HandyMusic 1.2

Macro instrument sound driver for the Atari Lynx
Care and Feeding Instructions

Written and Design by: Osman Celimli

Table of Contents

What is HandyMusic?

HandyMusic is a music and sound effects driver for the Atari Lynx based upon macro instruments. This allows for instruments to have all of the complexities of sound effects instead of just simple ADSR envelopes, as the instruments themselves are considered to be sound effects played with a frequency offset by the driver. Single channel 8KHz PCM Playback is also supported, and samples are streamed from the cartridge to keep a small memory footprint.

Bastian Schick's BLL kit is required to use HandyMusic, although you are free to modify HandyMusic for other environments (or other platforms). The contents of the development package should be directly extracted to BLL's C:\Lynx folder.

HandyMusic was designed specifically for the Lynx and its limited memory, and thus only uses about 1.7KB of memory for the sound driver itself, which is expected to reside in the $A000-$A6AF range of RAM. Operation is fairly simple and after initialization, HandyMusic should be called once every VBlank through a JSR to "HandyMusic_Main." All decoding of the music script, instrument envelope updates, and sound effect envelope updates are performed during this call. Thus, all timing in HandyMusic is performed based upon a 60Hz tick. Greater precision may be obtained by tying the driver to a faster timer base (such as 120Hz or 240Hz), but this is not recommended due to the increased CPU overhead.

This document is intended to be a reference for HandyMusic's data formats and general operation. If anything is unclear, it may be helpful to look at HandyMusic's source, which is fairly documented.

HandyMusic is completely free to use and modify in your own projects. However, the authors are in no way responsible for any personal distress, harm, or destruction of property while using HandyMusic; however unlikely it may be.

- **Memory Usage:**

  HandyMusic in its entirety is designed to occupy $A000-$BFFF on the Lynx, and is broken into three parts: The driver itself, a sound effects block, and the music data. They should all be allocated in the following fashion:

  - **HandyMusic Driver: $A000-$A6AF**
  - **Sound Effects Block**

    This may be located anywhere in memory by setting the appropriate variables (HandyMusic_SFX_AddressTableLoLo/LoHi/HiLo/LoLo, HandyMusic_SFX_AddressTablePriLo/Hi) in HandyMusic. It is most convenient to place it in the **$A6B0-$AFFF** range right after the driver.
  - **Music Block: $B000-$BFFF**

    The current music track.

- **Hardware Dependencies:**

  In addition to controlling the Lynx's audio hardware, HandyMusic requires use of the following components.

  - **Timer 3 Hardware**

    This is used for PCM Playback

- **Commonly Used Subroutines:**

  The subroutines usually required by the game programmer are listed below along with details of their operation.

  - **HandyMusic_Init**
    - The initialization routine, should be called once at system startup.
  - **HandyMusic_Main**
    - The entry point for HandyMusic's processing. Call every VBlank.
  - **HandyMusic_PlaySFX**
    - Play the sound effect whose number is stored in A.
  - **HandyMusic_StopSoundEffect**
    - Stops a sound effect whose priority is in A.
  - **HandyMusic_PlayMusic**
    - Plays the music block loaded into $B000-$BFFF.

- **HandyMusic_StopMusic**
  - Stops the currently playing music.
- **HandyMusic_StopAll**
  - Stops all currently playing music and sound effects.
- **HandyMusic_Pause**
  - Pauses HandyMusic and silences all channels (such as when a game is paused).
- **HandyMusic_UnPause**
  - Restores HandyMusic from a paused state, resuming any previously playing music or sound effects
- **HandyMusic_LoadPlayBGM**
  - Stops playback of the current music track, and loads another track from the cartridge whose number is in A, then begins playback. This routine is "PCM Safe" in that it will wait for the current PCM Sample to finish streaming before it loads the new music track from the cartridge.
- **PlayPCMSample**
  - Starts streaming the PCM Sample to Channel 0 whose sample number is in A.

Required Pre-Initialization Variables:

These variables must be set by the programmer prior to calling HandyMusic_Init in order to ensure proper operation of the driver.

- **HandyMusic_SFX_AddressTableLoLo**
  The low byte of the SFX low address table.
- **HandyMusic_SFX_AddressTableLoHi**
  The high byte of the SFX low address table.
- **HandyMusic_SFX_AddressTableHiLo**
  The low byte of the SFX high address table.
- **HandyMusic_SFX_AddressTableHiHi**
  The high byte of the SFX high address table.
- **HandyMusic_SFX_AddressTablePriLo**
  The low byte of the SFX priority table.
- **HandyMusic_SFX_AddressTablePriHi**
  The high byte of the SFX priority table.

Required Constants:

These constants must be defined prior to assembling HandyMusic.

- **FileNum_MusicBase**
  The file number of the first music track stored on the cartridge (all music files are assumed to be located sequentially).
- **FileNum_SampleBase**
  The file number of the first PCM Sample on the cartridge (all samples are assumed to be located sequentially).

Audio Channel Structure

The Lynx contains four identical audio channels which vaguely resemble its eight hardware timers. A counter is used to clock a polynomial counter, which drives the waveform generation hardware. There is no envelope hardware whatsoever, and HandyMusic generates all envelopes in software. However, for all intents and purposes, and because of the way HandyMusic handles the abstraction of the Lynx's audio hardware, each channel has the following properties:

- **Priority:** The current priority of the instrument or sound effect playing in the channel. When sound effects and instruments compete for a given audio channel, those with higher priorities win out. A priority of zero indicates the channel is currently free (no one is using it). **DO NOT USE THE SAME PRIORITIES FOR INSTRUMENTS AND SOUND EFFECTS.**
- **Base Frequency:** A 10-bit value representing the current base frequency of the channel. This is set to zero when playing a sound effect, but is used for the note frequency on instruments. This is actually stored in 16.8 precision, but the bottom eight and top six bits are ignored by the hardware and used only to simplify calculations. Each frame the Base Pitch Adjust gets added to the current Base Frequency, with the new value overwriting the old. This is useful for pitch slides in music tracks.
- **Base Pitch Adjust:** A 10-bit value which is added to the Base Frequency every audio frame, useful for things like pitch slides in music tracks. This is actually stored in 16.8 precision, but the bottom eight and top six bits are ignored by the hardware and used only to simplify calculations. Like the base frequency, this is note exclusive and is set to zero when playing a sound effect.
- **Frequency Offset:** A 10-bit value used as the offset from the base frequency. This is the sole frequency used by sound effects, but is used by notes for variation from their base frequency. This is actually stored in 16.8 precision, but the bottom eight and top six bits are ignored by the hardware and used only to simplify calculations. Each frame the Frequency Offset Pitch Adjust gets added to this value, with the new value replacing the old. Thus the actual timer write used to drive the polynomial counter at any given audio frame is:

(Frequency Offset += Frequency Offset Pitch Adjust) + (Base Frequency += Base Pitch Adjust)

Where this is a 10-bit result, bits 9-7 are used as the prescale value, and 6-0 are used as the divider value. Note that HandyMusic treats the prescale and divider values a differently than the hardware, so consider them to work like this:

Prescale Value:	Clock:
0-1	1us (Consider the Divider 8 bits in this case)
2	2us
3	4us
4	8us
5	16us
6	32us
7	64us

While the divider is a 7 bit value. Thus the final clock is:

$$\frac{1}{\text{Prescale Clock} * (\text{Divider Value}+1 \text{ if Prescale is } <2, \text{ or } +128 \text{ If } >=2)}$$

Which ranges from 61.5Hz to 1MHz in a nonlinear scale. Note that there is NO clipping protection in any of these calculations. So be careful with your frequency choices.

When converting between frequencies (Hz) and HandyMusic's 16.8 format, the following equation should be observed:

F = Desired Frequency
p = Number of Polynomial Counter clocks for one full period of the waveform
For example, this would be 2 for a 50% duty cycle pulse using feedback setting $01, or 3 for a 33% duty cycle pulse using feedback setting $3

```
Fp = F*p;

if(Fp > 1000000.0) div = 0;
else if(Fp > 3906.25) div = (1000000/Fp)-1;
else if(Fp > 1953.13) div = (500000/Fp)+128;
else if(Fp > 976.563) div = (250000/Fp)+256;
else if(Fp > 488.281) div = (125000/Fp)+384;
else if(Fp > 244.141) div = (62500/Fp)+512;
else if(Fp > 122.07) div = (31250/Fp)+640;
else if(Fp > 61.0352) div = (15625/Fp)+768;
else div = 1023;
```

div = HandyMusic Frequency value used in bits 0-9 of the 16.8 format. All other bits should be set to zero.

- **Frequency Offset Pitch Adjust:** A 10-bit value which is added to the Frequency Offset every audio frame, useful for things vibrato in notes and frequency sweeps in sound effects. This is actually stored in 16.8 precision, but the bottom eight and top six bits are ignored by the hardware and used only to simplify calculations.
- **Volume:** A simple, 8.8 precision volume. Only the top 8 bits are significant to the hardware. Each audio frame the Volume Adjustment is added to this value, the new result replacing the old value. There is no clipping in this calculation, be careful. Note that the 8-bit value written to the volume register is signed, so a negative value is just a positive value with a different phase. Also, the actual volume of the audio channel depends upon the channel mode. In nonintegrated mode, the amplitude of the pulse generated by the hardware is the same as this value. In integrate mode, the output value is a running total of the previous volumes, which are either added or subtracted based upon the output of the poly counter (1=add volume, 0=subtract volume).
- **Volume Adjustment:** A simple, 8.8 precision volume adjustment. Only the top 8 bits are significant to the hardware. Each frame this is added to the Volume value, the new result replacing the old. This is useful for volume envelopes in both instruments and sound effects.
- **Panning:** An 8-bit value representing the panning of the channel. Bits 7-4 are the attenuation for the left speaker, and bits 3-0 are the attenuation for the right speaker. 1111 is loudest, 0000 is off. This is only useable for music, all sound effects are forced to use a panning value of $FF (center). Note that this really only does anything in the Lynx II, as the original Lynx is monophonic.
- **Waveshape Selector Mode:** The Lynx has two methods for generating waveforms based upon the output of its polynomial counter. In nonintegrate mode, the output of the polynomial counter is directly reflected as a pulse waveform with an amplitude equivalent to the contents of the Volume setting. These are generally square waveforms. In intergrate mode, the current amplitude of the channel is adjusted based upon the output of the polynomial counter. If the output of the polynomial counter is 1, the channel's amplitude is increased by the value in the volume register. If the output is zero, the channel's amplitude is decreased respectively. These are much more triangular waveforms.

- **Shift Register:** The 12-Bit contents of the polynomial counter's shift register.
- **Feedback Taps:** 9-Bits of feedback connected to outputs 11, 10, 7, 5, 4, 3, 2, 1, and 0 of the shift register in the polynomial counter. This and the shift register directly effect the waveform generated. For example, a shift register setting of 0, and feedback tap 0 set to 1, a square pulse will be generated by the polynomial counter.
- **Writeback Disabling:** HandyMusic will release control of any channel flagged as having writebacks disabled. Music and sound effects will continue to decode normally, but will not touch the actual audio hardware. This is useful for temporarily borrowing the sound hardware for other uses. For example, writebacks on Channel 0 are temporarily disabled while playing PCM samples in HandyMusic.

Instruments and Sound Effects

In HandyMusic, instruments and sound effects have been merged into a single entity. This not only allows the programmer to create complex sounding instruments, but allows HandyMusic to use less space in the Lynx's already limited memory, leaving more for use by game software.

However, while the instruments and sound effects are decoded identically, they are not stored together. Sound effects are kept on their own in a specially formatted block which may be located anywhere in memory, while the instruments for a particular song are always packed along with it.

The basic format for an instrument or sound effect definition is a simple scripting language supporting looping and termination which is used to change the state of the audio hardware over time. A description of the formatting and encoding of the instruments and sound effects follows.

- **Instrument/SFX Header:**

Each instrument/sound effect contains a 112-bit header which is decoded before any of its script is processed. The header is formatted as follows:

```
[NoteOff Lo][NoteOff Hi][ShiftReg Lo][ShiftReg Hi]
0           8           16           24
[Feedback Lo][Feedback Hi + Integrate Flag]
32           40
[Volume]
48
[Volume Adjustment Lo,Decimal]
56
[Frequency Offset Lo,Hi]
72
[Frequency Offset Adjustment Lo,Hi,Decimal]
88                                       111
```

  - **NoteOff Lo/Hi**
    The low and high addresses of the note off section of the instrument script. This is used exclusively for instruments, and is empty for sound effects.
  - **ShiftReg Lo/Hi**
    Initial setting of the polynomial counter's 12-bit shift register. The contents of the low variable directly correspond to bits 0-7 of the shift register. However bits 8-11 are shifted up into bits 7-4 of the high variable to better reflect the actual Lynx register structure.
  - **Feedback Lo/Hi+Integrate Flag**
    These contain the inital settings for the feedback register and integrate mode flag. However, their organization is not very straightforward. The low variable contains bits 0, 1, 2, 3, 4, 5, 10, and 11 of the feedback enable register. The high variable contains feedback bit 7 in its own bit 7, and the integrate flag in bit 5. The rest are unused.
  - **Volume**
    The one byte initial volume setting. The decimal is left out here and is always zeroed at the start of an instrument or sound effect.
  - **Volume Adjustment**
    The two byte initial volume adjustment value. First is the one byte volume adjustment value, then the one byte decimal.
  - **Frequency Offset**
    The two byte initial frequency offset value. First the low byte, then the high. The decimal is excluded and always assumed to be zero.
  - **Frequency Offset Adjustment**
    The three byte initial frequency offset adjustment. First the low byte, then the high, and finally the decimal.

- ## Instrument/SFX Script:

Following the instrument/sound effect's header is its sound script. This script is a simple bytecode with commands for adjusting the properties of the audio channel and controlling the execution path of the sound script itself. The commands, their format, and operations are listed below:

  - **0: Stop Script Decoding**
    - Format: `[0] (1 byte)`
    - Immediately stops the decoding of the sound script and frees the channel.
  - **1: Wait**
    - Format: `[1][Number of Frames] (2 bytes)`
    - Pauses sound script decoding for the specified number of frames.
  - **2: Set Shift, Feedback, and Integrate Mode**
    - Format: `[2][ShiftReg Lo][ShiftReg Hi][Feedback Lo] [Feedback Hi + Integrate Flag] (5 bytes)`
    - Replaces the current shift and feedback register contents with the specified new values, stored in the same format as in the instrument/sfx header.
  - **3: Set Volume and Volume Adjustment**
    - Format: `[3][Volume][Volume Adjustment][Volume Adjustment Decimal] (4 bytes)`
    - Replaces the current volume and volume adjustment values with the specified new values.
  - **4: Set Frequency Offset and Frequency Offset Adjustment**
    - Format: `[4][Frequency Offset Lo][Frequency Offset Hi] [Frequency Offset Adjustment Lo] [Frequency Offset Adjustment Hi] [Frequency Offset Adjustment Decimal] (6 bytes)`
    - Replaces the current frequency offset and frequency offset adjustment values with the specified new ones.
  - **5: Set Loop Point**
    - Format: `[5][Number of Times to Loop] (2 bytes)`
    - Defines the location in the script following this command as a loop point which will be returned to the specified number of times. If a negative number is used, the loop will continue infinitely.
  - **6: Loop**
    - Format: `[6] (1 byte)`
    - If the loop is not infinite, the loop counter is decremented and unless the counter has reached zero, the script decoder will continue decoding at the loop point. Loops may be four-deep.

- ## Instrument/SFX Packing:

Instruments and sound effects are packed together in the following format which may be placed anywhere in memory (assuming the pointers used are correct) for sound effects, and will be packed along with each piece of music for instruments.

- **Instrument/SFX Low Address Pointers**
  - Contains all of the low bytes of the sound script addresses. Max 256 entries.
- **Instrument/SFX High Address Pointers**
  - Contains all of the high bytes of the sound script addresses. Max 256 entries.
- **SFX Priorities (Excluded for Instrument Blocks)**
  - Contains all the priorities of the sound scripts. Max 256 entries.
- **The sound scripts themselves follow in any order you wish**

Music

Music, like sound effects and instruments, uses a simple scripting language. Instruments may be played for various lengths of time with specified frequency offsets, pitch slides, panning, and timing. In most respects, the HandyMusic format may be considered a stripped down MIDI script composed only of note on, note off, panning, pitch slide, and rest commands. Looping is also supported, and like the sound effects, the loops may be four levels deep. Infinite loops as applicable in sound effects are identical in music scripts. Script patterns/subroutines may also be called and returned from, with the same depth limit as loops. PCM sample cues may be used in Channel 0 only, allowing playback of 8KHz samples in time with music.

As the Lynx has four channels, each music script is composed of up to four voices, all of which have a priority which is adjustable over the course of the music script's life. This allows tracks of music to become more or less important than the sound effects competing with them for the hardware. By specifying a priority of zero, a music script is stopped, so a piece of music which does not need all four channels may use less by specifying an initial priority of zero in its header.

Instruments for a given piece of music are packed with it, located after the header, but before the music scripts themselves.

- **Music Header:**

  Located before each piece of music's instrument data and sound scripts is a 128-bit header containing information about the track priorities, locations, and instrument table pointers. The format is as follows:

```
[Track 0 Priority][Track 1 Priority]
0                 8
[Track 2 Priority][Track 3 Priority]
16                24
[Track 0 Script Lo Address]
32
[Track 1 Script Lo Address]
40
[Track 2 Script Lo Address]
48
[Track 3 Script Lo Address]
56
[Track 0 Script Hi Address]
64
[Track 1 Script Hi Address]
72
[Track 2 Script Hi Address]
80
[Track 3 Script Hi Address]
88
[Instrument Low Address Table Pointer Lo,Hi]
96
[Instrument High Address Table Pointer Lo,Hi]
112                                       128
```

  - **Track X Priority**

    The priority of the given track at its start, if this is a value of zero, the track is effectively ignored. This may be used to generate music with less than four tracks.
  - **Track X Script Lo/Hi Address**

    The starting address of the sound scripts for each track, which should be located after the instrument block.
  - **Instrument Low/High Address Table Pointers**

    The addresses of two tables which contain the low and high addresses of the instrument scripts included with the piece of music.

- **Music Script:**

  Following a music track's header and instrument block is its music scripts, of which there may be up to four. The scripting commands are made up of one byte blocks and are slightly similar to those of sound effects, with a few changes. The commands, their format, and descriptions of their operations are listed below:

  - **0: Set Priority**
    - Format: **`[0][Priority] (2 bytes)`**
    - Sets the priority of the track relative to the sound effects. Higher priorities win out when competing for channels, the same priorities should **never** be used between sound effects and instruments. **A priority of zero stops the track from decoding.**
  - **1: Set Panning**
    - Format: **`[1][Panning] (2 bytes)`**
    - Sets the panning of the instruments played in the current channel.
  - **2: Note On**
    - Format: **`[2][Instrument][Base Frequency Lo]`**
      `[Base Frequency Hi][Delay Lo] (5 bytes)`
    - Plays a given instrument with the specified base frequency, then waits for the given one byte delay
  - **3: Note Off**
    - Format: **`[3][Delay Lo] (2 bytes)`**
    - Forces the currently playing instrument into the note off portion of its script, then waits for the specified one byte delay.
  - **4: Set Base Frequency Adjustment**
    - Format: **`[4][Base Frequency Adjustment Lo]`**
      `[Base Frequency Adjustment Hi]`
      `[Base Frequency Adjustment Dec] (4 bytes)`
    - Sets the Base Frequency Adjustment value, which can be used for pitch slides, etc. This value is initialized to zero on the start of a song.
  - **5: Set Loop Point**
    - Format: **`[5][Number of Times to Loop] (2 bytes)`**
    - Defines the location in the script following this command as a loop point which will be returned to the specified number of times. If a negative number is used, the loop will continue infinitely.
  - **6: Loop**
    - Format: **`[6] (1 byte)`**
    - If the loop is not infinite, the loop counter is decremented and unless the counter has reached zero, the script decoder will continue decoding at the loop point. Loops may be four-deep.
  - **7: Wait**
    - Format: **`[7][Delay Lo][Delay Hi] (3 bytes)`**
    - Stops decoding for the specified two byte delay.
  - **8: Play Sample**
    - Format: **`[8][Sample Number] (2 bytes)`**
    - Begin playback of the specified PCM sample. Only usable in Channel 0.
  - **9: Pattern Call**
    - Format: **`[9][Address Lo][Address Hi] (3 Bytes)`**
    - Jumps to the address of the music script given, and sets up the current position in the music script as the destination for the Pattern Return command.

- **10: Pattern Return**
  - Format: **`[A] (1 byte)`**
  - Returns to the portion of the music script which was being played before the last Pattern Call command.

• Music Data Packing:

Music data is stored in a block format consisting of the music header, instrument block, and track data. It is expected to reside at $B000-$BFFF only. New music data may be used by stopping playback of the current music track, and loading another in this memory space.

- **Header**
  - The Song Header
- **Instrument Block**
  - Two tables of the high and low addresses of the instrument scripts (see instruments/sound effects secton), followed by the instruments themselves.
- **Track Data**
  - The music script data for up to four tracks of music.

PCM Sample Playback

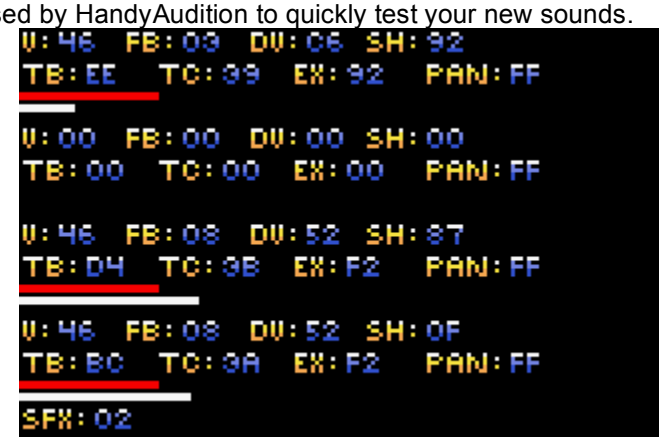
HandyMusic supports streaming a single PCM Sample from the game cartridge on request by the music script or a call to **`PlayPCMSample`**. Samples are required to be stored as 8KHz 8-Bit signed monophonic raw PCM data. There is no concept of priority between samples and the music or sound effects, and sample playback is always performed in Channel 0. Any music or sound effects currently occupying that channel will be muted for the duration of the sample playback, but will continue to decode normally.

As PCM samples are streamed from the cartridge, it is not safe to access the cartridge interface while a PCM samples is playing. Thus it may be wise to ensure **`Sample_Playing`** is equal to zero before loading from the cartridge in your game software. Any loading routines included with HandyMusic such as **`HandyMusic_LoadPlayBGM`** automatically check for activity by the sample playback routine and will wait for it to finish before accessing the cartridge for any of their own data.

IRQ-Based Sample playback is extremely resource intensive on the Lynx, especially at 8KHz. Thus it is suggested that sample playback only be used in non-game critical areas or in a situation where the game tick is less than 60Hz.

HandyAudition

HandyAudition is a simple Lynx program for testing composed music and sound effects without having to configure HandyMusic for your current game project. The state of the audio hardware registers are displayed to help with script debugging. Simply swap out the sound effect and music blocks used by HandyAudition to quickly test your new sounds.



HandyMusic playing some sound effects and music in HandyAudition.

The default controls for HandyAudition are as follows:

- **Left/Right : Select Sound Effect to Play**
- **A : Play Sound Effect**
- **B : Stop Sound Effect**
- **Option 1: Play Music**
- **Option 2: Stop Music**

Label Guide:

- **V: Channel Volume**
- **FB: Low Feedback Register**
- **DV: Direct Volume (Actual channel output amplitude)**
- **SH: Low Shift Register**
- **TB: Timer Backup**
- **TC: Timer Control**
- **EX: Extra Audio Bits**
- **PAN: L/R Attenuation, will read as open bus in the original Lynx**