 Data. If Timer 1 is enabled, the value in this register will be incremented until it overflows. Upon overflow, the sound card will signal a TIMER interrupt (INT 08) and set bits 7 and 6 in its status byte. The value for this timer is incremented every eighty (80) microseconds.

**Byte 03** Timer 2 Data. If Timer 2 is enabled, the value in this register will be incremented until it overflows. Upon overflow, the sound card will signal a TIMER interrupt (INT 08) and set bits 7 and 5 in its status byte. The value for this timer is incremented every three hundred twenty (320) microseconds.

**Byte 04** Timer Control Byte

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| IRQ Reset | Tmr1 Mask | Tmr2 Mask | unused | | | Tmr2 Ctrl | Tmr3 Ctrl |

bit 7 - Resets the flags for timers 1 & 2. If set, all other bits are ignored.

bit 6 - Masks Timer 1. If set, bit 0 is ignored.

bit 5 - Masks Timer 2. If set, bit 1 is ignored.

bit 1 - When clear, Timer 2 does not operate.
When set, the value from byte 03 is loaded into Timer 2, and incrementation

begins.

bit 0 - When clear, Timer 1 does not operate.
When set, the value from byte 02 is loaded into Timer 1, and incrementation begins.

**Byte 08** CSM Mode / Keyboard Split.

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| CSM sel | Key spl | unused | | | | | |

bit 7 - When set, selects composite sine-wave speech synthesis mode (all KEY-ON bits must be clear). When clear, selects FM music mode.

bit 6 - Selects the keyboard split point (in conjunction with the F-Number data). The documentation in the Sound Blaster manual is utterly incomprehensible on this; I can't reproduce it without violating their copyright.

**Bytes 20-35** Amplitude Modulation / Vibrato / Envelope Generator Type / Keyboard Scaling Rate / Modulator Frequency Multiple

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| Amp Mod | Vib | EG Typ | KSR | Modulator Frequency Multiple | | | |

bit 7 - Apply amplitude modulation when set; AM depth is controlled by the AM-Depth flag in address BD.

bit 6 - Apply vibrato when set; vibrato depth is controlled by the Vib-Depth flag in address BD.

bit 5 - When set, the sustain level of the voice is maintained until released; when clear, the sound begins to decay immediately after hitting the SUSTAIN phase.

bit 4 - Keyboard scaling rate. This is another incomprehensible bit in the Sound Blaster manual. From experience, if this bit is set, the sound's envelope is foreshortened as it rises in pitch.

bits 3-0 - These bits indicate which harmonic the operator will produce sound (or modulation) in relation to the voice's specified frequency:

0 - one octave below

1 - at the voice's specified frequency
2 - one octave above
3 - an octave and a fifth above
4 - two octaves above
5 - two octaves and a major third above
6 - two octaves and a fifth above
7 - two octaves and a minor seventh above
8 - three octaves above
9 - three octaves and a major second above
A - three octaves and a major third above
B - *three octaves and a major third above*
C - three octaves and a fifth above
D - *three octaves and a fifth above*
E - three octaves and a major seventh above
F - *three octaves and a major seventh above*

**Bytes 40-55** Level Key Scaling / Total Level

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| Scaling Level | | 24 dB | 12 dB | 6 dB | 3 dB | 1.5 dB | .75 dB |

bits 7-6 - causes output levels to decrease as the frequency rises:
- 00 - no change
- 10 - 1.5 dB/8ve
- 01 - 3 dB/8ve
- 11 - 6 dB/8ve

bits 5-0 - controls the total output level of the operator. All bits CLEAR is loudest; all bits SET is the softest. Don't ask me why.

**Bytes 60-75** Attack Rate / Decay Rate

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| Attack Rate | | | | Decay Rate | | | |

bits 7-4 - Attack rate. 0 is the slowest, F is the fastest.

bits 3-0 - Decay rate. 0 is the slowest, F is the fastest.

**Bytes 80-95** Sustain Level / Release Rate

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| Sustain Level | | | | Release Rate | | | |

bits 7-4 - Sustain Level. 0 is the loudest, F is the softest.

Bit 7 - 24 dB
Bit 6 - 12 dB
Bit 5 - 6 dB
Bit 4 - 3 dB

bits 3-0 - Release rate. 0 is the slowest, F is the fastest.

**Bytes A0-B8** Octave / F-Number / Key-On

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| F-Number (least significant byte) | | | | | | | |

**(A0-A8)**

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| Unused | | Key On | Octave | | | F-Number most sig. | |

**(B0-B8)**

bit 5 - Channel is voiced when set, silent when clear.

bits 4-2 - Octave (0-7). 0 is lowest, 7 is highest.

bits 1-0 - Most significant bits of F-number.

In octave 4, the F-number values for the chromatic scale and their corresponding frequencies would be:

| F Number | Frequency (decimal) | Note |
|---|---|---|
| 16B | 277.2 | C# |
| | | |

| | | |
|---|---|---|
| 181 | 293.7 | D |
| 198 | 311.1 | D# |
| 1B0 | 329.6 | E |
| 1CA | 349.2 | F |
| 1E5 | 370.0 | F# |
| 202 | 392.0 | G |
| 220 | 415.3 | G# |
| 241 | 440.0 | A |
| 263 | 466.2 | A# |
| 287 | 493.9 | B |
| 2AE | 523.3 | C |

**Bytes C0-C8** Feedback / Algorithm

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| unused | | | | Feedback | | | Decay Alg |

bits 3- Feedback strength. If all three bits are set to zero, no feedback is present.
1 - With values 1-7, operator 1 will send a portion of its output back into itself. 1 is the least amount of feedback, 7 is the most.

bit 0 - If set to 0, operator 1 modulates operator 2. In this case, operator 2 is the only one producing sound. If set to 1, both operators produce sound directly. Complex sounds are more easily created if the algorithm is set to 0.

**Byte BD** Amplitude Modulation Depth / Vibrato Depth / Rhythm

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| AM Dep | Vib Dep | Rhy Ena | BD | SD | TOM | Top Cym | HH |

bit 7 - Set: AM depth is 4.8 dB
Clear: AM depth is 1 dB

bit 6 - Set: Vibrato depth is 14 cent
Clear: Vibrato depth is 7 cent

bit 5 - Set: Rhythm enabled (6 melodic voices)
Clear: Rhythm disabled (9 melodic voices)

bit 4 - Bass drum on/off

bit 3 - Snare drum on/off

bit 2 - Tom tom on/off

bit 1 - Cymbal on/off

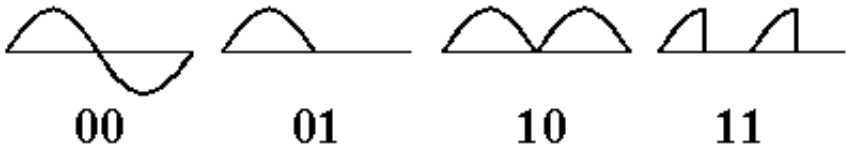
bit 0 - Hi Hat on/off

Note: KEY-ON registers for channels 06, 07, and 08 must be OFF in order to use the rhythm section. Other parameters such as attack/decay/sustain/release must also be set appropriately.

**Bytes E0-F5** Waveform Select

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| unused | | | | | | Waveform Select | |

bits 1- When bit 5 of address 01 is set, the output waveform will be distorted
0 - according to the waveform indicated by these two bits:




## Detecting a Sound Card

According to the AdLib manual, the 'official' method of checking for a sound card is as follows:

1. Reset both timers by writing 60h to register 4.
2. Enable the interrupts by writing 80h to register 4.
   **NOTE:** this must be a separate step from number 1.
3. Read the status register (port 388h). Store the result.
4. Write FFh to register 2 (Timer 1).
5. Start timer 1 by writing 21h to register 4.
6. Delay for at least 80 microseconds.
7. Read the status register (port 388h). Store the result.
8. Reset both timers and interrupts (see steps 1 and 2).
9. Test the stored results of steps 3 and 7 by ANDing them with E0h. The result of step 3 should be 00h, and the result of step 7 should be C0h. If both are correct, an AdLib-

compatible board is installed in the computer.

## Making a Sound

Many people have asked me, upon reading this document, what the proper register values should be to make a simple sound. Well, here they are.

First, clear out all of the registers by setting all of them to zero. This is the quick-and-dirty method of resetting the sound card, but it works. Note that if you wish to use different waveforms, you must then turn on bit 5 of register 1. (This reset need be done only once, at the start of the program, and optionally when the program exits, just to make sure that your program doesn't leave any notes on when it exits.)

Now, set the following registers to the indicated value:

| REGISTER | VALUE | DESCRIPTION |
|---|---|---|
| 20 | 01 | Set the modulator's multiple to 1 |
| 40 | 10 | Set the modulator's level to about 40 dB |
| 60 | F0 | Modulator attack: quick; decay: long |
| 80 | 77 | Modulator sustain: medium; release: medium |
| A0 | 98 | Set voice frequency's LSB (it'll be a D#) |
| 23 | 01 | Set the carrier's multiple to 1 |
| 43 | 00 | Set the carrier to maximum volume (about 47 dB) |
| 63 | F0 | Carrier attack: quick; decay: long |
| 83 | 77 | Carrier sustain: medium; release: medium |
| B0 | 31 | Turn the voice on; set the octave and freq MSB |

To turn the voice off, set register B0h to 11h (or, in fact, any value which leaves bit 5 clear). It's generally preferable, of course, to induce a delay before doing so.

## Acknowledgements

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