

Open Game Module

SPARKLETRON

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1 Introduction

Open Game Module (OGM) is a open source expansion card for the Colecovision. This module is Super Game Module (SGM) compatable. This means all SGM games will run when this module is used with a Colecovision. The sound is expanded with a Yamaha YMZ284 instead of the GI AY chip.

1.1 Specifications

- 32KiB of RAM
- YMZ284 Sound Chip
- MAX7000S CPLD (EPM7064SLC)
- PCB, two layer

1.2 Parts List

1.2.1 electronics

Item	Qty	Reference(s)	Value
1	1	J1	Connector, 60 pin
2	4	C1, C2, C3, C4	100pF
3	1	U1	EPM7064SLC-10
4	1	U2	YMZ284
5	1	U3	HM62256BLP
6	1	R5	470R
7	1	R6	4k7
8	4	R1, R2, R3, R4	1k
9	1	J2	Pin Header, 10 pin

1.2.2 hardware

Item	Qty	Reference(s)	Value
1	4	S1	#2-32 x 1/4 Fastenal 0148209, screw
2	1	TOP	top.stl 100.00
3	1	BOTTOM	bottom.stl 100.00

2 Building

This document assumes some Electrical Engineering knowledge. Building circuits is not trivial due to the mix of SMD and through hole components. What follow are general steps to build the OGM.

- Create PCB from schematic/gerber/open_game_module.zip
- Populate PCB
- Power up and program CPLD
- 3D print case
- Assemble OGM circuit board and case.

2.1 Directory Guide

Below highlights important folders from the root of the OGM.

1. **docs** Contains all documentation related to this project.
 - **datasheets** Contains all datasheets for components.
 - **manual** Contains user manual and github page that are generated from the latex sources.
 - **schematic** PDF of the KiCAD schematic.
2. **schematic** KiCAD v8.X schematic and PCB designs
 - **gerber** Contains gerber files and archives for production.
3. **src** CPLD bitstream source
 - **open_game_module** Contains verilog source code and constraints
 - **quartus13sp01** Quartus project used to generate bitstream. POF file located here.

2.2 Dependencies

The following are the dependencies needed to build the bitstream and PCB for the system.

- Quartus 13.0 sp1
- python 3.X
- KiCAD v8.X

2.2.1 Open Game Module Glue File List

- src
 - 'src/open_game_module.v': 'file_type': 'verilogSource'
- constr
 - 'constr/open_game_module.sdc': 'file_type': 'SDC'
- tb
 - 'tb/tb_open_game_module.v': 'file_type': 'verilogSource'

2.2.2 Fusesoc

Fusesoc is used for the simulation target only. There are no build targets due to the use of Quartus 13.0sp1. This makes the use of it a bit silly. It does make it easier to use in future projects where the RAM,ROM,CPU,VDP, and Sound chips are also IP cores.

2.2.3 Open Game Module Glue Targets

- default
 - Info: Default IP target for future tool intergration.
 - src
 - constr
- sim
 - Info: Simulation target for basic test bench.
 - src
 - tb

2.2.4 Quartus

This project uses the last version of Quartus that supports the MAX7000S series. The version is 13.0sp1. The project is located at src/quartus13sp01/. Once you have the project open please follow the softwares steps for building and programming the CPLD bitstream.

2.3 PCB

The top has all the components of the circuit. The bottom contains none. This is a simple two layer board with a card edge. The card edge must have the pins of the socket bent to make contact and be soldered to it. The right angle connector is double the cost of the vertical one. Plus these are easier to obtain.

Figure 1: Top

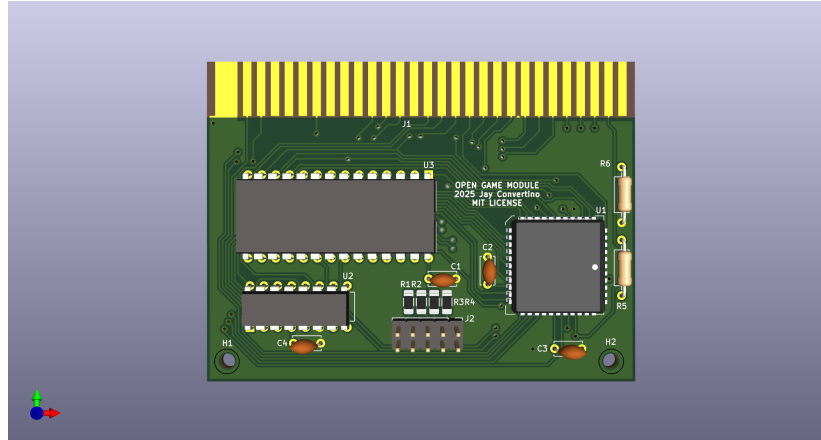
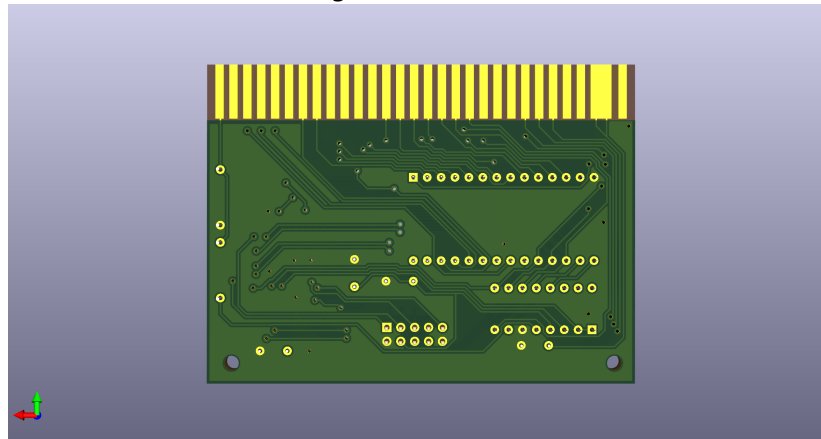


Figure 2: Bottom



2.4 3D Printed Case

The 3D printed case has been tested on two different printers. It has only been tested with ABS filament. The parts list for the 3D printed case has the STL file name in the value and the XXX.X value is the scale size. In general I recommend the following steps for assembly.

1. Bottom, sit pcb aligned to screw holes.
2. Top, sit top half on top and install screws.

2.5 CPLD Programming

There is one device that need to be programmed which is the CPLD (complex programmable logic device). This is programmed with quartus using the JTAG header to upload the bitfile.

Quartus 13.0sp1 is the easiest way to build and program the MAX7000 CPLD. You will need an altera blaster. I recommend the chinese clone blasters, they actually worked the best. While the worst was the Terasic blaster which did not work at all. As for instructions on how to program it in Quartus, please see the software for details.

3 Usage

3.1 Console

The expansion module must be firmly inserted into the expansion connector of the Colecovision. If you have issues, be sure to clean the connectors.

1. **Open Expansion Cover** 
2. **Insert Open Game Module** 

3.2 Software Programming

Module Documentation has indepth details for using the OGM register bits. You could do this in many different ways, but having the SDCC compiler know ahead of time that the RAM is there works well for me. There are different stragies that could be done for this but I feel this is the simplest way. Other methods can provide better detection of the OGM. The psudo code steps are as follows.

1. Setup expansion RAM, (NOTE COULD CHECK IF REGISTER VALUE IS EQUAL TO THE DEFAULT TO VERIFY SGM)
2. Setup IRQS
3. Copy IRQs to RAM where ROM jumps used to be.
4. Setup Sound CHIP, (READ BACK TO CHECK EXISTANCE)

3.2.1 Assembly Code For RAM Init

This brief assembly code doesn't actually check for the SGM it simply enables the ram registers, sets the irq, and starts main. This code is taken from RODAC and isn't complete, see RODAC coleco_sgm arch crt0.s for complete code.

```
_SGM_RAM_ENA_PORT    .equ 0x0053
_SGM_BIOS_SWAP_PORT  .equ 0x007F
_NMI_SIZE             .equ (_irq_nmi_end - _irq_nmi + 1)
_SPIN_SIZE            .equ (_irq_spin_end - _irq_spin + 1)
;setup for super game module.
ld a,#0x01
out (_SGM_RAM_ENA_PORT), a
ld a,#0x0D
out (_SGM_BIOS_SWAP_PORT), a
;setup ram locations with irq vectors?, 0x8 etc.
```



```

;reti
ld a,#0xED
ld (0x08),a
ld (0x10),a
ld (0x18),a
ld (0x20),a
ld (0x28),a
ld (0x30),a
ld a,#0x4D
ld (0x09),a
ld (0x11),a
ld (0x19),a
ld (0x21),a
ld (0x29),a
ld (0x31),a
;copy code to ram
;nmi first
ld bc, #_NMI_SIZE
ld hl, #_irq_nmi
ld de, #0x0066
ldir
;spin
ld bc, #_SPIN_SIZE
ld hl, #_irq_spin
ld de, #0x0038
ldir
ld      sp, #0x8000
call gsinit
call _main
rst    0x0

```

3.2.2 C Code for SDCC

The code below is based on using SDCC 4.X.X as the C compiler with a custom crt0.s. Essentially for the sound chip you need to communicate with it by writing an address to it to use, then the data. You can also read from the it to verify the chip exists and that the OGM is working. Though for the OGM its chip does not have a read function. It is emulated for registers 0, 2, and 4 (0=1, 2=3, and 4=5) in the CPLD so all opcode/team pixelboy games will startup correctly.

```

#define GI_SND_CP_ADDR      0x50
#define GI_SND_WDATA_ADDR  0x51
#define GI_SND_RDATA_ADDR  0x52

```

```

__sfr __at(GI_SND_CP_ADDR)    GI_SND_CP_PORT;
__sfr __at(GI_SND_WDATA_ADDR) GI_SND_WDATA_PORT;
__sfr __at(GI_SND_RDATA_ADDR) GI_SND_RDATA_PORT;

/** send address to chip */
inline void sendAddr(uint8_t addr)
{
    di();

    GI_SND_CP_PORT = addr;

    ei();
}

/** send data to chip */
inline void sendData(uint8_t data)
{
    di();

    GI_SND_WDATA_PORT = data;

    ei();
}

/** send data to chip */
inline void readData(uint8_t data)
{
    di();

    data = GI_SND_RDATA_PORT;

    ei();
}

```

4 Architecture

The OGM architecture emulates the Super Game Module. This is done with a CPLD which performs the RAM (32KiB) and sound (YMZ284) selects. It also caches the the sound writes for later reads. For the RAM selects this is done by emulating the original 74LS138 decoders. This is used to disable the internal RAM with the register at 0x53 by writing one to bit zero. This will remove the internal 1KiB and extend the console to 24KiB. Then to swap out the ROM for RAM for an additional 8KiB the register 0x7F has a zero written to bit one (default

value for the register is 0x0F). For the sound, all writes to register 7 and lower have an address cache to store the last address requested. This is due to the architecture of the original chip where the address is selected and then a read is performed. With the address set a subset of the register addresses are mapped to cache registers on the CPLD. See the section after this one for the mapping. This allows the cheaper YMZ284 to be used for sound generation. There are two resistors used to pad the output of the YMZ284 for acceptable levels when mixed with the original in the console. The console internally has a DC blocking capacitor, so no additional capacitors are needed.

4.1 Fix for opcode games

Opcode super game module mega cart games have a particular check for the sound chip in there startup routine.

1. Set AY register address to 0x00
2. Write the value 0xAA to AY (register 0x00).
3. Set AY register address to 0x02
4. Write the value 0x55 to AY (register 0x02).
5. Set AY register address to 0x00
6. Read the value from AY (register 0x00).
7. Compare to value originally written (0xAA), fail if not matching
8. Set AY register address to 0x02
9. Read the value from AY (register 0x02).
10. Compare to value originally written (0x55), fail if not matching.

The hack fix for my setup is to only have 4 8 bit registers for 0,1,2,3,4,5,6, and 7. The mapping is AY Software Register ADDRESS => Cache Register ADDRESS

- 0 => 0
- 1 => 0
- 2 => 1
- 3 => 1
- 4 => 2
- 5 => 2
- 6 => 3
- 7 => 3

5 Code Documentation

This section documents the verilog code for the CPLD in detail.

open_game_module.v

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DATES

2025/04/19

INFORMATION

Brief

Colecovision Emulation of the Super Game Module using a YMZ284 for audio.

License MIT

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open_game_module

```
module open_game_module (  
    input  
    clk,  
  
    10:0]  
    A,  
    input  
    MREQn,  
    input  
    RFSHn,  
    input  
    IORQn,  
    input  
    WRn,
```

```

    input
    RESETn,
    input
    RDn,

    7:0]
    D,
    output
    RAM_CSn,
    output
    RAM_OEn,
    output
    AY_CSn,
    output
    AY_AS
)

```

Colecovision Super Game Module Glue Logic

Ports

clk input	Clock for all devices in the core
A input[10: 0]	Address input bus from Z80
MREQn input	Z80 memory request input, active low
RFSHn input	Refresh request, active low
IORQn input	Z80 IO request input, active low
WRn input	Z80 Write to bus, active low
RESETn input	Input for reset, active low
RDn input	Z80 Read from bus, active low
D inout[7: 0]	Z80 8 bit data bus, tristate IN/OUT
RAM_CSn output	RAM chip select, active low
RAM_OEn output	RAM Output enable, active low
RAM_WEn	RAM write enable, active low
AY_CSn output	AY sound chip chip select
AY_AS output	AY data or register select

REGISTER INFORMATION

Core has 3 registers at the IO addresses that follow.

SOUND_ADDR_CACHE	h50
SOUND_CACHE	h51
RAM_24K_ENABLE	h53

SWAP_BIOS_TO_RAM h7F

SOUND_ADDR_CACHE

```
localparam SOUND_ADDR_CACHE = 8'h50
```

Defines the address of r_snd_addr_cache

SOUND ADDR CACHE REGISTER	
1:0	
CACHE LAST ADDRESS WRITE TO AY SOUND CHIP, BITS 2:1	

Setup an address for cache the sound address so each write will be to a proper address (opcode games need to write multiple and read multiple addresses) The register is only 4 bits since there are only 16 registers max.

SOUND_CACHE

```
localparam SOUND_CACHE = 8'h51
```

Defines the address of r_snd_cache

SOUND CACHE REGISTER	
7:0	
CACHE LAST WRITE TO AY SOUND CHIP	

Cache Sound Chip as the SGM games read from it (Yamaha chip does not have a read like a GI does).

RAM_24K_ENABLE

```
localparam RAM_24K_ENABLE = 8'h53
```

Defines the address of r_24k_ena

24K RAM ENABLE REGISTER	
7:1	0
ZERO	ENABLE 24K RAM, ACTIVE HIGH

Super Game Module 24K RAM enable using bit 0 (Active High)

SWAP_BIOS_TO_RAM

```
localparam SWAP_BIOS_TO_RAM = 8'h7F
```

Defines the address of r_swap_ena

SWAP BIOS TO RAM REGISTER			
7:4	3:2	1	0
ZERO	ONE	BIO TO RAM SWAP, ACTIVE LOW	ONE

Super Game Module BIOS to RAM swap on bit 1 (Active Low)

r_snd_addr_cache

```
reg [ 1:0] r_snd_addr_cache = 0
```

register for SOUND_ADDR_CACHE See Also: [SOUND_ADDR_CACHE](#)

r_24k_ena

```
reg [ 7:0] r_24k_ena = 0
```

register for RAM_24K_ENABLE See Also: [RAM_24K_ENABLE](#)

r_swap_ena

```
reg [ 7:0] r_swap_ena = 8'h0F
```

register for 8K RAM/ROM swap See Also: [SWAP_BIOS_TO_RAM](#)

r_snd_cache

```
reg [ 7:0] r_snd_cache[3:0]
```

register for SOUND_CACHE See Also: [SOUND_CACHE](#)

ASSIGNMENT INFORMATION

How signals are created

s_enable

```
assign s_enable = (  
  RFSHn &  
  
  MREQn  
)
```

Decided to keep the same method used internally as the coleco. This emualtes the original ttl chip logic.

s_y0_selIn


```

assign s_y0_sel0 = ~(
                                s_enable & ~A[10] & ~
A[9] &
A[8]
)

```

Address h0000, ROM/RAM

s_enable Enable decoder

A[10:8] Address lines used for select lines (actually lines A[15:13]).

s_ram2_csn

```

assign s_ram2_csn = ~(
                                s_enable & ~A[10] & ~
A[9] &
A[8]
)

```

Address h2000, RAM

s_enable Enable decoder

A[10:8] Address lines used for select lines (actually lines A[15:13]).

s_ram1_csn

```

assign s_ram1_csn = ~(
                                s_enable & ~A[10] & ~
A[9] &
A[8]
)

```

Address h4000, RAM

s_enable Enable decoder

A[10:8] Address lines used for select lines (actually lines A[15:13]).

s_ram0_csn

```

assign s_ram0_csn = ~(
                                s_enable & ~A[10] & ~
A[9] &
A[8]
)

```

Address h6000, RAM

s_enable Enable decoder

A[10:8] Address lines used for select lines (actually lines A[15:13]).

s_ram_csn

```
assign s_ram_csn = (
  (s_y0_seln | r_swap_ena[1]) & (s_ram2_csn | ~r_24k_ena[0]) & (s_ram1_csn |
    s_ram0_csn | ~r_24k_ena[0])
)
```

RAM Chip select when address is requested (active low). When the 24k is not enabled, use internal memory.

(s_y0_seln r_swap_ena[1])	address range starting at h0000, swap bios/rom bit is enabled (1 is disabled).
(s_ram1_csn ~r_24k_ena[0])	address range starting at h4000, 24k enable bit from register.
(s_ram2_csn ~r_24k_ena[0])	address range starting at h2000, 24k enable bit from register.
(s_ram0_csn ~r_24k_ena[0])	address range starting at h6000, 24k enable bit from register.

RAM_OEn

```
assign RAM_OEn = RDn | s_ram_csn
```

RAM Output enable when read is requested (active low).

RDn Z80 read request, active low.

s_ram_csn See Also: [s_ram_csn](#)

RAM_CSn

```
assign RAM_CSn = s_ram_csn
```

RAM Chip Select output assignment.

s_ram_csn See Also: [s_ram_csn](#)

DECODER INFORMATION FOR SUPER GAME MODULE

How address decoder is created for Super Game Module, using a YMZ284.

SGM IO REG Clocked IO decoder for Super Game Module.

AY_AS

```
assign AY_AS = (
  A[7:0]
  =
  8'h50 & ~IORQn & ~WRn ? 1'b0 : 1'b1
)
```

h50 is the address select, when selected its in data mode

A[7:0] If address matches h50, enable

IORQn Active IO request, enable

WRn Z80 write is active, enable

s_ay_sound_csn

match both h50 and h51 by ignoring bit 0. Enable AY sound chip.

A[7:0] If address matches h50 or h51, enable

IORQn Active IO request, enable

WRn Z80 write is active, enable

D

```
assign D = (
  A[7:0]
  =
  = 8'h52 & ~IORQn & ~RDn ? r_snd_cache[{2'b00, r_snd_addr_cache}] : 8'bzzzzz
)
```

read cached register from previous write (AY emulation), at set address location.

A[7:0] If address matches h52, enable

IORQn Active IO request, enable

RDn Z80 read is active, enable

6 Drawings and Schematics

This section has CAD drawings and schematics.

