ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #37332

BYOE - DIY Handheld Video Game Console

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ASEE 2022 Conference - DELOS Division – BYOE Session

Abstract

As of 2021 there were an estimated 3 billion people worldwide playing video games [1]. A significant percentage of those 3 billion people were high school and college-aged [1]. Video games are becoming a normal sight around the world. In the past decade, the world has seen the introduction of budget-friendly SBCs (Single Board Computers), microcontrollers, 3d printers, and massive contributions from the open-source community. [1, 2, 3, 4] This has made the design and implementation of a DIY handheld video game console more affordable and realizable.

The main component of the project consists of an SBC, an operating system to run on the SBC, a HID (Human Interface Device), a power system, a 3d printed case, a display, and speakers. The SBC used in this project is a Raspberry Pi 4B, however almost any other Raspberry Pi SBCs will work in this project (design considerations need to be made when using a Raspberry Pi SBC of a different form factor). The operating system used is known as Lakka, which is a lightweight Linux distribution used for retro gaming. However almost any other Raspbian based OS will work. The HID used is made using stripboard, conductive silicone pads, a ATmega32u4 microcontroller, PSP (PlayStation Portable) joysticks, and an Arduino library known as the Arduino Joystick Library. The power system utilizes the IP5328P, which is a fast charge power management SOC (System on a Chip) that handles the charging and discharging of lithium batteries. The SOC can supply up to 3.1amps at 5 volts, which is enough for this project. Four 3200 MaH 18650 lithium-ion batteries wired in parallel are used with the IP5328P. Using 4 high capacity 18650 lithium-ion batteries allows for a long console runtime. The flow of power is controlled by a latching circuit that utilizes a P-FET. The P-FET can connect and disconnect the power using a tactile switch. The 3D printed housing was designed in Autodesk Fusion 360. The 3D model was sliced with Cura and printed using HTPLA filament. HTPLA filament can be heat treated in order to withstand much high temperatures. 3D prints were printed with 1.75mm filament and a 0.4mm nozzle. Brass inserts for screws were used and were pressed into the model using a soldering iron. The display is a 5-inch TFT LCD that uses a 40 pin FPC connector. The raspberry pi will send a display signal to the LCD via DPI(RGB888). The speaker system consists of two 16x9mm rectangular micro speakers. The sound system is still a work in progress, driving micro speakers requires special attention to filtering out low frequencies. Perceived audio will be low if this is not done.

Pedagogical Context

Handheld gaming consoles comprise multiple systems. For this reason, it is recommended that this project be split into various experiments and teaching opportunities. For example, this project could supplement a related course, or extracurricular activity. The design and components are for demonstration and are completely subjective. It is encouraged to personalize and or deviate from the demonstrated design in order to foster creativity and resourcefulness.

Much of the hardware used for this handheld gaming console was selected to be accessible and affordable. The design and assembly of the demonstrated handheld gaming console should be relatively manageable with standard engineering lab resources.

Sample Applications

1. **Single Board Computing:** The so-called 'heart' of this handheld video game console is a Raspberry Pi 4 SBC. Working with the SBCs in this project will give students the opportunity to experience and explore the versatility of the Raspberry Pi series of SBCs.
2. **3D Modeling and Design:** 3d modeling and design is a significant part of this project. By designing the casing and buttons of this handheld gaming console students can become more familiar with 3D design processes. Students can become more familiar with designing 3D printed parts. Students will also become more familiar with the properties of different types of 3d printed filaments and why it is sometimes more beneficial to use one filament over the other due to the filament's physical properties.
3. **Human Interface Devices**: The use of microcontrollers like the ATmega32u4 and custom Arduino libraries like the Arduino Joystick Library allows for the creation of highly customizable HIDs (Human Interface Device). This not only helps students become more familiar with microcontroller programming, but it also introduces students to parsing analog and digital inputs for use as HIDs.
4. **Display Interfacing:** The handheld gaming console utilizes DPI (Display Parallel Interface) to output a display from the Raspberry Pi to a TFT LCD. This alternative way to connect a display to a raspberry pi showcases the SBC GPIO alternative functions. This is also a great way for students to learn about alternative display methods and functionalities of DPI and the Raspberry Pi.
5. **Power Management:** Powering portable devices with lithium-ion batteries require a power management solution. In the case of this project the use of a specific power management SOC, a IP5328P is used in order to manage both power and the lithium-Ion batteries. It is highly encouraged to review the IP5328P datasheet, as this SOC has many power management functionalities centered around lithium-ion batteries.
6. **Thermal Management:** Thermal management for this project should be a consideration as some of the Raspberry Pi SBC components like the CPU can rise to over 80 degrees Celsius based on utilization. Once some of these components reach 80 to 85 degrees Celsius the Raspberry Pi SBC will begin thermally throttle itself in order to protect itself from overheating [4]. Thermal throttling can reduce performance of the whole system. Employing a thermal solution like small heat sinks and vents can assist in wicking away excess heat.

Handheld Video Game Console Design

The handheld video game console housing design is arguably one of the most important aspects of this project. The way the housing is designed will dictate the placement of all components, and the ergonomics of the handheld console. Figure 1 shows the console from different views.

Hardware and Electronics

The use of HTPLA filament is recommended and used for most of the 3d printed parts in this project. Parts that will be subjected to high heat like the backplate and the mounting bracket between the LCD and the backplate can be heat treated for up to three times the heat resistance

compared to normal PLA [3]. The Raspberry Pi 4 for this project was modified, the GPIO pins, double stack USB receptacles, and LAN/Ethernet receptacle were de-soldered and removed to make the Raspberry Pi 4 thin enough to fit the case design. New single stacked USB receptacles were soldered onto the board. This step is optional and is dependent on housing design. The IP5328P board was also modified, the USB A receptacles were removed to save space. Stripboard was cut into appropriate sizes and soldered up then silicone conductive pads were placed on top to send HIGH/LOW signals to the ATmega32u4 when pressed. The FPC breakout with backlight driver was wired up in RGB888 so the LCD is getting 24-bit color via DPI through the Raspberry Pi GPIO. Figure 2 shows the steps and final prototype.

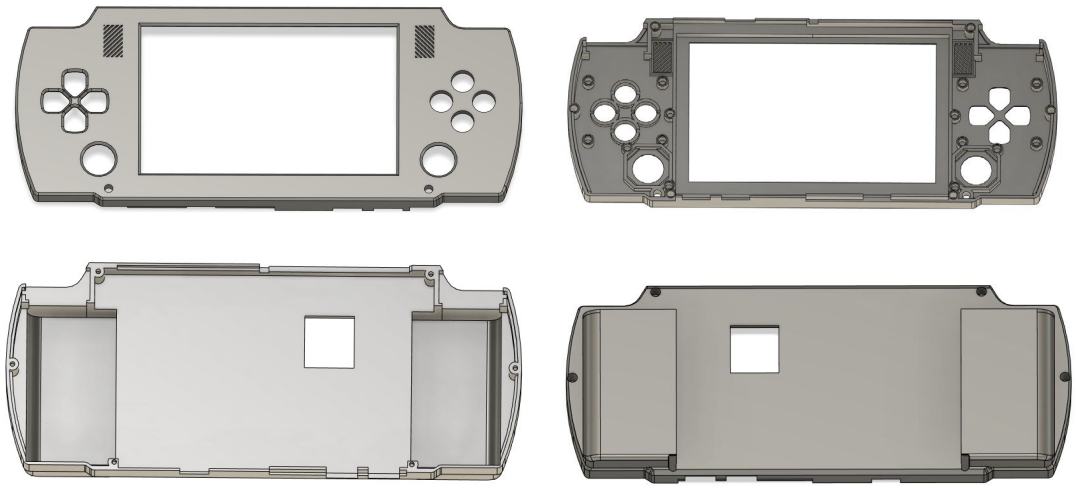

Figure 1: Front and back view of the front and back housing

Figure 2 - Handheld Video Game Console Implementation

Bill of Materials

Part	Description	Manufacturer	Mfg. Part #	Vendor	Vdr Part #	Price	Qty	Total
Raspberry Pi 4B	Raspberry Pi 4B 4GB	Raspberry Pi Foundation	Raspberry Pi 4B 4GB	Vilros	RP4B4GB	45.00	1	45.00
TFT LCD	5.0" 40-pin 800x480 TFT Display without Touchscreen	Adafruit	1680	Adafruit	1680	29.95	1	29.95
HTPLA Filament	500g of HTPLA	Proto-Pasta	HTP31710-BLK	Proto-Pasta	HTP31710-BLK	25	1	25
AdaFruit TFT Friend	40-pin TFT Friend - FPC Breakout with LED Backlight Driver	Adafruit	1932	Adafruit	1932	9.95	1	9.95
Adafruit ItsyBitsy	Adafruit ItsyBitsy 32u4 - 5V 16MHz	Adafruit	3677	Adafruit	3677	9.95	1	9.95
MicroSD Card	32GB microSDHC UHS-I Memory Card	PNY	P-SDU32G-U185GW-GE	Bestbuy	6327962	6.99	1	6.99
Adafruit Push-button Power Switch	Adafruit Push-button Power Switch Breakout	Adafruit	1400	Adafruit	1400	5.95	1	5.95
Stripboard	100mm W x 80 mm L Traditional Stripboard	Busboard	ST2	Mouser	854-ST2	5.50	1	5.50
IP5328P Powerbank PCB	IP5328P Powerbank PCB	SZYTF	IP5328P	SZYTF	IP5328P	3.55	1	3.55
PSP Joystick	PSP 2-Axis Analog Thumb Joystick	Adafruit	444	Adafruit	444	3.50	2	7.00
18650 Lithium Ion Batteries	DLG INR18650-320	DLG	INR18650-320	Liion Wholesale	dlg3100mAh	3.43	4	13.72
M2*3 Brass Inserts	M2*3 brass inserts (heat set) 50 pcs	NEWHONGHUIDA	M2*3	Aliexpress	M2*3	2.47	1	2.47
M2*4 Screws	M2*4 Screws 50 pcs	WHOOPEE	SS04	Aliexpress	SS04	1.20	1	1.20
USB-A Receptacle	USB-A Receptacle	Kycon, Inc.	KUSBEX-ASFS1N-W	Digikey	2092-KUSBEXASFS1N-W-ND	0.83	2	1.66

Conductive Silicone Set for PS4 Controller	PS4 Controller Conductive Silicone Pads	Juchen Electronics	PS4CPAD	Aliexpress	PS4CPAD	0.25	1	0.25
Heatsink for RPi 4	Small Aluminum Heatsink	TZT	RP-AHSBLK	Aliexpress	RP-AHSBLK	0.25	1	0.25
Tactile momentary micro switch	Tactile momentary micro switch -6*6*7	Hilitchi	HTPB-200	Amazon	HTPB-200	0.05	5	0.25
Wire	30 AWG Stranded Wire	Various					5ft	0
Wire	22 AWG Stranded Wire	Various					1ft	0
Polyimide Tape	Polyimide Tape	Various						0
Solder	Solder	Various						0
Hot Glue	Hot Glue	Various						0
						TOTAL		**168.64**

Conclusion

The handheld video game console prototype was inspired by the student author's desire to combine an entertaining project with many of the learning objectives found in STEM lab experiments. While designing and implementing the project and prototype, the student author was able to apply many of the concepts learned as an Electrical and Computer Engineering Technology major. A demonstration of the prototype can be found here: Demonstration of Handheld Video Game Console ASEE 2022 .

References

[1] Newzoo, "Global Games Market Report 2021." .

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[3] "HTPLA," proto-*pasta*. [Online]. Available: https://www.proto-pasta.com/pages/high-temp-pla. [Accessed: 03-Feb-2022].

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[5] K. R. Raghunathan, "History of microcontrollers: First 50 years," *IEEE Micro*, vol. 41, no. 6, pp. 97–104, 2021.