4.1 Programming the YM3812

This section provides information about the Ad Lib Music Synthesizer Card for advanced programmers who wish to program it directly. There is information on the components of the card, a technical description of the operators, the input / output map and a register reference section.

The Ad Lib Music Synthesizer Card

The card is equipped with a vibrato oscillator, an amplitude oscillator (tremolo), a noise generator which allows for the combination of a number of frequencies, two programmable timers, composite sine wave synthesis and 18 operators.

A white noise generator is used to create rhythm sounds. This white noise generator uses voices 7 and 8 (melodic voices), frequency information (Block, F-Number, Multi), and the proper phase output. Various rhythm sounds are produced by combining this output signal with white noise. The resulting signal is then sent to the operators. Experience has shown that the best ratio for the two frequencies is 3:1 (melodic voice 7 frequency = 3 times melodic voice 8 frequency). Finally, envelope information is multiplied with the wave table output. As the envelope is set for one operator which corresponds to a single rhythm instrument, the values which express that instrument's characteristics are set in the parameter registers in the same manner as for melody instruments.

Operators

The ALMSC uses pure sine waves that interact together to produce the full harmonic spectrum for any voice. Each digital sine wave oscillator is combined with its own envelope generator to form an "operator".

An operator has 2 inputs and 1 output. One input is the pitch oscillator frequency and the other is for the modulation data. The frequency and modulation data (phases) are added together and converted to a sine wave signal. The phase generator (PG) converts the frequency (w) into a phase by multiplying it by time (t). An envelope generator (EG) produces a time variant amplitude signal (ADSR). The EG's output is then multiplied by the sine wave and output to the outside world.

The operator output can be expressed as a mathematical expression:

F(t) = E(t) sin(wt + _)

E(t) is the output from the EG, w is the frequency, t is time and _ is the phase modulation.

The operators can be connected in three different ways: additive, frequency modulation and composite sine wave.

- **FM synthesis**
  FM synthesis uses two operators in series. The first operator, the modulator, modulates the second operator via its modulation input. The name given to the second operator is the carrier. The modulator can feed back its output into its modulation data input;

  $F_m(t) = E_m(t)\ \sin(w_m t + ßF_m(t))$ Modulator and feedback
  $F_c(t) = E_c(t)\ \sin(w_c t + F_m(t))$ Carrier and Modulator

- **Additive synthesis**
  Additive synthesis connects two operators in parallel, adding both outputs together. This method of synthesis is not as interesting as FM synthesis, but it can generate good organ type sounds.

  The simplified formula for the additive synthesis is:

  $F(t) = E_1(t)\ \sin(wt + \_{}_1) + E_2(t)\ \sin(wt + \_{}_2)$

- **Composite sine wave synthesis**
  Composite sine wave synthesis (CSW) may be used to generate speech or other related sounds by playing all voices simultaneously. When using this mode the card cannot generate any other sounds. This mode is not used because other methods have proved to provide better quality speech.

ALMSC Input / Output Map

The ALMSC is located at address 388H in the i/o space. The card decodes two addresses: 388H and 389H. The first address is used for selecting the register address and the second is used for writing data to the selected register. There also exists the possibility of using three other addresses: 218H, 288H and 318H. The port address is currently hard-wired, but address jumpers may be added in the future so you may want to take into account the possibility of using different addresses when programming. Here is a register map of the ALMSC:

Because of the nature of the card, you must wait 3.3 µsec after a register select write and 23 µsec for a data write. Only the status register located at address 388H can be read.

For many parameters, there is one register per operator. However, there are holes in the address map so that the operator number cannot be used as an offset into the map. The operator offsets are as follows:

For example, the KSL/TL registers are at 40H-55H. If we wish to access the register for operator 8, we must write to register 49H (NOT 48H).

Register Reference

Test Register/WSE

This register must be initialized to zero before taking any action. The wave select enable/disable bit (WSE) is D5. If set to 1, the value in the WS register will be used to select the wave form used to generate sound. If the WSE is set to 0, the value in the WS register will be ignored and the chip will use a sine wave. (The available waveforms are detailed later in this section).

Timers

The timers are not wired on the card. However, the following information is included since the timers can be used to detect the presence of our card in the computer.

Timer-1 is an upward 8 bit counter with a resolution of 80 µsec. If an overflow occurs, the status register flag FT1 is set, and the preset value (address = 02) is loaded into Timer-1. Timer-2 (address = 03) is an upward 8 bit counter just like Timer-1 except that the resolution is 320 µsec.

$$T_{overflow}(ms) = (256-N) * K$$

N is the preset value and K is the timer constant equal to 0.08 for Timer-1 and 0.32 for Timer-2. Register address 04 controls the operation of both timers. ST1 and ST2 (start/stop T1 or T2) bits start or stop the timers. When the corresponding bit is 1 the counter is loaded and counting starts, but when 0 the counter is held.

The Mask bits are used to gate the status register timer flags. If a mask bit is 1 then the corresponding timer flag bit is kept low (0) and is active when the mask bit is cleared (0). The most significant bit (MSb) is called IRQ-RESET. It resets timer flags and IRQ flag in the status register to zero. All other bits in the control register are ignored when the IRQ-RESET bit is 1.

Status Register

Reading at address 388H yields the following byte of information:

D0 - D4 are unused.
D5 Timer 2 flag: Set to 1 when the preset time in Timer 2 has elapsed. The flag remains until reset.
D6 Same as D5, except for Timer 1.
D7 IRQ flag: set if D5 or D6 are 1.

As mentioned earlier, the timer interrupts are not connected, but the timers can be used to detect the presence of the board as follows:

1. Reset T1 and T2: write 60H to register 4.
2. Reset the IRQ: write 80H to register 4 (this step must NOT be combined with Step #1).
3. Read status register: read at 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 µsec.
7. Read the status register and save the result.
8. Reset T1, T2 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 an ALMSC board is not present. (NOTE: You should AND the result bytes with E0H as the unused bits are undefined.)

CSM/Keyboard Split

This register (address = 08) will determine if the card is to function in music mode (CSM = 0) or speech synthesis mode (CSM = 1) as well as the keyboard split point.

When using composite sine wave speech synthesis mode all voices should be in the KEY-OFF state. The bit NOTE-SEL (D6) is used to control the split point of the keyboard. When 0, the keyboard split is the second bit from the MSb (bit 8) of the F-Number. The MSb of the F-number is used when NOTE-SEL = 1. This is illustrated in the following table:

AM/VIB/EG-TYP/KSR/Multiple

This group of registers (addresses 20H to 35H), one per operator, controls the frequency conversion factor and modulating wave frequencies corresponding to the frequency components of music.

The MULTI 4-bit field determines the multiplication factor applied to the input pitch frequency in the PG section. That is, an operator's frequency will automatically be multiplied according to the value in this field. The multiplication factors are given in the following table:

The operator output can then be expressed, with "_" as the multiplication factor, as follows:

$$F(t) = E_c(t) \sin(\_{c}w_c t + E_m \sin(\_{m}w_m t))$$

The KSR bit (position = D4) changes the rates for the envelope generator (EG). This parameter makes it possible to gradually shorten envelope length (increase EG rates) as higher notes on the keyboard are played. This is particularly useful for simulating the sound of stringed instruments such as piano and guitar, in which the envelope of the higher notes is noticeably shorter than the lower notes. The actual rate is then equal to the ADSR value plus an offset:

Actual rate = 4*Rate + KSR offset

The KSR offset is specified in the following table:

The EG-Type activates the sustaining part of the envelope when the EG-Type is set (1). Once set, an operator's frequency will be held at its sustain level until a KEY-OFF is done.

The VIB parameter toggles the frequency vibrato (1 = on, 0 = off). The frequency of the vibrato is 6.4 Hz and the depth is determined by the DEP VIB bit in register 0BDH.

The AM parameter is similar to the VIB parameter except that it is an amplitude vibrato (tremolo) of frequency 3.7Hz. The amplitude vibrato depth is determined by the DEP AM bit in register 0BDH.

KSL/Total Level

These registers (addresses 40H to 55H, 1 per operator) control the attenuation of the operator's output signal. The KSL parameter produces a gradual decrease in note output level towards higher pitch notes. Many acoustic instruments exhibit this gradual decrease in output level. The KSL is expressed on 2 bits (value 0 through 3). The corresponding attenuation is given below:

D7	D6	Attenuation
0	0	0
1	0	1.5dB/oct
0	1	3.0dB/oct
1	1	6.0dB/oct

The Total Level (TL) attenuates the operator's output. In FM synthesis mode, varying the output level of an operator functioning as a carrier results in a change in the volume of that operator's voice. Attenuating the output from a modulator will change the frequency spectrum produced by the carrier. In additive synthesis, varying the output level of any operator varies the volume of its corresponding voice. The TL value has a range of 0 through 63 (6 bits). To convert this value into an output level, apply the following formula:

$$\text{Output level} = (63 - TL) * 0.75\text{dB}$$

ADSR

These values change the shape of the envelope for the specified operator by changing the rates or the levels. The attack (AR) and the decay (DR) rates are at addresses 60H to 75H (1 per operator). The Sustain Level (SL) and Release Rate (RR) are located at addresses 80H to 95H. All of these values are 4 bits in length (range 0 to 15). Refer to the diagram on page 11 for more information.

The attack rate (AR) determines the rising time for the sound. The higher the value in this register, the faster the attack.

The decay rate (DR) determines the diminishing time for the sound. The higher the value in the DR register, the shorter the decay.

The sustain level (SL) is the point at which the sound ceases to decay and changes to a sound having a constant level. The sustain level is expressed as a fraction of the maximum level. When all bits are set, the maximum level is reached. Note that the EG-Type bit must be set for this to have an effect.

The release rate (RR) determines the rate at which the sound disappears after a Key-Off. The higher the value in the RR register, the shorter the release time.

BLOCK/F-Number

These parameters determine the pitch of the note played. The Block parameter determines the octave while the F-Number (10 bits) further specifies the frequency. The following formula is used to determine the value of F-Number and Block:

$$\text{F-Num} = F_{mus} * 2^{(20-b)} / 49.716\text{ kHz}$$

In this formula, F_{mus} is the desired frequency (Hz) and "b" is the block value (0 to 7). Refer to Appendix C for a table of note frequencies.

The D5 bit in the register that contains the BLOCK information is called KEY-ON (KON) and determines if the specified voice (0 to 8) is enable (1) or disable (0). The lower bits of F-Number are at location A0H through A8H (1 per voice) and the 2 MSb are at positions D0 and D1 of addresses B0H to B8H.

Rhythm/AM Dep/VIB Dep

This register allows for control over AM and VIB depth, selection of rhythm mode and ON/OFF control for various rhythm instruments. Bit D5 (R) is used to change the mode from melodic (0) to percussive (1). When in percussive mode, bits D0 through D4 are the KEY-ON/KEY-OFF controls for the rhythm instruments listed below. The KEY-ON bit in registers B6H, B7H and B8H must always be 0 when in percussive mode.

D0	Hi-Hat
D1	Cymbal
D2	Tom-Tom
D3	Snare Drum
D4	Bass Drum

The AM Depth is 4.8dB when D7 is 1 and 1dB when 0. The VIB Depth is 14 cents when D6 is 1, and 7 cents when zero. (A "cent" is 1/100th of a semi-tone.)

FeedBack/Connection

These two parameters influence the way the operators are connected together and the ß factor in the feedback loop of the modulator. These parameters are assigned 1 per voice at locations C0H through C8H. The Connection bit (C) determines if the voice will be functioning in Additive synthesis mode (C = 1) of in Frequency modulation mode (C = 0). The other parameter, Feedback (FB), gives the modulation factor, ß, for the feedback loop:

Wave Select

The WS parameter enables the card to generate other kinds of wave shapes. This is done by changing the sine function of the specified operator. (Note that the WSE bit must be set in order to use this feature.) The addresses of this feature are E0H to F5H. The following figure gives the corresponding wave forms: