CloudShell 2 • Home Automation • Cloud Print • ODROID-XU4 Case

ODROID Magazine

Year Four
Issue #40
Apr 2017

Meet WALTER:

The vintage looking robot powered by your ODROID

Laptop with ODROID-C1+/C2

Celebrating Forty issues of ODROID Magazine: A retrospective of all our publications

What we stand for.

We strive to symbolize the edge of technology,
future, youth, humanity, and engineering.

Our philosophy is based on Developers.
And our efforts to keep close relationships with
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EDITORIAL

Welcome to our 40th issue! When we started publishing the magazine in 2014, there were only two people, Bruno and Rob Roy, producing ODROID Magazine. We've since grown the team to eight people and publish in both English and Spanish. We are continually amazed by the creative and innovative projects that the ODROID community sends our way for publication, and do our best to educate the open source hacking community with a variety of software and hardware articles.

Our featured project this month is an amazing retro-looking robot named Walter. He was designed to resemble a 20th century science fiction home servant, complete with dials, knobs, and an avocado green finish! Another interesting project is the ODROID-C2 Wawa laptop, which is an affordable way for children to get started with computers. Miltiadis shows us how to set up a home automation device to control electrical devices, Joshua teaches us how to use Google Cloud Print with any ODROID, and @hominoid presents a gorgeous 3D printed case for the ODROID-XU4 that you can make at home.

ODROID Magazine, published monthly at http://magazine.odroid.com, is your source for all things ODROIDian.
Hard Kernel, Ltd. • 704 Anyang K-Center, Gwanyang, Dongan, Anyang, Gyeonggi, South Korea, 431-815
Hardkernel manufactures the ODROID family of quad-core development boards and the world's first ARM big.LITTLE single board computer.
For information on submitting articles, contact odroidmagazine@gmail.com, or visit http://bit.ly/1yplmXs.
You can join the growing ODROID community with members from over 135 countries at http://forum.odroid.com.
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ODROID-C1+

ODROID-C0

OWEN ROBOT KIT

ODROID-C2

VU7 TABLET KIT

Hardkernel's EXCLUSIVE North American Distributor

OUR AMAZING ODROIDIAN STAFF:

Rob Roy, Chief Editor

I'm a computer programmer in San Francisco, CA, designing and building web applications for local clients on my network cluster of ODROIDs. My primary languages are jQuery, Angular JS and HTML5/CSS3. I also develop prebuilt operating systems, custom kernels and optimized applications for the ODROID platform based on Hardkernel's official releases, for which I have won several Monthly Forum Awards. I use my ODROIDs for a variety of purposes, including media center, web server, application development, workstation, and gaming console. You can check out my 100GB collection of ODROID software, prebuilt kernels and OS images at `http://bit.ly/1fsaXQs`.

Bruno Doiche, Senior Art Editor

Worked night and day to create the ODROID Magazine retrospective in celebration of our 40th issue!

Manuel Adamuz, Spanish Editor

I am 31 years old and live in Seville, Spain, and was born in Granada. I am married to a wonderful woman and have a child. A few years ago I worked as a computer technician and programmer, but my current job is related to quality management and information technology: ISO 9001, ISO 27001, and ISO 20000. I am passionate about computer science, especially microcomputers such as the ODROID and Raspberry Pi. I love experimenting with these computers. My wife says I'm crazy because I just think of ODROIDs! My other great hobby is mountain biking, and I occasionally participate in semi-professional competitions.

Nicole Scott, Art Editor

Nicole is a Digital Strategist and Transmedia Producer specializing in online optimization and inbound marketing strategies, social media management, and media production for print, web, video, and film. Managing multiple accounts with agencies and filmmakers, from web design and programming, Analytics and Adwords, to video editing and DVD authoring, Nicole helps clients with the all aspects of online visibility. Nicole owns anODROID-U2, a number of ODROID-U3's, and Xu4's, and looks forward to using the latest technologies for both personal and business endeavors. Nicole's web site can be found at http://www.nicolecscott.com.

James LeFevour, Art Editor

I'm a Digital Media Specialist who is also enjoying freelance work in social network marketing and website administration. The more I learn about ODROID capabilities, the more excited I am to try new things I'm learning about. Being a transplant to San Diego from the Midwest, I am still quite enamored with many aspects that I think most West Coast people take for granted. I live with my lovely wife and our adorable pet rabbit; the latter keeps my books and computer equipment in constant peril, the former consoles me when said peril manifests.

Andrew Ruggeri, Assistant Editor

I am a Biomedical Systems engineer located in New England currently working in the Aerospace industry. An 8-bit 68HC11 microcontroller and assembly code are what got me interested in embedded systems. Nowadays, most projects I do are in C and C++, or high-level languages such as C# and Java. For many projects, I use ODROID boards, but I still try to use 8bit controllers whenever I can (I'm an ATMEL fan). Apart from electronics, I'm an analog analogue photography and film development geek who enjoys trying to speak foreign languages.

Venkat Bommakanti, Assistant Editor

I'm a computer enthusiast from the San Francisco Bay Area in California. I try to incorporate many of my interests into single board computer projects, such as hardware tinkering, metal and woodworking, reusing salvaged materials, software development, and creating audiophile music recordings. I enjoy learning something new all the time, and try to share my joy and enthusiasm with the community.

Josh Sherman, Assistant Editor

I'm from the New York area, and volunteer my time as a writer and editor for ODROID Magazine. I tinker with computers of all shapes and sizes: tearing apart tablets, turning Raspberry Pis into PlayStations, and experimenting with ODROIDs and other SoCs. I love getting into the nitty gritty in order to learn more, and enjoy teaching others by writing stories and guides about Linux, ARM, and other fun experimental projects.

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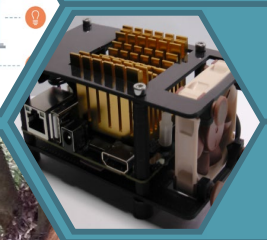

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BUILDING A ROBOT

MEET WALTER, THE ROBOT FROM 1968

by Jochen Alt

Ever since man built the first robot, he wanted it to look like himself. However, I created my own robot named Walter, and I wanted to make it look vintage, and as professional as possible. Walter's case has no visible humps or bulges with motors or gearboxes, nor any messy exposed cables. I have a few problems with many of the DIY robots. Most of them remind me of my dentist's equipment, or they use servos. Servos are picked mostly for convenience, since the encoder is built-in already and they are easy to control. The problem with this is, when it comes to high torque, the connection of the servo with the actuator becomes difficult, and are hard to make using 3D printed material. If the servo or the flange moves just a little bit within its housing, the play will magnify to a significant amount at the end of the actuator. The required precision to avoid this is way above hobby grade components.

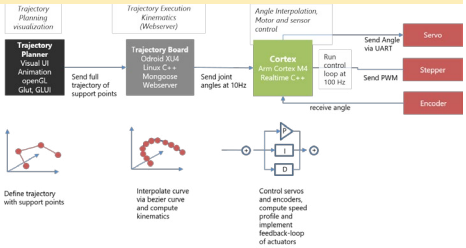
Servos are boringly easy to use, and no fun in construction. A motor with a belt drive and a separate angle sensor solves this, since it provides low backlash and allows the electronics to compensate for imprecise parts with the sensor placed separately from the motor. Additionally, the motor of an actuator can be placed in the previous joint, lowering the centre of gravity of each actuator.

When a belt drive is used, the choice of using stepper motors is natural, since an additional gearbox is not necessary anymore. When the torque is high, then the belts should compensate for the vibrations coming from the stepping nature of the motors. I started out with an OpenCV application simulating the construction, and ended with a the final construction seen in Figure 1.

Figure 1 - Walter and a beautiful arrangement of flowers

The software part was not easy, and was especially time consuming. Most robot makers stop as soon as the limbs are moving, which always looks unfinished. However, making the full software stack including trajectory planning meant four months of work when I only had time on the weekends. Some parts are really difficult, such as inverse kinematics. The data flow of the full stack is shown in Figure 2.

Figure 2 - Data flow of the full stack



System Parts

Trajectory Planner: This is a UI for planning trajectories. Trajectories are planned by defining single support points. After planning is done, the trajectory is transferred to the Executor. More information can be found at http://bit.ly/2nQc22P, and the source code is available at http://bit.ly/2nz6sSf.

Trajectory Execution: This component consists of a webserver that runs trajectories by interpolating Bézier curves between support points, computing the inverse Kinematics per pose and sends the resulting series of angles to the controller. More information is at http://bit.ly/2n4rxRm, and the source code is available at http://bit.ly/2nhz6Fc. An explanation of the kinematics involved can be found at http://bit.ly/2nTM52X.

Cortex: This low-level component takes interpolated poses and controls the actuators accordingly by applying control algorithms. Servos are controlled directly by the cortex controller board using a serial interface. Steppers do not have an internal feedback loop, so we need rotary encoders detecting

the absolute angle of the joint and allowing to implement feedback controllers. More information is available at http://bit.ly/2ogvbYn, and the source code may be downloaded from http://bit.ly/2n4pJaN. An explanation of the PID controller may be found at http://bit.ly/2nQiQ0r.

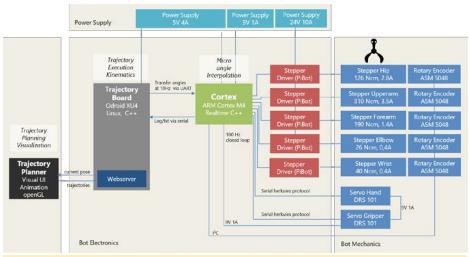


Figure 3 - Cortex-centric diagram

On the mechanical side, we have two actuators driven by a servo, mainly due to space restrictions, and five actuators driven by a stepper/rotary encoder combination. Details about the construction can be found at http://bit.ly/2n4AZ70.

The steppers are driven by 3D-printed components, PiBot Stepper Driver, based around the popular IC Toshiba 6600 (4.5A max). The stepper drivers are directly connected to the ARM Cortex receiving joint angles at 10Hz, interpolating in between the points, and sending the PWM signal to the stepper drivers and to the servos. Besides micro interpolation of the trajectory, the controller board takes care of the speed profile by limiting the acceleration and speed of each actuator. The controller board is a DIY PCB based on an ARM Cortex M4, Teensy 3.5, running the control loop at 100 Hz. I started with an ATmega 644, but it turned out that the ATmega was not able to control 5 steppers with the proper sample rate, let alone reading 5 encoders. In a previous project, I solved this by using 16-bit fixed point arithmetics instead of floating point, which gave a performance boost but, resulted in a mess of source code.

The trajectory controller board is encapsulated by a web server exposing the current movement and accepting commands like new trajectories.

Figure 4 - Control cabinet

In Figures 5 and 6, we see the control cabinet in its natural environment, accompanied by a Japanese flower arrangement. The innards is a scaffold holding the power supply, the stepper drivers, and some smaller PCBs.

Figure 5 - Side View Diagram of the control cabinet

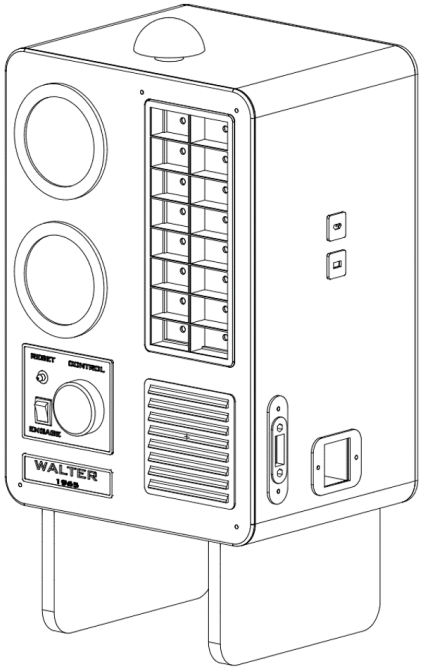
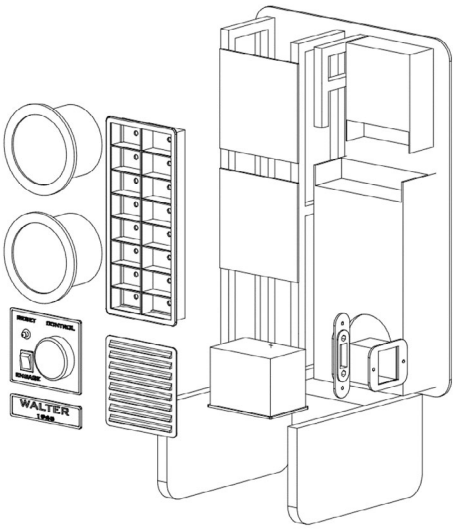


Figure 6 - Exploded view of control cabinet



I tried to give it an East German vintage style, by using these great looking rounded panel meters that I got from eBay and a panel of mostly useless lamps.

Figure 7 - Another view of Walter

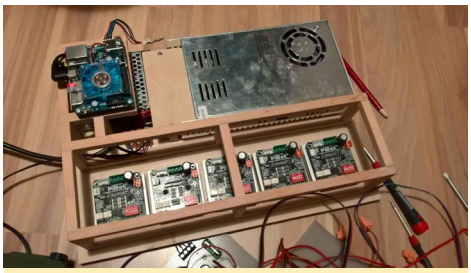


Figure 8 - Inside view of the cabinet

All sockets are on the left side of the wooden box, and the biggest 28-pin socket is for the cable containing lines for the steppers, encoders, and servos. Above it there are two USB ports, one for the ODROID-XU4's serial interface, which is handy if Wifi is not working, and one for the Walter's ARM Cortex. The power supplies are fixed on the backside with screws, and the scaffolding for electronics is glued to the backside as well. The picture on the right shows the tidy version of the inners with power supplies and stepper drivers only. When the other PCBs are added and all the wiring is done, make sure to close the

box! I also included a nice emergency stop button on top of the box.

Downloads

CAD Models: Designs made with TurboCAD, used to 3D-print all parts: http://bit.ly/2n5E2fh

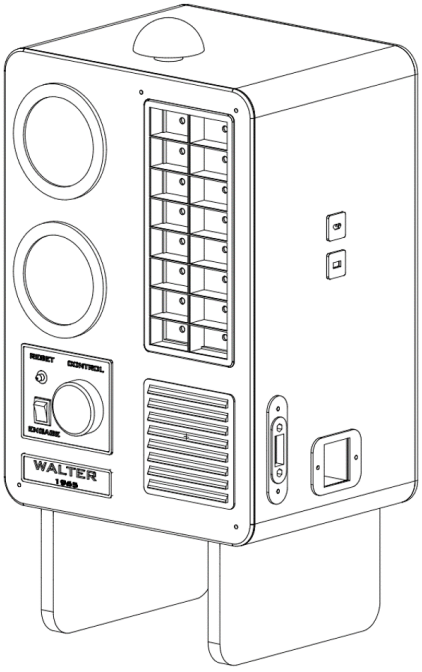
Schematics: Cortex and Power Supply PCB made with KiCAD: http://bit.ly/2mCIEO1

Source Code: C++ code of the cortex, trajectory planner, and web server: http://bit.ly/2o4nx3X

Datasheets of components Walter is made of: http://bit.ly/2n5eMGg

Zip, which includes all of the above: http://bit.ly/2mCGVbc

To check out a video of Walter in action, visit youtu.be/XK3Wcrrc-C8U. For more detailed information about Walter, please visit the documentation at http://bit.ly/2ncR0bb, or send comments, questions, or suggestions via the Hackaday page at http://bit.ly/2n5zo0U.



ODROID-C2 WAWA LAPTOP

IMPROVING CHILDREN'S EDUCATION

by Javier Carrasco

We are always proud to see ODROIDs being used in education!

For the last three years, I have had the opportunity to travel throughout most of Peru for work, visiting everywhere from great urban population centers to rural farmhouses. In all of these places, I saw one particular common thread: a lack of quality in education and access to new technologies. For example, in the last international PISA quality tests, the results of my country showed a tremendous deficit in educational quality, and children of the RBE (Regular Basic Education) are unaware of the use of technological tools.

This is why I created the Wawa Laptop. I am inspired by both my travel experiences and my children, who also motivate me to continue and maintain the project. I recruited family and friends to help with the project, and so I put into action a plan for the Wawa laptop with a clear goal: to contribute to improving the quality of education in our country and the region.

I started my project by working with a Raspberry Pi, using a core Linux environment which I adapted by adding a useful and attractive visual environment (GUI). At the time, I was developing the project as a desktop for user assembly. It had a keyboard, mouse, HDMI cable, power cable and WiFi dongle.

In August, we won the Andes Accelerator incubator contest at the University San Martin de Porres in Lima, Peru. The disruption-oriented prize gave its winners many of the tools and ways to build a successful product, including training, mentoring, presentations, and advice. This allowed us to bring our ideas together and move it to the next level.

At the end of 2015, I discovered Hardkernel and their SBC boards. The one that most attracted my attention was the ODROID-C1+, mostly because it not only supported both Linux and Android, but also had far better performance than the Raspberry Pi. We also started to consider building a screen into the device like a laptop, rather than a desktop that you'd plug a monitor into. We tested various screen options until we settled on a 10.1-inch HD screen. I was using a variety of SBC boards at the

time, but ODROID ultimately won me over with its robustness, versatility and power for implementing our first prototypes of the Wawa.

As we progressed with the project, many changes arose, because of the information we were collecting on other projects in Peru that preceded us, such as One Laptop Per Child (OLPC). We used this information to help our investigation into the idea of an educational model of the Wawa for children in cities and rural towns across Peru. We've recently completed our first public prototypes, and have begun implementing the operating system design.

A closer look at the Wawa and its internals

I was in touch with a friend of the ODROID community, who has a project to power an ODROID with two operating systems in tandem called VolksPC, so we based our OS on that core technology, and adapted Android and Linux with various educational apps such as Scratch, and free useful software like GIMP, office software, and Inkscape, that we think will best serve the children to whom we deliver these devices.

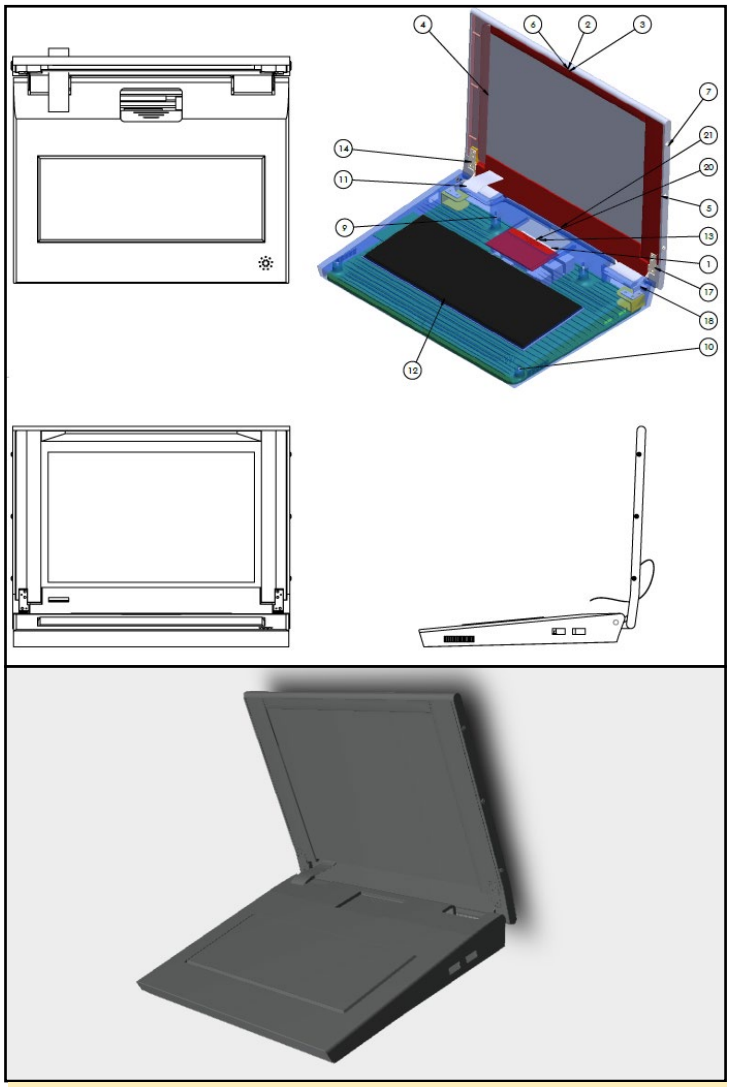
We decided to energize the Wawa with a choice of either a portable solar panel or direct power. One goal as we developed the Wawa was to offer some environmentally sustainable options, since electricity is scarce in many parts of Peru due to its geography, and we wanted to address our own ecological interests. We searched and tested different types of solar panels and performed various tests until we found the one we currently use, which can offer three hours of continuous usage with a fully charged battery.

A look at the Wawa GUI on Android and Linux

The access and development of robotics, home automation and IoT (Internet of Things) is a very important aspect of our project as well. That is why we decided to have a direct access to the GPIO ports so that children can interact and develop everything related to these issues, keeping in mind that the education curriculum in my country is betting on the insertion of robotics in education through a project with the Lego WeDo tool. We plan to develop the Wawa Laptop to be compatible with this tool.

We contacted the talented team at the National University of Engineering (UNI) and came up with the current Wawa Laptop design. We sought to include all the knowledge acquired in recent years and focus on the use of the GPIO ports too. We also made the impression using z-ultra material, which gives us a very nice finish.

We developed a packaging concept, called "The Treasure Chest", which focuses on highlighting the Wawa Laptop as a treasure for the children, as they will discover the technology and connect with the world, upgrading all their skills for the benefit of their family, community, and country.



Design mockups of the Wawa Laptop

We have an integral distribution plan that accompanies our Wawa Laptops as we reach the many communities that we hope to bring this device to. In the services area, we will include training and technical support for both teachers and student, as well as enterprise-like services, such as monitoring, tracking, and traceability. By doing so, we will be able to carry out our objectives, which are: improving educational quality, allowing access to multiple opportunities for research and learning, promoting technological literacy, and filling the gaps between public and private education. We plan to launch a fundraising campaign via Kickstarter.

The idea that we have is to put together a campaign to bring the Wawa Laptop to the largest number of schools that do not have access to technology, to provide children with the tools they need to upgrade their skills, and help make them the next leaders required by the country and region, with education, information and knowledge. For more information, please visit the Wawa Laptop website at `www.wawaperu.org`.

Materials

ODROID-C2
ODROID-C2 RTC Shield
AmeriDroid USB Audio Adapter
3 Watt Stereo Amplifier
8 Ohm, 2 Watt Mini Speaker
Hardkernel Wi-Fi Dongle
Pantalla 10.1 IPS HD Display
Zortrax Impresora 3D Printer and Z-ULTRAT (3D Printed Case Filament)
Portable Solar Powered External Battery
Teclado + Trackpad
Bluetooth Wireless Keyboard
Hardkernel 720P Camera

The Wawa "Treasure Box" packaging design

A final look at the Wawa for our upcoming Kickstarter project

ISSUE
40
Can you believe we are on the 40th issue already?
It's about time we recap our antics, let's go!

FORTY ISSUES, A RECAP

IF YOU HAVEN'T READ THEM ALL, IT'S YOUR LUCKY DAY!

by ODROID Magazine Team

In November of 2013, there was a message in the ODROID forum, where some users were thinking about doing an e-magazine for the ODROID. Soon enough, a bunch of them gathered together to publish the very first issue of our beloved magazine.

Note: *Click any magazine image to view its online PDF*

ISSUE #1

The first issue, in fact, took about two months to get all the articles, assemble the very first PDF, and get it published on the magazine.odroid.com website. It was 27 pages long and it was then that our mellow, relaxed and funny editorial style began.

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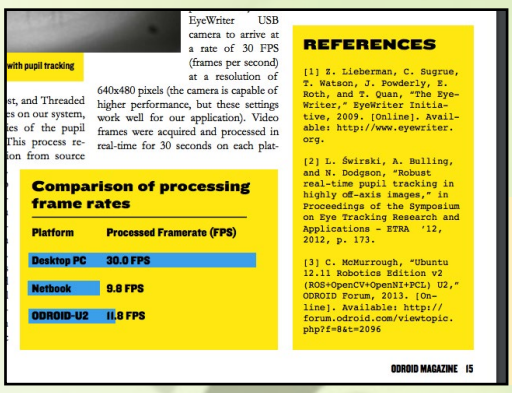
EyeWriter USB camera to arrive at a rate of 30 FPS (frames per second) at a resolution of 640x480 pixels (the camera is capable of higher performance, but these settings work well for our application). Video frames were acquired and processed in real-time for 30 seconds on each plat-

Comparison of processing frame rates

Platform	Processed Framerate (FPS)
Desktop PC	30.0 FPS
Netbook	9.8 FPS
ODROID-U2	11.8 FPS

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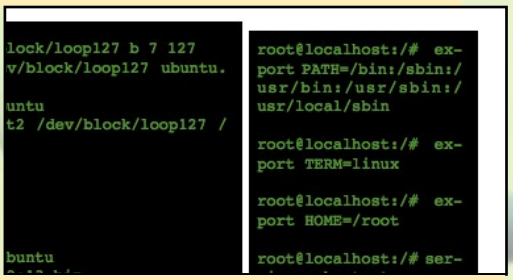
In the beginning our text boxes were splashingly yellow!



And our codes on the screen were on an old green screen CRT

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ISSUE #4

On issue four, we packed an ODROID inside a truck, showing the world that we could take our computers inside everything we wanted and take them everywhere.

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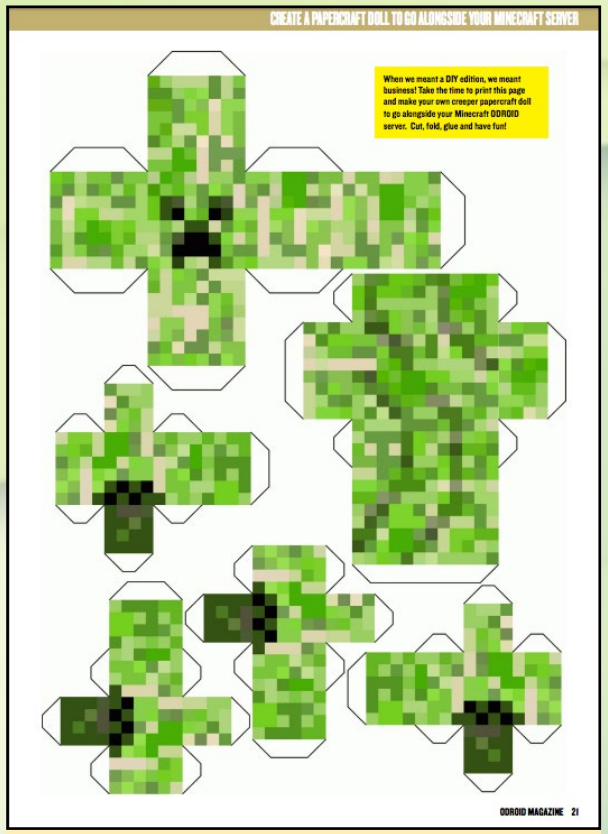
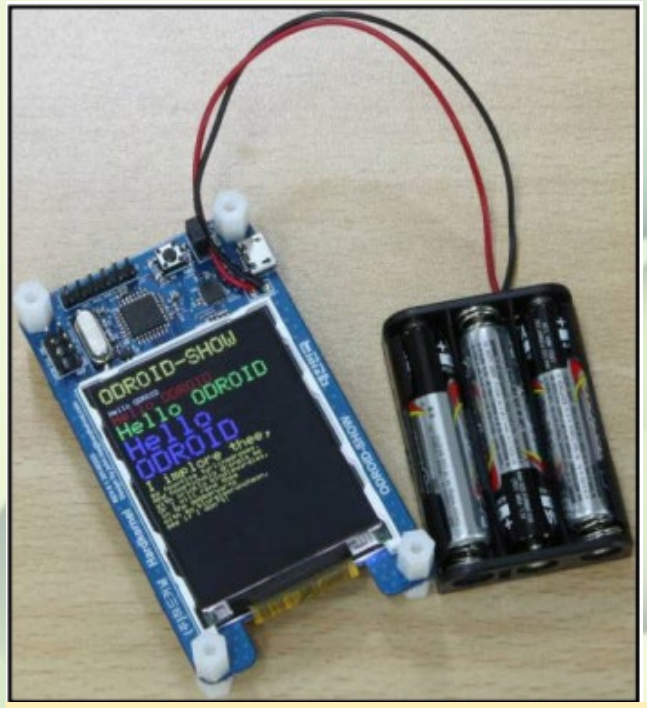


We had an amazing tutorial teaching how to build a minecraft server, and as a bonus, we published a cool creeper papercraft for you to build!

With this column, we started to phase out our blasting yellow colors on our template.



It wasn't christmas, but felt like it with that many goodies!

ISSUE #5

In this issue, we started our love affair with robots! Robots everywhere, robots forever, alongside with the premier of the ODROID-UPS and the ODROID-SHOW accessories.

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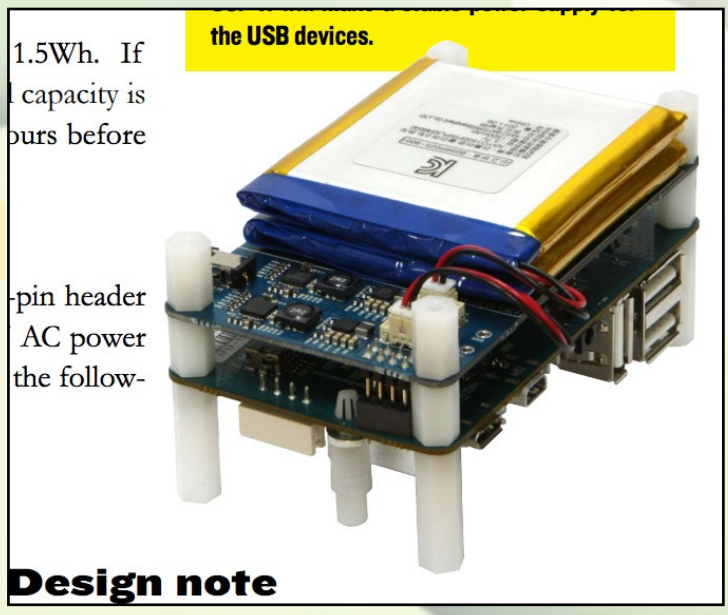

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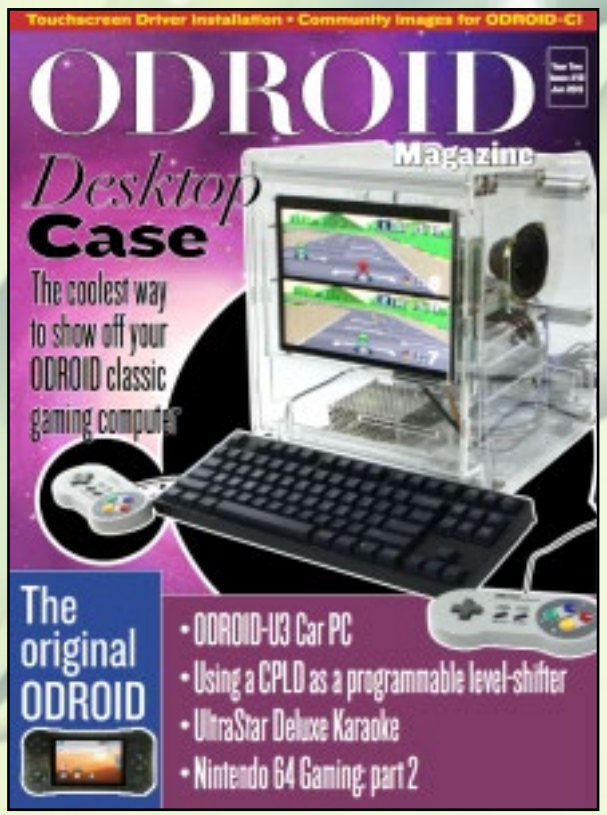

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ISSUE #40 – Wait a minute... Is this some sort of an inception thing?

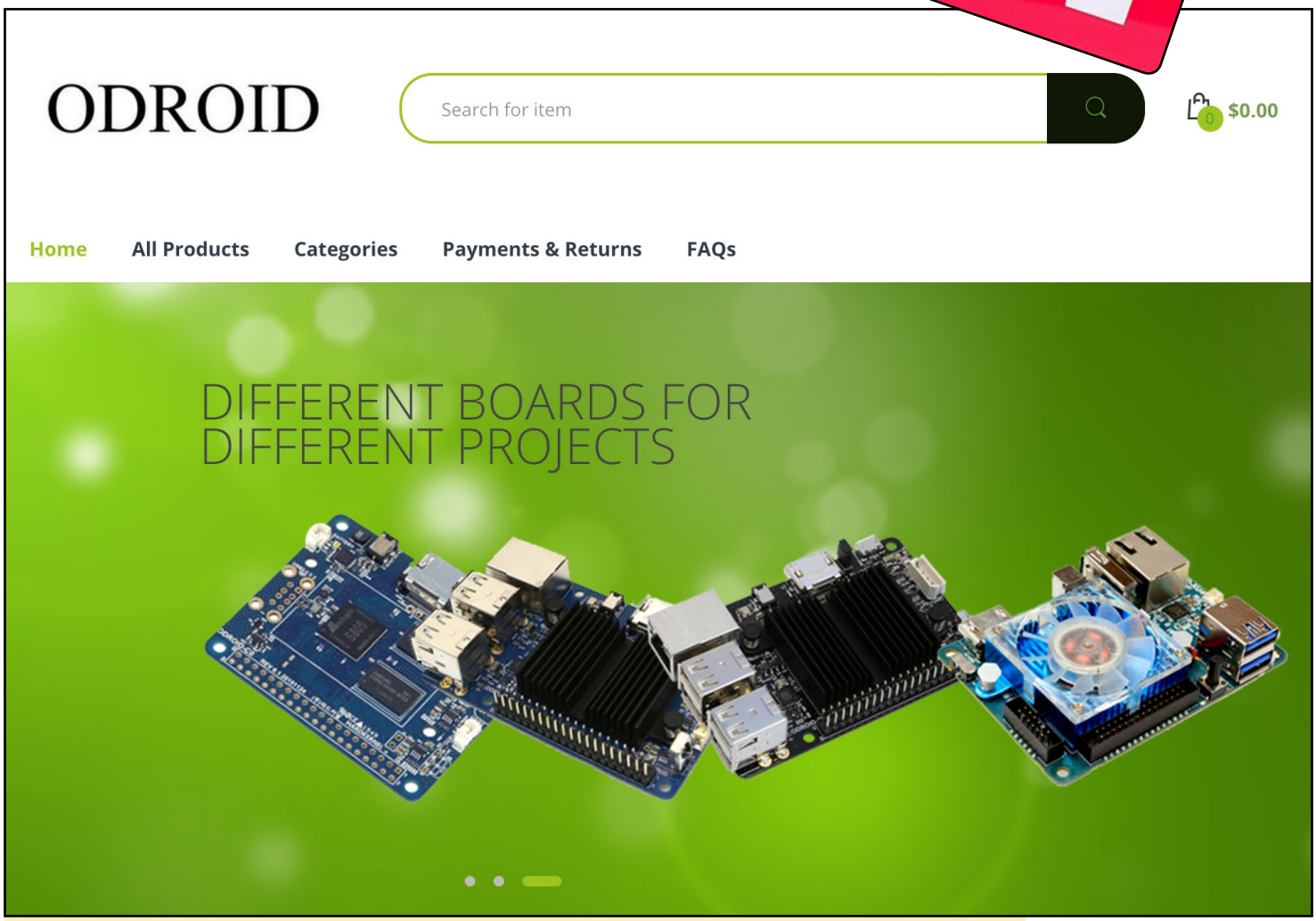
But thanks for being around these forty issues! We're just getting started!

A NEW ODROID STORE IS OPENING IN THE US

VISIT ODROIDINC.COM

by Rob Roy (robroy)

A new Hardkernel distributor has just opened an online store in the United States, which offers their complete catalog of products, including the ODROID-XU4, ODROID-C0, ODROID-C1+ and ODROID-C2. The site calculates bulk discounts for a number of products and several shipping options for fast delivery. It will be opening in mid-April, so make sure to visit the new website at `www.odroidinc.com` for all of your single board computer needs.



The new odroidinc.com home page, which offers all of the current Hardkernel boards to US customers

CLOUDSHELL-2 FOR THE ODROID-XU4

A DIY HIGH-PERFORMANCE NAS WITH RAID

by Brian Kim and John Lee

The CloudShell-2 for the ODROID-XU4 is an affordable DIY Network Attached Storage (NAS) Solution with RAID support. Like the original CloudShell, it includes a color LCD and IR receiver on the front, but adds support for USB Attached SCSI (UAS or UASP) and useful data storage technologies (RAID-0, RAID-1 and SPAN). It offers dual slots for 3.5" HDD/SSD drives, which is also compatible with 2.5" HDD/SSD drives. The CloudShell-2 also includes a USB 3.0 to SATA bridge (JMicron JMS561), which supports UAS and allows installation of a dual 3.5"/2.5" SATA HDD/SDD drive.

Specifications

ODROID-XU4 (not included)

- CPU: Exynos-5422 Cortex A15 and Cortex A7 big. LITTLE processor
- Architecture: ARM 32bit
- CPU Frequency: Quad 2 GHz(A15) + Quad 1.5 GHz(A7)
- Memory: 2 Gbyte LPDDR3 RAM
- Support OS: Ubuntu 16.04 on Kernel 4.9 LTS, Android 4.4.4 on Kernel 3.10 LTS

Storage

- 2 Drive Bays
- Supported size : 3.5" SATA HDD

Supported RAID Type

- Basic(PM)
- JBOD
- RAID 0
- RAID 1

External Ports (with ODROID-XU4)

- USB 2.0 Port, USB 3.0 Port
- Gigabit Ethernet Port
- HDMI Port

Appearance

- Color: Clear, Smoky Blue
- Size (Height x Width x Depth): 140 mm x 110 mm x 221.5 mm
- Weight: 0.64kg(without HDD), 2.15kg(with 2 x HDD)

Others

- Fan 92 mm x 92 mm (cool, quiet mode)
- IR Receiver (remote controller not included)
- 2.8" 320x240 TFT LCD
- 15V 4A Power Input

Figure I - Hardware Details of the CloudShell-2 Board

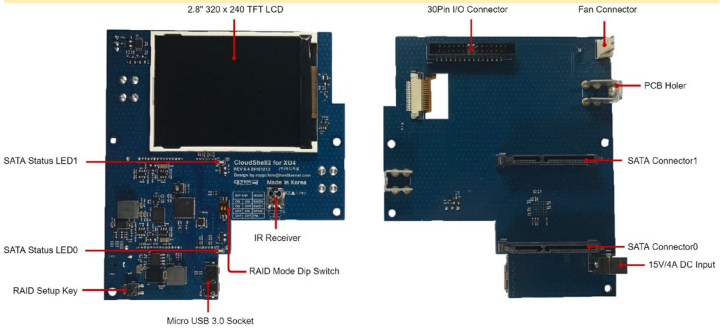
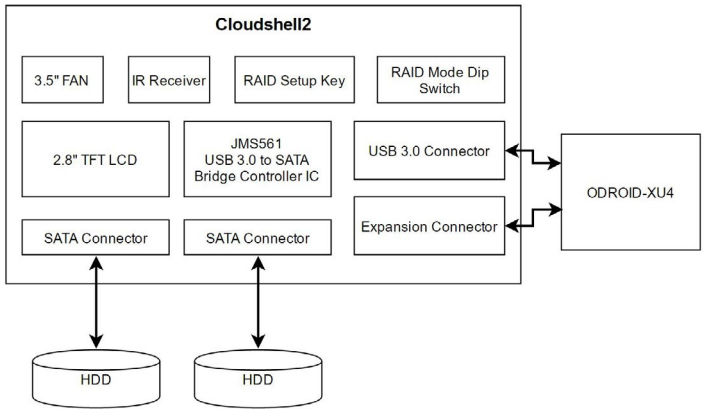


Figure 2 - Block Diagram of the CloudShell-2



```
root@odroid:/media/hdd# lsusb -t
/:  Bus 06.Port 1: Dev 1, Class=root_hub, Driver=xhci-hcd/1p, 5000M
    |__ Port 1: Dev 2, If 0, Class=Vendor Specific Class, Driver=r8152, 5000M
/:  Bus 05.Port 1: Dev 1, Class=root_hub, Driver=xhci-hcd/1p, 480M
/:  Bus 04.Port 1: Dev 1, Class=root_hub, Driver=xhci-hcd/1p, 5000M
    |__ Port 1: Dev 2, If 0, Class=Hub, Driver=hub/2p, 5000M
        |__ Port 2: Dev 3, If 0, Class=Mass Storage, Driver=usb-storage, 5000M
/:  Bus 03.Port 1: Dev 1, Class=root_hub, Driver=xhci-hcd/1p, 480M
    |__ Port 1: Dev 2, If 0, Class=Hub, Driver=hub/2p, 480M
/:  Bus 02.Port 1: Dev 1, Class=root_hub, Driver=exynos-ohci/3p, 12M
/:  Bus 01.Port 1: Dev 1, Class=root_hub, Driver=exynos-ehci/3p, 480M
root@odroid:/media/hdd# dd if=/dev/zero of=test oflag=direct bs=8M count=256
256+0 records in
256+0 records out
2147483648 bytes (2.1 GB, 2.0 GiB) copied, 12.9491 s, 166 MB/s
root@odroid:/media/hdd# dd if=test of=/dev/null iflag=direct bs=8M
256+0 records in
256+0 records out
2147483648 bytes (2.1 GB, 2.0 GiB) copied, 10.376 s, 207 MB/s
root@odroid:/media/hdd# lsusb -t
/:  Bus 06.Port 1: Dev 1, Class=root_hub, Driver=xhci-hcd/1p, 5000M
    |__ Port 1: Dev 2, If 0, Class=Vendor Specific Class, Driver=r8152, 5000M
/:  Bus 05.Port 1: Dev 1, Class=root_hub, Driver=xhci-hcd/1p, 480M
/:  Bus 04.Port 1: Dev 1, Class=root_hub, Driver=xhci-hcd/1p, 5000M
    |__ Port 1: Dev 2, If 0, Class=Hub, Driver=hub/2p, 5000M
        |__ Port 2: Dev 3, If 0, Class=Mass Storage, Driver=uas, 5000M
/:  Bus 03.Port 1: Dev 1, Class=root_hub, Driver=xhci-hcd/1p, 480M
    |__ Port 1: Dev 2, If 0, Class=Hub, Driver=hub/2p, 480M
/:  Bus 02.Port 1: Dev 1, Class=root_hub, Driver=exynos-ohci/3p, 12M
/:  Bus 01.Port 1: Dev 1, Class=root_hub, Driver=exynos-ehci/3p, 480M
root@odroid:/media/hdd# dd if=/dev/zero of=test oflag=direct bs=8M count=256
256+0 records in
256+0 records out
2147483648 bytes (2.1 GB, 2.0 GiB) copied, 9.27017 s, 232 MB/s
root@odroid:/media/hdd# dd if=test of=/dev/null iflag=direct bs=8M
256+0 records in
256+0 records out
2147483648 bytes (2.1 GB, 2.0 GiB) copied, 9.02329 s, 238 MB/s
```

Figure 3 - I/O Performance Comparison: Non-UAS vs. UAS on ADATA SP900 SSD

Improvements over the CloudShell

One of the key features of the CloudShell-2 is USB-Attached SCSI (UAS). UAS is a new computer protocol used to move data to and from USB storage devices. UAS depends on the USB protocol, and uses the standard SCSI command set. UAS provides faster transfers compared to previous USB Storage protocols, which is called Bulk-Only Transport (BOT). UAS was introduced as part of the USB 3.0 standard, but can also be used with devices complying with the slower USB 2.0 standard, assuming compatible hardware, firmware and drivers.

Another important feature of the CloudShell-2 is Redundant Array of Independent Disks (RAID). RAID is a data storage virtualization technology that combines multiple physical disk drive components into a single logical unit for the purposes of data redundancy, performance improvement, or both. Data is distributed across the drives in one of several ways, referred to as RAID levels, depending on the required level of redundancy and performance. The different schemes, or data distribution layouts, are named by the word RAID followed by a number, for example, RAID 0 or RAID 1. Each schema, or RAID level, provides a different balance among the key goals: reliability, availability, per-

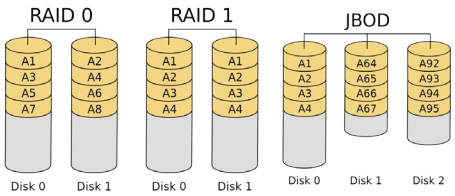


Figure 4 - RAID 0, RAID I and JBOD

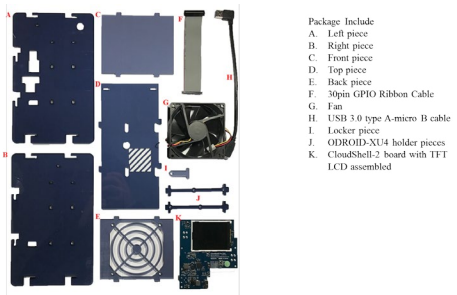


Figure 5 - Pieces included in the Cloudshell-2 kit

Figure 6 - Screw the left and right pieces to the hard disks (A + B + P)

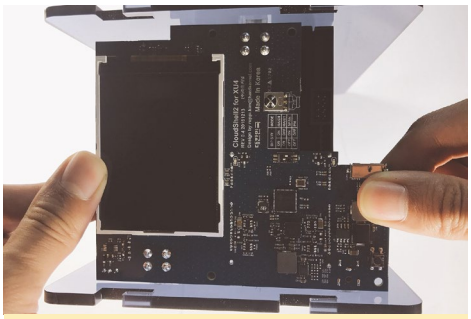


Figure 7 - Attach the CloudShell-2 board to the hard disks (K)

Figure 8 - Screw the CloudShell-2 board to the left and right pieces (O)

Figure 9 - Assemble the fan and back piece and place the fan at the back side, making sure to use only 3 screws in this step (E + G + N)

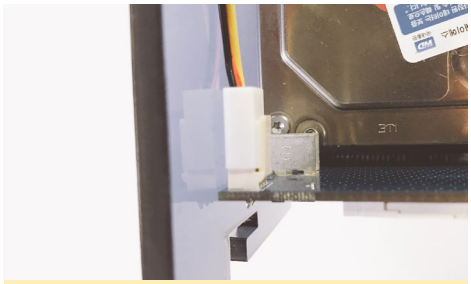


Figure 10 - Insert the FAN cable into the CloudShell-2 board

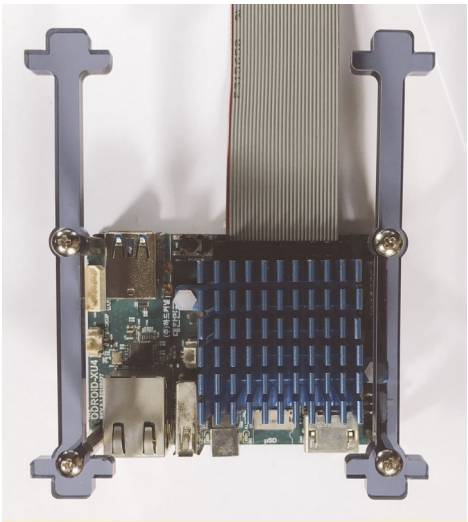


Figure 11 - Assemble the ODROID-XU4 and XU4 holder pieces (J + L + M)

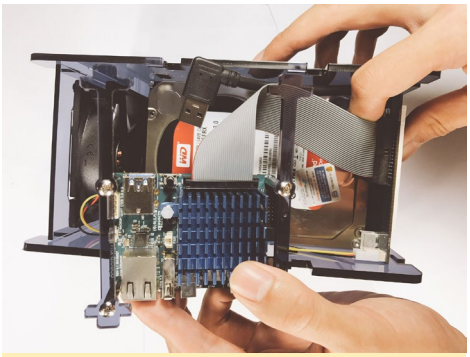


Figure 12 - Connect the GPIO ribbon cable and USB 3.0 cable between the ODROID-XU4 and the CloudShell-2 board (F + H)

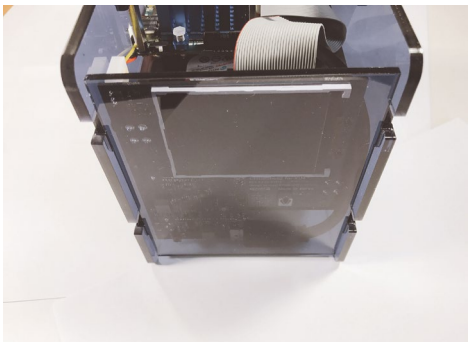


Figure 13 - Place the front piece at the front side (C)

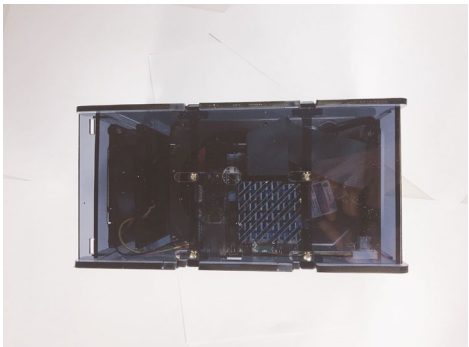
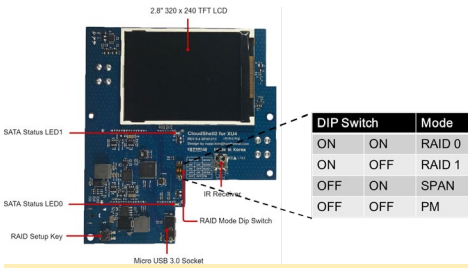


Figure 14 - Attach the top piece (D)

Figure 15 - Put the locker piece and screw it on (I + N)

Figure 16 - The completed Cloudshell-2 kit

formance, and capacity. RAID levels greater than RAID 0 provide protection against unrecoverable sector read errors, as well as against failures of whole physical drives. CloudShell-2 supports both RAID 0 and RAID 1.



DIP Switch		Mode
ON	ON	RAID 0
ON	OFF	RAID 1
OFF	ON	SPAN
OFF	OFF	PM

Figure 17 - RAID Mode Selection

CloudShell-2 also offers JBOD (Just a Bunch of Disks) as well as RAID. JBOD generally refers to a collection of hard disks that have not been configured to act as a redundant array of independent disks (RAID) array. Rather than configuring a storage array to use a RAID level, the disks within the array are either spanned or treated as independent disks. A spanning configuration uses a technique called concatenation to combine the capacity of all of the disks into a single, large logical disk. CloudShell-2 provides both spanning and independent disk modes as SPAN and PM mode.

RAID settings

There are four data storage modes on the CloudShell-2: RAID 0, RAID 1, SPAN and PM. This means that the hard disks will be detected separately in PM mode.

To select the RAID mode, set the RAID Mode DIP Switch to the setting that you want, then apply power while pressing the RAID Setup Key button until booting is complete.

FTP and SAMBA

This section describes how to install file servers like FTP and Samba, which are usually installed by default on commercial NAS devices. We used an Ubuntu 16.04.2 trial image with the 4.9.x LTS Kernel (http://bit.ly/2nKRPMn) for this, because the previous 3.10.x kernel does not support UAS. For instructions on how to burn the Ubuntu image to SD card or eMMC, please refer to http://bit.ly/2nKNNn9. In order to access the terminal of ODROID-XU4, use an SSH client to remote into the device, or access the serial console via the USB-UART module kit (http://bit.ly/1nhQuIm). The SSH server is installed by default in Ubuntu 16.04.2.

The first step is to update the system to the latest software versions:

```
$ sudo apt update && sudo apt \
upgrade && sudo apt dist-upgrade
```

Next, add the mount point of the HDD/SSD storage. The dual HDD/SSDs will be detected as "/dev/sda" which is the single logical storage in RAID 0/RAID 1/SPAN mode, and will be detected as "/dev/sda" and "/dev/sdb" in PM mode. Note that the next step includes formatting of the HDD/SSD. If the storage contains important data, make sure to backup the data before

running the commands below.

```
$ su -
# mkfs.ext4 /dev/sda
# mkdir /media/hdd
# echo "/dev/sda    /media/hdd
ext4    defaults    0    1" >> /
etc/fstab
# reboot
```

Create a new account called "cloudshell", which will be used for FTP and Samba access. This account does not need an available shell, so, set "/bin/false" for the shell for security reasons. The home directory of the cloudshell user is where the HDD/SSD is mounted (/media/hdd).

```
$ su -
# echo "/bin/false" >> /etc/
shells
# useradd  cloudeshell -d /media/
hdd -s /bin/false
# passwd cloudshell
(Set the password of cloudshell)
# chown cloudshell.cloudshell -R
/media/hdd/
# chmod 755 -R /media/hdd/
```

Next, install FTP and Samba server, selecting "standalone" when prompted:

```
$ sudo apt install -y proftpd
samba
```

The proftpd configuration file is located at /etc/proftpd/proftpd.conf. If you need to set up anonymous access, modify the /etc/proftpd/proftpd.conf file. There are a lot of configuration options for FTP and Samba server. In this article, we will use only the basic setting. Add the following configuration options to the end of the /etc/samba/smb.conf file:

```
[Shared]
comment = CloudShell-2 File
Server
path = /media/hdd
guest ok = yes
browseable = yes
create mask = 0644
directory mask = 0755
read only = no
writable = yes
force user = cloudshell
```

Performance optimization

This section describes some performance optimizations known well to the ODROID community. Exynos 5422, which is the CPU installed in the ODROID-XU4, uses the big.LITTLE architecture. The little cores (Cortex-A7) are assigned to CPU 0 - CPU 3, and the big cores (Cortex-A15) are assigned to CPU 4 - 7. Although their CPU ordering can change via kernel modification, the little core is used as CPU 0. It is necessary to adjust the network and storage interrupts assigned to CPU 0.

A maximum transmission unit (MTU) is the largest size packet or frame in mac layer. The MTU size is set to 1500 by default. ODROID-XU4 supports the large MTU size called jumbo frame.

Receive Packet Steering (RPS) is used to direct packets to specific CPUS for processing. RPS helps to prevent the hardware queue of a single network interface card from becoming a bottleneck in network traffic. Add the lines below in /etc/rc.local, which modifies the MTU size, interrupt assignments and RPS settings:

```
$ ifconfig eth0 mtu 6975
$ echo 5 > /proc/irq/143/smp_af-
finity_list
$ echo 6 > /proc/irq/144/smp_af-
finity_list
$ echo f > /sys/class/net/eth0/
queues/rx-0/rps_cpus
```

To improve Samba performance, some modifications are necessary in the Samba configuration file. These configuration options enable caches and adjust protocol feature for improved Samba performance. Add the configurations below to the [global] section of the /etc/samba/smb.conf file:

```
write cache size = 524288
getwd cache = yes
use sendfile = yes
min receivefile size = 16384
socket options = TCP_NODELAY IP-
TOS_LOWDELAY
```

For more information about NAS settings, please refer to "Setting up your XU4 as a General-Purpose Network Attached Storage (NAS) Device" article in the February 2017 issue of ODROID Magazine (http://bit.ly/2mWHOHa).

Enable TFT LCD

The TFT LCD of CloudShell-2 works via SPI. The fbtft_device module is able to display the frame buffer console on the TFT LCD. In order to enable the TFT LCD, add the module configurations as shown below:

```
$ sudo -s
# echo "options fbtft_device
name=hktft9340 busnum=1 ro-
tate=270" > /etc/modprobe.d/
odroid-cloudshell.conf
# echo "spi_s3c64xx" >> /etc/
modules
# echo "spidev" >> /etc/modules
# echo "fbtft_device" >> /etc/
modules
```

The commands above will ensure that the LCD is configured at every boot. Next, remove the blacklists on the Serial Peripheral Interface (SPI) by editing the file /etc/modprobe.d/blacklist-odroid.conf:

```
# Comment the required lines

# IO Board
blacklist ioboard_bh1780
blacklist ioboard_bmp180
```

```
blacklist ioboard_keyled
```

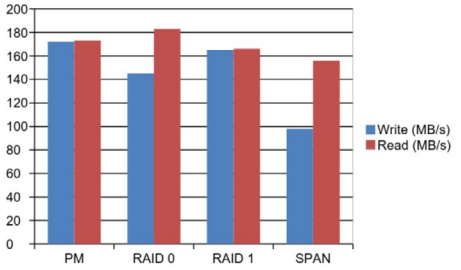


Figure 18 - I/O Read/Write Performance on each storage mode on 2 x WD Red 6TB HDD

Figure 19 - FTP and Samba Upload/ Download Performance on 2 x WD Red 6TB HDD, RAID 1 mode

```
# SPI
# blacklist spidev
# blacklist spi_s3c64xx

# 3.2" LCD Touchscreen driver
blacklist ads7846
```

If the system uses the lightdm desktop manager for the GUI desktop environment, then disable lightdm in order to use the framebuffer console:

```
$ sudo systemctl disable lightdm
```

Reboot the ODROID-XU4 with the HDMI cable disconnected, which will the allow the frame buffer console to be displayed on the TFT LCD.

Performance Results

As shown in Figures 18 and 19, both I/O read/write performances and file server upload/download performances results are very impressive. Further information is available in the Hardkernel Wiki page at http://bit.ly/2mXC2Vr.

GOOGLE CLOUD PRINT FOR ODROID-C2

by Joshua Sherman

Google Cloud Print (http://bit.ly/2nynbEB) is a technology that allows you to print over the web from anywhere to any printer. Using Google Cloud Print, you can make your home and work printers available to you and anyone you choose, from the applications you use every day. Google Cloud Print works on your phone, tablet, Chromebook, PC, and any other web-connected device you want to print from, including your ODROID.

To set up Google Cloud Print on an ODROID-C2, first install the Ubuntu 16.04 LTS edition. You'll want to use the one with a GUI (http://bit.ly/2ost3g8), as it's easier to configure cloud print using Chromium's own compatibility with Google's cloud printing technology.

Once you're finished installing your Ubuntu image, it's time to install a VNC Server. It's always easier to leave an ODROID somewhere as a convenient, headless device, than to constantly need to plug a screen into it:

```
$ sudo apt-get install tightvnc-
server
```

Before we get started VNCing into our ODROID, we need to set a password we can use once we connect. You can do this by typing:

```
$ vncserver
```

Once you do this, you'll be prompted to enter a password and confirm it.

Next, let's add a printer to our ODROID that we can use for Cloud Print. I used a network printer, otherwise you'll want to connect to your printer in whatever way is necessary, such as to a Windows computer via SAMBA if that's where it's connected via USB. Since we're using Ubuntu 16.04 LTS, we have a host of built-in drivers for network, SAMBA, and even direct USB access to printers of all shapes and sizes.

Click System in the MATE environment menu, then select "Control Center" and "Printers" to open the printer dialog. Add your printer, click "Forward", and select your printer's specific driver, which in my case was a Samsung network printer with an IP assigned by my router. Click "Apply", then print a test page to make sure everything is working before proceeding. We want to make sure the ODROID can print on its own successfully, in case we have problems later on.

Google Cloud Print is easy to use because it's compatible with countless devices by using your Google Account to

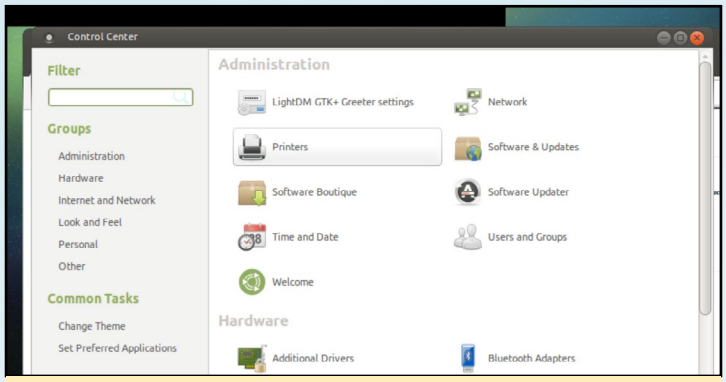


Figure I - Accessing the Control Center

send out print requests. This means you can use any device that can detect a printer on the network (and run Chrome) as a server to receive print requests, while using almost any device that can access your Google Drive (such as an Android smartphone, your laptop, etc.) to send out print requests. Open Chromium, then select the menu on the top right and click "Settings".

Next, Scroll down and click "Show Advanced Settings". Continue scrolling to "Google Cloud Print" and click "Manage" and then select "Add Printer". You'll need to log into your Google Account in order to give your ODROID an account to associate with for receiving and sending print requests.

If you successfully added your printer earlier, then your device should be available in a list of devices that Google is

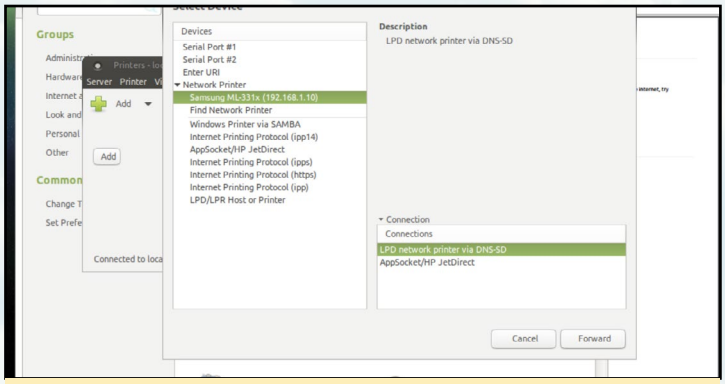


Figure I - Accessing the Control Center

requesting to add to your Google Cloud Print account. To confirm this, click "Add" button at the bottom of the screen.

That's it! You're all set. What's great is that you can now print stuff at home, even while you're not there. This is especially convenient if you like to have coupons, forms, and other stuff you may print while at work, but wish to have waiting for you when you get home.

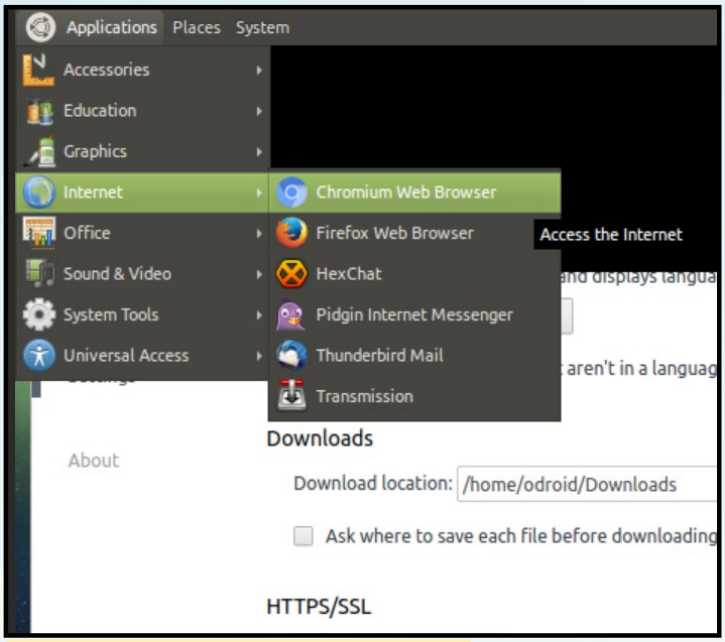


Figure 3 - Accessing Chromium

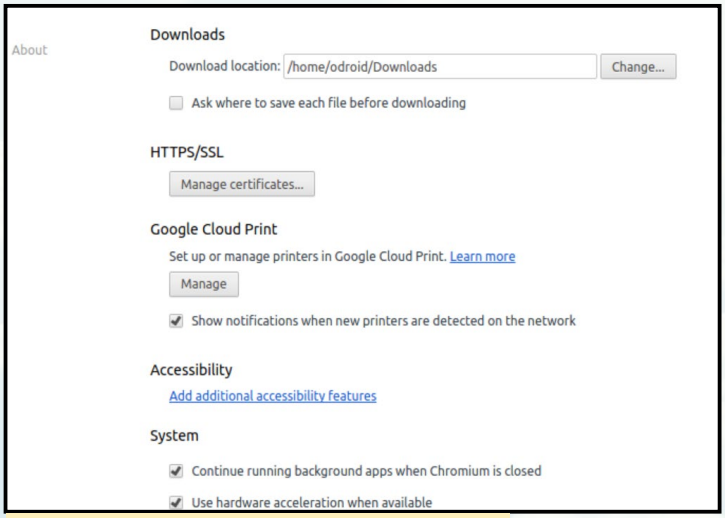


Figure 4 - Cloud Print "Add Printer" dialog

CONTROL ANY ELECTRICAL DEVICE WITH AN ODROID-C2

A SAMPLE PROJECT

by Miltiadis Melissas (miltos)

It was always a 20th-century dream that there will be an era when every electrical apparatus at home will be controlled by a single click from any web enabled device, such as a PC, tablet, or smart TV, from everywhere. This era has come, and today we will present you with a way to control almost any electrical device with a single click from any other device that has access to the web.

We will use a spotlight as an example, but this could be easily substituted with a refrigerator, a washing machine, or an electric coffee pot, for example. We did one simplification, however, which is to electrify the spotlight with 12V DC instead of 220V AC current, primarily for safety reasons. We encourage the users of this guide to do the same, as it is very easy to expose oneself to hazardous electric shocks!

The relay module we use with the ODROID-C2 in this project can easily be connected to a 220V power source, driving any electric device (up to 10A). Experienced users can try to work with these voltages, making sure to take all safety precautions. Let us delve into the endless potential of the ODROID-C2.

Hardware requirements

- ODROID-C2 (http://bit.ly/1oTJBya)
- 5V 1/2/4/8 Channel Relay Board Module ARM AVR DSP PIC (http://ebay.eu/2ncLWD8)
- Lamba JM/84211 3W 3000K 12V or any other compatible spotlight
- Dupon wires female-to-female, male-to-male (http://ebay.eu/2mDWf6Q)
- 4 X LS 14500 3.7V 2300mAh Li-ion batteries (http://ebay.eu/2m0F7EI)

Software requirements

- Ubuntu 16.04 v2.0 from Hardkernel (http://bit.ly/2cBibbk)
- Python 2.3 or 3.3 preinstalled with Ubuntu
- WiringPi Library for controlling the ODROID-C2 GPIO pins. You can learn how to install this at http://bit.ly/2ba6h8o
- CoffeeCup Free HTML Editor (http://bit.ly/2lCxgB8)
- PuTTY * - We are going to need to be able to connect to our ODROID-C2 via SSH, and PuTTY is the perfect client to do this (http://bit.ly/2kFVngX)
- FileZilla - We are going to need a way to transfer files onto the ODROID-C2 using SFTP, which is FTP over SSH (http://bit.ly/1gEw9op)

Connecting it together

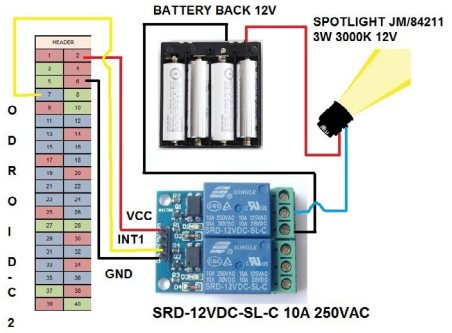


Figure 1 - Block diagram

The design of this project is very simple, and the Songle relay plays the most critical role. We have connected the GND of the Songle relay with the pin6 of ODROID-C2 (GND). The VCC pin of the relay is connected directly to pin2 of ODROID-C2, which provides 5V to this circuit and electrifies the electric coil of the relay). Finally, the INT1 pin of the relay is connected with pin7 of our ODROID, which is the pin that actually controls the relay, which is the ONs and OFFs of this device. From the other side of the Songle relay, there is a simple switch on which we have connected the spotlight through the battery or the mains. Please refer to the schematic in Figure 1 for a clear idea of this circuity. As a technical reference regarding the ODROID-C2 pins, we have used the excellent PIN Map provided by Hardkernel at http://bit.

ly/2aXAlmt. According to this map, pin2=5V, pin6=GND and pin7=GPIOX.BIT21 (General Purpose Input/Output Pin). All of the connections were made by using the Dupon female-to-female, male-to-male or male-to-female wires. Now that our hardware is ready, let us see how to build the software and bring it all together.

Designing a simple web page

We used the free CoffeeCup HTML editor to design a simple HTML web page for controlling the spotlight. On this page, we added the images of two buttons in order to control the spotlight, represented by the ON and the OFF buttons. Please refer to Figure 2 for a view of this page. The whole project is controlled by using a Web UI. In order to achieve this, we have hyperlinked those buttons to the relevant Python scripts songleon.py and songleoff.py that control the ON and OFF of the spotlight. Instructions on how to write those programs in Python are provided on the section called "Connecting the Application to the Web below.

Figure 2 - Web page

When you finally design your website, make sure that your home page is called index.php and not index.html, just to keep things uniform. However, we are only going to be using two PHP scripts, songleon.php and songleoff.php, to control the spotlight. The Python and PHP code we need to write is very simple and well documented.

Installing the server

In order to use the ODROID-C2 as a web server in this project, we have to install all of the necessary server software components. In addition, since we want a simple HTML server, we will install Apache with PHP (server-side scripting-language) support on the ODROID-C2. The following steps can be performed with PuTTY. Accessing the ODROID-C2 with this SSH client is well documented. All you need is the ODROID-C2's IP address.

Apache server software is the most widely used web server software today. Here's how to install Apache with PHP support:

```
odroid@odroid:~# sudo apt-get install apache2 php
libapache2-mod-php
```

When prompted to continue, enter "y" for yes. Next, enable and start Apache:

```
odroid@odroid:~# systemctl enable apache2
odroid@odroid:~# systemctl start apache2
odroid@odroid:~# systemctl status apache2
```

Test Apache

Open your web browser and navigate to http://localhost/ or http://<server-ip-address>/. This is the address of your ODROID-C2 on your local network. You can find it by just typing:

```
odroid@odroid:~# ifconfig
```

You will see a page similar to one shown in Figure 3.

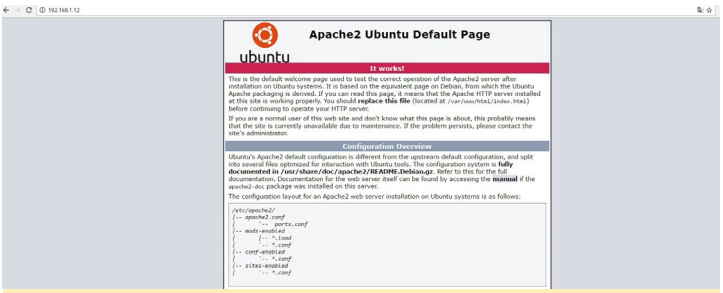


Figure 3 - Apache test

Test PHP

To test PHP, create a sample testphp.php file in Apache document root folder:

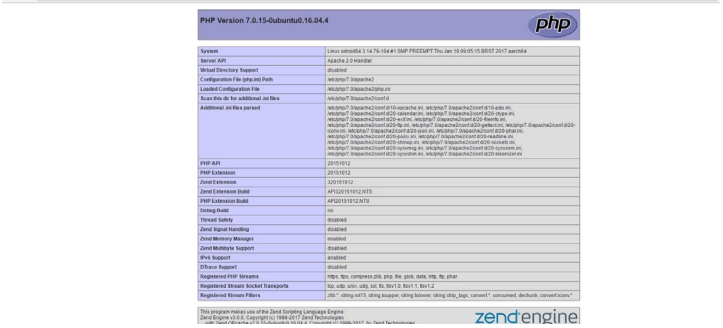
```
odroid@odroid:~# sudo nano  /var/www/html/testphp.php
```

Add the following lines and save the file:

```
<?php
phpinfo();
?>
```

Next, restart the Apache service:

Figure 4 - PHP information



```
$ sudo systemctl restart apache2
```

Navigate to http://server-ip-address/testphp.php. It will display all the details about PHP such as, version, build date and commands, to name a few. Pleaser refer to Figure 4 for more information.

Installing FTP server

Install an FTP server such as vsftpd using the following command:

```
$ sudo apt-get install vsftpd
```

Edit the FTP configuration file by typing:

```
$ sudo nano /etc/vsftpd.conf
```

and make the the following changes:

- Hit ctrl+W and search for anonymous_enable=YES, and change it to anonymous_enable=NO
- Remove the # from in front of local_enable=YES
- Remove the # from in front of write_enable=YES
- Skip to the bottom of the file and add force_dot_files=YES
- Hit ctrl+X to exit and enter y to save and hit <ENTER> to confirm

Then, restart vsftpd:

```
$ sudo service vsftpd restart
```

Publishing to the web

By now, you should have a website that you can transfer over to the ODROID-C2. Once you have performed all the previous steps and have verified that you can view your website on another computer, we can move onto making the website turn ON our lamp using the 5V 1/2/4/8 Channel Relay Board Module ARM AVR DSP PIC.

Inside your website directory, create a new PHP file called songleon.php containing the following code snippet, then save the file:

```
<?php
system("echo odroid | sudo -S
python /var/www/html/scripts/
lights/songleon.py"); header(
'Location: 'index.php' ) ;
?>
```

Next, create a folder in the website directory called "scripts", then create a subfolder inside it called "lights", and inside there, create a new file called songleon.py. This will be the python script that turns our lamp on. Inside there, enter the following code, then save the file:

```
import wiringpi2 as odroid
odroid.wiringPiSetup()
odroid.pinMode(7,1)
odroid.digitalWrite(7,0)
```

Go back to your web page in design/edit mode, and make sure the hyperlink for your "on" button links to the songleon.php. Now, when you click the button, the songleon.php script will execute the songleon.py python script, resulting in the lamp turning on. We are finally ready to make it turn off.

Inside the website directory, create a new file called songleoff.php. Inside this, file enter the following code snippet, then save it:

```
<?php
system("echo odroid | sudo -S
python /var/www/html/scripts/
lights/songleoff.py"); header(
'Location: 'index.php' ) ;
?>
```

Again, make sure your file path is the same, so that this works. Also, set your redirection rules to redirect to the page of your choice. Then, make a new file in the scripts\lights\ folder called sognleoff.py. Inside this file, enter the following code, then save the file:

```
import wiringpi2 as odroid
odroid.wiringPiSetup()
odroid.pinMode(7,1)
odroid.digitalWrite(7,1)
```

Add a hyperlink to songleoff.php to your "off" button, which should make your lamp turn off. You now have a website that can control your lights!

Transfer to Apache

It is very easy to login into your ODROID-C2 apache web server with Filezilla as soon as you know the ODROID-C2's IP address. If you have previously logged in with SSH into your ODROID-C2 with PuTTY, you can find it out by typing:

```
odroid@odroid:~# ifconfig
```

You have to give your name and password of "odroid" and "odroid". You will be immediately taken to the ODROID-C2 root file system. From there, navigate to /var/www/html/ folder, and inside this directory, copy the files from your local drive to the above directory. Here are all the files and folders that you have to copy from this local directory:

- index.php
- songleon.php
- songleoff.php and finally the folder /scripts/lights/ with
- songleon.py and songleoff.py

Now you are done with the main part of project. One final word of advice: in order for you to have access to the execution of the scripts controlling the spotlight (songleon.py and songleoff.py), you have to change the permissions/rights of all the files and folders previously mentioned. We recommend just for the sake of this project to give them full access with read, write, and execute privileges for root:

```
$ sudo chown 755 /var/www/html/
index/php
```

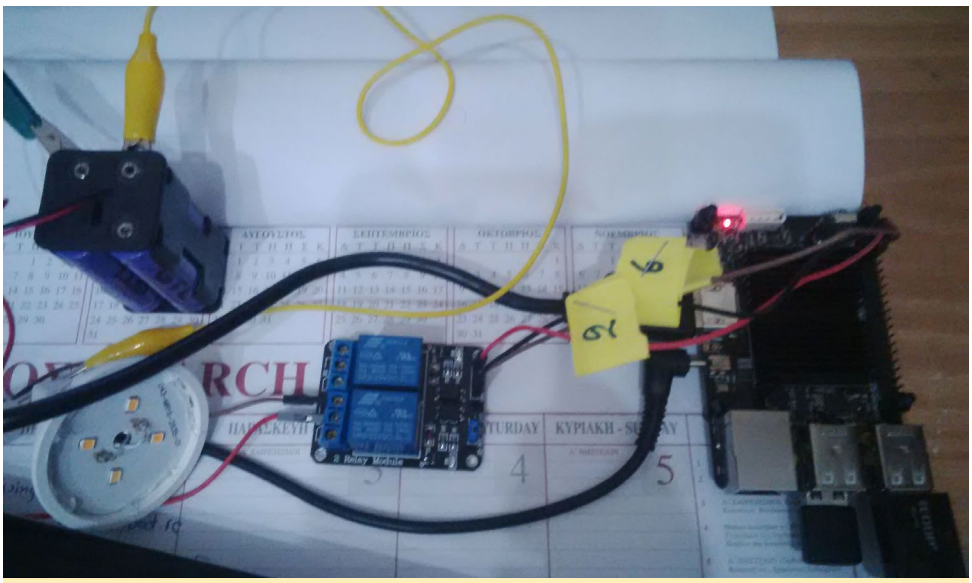


Figure 5 - Hardware setup

In addition, you have to modify the sudoers file with nano editor:

```
$ sudo nano /etc/sudoers
```

Provide your password for any modifications and add the following line:

```
www-data ALL=(ALL) NOPASS-
WD ALL after this line: %sudo
ALL=(ALL:ALL) ALL
```

Testing the applications

Let's see if everything is working. From your computer, laptop, or tablet, navigate to your ODROID-C2's IP address in the browser, and click the "on" button. Are your spotlights lightening up your room? Now it's the click the "off" button. Click it and see your room's spotlight switched off. Success!

Final notes

We could give you a further guidance on how to control any electrical device remotely from the office, during travelling, or you are in an emergency. This is not a difficult step now that you've got the basic circuit working in your local network, but be advised that such a step comes with a security risk. Hackers may be interested in controlling your server by taking advantage of a weak password, a commonly used port, or wrong router settings. For that reason, we advise you to make your network secure and even change the password for the user ODROID-C2 to a stronger one. You now have the knowledge you need to build something innovative and inspiring for you and your peers.

ODROID Magazine is on Reddit!

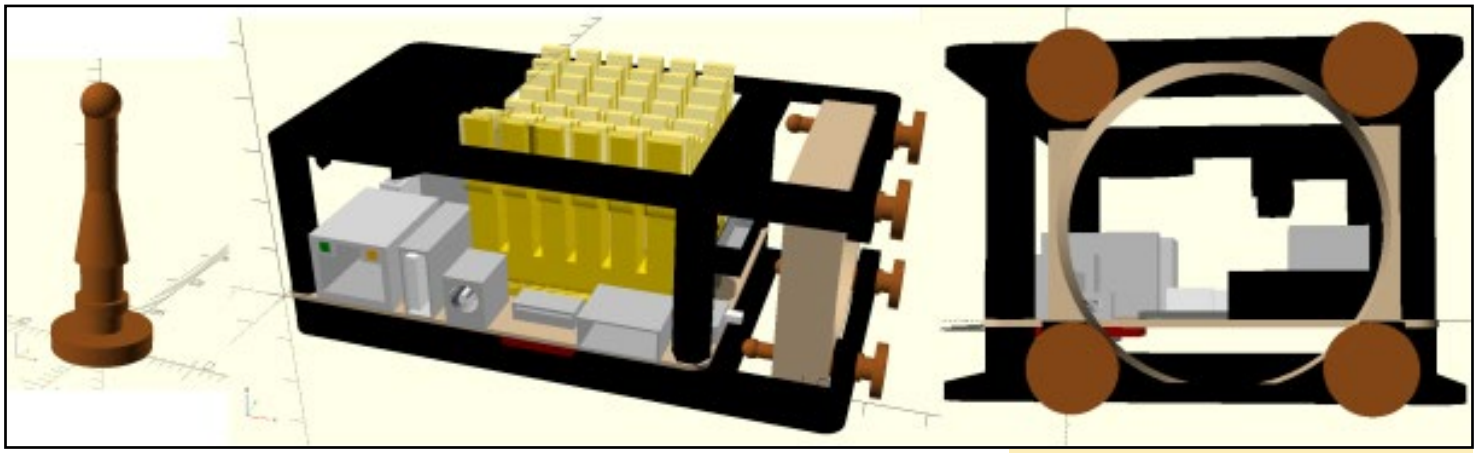
ODROID Talk Subreddit

http://www.reddit.com/r/odroid

XU4 CASE

A FUTURISTIC DESIGN FOR YOUR 3D PRINTER

by @hominoid

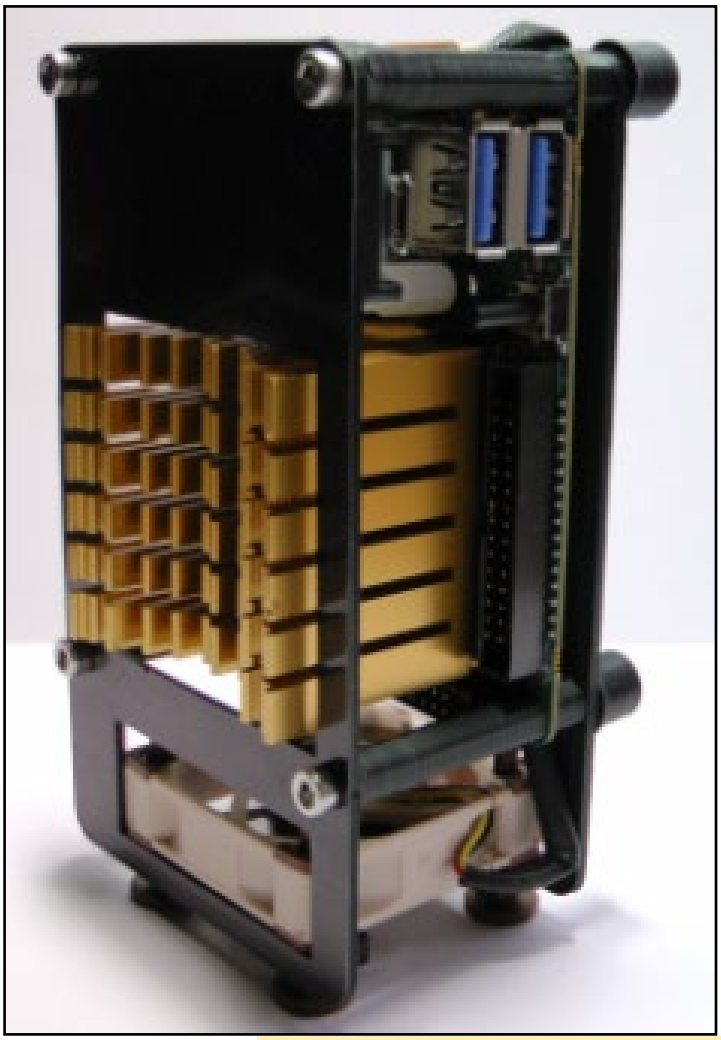


Conceptual design from OpenSCAD

I liked the paper case and the water cooled system that were presented in ODROID Magazine recently. They were both great examples, one of minimalist design and the other of maximum design possibilities. They both inspired me to pursue a design that I had in mind, which was more practical for my application: a split airflow configuration using a single fan to cool both sides of the PCB. The majority of the airflow would be on the heat sink, but some would also go under the bottom of the board, creating a system wide cooling approach of continuous airflow. Along with some system tuning, and as quiet as the Noctua fan is, I plan on running the fan continuously starting at 25% and increasing the RPM quickly to maintain minimal temperatures across a varying spectrum of uses.

The Noctua isolation mounts that came with the 40mm fan were used for the fan and as isolation feet in the vertical position. The gold universal Northbridge heatsink was rotated for better SOC coverage, and the required fin orientation is for side mount cooling. A battery and UART holder was integrated under the top as discussed at http://bit.ly/2ncUuKG, and as seen above the USB3 ports in the photo. The nut holders double as feet in the horizontal position and help protect surfaces.

Operationally, the case design has performed as expected. It has very similar performance characteristics as a top mounted fan with the additional benefit of bottom side cooling. If run passively, the vertical orientation should help heat rise away from the system and minimize thermal pooling underneath. I have a couple of other tweaks that I would like to try in the future, such as adding a raised copper perch of 2-5mm to increase thermal transfer and accommodate airflow under the



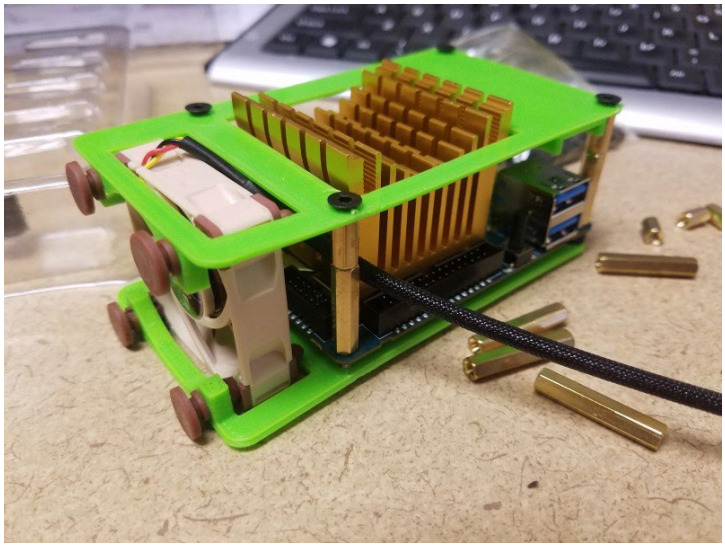
Side view of the 3D printed case

Top view showing the heatsink opening

heat sink. If I can get sufficient airflow under the heat sink, it may increase the efficiency of the SOC and support chip cooling. I might also try some custom duct work to direct airflow better. The OpenSCAD case design file is attached for anyone interested.

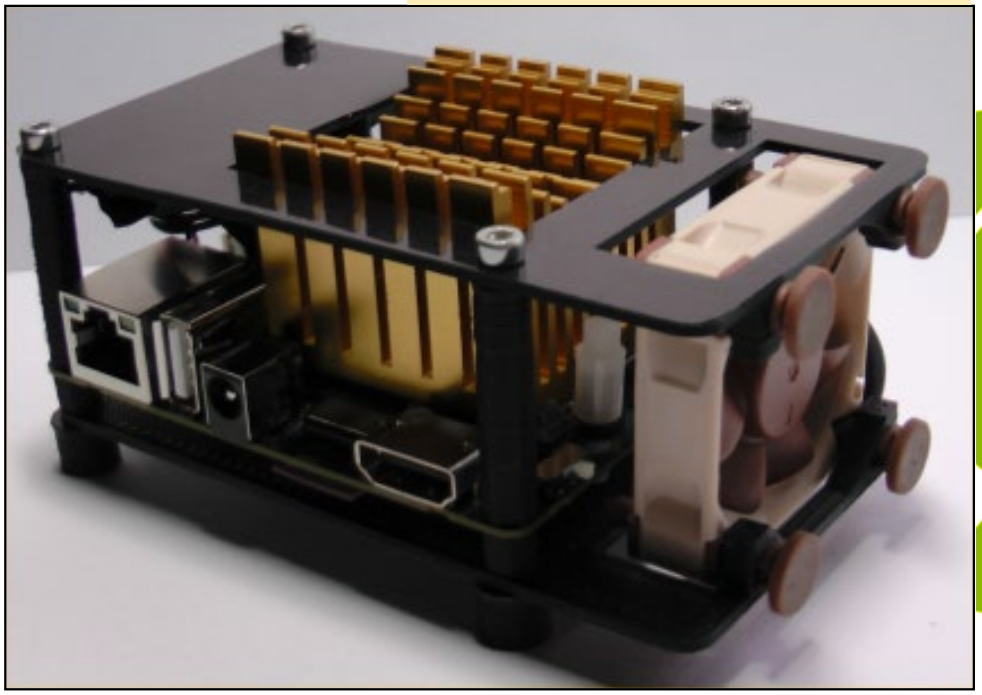
The SCAD design file is available for download at http://bit.ly/2npvsJo. Make sure you have the XU4 Model library (http://bit.ly/2mL0PRF) in the same working directory, which includes supporting accessories.

For comments, questions, and suggestions, please visit the original thread at http://bit.ly/2nbumiy. Components for this case are also available at www.ameridroid.com, which also offers other 3D printed cases.



Ameridroid case available for purchase

Closeup of the fan, Ethernet and HDMI port



MEET AN ODROIDIAN

CHARLES PARK, HARDKERNEL CO-FOUNDER

edited by Rob Roy (@robroy)

As a co-founder of Hardkernel, what is your vision for the company?

Our vision is to find, create, share, and enjoy fun technologies and peripherals.

What do you like most about the ODROID community?

My favorite forum is the Projects forum. I am very surprised to try many things with our board, and sometimes I want to try it together. I like that forum because I can think of new ideas and items while watching other projects going on.

How did you get started with computers?

I started my microcomputer club activities on the recommendation of my teacher in high school. On the day that I started my club activities for the first time, I first found out that I had a computer, and it was so fun and so amazing. The first computer I used was an 8-bit computer called MSX. The computer automatically went to the BASIC screen when the power was turned on. I found out that MSX was built with a Z80 processor, and I started learning how to build a microcomputer with the Z80 processor.

Charles' two boys enjoy spending time with their father outdoors

Charles relaxing with his family

How did you meet the other founders of Hardkernel?

We have been working together in Digital Cube Co.,Ltd, which specializes in MP3 / PMP development / production from 2000 to 2009. When we left the company in 2009, we got together and discussed the business.

What are some of your favorite projects that you've seen ODROIDs being used for?

My favorite project is the ODROID Arcade Box, which I made together with some friends last month. It is a project that my children and I can enjoy together.

His family loves him very much!

Do you have any personal projects that you're working on using ODROIDs?

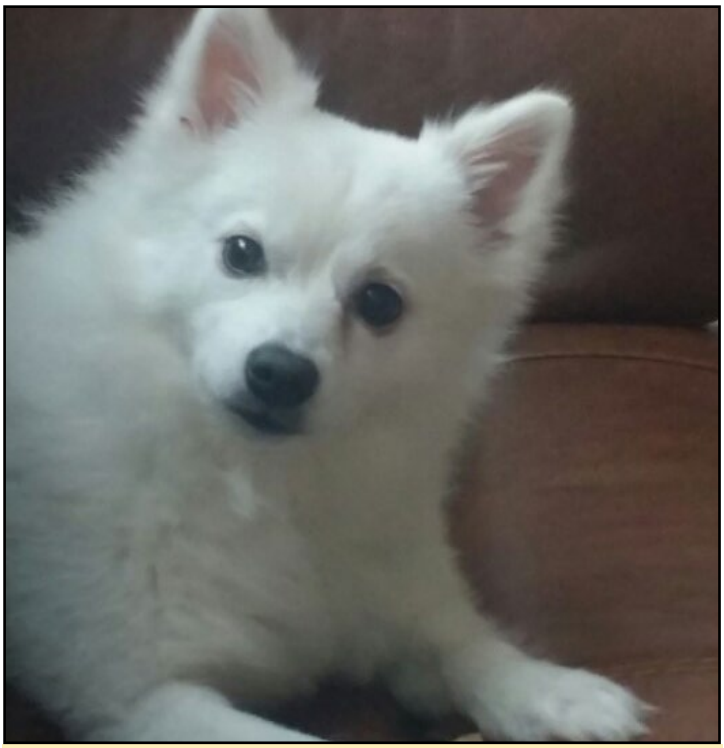
I do not have one yet, but I am thinking of making a CCTV to watch our house puppy while we're gone.

What is coming up next for Hardkernel and ODROID in 2017?

In 2017, we are planning another 64-bit ARM platform and a 64-bit X86 platform, and we are also considering an upgraded version of XU4.

What other interest and hobbies do you enjoy?

I am very interested in 3D design. I am studying the program of Solidworks and I would like to use the program to make furniture for home or acrylic case suitable for ODROID products.



Charles' family dog gives lots of advice and inspiration for many of the innovations at Hardkernel