Summary

The MBHP_Genesis module provides all the hardware necessary to support one of each YM2612/YM3438 (OPN2) and SN76489/94/96 (PSG) sound chips and interface them to a microcontroller (including one of the MIDIbox core modules). In addition, the circuit and board are designed so that up to four MBHP_Genesis modules may be stacked on top of each other to run up to four sets of sound chips, with simple pin/socket headers connecting the boards and no additional wiring needed.

Features:

- High-speed parallel interface to both sound chips, optimized for CORE_STM32F4 ports J10A and J10B, but compatible with most MCUs; requires no other signal connections to the core
- SN76489/94/96 has data latch with automatic deselection, so the MCU can write to it and then immediately use the bus for other things, rather than having to leave the data on the bus until the chip asserted READY
- YM2612/3438 Test and /IRQ pins, and SN76489/94/96 Ready pin, are readable from the core via the parallel interface
- YM2612/3438 Test pin has selectable direction (with protection), and both Test and /IC pins can be written to from the core via the parallel interface
- Analog buffering, filtering, and mixing onboard, all from same +5V power supply (no bipolar +/-12V supply), with OPN2/PSG mixer/pan/volume potentiometer connections
- Filter cutoff frequency selectable between two options (unfiltered or Mega Drive Model 1 mode), separately selectable for OPN2 channels and PSG channel; selection controlled via parallel interface
- SN76494/96 Audio In pin fully supported, with protection
- Separate oscillators for each sound chip; supports 8-DIP or 5x7mm SMT packages
- All parts DIP/through hole (no SMT) (except for optional SMT oscillator)
- Smallest footprint (cheapest board) possible
- Many components may be left unstuffed if certain features not desired

Disadvantages:

- Very dense layout
- Larger board than it would be if all the glue logic was removed, and more wires were used to interface to the core (though certain aspects if 2 or 4 boards were used, e.g. reading Ready signals from the PSGs, would require multiple wires or additional logic)
- Parallel interface is +5V, which may cause issues with CORE_STM32F4 (3.0V) or other MCUs at 3.3V. If using only one MBHP_Genesis module, it *might* work (pending testing) assuming the core tolerates 5V inputs (as CORE_STM32F4 does). However, for two or more boards, due to fanout, an external level shifter circuit will be required. See MBHP_Genesis_LS.

MBHP_Genesis Module Hardware

Links

- Schematic (rev. 1e1, for production version boards rev. 1e) (full size version try here)
- Board layout image
- Board 3D (CGI) image
- Board dimensions image
- MIDIbox Gallery for MIDIbox Quad Genesis, containing many pictures of the MBHP_Genesis module
- Video of MBHP_Genesis module playing some VGM files, powered by the MBHP_CORE_STM32F4 module

Pinout

Most of this is really easy to read off the schematic, but here you go anyway.

J1: +5VPWR

+5V power input to the module.

Pin	Label	Function
1	+5VD	5V supply to board. The “D” stands for “digital”, in comparison to the +5VA net which is the supply for all analog circuitry.
2	GND	Ground. Common to analog and digital. Not connected to the mounting holes.

J2: MULTI_CS

Chip-select lines generated by the decoder on the first board, for the sound chips on the other three boards.

Pin	Label	Function
1	–	/CS for PSG and onboard registers on Board 4
2	–	/CS for YM2612 on Board 4
3	–	/CS for PSG and onboard registers on Board 3
4	–	/CS for YM2612 on Board 3
5	–	/CS for PSG and onboard registers on Board 2
6	–	/CS for YM2612 on Board 2

J3: ADDR_SEL

This is a fun one. This connector allows you to specify which board each board is, by selecting which pair of /CS lines from the decoder are used on each board. It shares pads with the decoder, U3. Here's how to connect it:

1. On board 1, stuff U3 and its bypass capacitor C3, but don't connect anything in J3.
2. On board 2, don't stuff U3 or C3, but connect two wires on the top of the board, one from U3:13

to J3:2, and one from U3:12 to J3:1. They should follow the first two angled lines on the footprint for J3 under U3.
3. On board 3, same thing but connect U3:11 to J3:2 and U3:10 to J3:1. These two wires should follow the second set of lines on the board, the non-angled ones.
4. On board 4, same thing but connect U3:9 to J3:2 and J3:3 to J3:1. These two wires should follow the last pair of lines on the board, angled in the opposite direction.

The overall effect is that the eight signals from the decoder are distributed in pairs to each of the boards. J3:2 and J3:1 are connected to U3:15 and U3:14, so on the first board the decoder drives the two /CS lines directly.

J5: EXT_IO

For those who prefer to have separate wires from the module to the core for the additional signals to/from the sound chips, rather than using the parallel interface to read/write them, this header brings them out.

Pin	Label	Function
1	/IC	YM2612/3438 reset signal. Don't drive this pin externally if U6 is stuffed!
2	/IRQ	YM2612/3438 interrupt request signal. Goes low when one of the OPN2 timers overflows if configured approrpriately.
3	TEST	YM2612/3438 Test signal. See Notes about the YM2612's Test pin.
4	Ready	SN76489/94/96 Ready signal. Also called /BUSY. Goes high when the chip is ready to receive new data.

J6: PSG_IN

Audio input to the PSG's analog audio input pin, if the PSG used is a SN76494 or SN76496.

Pin	Label	Function
1	–	Audio input. See the PSG's datasheet, and choose the value of R7 accordingly.
2	GND	Ground.

J7: MIX

These are the three nodes where the audio signals from the different boards' YM2612 and PSG channels are mixed. The three pins correspond to the summing node of an inverting amplifier with first-order low-pass filter.

Pin	Label	Function
1	–	OPN2 Right channel summing node
2	–	PSG mono summing node
3	–	OPN2 Left channel summing node

R18, R19, R20

These are three-pin headers to connect potentiometers to adjust the relative volume (and panning if desired) of the OPN2 and PSG. As is obvious from the schematic, R18 is for OPN2 Left, R19 is for OPN2

Right, and R20 is for PSG. The potentiometer is 10k nominal (will work fine with 5k or 2k), audio type (A) preferred but not required. It is intended that a dual-gang potentiometer would be used to adjust the OPN2 levels together, and a separate single one for the PSG. If panning is desired, after the level potentiometers, connect a 20k or 50k potentiometer between the Left output and Right output (R18:2 and R19:2) with its wiper connected to +2.5V (R18:1).

J8: OUT

Analog audio output from all the modules together. Low-impedance output, referenced to ground.

Pin	Label	Function
1	–	Left channel output
2	GND	Ground
3	–	Right channel output

J10: DATA

Parallel address and data busses between MCU and module. Pins 1 through 10 connect to J11A on the core and pins 11 through 20 connect to J11B.

Pin	Label	Function
1	GND	Ground
2	–	No connection (+3.3V or +3V from the core, not used on module)
3	D0	Least-significant data line
4	D1	Data line
5	D2	Data line
6	D3	Data line
7	D4	Data line
8	D5	Data line
9	D6	Data line
10	D7	Most-significant data line
11	GND	Ground
12	–	No connection (+3.3V or +3V from the core, not used on module)
13	/CS	Chip Select for entire module, active-low
14	/RD	Read strobe for entire module, active-low
15	/WR	Write strobe for entire module, active-low
16	A0	Least-significant address line, selects OPN2 address or data
17	A1	Address line, selects OPN2 register set and PSG/register on write
18	A2	Address line, selects OPN2 or PSG/registers
19	A3	Address line, selects board index LSB
20	A4	Most-significant address line, selects board index MSB

Parts list

Mouser part numbers are included for convenience, all parts (besides the two sound chips) are standard and should be available at any electronics site (e.g. Reichelt). Parts labeled “buy in bulk”

should already be in your electronics inventory; they are of course available at Mouser and elsewhere if you don't have any, but you should probably buy many more than are necessary for this project (e.g. resistors in sets of 100 or 200 of the same value from eBay).

Qty	Ref. Deg.	Part Name	Mouser Part Number	Description / Notes
1	U1	YM2612 or YM3438	N/A	OPN2 chip, available on eBay for about $5 or less
1	U2	SN76489 or SN76494 or SN76496	N/A	PSG chip, available on eBay for about $2 or less
1	U3	74HC137	595-CD74HC137E	3-to-8 decoder with enable, for selecting board and sound chip
1	U4	MCP6004	579-MCP6004-I/P	Rail-to-rail 5V quad op-amp with appropriate characteristics
1	U5	MCP6002	579-MCP6002-I/P	Rail-to-rail 5V dual op-amp with appropriate characteristics
1	U6	74HC174	595-SN74HC174N	Hex flip-flop for board data input bits; CD40174 works but 74HC174 preferred due to stronger drive capability
1	U7	74HC125	595-SN74HC125N	Quad tristate buffer for board data output bits
1	U8	74HC4075	595-CD74HC4075E	Triple 3-input OR for glue logic; CD4075 (barely) works but voltage levels are not pretty in Q2-Q3-U2 circuit, 74HC4075 much preferred
1	U9	CD4066	595-CD4066BE	Quad transmission gate, for digitally-switchable filter capacitors
1	U10	74HC573	595-SN74HC573AN	Octal transparent latch, for storing data to PSG so bus may be used for other transactions
1	[U1]	24-pin 0.6“ DIP socket	517-4824-6000-CP	Socket for OPN2
3	[U2], [U3], [U6]	16-pin 0.3” DIP socket	571-1-2199298-4	Sockets for three 16-pin DIP ICs
4	[U4], [U7], [U8], [U9]	14-pin 0.3“ DIP socket	571-1-2199298-3	Sockets for four 14-pin DIP ICs
1	[U5]	8-pin 0.3” DIP socket	571-1-2199298-2	Socket for MCP6002
1	[U10]	20-pin 0.3“ DIP socket	571-1-2199298-6	Socket for 74HC573
1	Y1 or Y3	7.67 MHz (or 8 MHz) oscillator	774-MXO45HS-3C-8.0	Oscillator (either half-size/8-DIP or 5x7mm SMD) at desired OPN2 frequency. MIDIbox Genesis firmware will correct frequencies to match original VGM pitch, but if this is your own project, careful selection and/or custom clock circuitry may be necessary.
1	Y2 or Y4	3.58 MHz (or 4 MHz) oscillator	520-TCH357-X	Oscillator (either half-size/8-DIP or 5x7mm SMD) at desired PSG frequency. MIDIbox Genesis firmware will correct frequencies to match original VGM pitch.

Qty	Ref. Deg.	Part Name	Mouser Part Number	Description / Notes
3	Q1, Q2, Q3	2N7000 or BS170	821-TSM2N7000KC821-T or 512-BS170	Any small-signal N-channel MOSFET with the gate as the center pin; the board silkscreen is for 2N7000, if you use BS170 (as I did) mount them backwards to match the source and drain pins.
-	J1, J2, J5, J6, J7, J8	0.1” pin headers	Buy in bulk	Headers; J1, J2, and J7 connect all boards together, so put sockets on one side of the boards and have the pins sticking through on the other sides. J5 and J6 are individual on each board if used, and J8 is only on the final board.
-	J10	0.1“ dual row pin headers	Buy in bulk	Headers; J10 connects all boards together, so put sockets on one side of the boards and have the pins sticking through on the other sides.
1	L1	10 uH inductor	434-SMCCN-100K-02	For LC filter for analog power rail
2	C12, C13	100 uF electrolytic	Buy in bulk	Power rail filter caps
4	C15, C16, C17, C18, C31, C32	10 uF electrolytic	Buy in bulk	Analog power rail filter caps
3	C20, C21, C22	10 uF bipolar electrolytic	647-UVP1C100MDD	Audio high-pass filter caps
13	C1:C11, C14, C19	0.1 uF ceramic / monolithic / film	Buy in bulk	IC power rail filter caps
3	C23, C24, C25	180 pF ceramic / etc.	Buy in bulk (maybe)	Stability filter caps (above hearing range)
3	C26, C27, C28	1 nF ceramic / etc.	Buy in bulk	Filter caps for Mega Drive / Genesis - style filter
2	C29, C30	100 pF ceramic / etc.	Buy in bulk	Stability filter caps (above hearing range)
2	R1, R3	10k ohm 5% or better 0.25W carbon-film or metal-film axial through-hole vertically-mounted resistor	Buy in bulk	Pull-ups for digital lines
2	R2, R6	1k blah blah blah regular resistor	Buy in bulk	R2: protecting TEST pin from contention, R6: part of Q2-Q3-U2 latch circuit
1	R4	2.2k resistor	Buy in bulk	Pull-up for PSG READY line
1	R5	47k resistor	Part of Q2-Q3-U2 latch circuit	
1	R7	220 ohm resistor or DNP	Buy in bulk	Protection for SN76494/SN76496 audio input (omit for SN76489 as there is no audio input)

Qty	Ref. Deg.	Part Name	Mouser Part Number	Description / Notes
2	R8, R9	2.2k resistor or DNP	Buy in bulk	Load for YM2612 (omit for YM3438)
1	R10	1.5k resistor	Buy in bulk	Load for PSG
2	R11, R12	22k or 47k	Buy in bulk	Mixing resistors for OPN2: 22k for YM2612, 47k for YM3438
2	R15, R16	47k or 10k	Buy in bulk	Mixing resistors for OPN2: 47k for YM2612, 10k for YM3438
3	R14, R33, R34	—	—	Do not populate
7	R13, R17, R21, R22, R25, R26	47k resistor	Buy in bulk	Mixing and filtering resistors
1	R18/R19	10k potentiometer(s)	Front panel specific	OPN2 volume control; single dual-gang 10k audio (or linear) potentiometer, to be mounted on your front panel
1	R20	10k potentiometer	Front panel specific	PSG volume control; regular 10k audio (or linear) potentiometer, to be mounted on your front panel
2	R23, R24	220k resistors	Buy in bulk	If you want a louder PSG, reduce the value
2	R27, R28	100k resistors	Buy in bulk	High-pass filter resistors
2	R29, R30	220 ohm resistors	Buy in bulk	Audio output short-circuit protection resistors
2	R31, R32	10k 1% resistors	Buy in bulk	For voltage divider to set the virtual ground

Mixing resistors

Previously I had a section here about the different use cases and what values of resistors to use for R11 through R17. But since I've finished the hardware for two MIDIbox Quad Genesises, one with four YM2612s and one with four YM3438s, I think the values are pretty much final at this point. I have not tested extreme cases for clipping (e.g. all four YM3438s in DAC Override mode playing peak-to-peak samples), but my calculations based on measurements of normal audio suggest that even this won't clip (though to be honest, I'm not sure if clipping in that situation would be a bad thing).

The values I used for my quad builds are on the schematic and in the parts list. The normal values are for use with YM2612s, and the values in parentheses are the ones to use with YM3438s. All other parts which just show one value are the same on both builds.

Component stuff chart

Here is a chart of what components should be stuffed on each build configuration I could think of. In most cases, several of these build configurations will be active at the same time (e.g. in a typical four-board setup, the top board is A, B or C, D, (E), F, G, H, I, M).

Label	Description
A	Any board you want to include a YM2612/3438
B	YM2612 only
C	YM3438 only
D	Any board you want to include a SN76489/94/96
E	If a PSG is included and it is SN76494 or SN76496 and you want Audio In support
F	If you want to read Test, /IRQ, or Ready via parallel interface
G	If you want to write Test or /IC via parallel interface
H	If you want digitally-controllable filter capacitors via parallel interface
I	If you want to read/write Test, /IRQ, /IC, or Ready directly to/from each board
J	One board, YM2612 only, no parallel glue logic
K	One board, SN764** only, no parallel glue logic
L	One board, both chips, no parallel glue logic
M	Two or four boards, first board; or one board, both chips and parallel glue logic
N	Two or four boards, second board
O	Four boards, third board
P	Four boards, fourth board

Here is the chart of all parts, and which configurations they should be stuffed in:

Parts	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
U1, C1, C14, C15, Y1 or Y3, C20, C21, R11, R12, R15, R16, C23, C24, R18, R19, R21, R22	X															
R8, R9		X														
R33, R34			X													
U2, C2, Y2 or Y4, U10, C10, Q2, Q3, R4:6, R10, C22, R13, R14, R17, C25, R20, R23, R24				X												
J1, C12, L1, C13, C11, U4, C4, C16, R31, R32, C18, C19, U5, C5, C17, R25, R26, C29, C30, C31, C32, R27:30, J8			X	X												
J6, R7					X											
U7, C7						X	X									
U8, C8						X	X	X								
U6, C6, Q1, R1							X									
U9, C9, C26:28								X								
J5									X							
Short U3:5 to U3:15										X						
Short U3:5 to U3:14											X					
Short U8:3 to U8:6											X	X				
U3, C3, J2												X	X			
Short U3:13 to J3:2, short U3:12 to J3:1														X		
Short U3:11 to J3:2, short U3:10 to J3:1															X	
Short U3:9 to J3:2, short J3:3 to J3:1																X
J10										X	X	X	X	X	X	X

Construction differences by sound chip type

Here's the relevant differences between the sound chips:

PSG Chip	Nominal clock	Audio in?
SN76489	4 MHz	No
SN76494	500 kHz	Yes
SN76496	4 MHz	Yes

OPN2 Chip	Technology	Audio output volume	“Ladder effect” DAC error
YM2612	NMOS	Quiet	Yes
YM3438	CMOS	Loud	No

For the PSG chips, the relevant differences are obvious: use the correct clock speed for the chip, and do or don't connect an audio input. It's much easier to find 4 MHz (or 3.58 MHz) oscillators for the '89 and '96 than a 500 kHz oscillator for the '94, so you're a bit on your own if you choose that chip.

For the OPN2 chips, the YM3438 is a complete reimplementation of the YM2612 in CMOS instead of NMOS. They also changed the output stage to get rid of some analog error in the YM2612's DAC, which produces a distinctive “ladder effect” sound in the audio output, as well as making the output about 10-20dB louder (which also produces excellent signal-to-noise performance). FM synthesis purists might be inclined to choose the YM3438; retro gaming fans will probably go with the YM2612, as this is the physical chip used in the Mega Drive / Genesis Model 1.

The differences for this module are relatively simple. For a YM2612, the audio outputs require a known load to perform to spec–these are R8 and R9. The value of 2.2k was taken from the Mega Amp design, but some experimentation may be warranted.

For a YM3438, no load is necessary (don't stuff R8 and R9), but it's loud enough that it may clip when four are mixed together. Also you may want to reduce the volume if you have two YM3438s and two YM2612s. This is set by the relative sizes of R11, R33, and R15 on the left channel, and R12, R34, and R16 on the right.

MBHP_Genesis Module Software

Memory map

Here's the memory map for the case of four modules in parallel with all features included:

(Syntax like VHDL: -=don't care, X=forced unknown, Z=high-impedance; MN = module index [00,01,10,11])

/CS	/RD	/WR	A4	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0
1	-	-	-	-	-	-	-	Z	Z	Z	Z	Z	Z	Z	Z
0	1	1	-	-	-	-	-	Z	Z	Z	Z	Z	Z	Z	Z
0	0	1	M	N	0	-	-	OPN2 Busy	X	X	X	X	X	OPN2 TmrA Oflw	OPN2 TmrB Oflw
0	0	1	M	N	1	-	-	PSG Ready	OPN2 Test	X	OPN2 /IRQ	X	X	X	X

/CS	/RD	/WR	A4	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0
0	1	0	M	N	0	0	0	OPN2 Address Write Part 1							
0	1	0	M	N	0	1	0	OPN2 Address Write Part 2							
0	1	0	M	N	0	-	1	OPN2 Data Write							
0	1	0	M	N	1	0	-	PSG Address/Data Write (latched)							
0	1	0	M	N	1	1	-	OPN2 /IC	OPN2 Test Data Out	OPN2 Test Data Dir	-	OPN2 Cap Select	-	-	PSG Cap Select
0	0	0	-	-	-	-	-	Illegal state, bus contention							

Bus timings

Idle

- /CS, /RD, and /WR are all 1. A4:0 and D7:0 are -.

Write cycle

- Set the data direction of D7:0 on the MCU to outputs.
- Write the write data to D7:0.
- Write A4:0.
- Write /WR to 0 (this can be done in the same operation as writing A4:0 above)
- Write /CS to 0 (this should not be the same operation as above, but ~20ns later)
- Set MCU data port pins to output mode.
- If the write is to the OPN2, wait a little over 6 OPN2 clocks. If the write is to the PSG latch or local register (OPN2 /IC, Test, Caps), wait about 50ns (propagation delay of all onboard logic).
- Set MCU data port pins to input mode.
- Write /CS to 1.
- Write /WR to 1.
- Set the data direction of D7:0 on the MCU to inputs.

For the OPN2, repeat the above for the data write.

Read cycle

- Write A4:0 to MN0– if the write was OPN2, or MN1–if the write was PSG.
- Write /RD to 0 (this can be done at the same time)
- Write /CS to 0 (not at the same time)
- Read D7:0. (If waiting for the chip to not be busy, loop here; output data to MCU is not latched, it will update in real time.)
- Write /CS to 1.
- Write /RD to 1.

Notes about the YM2612's Test pin

From reading photomicrographs of the YM2612 die and further related hacking work, it has been confirmed that this is an I/O pin, not just an output. Hence the MBHP_Genesis module contains circuitry to both read and write the pin on each YM2612 independently, as well as to select the pin direction. If the pin is mistakenly configured as an input (so the module drives it) while the YM2612 is also driving it, a protection resistor R2 allows the YM2612 to override the state of the line without damage to either device.

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