HANDS ON

Top ten Raspberry Pi projects

Gareth Halfacree peeks at some of the most imaginative and original uses for the tiny, lightweight personal computer

The Raspberry Pi has turned out to be a terrific success. Despite minimal third-party software support and manufacturing delays, it remains a bestseller, with buyers waiting weeks to receive their orders as production is ramped up to meet demand. Over the following pages, we discover exactly what people are doing with all these Pis and explore what future revisions may bring.

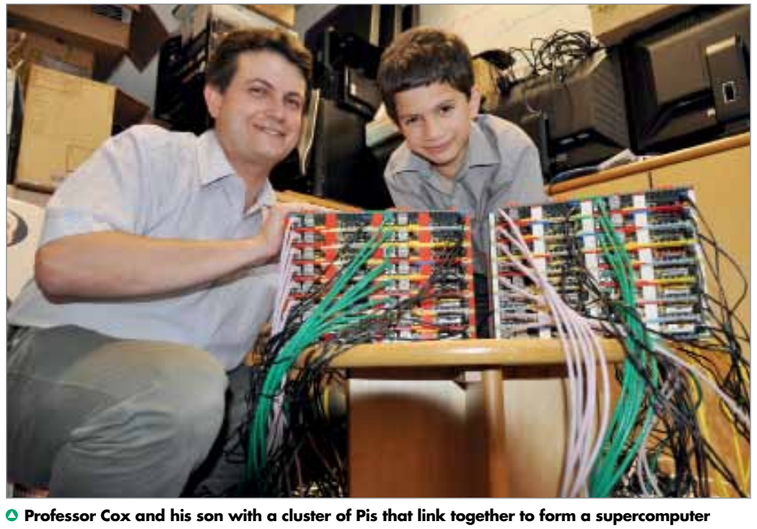
1 The Raspberry Pi supercomputer

As a computer, the Raspberry Pi itself is hardly the equal of the average desktop or laptop, yet some buyers have been investigating its suitability for high-performance computing – if only as an educational exercise. Professor Simon Cox of the University of Southampton, in partnership with fellow computational engineers and his six-year-old son, recently unveiled the first large-scale supercomputer cluster to be constructed entirely from Raspberry Pi hardware.

"As soon as we were able to source sufficient Raspberry Pi computers, we wanted to see if it was possible to link them together into a supercomputer," explains Cox. "We installed and built all of the necessary software on the Pi, starting from a standard Debian 'Wheezy' system image, and we've now published a guide so that you can build your own supercomputer."

At a cost of £2,500, the system boasts 64 nodes, 16GB of memory, 1TB of SD card storage and a Lego chassis. While its performance lags behind that of traditional supercomputers, Cox's creation provides a low-cost platform for experimenting with computing cluster technology – something that normally requires a hefty server environment and software simulation.

Details of the build are available at **www.pcpro.co.uk/links/219id1**, along with a guide to constructing a similar Pi cluster.



Professor Cox and his son with a cluster of Pis that link together to form a supercomputer

2 Translation goggles

Wearable computing has been "just around the corner" for decades now, but beyond the odd bulky wristwatch, little usable technology has hit the open market. Google's Project Glass is due to appear in shops some time next year, but for now the Pi is helping to fill the gap thanks to its small size, light weight and low power draw – so low it will run for hours from a cheap lithium-ion battery.

"We wanted to see if it was possible to link Raspberry Pis together into a supercomputer"

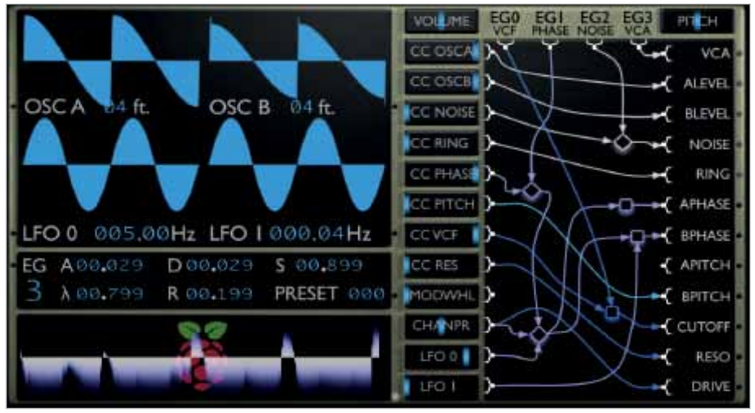
The most impressive wearable Pi effort so far has to be Will Powell's project, which turns two Raspberry Pi systems and a pair of digital glasses into the closest thing the world has seen to the universal translator of *Star Trek* fame. Combining a Vuzix STAR 1200 wearable display and a Jawbone Bluetooth microphone Pi, the system performs on-the-fly voice recognition and translation through Microsoft's publicly accessible application programming interface (API).

"I can have a conversation with Elizabeth, who speaks Spanish to me and I return with English," explains Powell. "I have never learnt Spanish, but using the glasses I can have a full conversation."

Details of the build, including a video of the system in action, are available on Powell's blog at **www.pcpro.co.uk/links/219id2**.

3 Solar-powered distributed computing

Another area where the Pi's low power demands are proving popular is distributed computing. Through projects such as Folding@home and SETI@home, computer users across the world have for years been contributing spare processor cycles to create a powerful supercomputer. Inevitably, those cycles have come at a cost of increased energy usage.



The Piana project turns the Raspberry Pi into an analogue synthesiser

The Raspberry Pi, however, can run from a solar panel, giving distributed computing fans a means of contributing environmentally friendly processing power to their favourite projects. The business of attaching a solar panel isn't particularly challenging, and Andrew Back has tackled the other half of the equation by porting the Berkeley Open Infrastructure for Network Computing (BOINC) distributed computing client to the Pi's ARMv6 instruction set.

"The idea of a self-contained, solar-powered BOINC appliance is attractive," Back writes of his experiments, "as it would not only address concerns over energy consumption but could take a novel and even decorative form, perhaps with a small E Ink screen to display computation statistics."

Details on how to install BOINC on the Raspberry Pi, and how to set up the SETI@home client, which analyses radio telescope data for signs of alien intelligence, can be found at **www.pcpro.co.uk/links/219id3**.

4 Musical instruments

Electronic synthesisers are incredibly versatile instruments, but they're frequently priced at the top end of most amateurs' bank balances. Given a little extra hardware and some clever software, however, a Raspberry Pi can be turned into just such a device – and that's exactly what the Piana project aims to do.

Taking its name from a portmanteau of "Pi" and "analogue", the project aims to create a MIDI-addressable software-based analogue synthesiser along the lines of the popular Moog Slim Phatty, with up to eight voices and an OpenGL ES-accelerated user interface that includes a live oscilloscope and adjustable component connections.

"All this – oscillators being alias-managed, bonkers modulation, Moogy roll-off filters, GPU[-powered GUI] interface with tons of oscilloscope vertices bouncing around in real-time – all of this runs on a stock 700MHz Raspberry Pi," project founder Omenie explains of his creation.

Piana is already capable of some impressive effects but it isn't the only effort to turn the Pi into a synthesiser: others are working to port the open source Pd software synthesiser to the Pi's ARM processor. More details on the Piana project are available on the official blog at **www.pcpro.co.uk/links/219id4**.

5 Marine robotics with the FishPi

The general-purpose input-output (GPIO) port on the Pi provides an easy means of interfacing with external hardware, and for many technical types that spells "robotics". Several small-scale projects have seen the Pi mated to off-the-shelf remote-control cars and the like, but the FishPi project goes a step further in its aims.

The brainchild of Greg Holloway, FishPi looks to create a fully autonomous marine surface vehicle capable of crossing the Atlantic Ocean without human intervention. As well as making heavy use of the Raspberry Pi's inter-integrated circuit (I²C) connectivity for the electronic speed controller, servo controller, GPS and electronic compass, the FishPi takes advantage of the Pi's low power draw in order to run the entire system from a solar panel.

The intention is eventually to produce a kit that will allow anyone to turn a Pi into a fully autonomous marine vehicle for purposes including environmental monitoring, detailed mapping, development of autonomous navigation systems and, as Holloway himself puts it, just "something to geek out to".

The FishPi project is still very much at the early stages of development, with Holloway actively seeking input on its development and production through the official website at **www.fishpi.org**.

6 Bare-metal programming

The processor at the heart of the Raspberry Pi, a Broadcom BCM2835 system-on-a-chip, is certainly slower than a desktop processor, but being a Reduced Instruction Set Computing (RISC) chip it's also more accessible for beginners to the subject. Taking advantage of this fact, the University of Cambridge – located conveniently close to the Raspberry Pi Foundation's headquarters – has launched a free online course dubbed Baking Pi, designed to teach anyone how to program an operating system from scratch in assembly language.

Although the example operating system components used in the course, created by Alex Chadwick, aren't going to rival Windows 8, it's a useful starting point for learning assembler.

"I have tried not to assume any prior knowledge of operating systems development or assembly code," Chadwick explains in

It's still in the early stages, but Greg Holloway is hoping to develop his FishPi into an autonomous marine surface vehicle, able to perform tasks such as environmental monitoring

Raspberry Pi Revision 2

The Raspberry Pi Foundation recently shifted manufacturing to Wales – and took the opportunity of moving factories to make modifications to the design of the circuit board. Although those with original boards needn't upgrade, the changes do add flexibility to an already capable device.

The most visible change is the addition of two mounting holes, drilled to accept an M2.5 screw. Where the earlier Pis required a case that would grip the board at the edges, it's possible to mount Revision 2 boards directly to almost any surface.

There have also been some more fundamental changes: the USB and Ethernet controller has been modified to reduce its operating temperature, and it's now possible to reset the BCM2835 system-on-chip processor by shorting Pin 1 to Pin 2 on the connector marked P6.

More importantly, the general-purpose input-output (GPIO) capabilities of the Revision 2 boards are improved by the addition of four more GPIO signals on a new connector, which can alternatively be used for digital audio output.

Currently, there's no way to guarantee that you'll get a Revision 2 board, but supplies of the original boards are running low; orders placed now have a good chance of receiving the updated hardware.

his course introduction; he warns that "it may be helpful to have some programming experience, but the course should be accessible without."

For those who have been thinking of dabbling in assembler for a while, perhaps after working with higher-level languages such as C and .NET, the free course provides a great introduction – and the lessons learned can be quickly applied to developing software for the Pi and for other ARM-based devices such as smartphones and tablets. The full course is accessible at **www.pcpro.co.uk/links/219id5**.

7 Space exploration

Putting a Raspberry Pi in space may sound extreme, but the device is well suited to such endeavours: it's passively cooled, with no moving parts, and can run from batteries or solar power. Several projects have appeared hoping to create Pi-powered micro-satellites, but the first to bear fruit is slightly more sedate: near-space photography using a Raspberry Pi, a webcam and a weather balloon.

Dave Akerman was the first to think of using the Pi as a lightweight near-space exploratory vehicle, and to date is the most successful: his Raspberry Pi in the Sky maiden voyage hit an altitude of 39,994m – only 300m short of a world record.

Achieving near-space flight did require a few modifications to the Pi, including heatsinks for improved cooling in the rarefied atmosphere, shorted-out USB fuses to increase output current for the webcam, and direct soldering to a high-amperage 5V power supply. But Akerman's modifications, detailed in full on his blog, are within reach of a hobbyist with a soldering iron and some spare time.

Akerman's experience as an amateur high-altitude balloonist certainly helped with the success of the Raspberry Pi in the Sky, but it's a project that has captured the imagination of many other Pi owners across the globe – and is only likely to be bettered when the first Pi reaches orbit.

Full details about the Raspberry Pi in the Sky mission can be found on Akerman's blog at **www.pcpro.co.uk/links/219id7**.

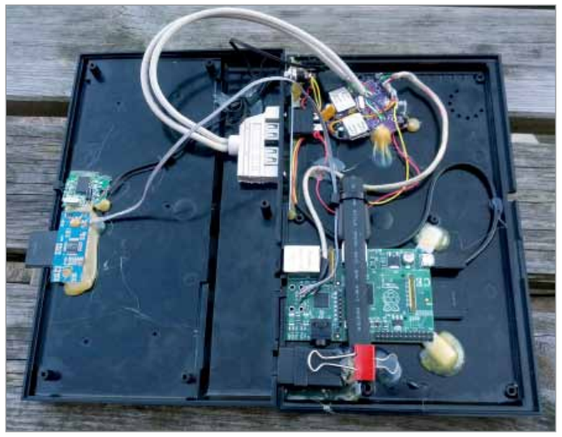
8 ZX Spectrum emulation

The compact form factor of the Raspberry Pi is exciting to retro-computing enthusiasts: for the first time, it's possible to emulate almost any home computer from the 1980s and 1990s – and a large chunk of arcade machines and games consoles, too – on a device the size of a pack of cards.

Steve Wilson, a fan of Sir Clive Sinclair's low-cost computers that helped define the 1980s, demonstrates the Pi's flexibility with his project to place one inside the casing of an original Sinclair ZX Spectrum. Using a variety of cheap additional components, Wilson has given an old rubber-keyed Spectrum a significant upgrade from its original 3.5MHz Z80 processor and 48KB of RAM.

"The initial problem was finding somewhere to locate the Pi with the minimum component removal," Wilson explains. "I knew I wanted

The University of Cambridge has launched Baking Pi, an online course that uses the Pi to teach beginners programming skills



Steve Wilson has placed a Pi inside a Sinclair ZX Spectrum, creating an emulator that can run original software and play Full HD video

Licences for codec formats can be purchased, transforming the Pi into a home theatre system

the Pi's USB ports internal, so they were the first to come off. The video-out connector was then the only problem, and swiftly resolved by its removal."

Once the keyboard is wired to a USB controller, Wilson will have something of a unique item: a Spectrum that can run original software through an emulator, but which can also play 1080p Full HD video as a home theatre system. Wilson's progress can be followed on his Twitter feed at **http://twitter.com/_SteveWilson_**.

9 Commercial products and services

One of the first projects to dip its toes into the water of Pi-powered commercial products is Shoop, a souvenir photo printer created by freelance software developer Brian de la Cruz.

"When I started selling my software, I saw a huge market for photo-souvenir solutions, and I became more and more interested in further innovating the business and offering fresh solutions to the market," he explains of his inspiration. "When I got my hands on a Raspberry Pi, a light bulb went on and Shoop was born."

> "Putting a Pi in space may sound extreme, but the device is suited to such endeavours"

Combining a Raspberry Pi and an inkjet printer, de la Cruz created a system that can accept image uploads over Wi-Fi from any smartphone or tablet. Templates are applied to the images, which are then printed – and the customer, naturally, charged.

The Foundation has indicated that it's happy to see the Pi used in profit-generating commercial enterprises, providing the various trademarks are respected and that a message declaring the product to be Raspberry Pi-powered is included somewhere on the packaging or website.

A video demonstrating the Shoop printer in action, missing only some security-related details, can be found on de la Cruz's blog at **www.pcpro.co.uk/links/219id6**.

10 Home theatre

The most accessible project in our list: setting up the Pi as a home theatre system requires no changes to the hardware. The Pi's multimedia-centric BCM2835 system-on-chip processor is capable of decoding and playing 1080p Full HD video content, but licensing restrictions on the codecs used had

previously meant that only H.264 format video was supported.

Recently, the Foundation announced a deal that allows those who desire broader video support access to two additional codec formats: MPEG2 and VC-1. The former, common to older video files and DVDs, costs an additional £2.40 in licensing, while Microsoft's (significantly less popular) VC-1 codec costs only £1.20 to enable.

The Foundation has also enabled H.264 hardware encoding, which is available for all Raspberry Pi systems via a free firmware update, along with support for the Consumer Electronics Control standard – meaning media playback on the Pi can be controlled using the remote control from a CEC-compatible HDMI-connected TV.

Using a freely available distribution such as Raspbmc, XBian or OpenELEC, the Raspberry Pi can become a powerful tool for media streaming and playback – and at less than £30, it's one of the cheapest high-definition playback devices on the market. More information on the newly released codecs, CEC support and using the Pi as a home theatre system can be found on the official Raspberry Pi blog at **www.pcpro.co.uk/links/219id8**.

Alternatives to the Raspberry Pi

The Raspberry Pi is by far the most popular microcomputing system today, but it isn't the only device on the market – and for some tasks, it may not be the best choice.

Low-power computing specialist VIA has launched a sub-brand, APC, which exists specifically to offer the Pi some competition. Its first product is a Neo-ITX system based on a WonderMedia 800MHz ARM11 processor with 512MB of RAM (**http://apc.io**). It offers a faster processor and double the memory, and comes in at a similar price – with an RRP of $49 compared to the Pi's £30, although it is around twice the size.

An older alternative is the BeagleBoard, an open hardware project packing a powerful ARM Cortex-A8 processor running at 1GHz alongside 512MB of low-power RAM (**http://beagleboard.org**). It's a step up in power from both the Pi and the APC, but comes at a significant cost: the BeagleBoard-XM, the latest revision, costs $149.

If your project is more about sensing and control, an ARM-based microcomputer may be overkill. A popular choice for robotics projects is the open source Arduino, which uses an Atmel microcontroller in place of a CPU (**http://arduino.cc**). Much simpler than a Pi – running at 16MHz and providing program storage space of only 32KB – it nevertheless boasts powerful features including 14 general-purpose input/output pins and 12 analogue input pins, and costs only £19.