Why-Pi

Why and how the Raspberry Pi came to be

Prepared for Jaycar Maker Hub (Sydney)
Raspberry Jam, 3.14 14th March 2020

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pyrmontbrewery.com

Raspberry Pi turns 8! *+ a gestation period of ~ 4 years*

I had the pleasure of working alongside Jack Lang at large telco in the UK in the late 1990s - Jack is one of the founders and (since retired) trustee of the Raspberry Pi foundation

I've also worked with the Raspberry Pi on various projects over the years including some, where I actually got paid!

I'm sharing some of Jack's story and will try and answer questions about the device, how the software works and maybe help you make it do whatever you want it to do

Raspberry Pi - what's that?

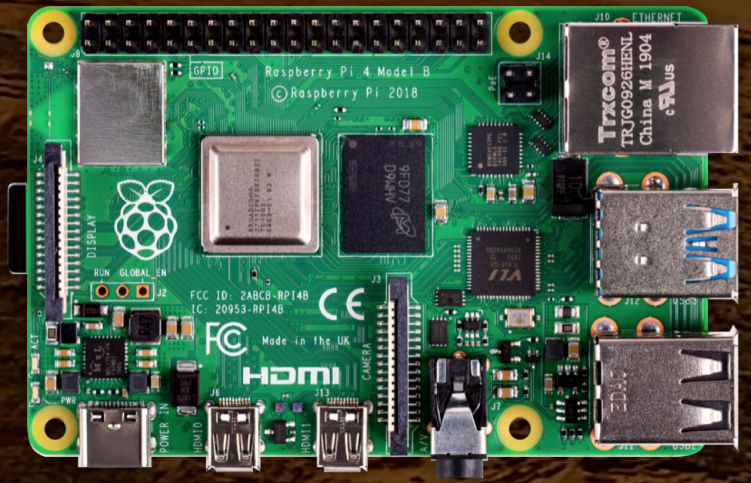
It's an affordable home computer ~ size of a credit card $35

More so, it's just the guts of a personal computer - with the intention you'll take that and go make it whatever you want

It's *real* purpose is **educational**

30 million have been sold worldwide since 29 February 2012!

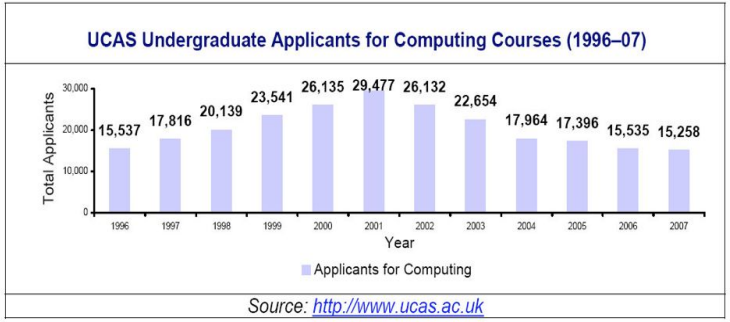
This is their story...

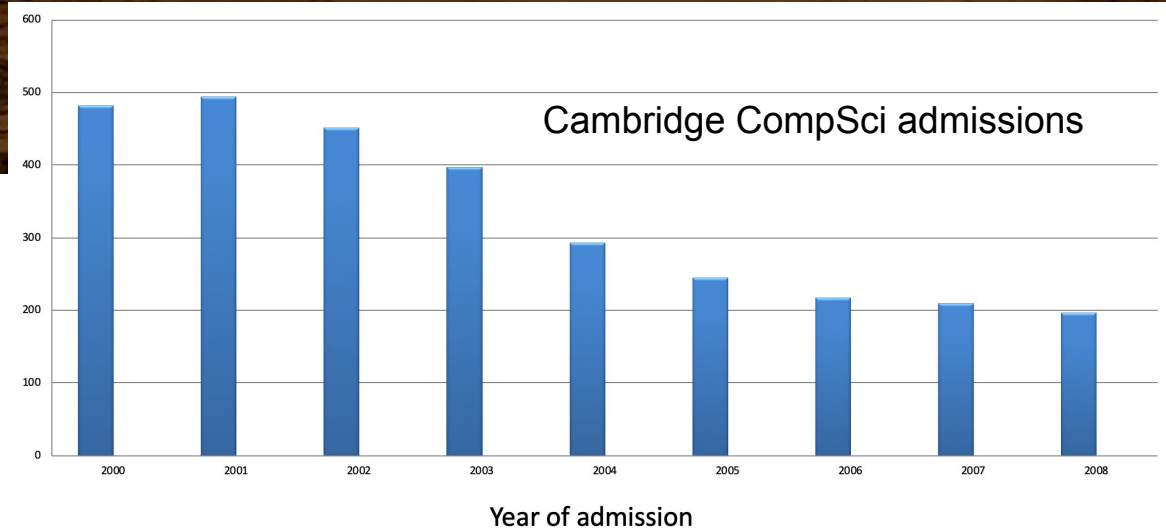


In the beginning...

The University of Cambridge department of Computer Science and Technology had a problem

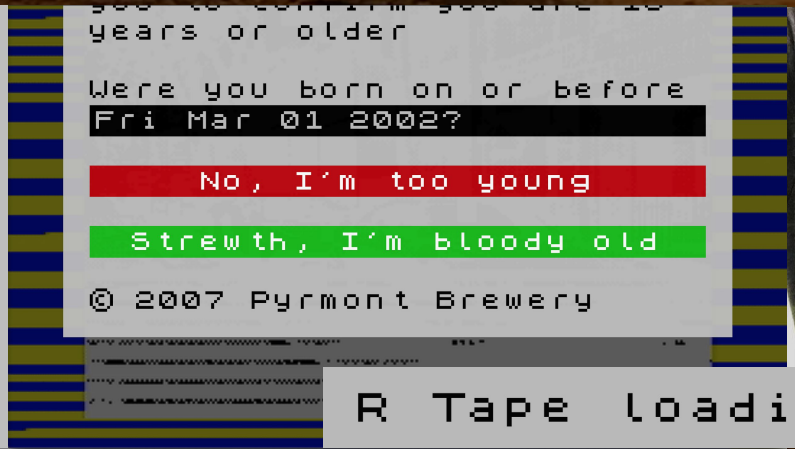
The student applications were dropping off and their initial general knowledge and experience was lower

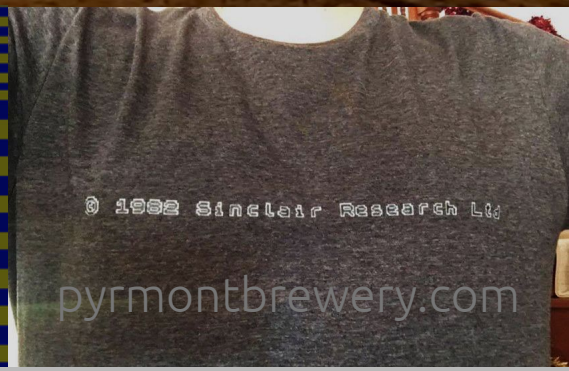


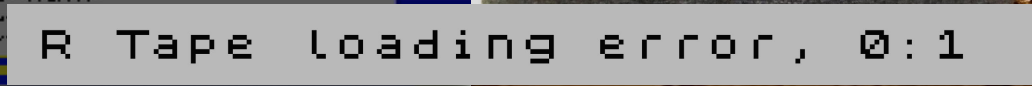


What changed?

In part this was due to how computing was approached in the 80s/90s vs today - kids like me used to actually *enjoy* programming on the Sinclair ZX Spectrum / C64 / Electron at home and the BBC Micro / Acorn Archimedes at school







Who's to blame?

Not entirely fair to pick on individuals but basically *closed* devices like games consoles, phones and tablets come with significant obstacles and a steep learning curve to get to a point where you can actually be programming them

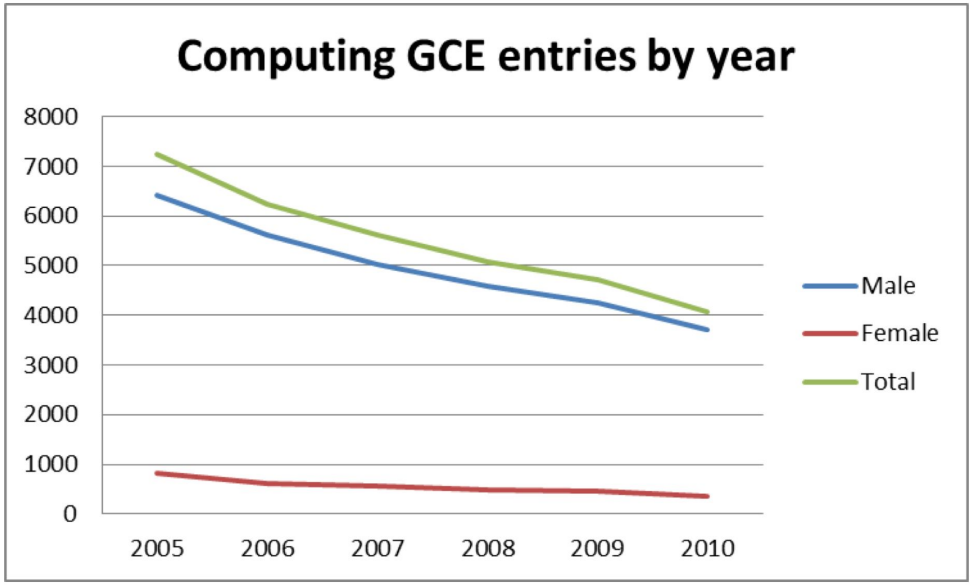
"To gain access to a command line, you have to download software, It has to ***occur to you*** *to do it."* [Mullins]

Why that's not so good...

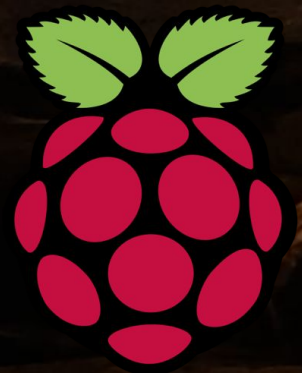
This all leads to *less enthusiasm* in the subject and some complacency that everything kind of seems ok in the industry

I myself was the only candidate to sit the (HSE equiv) exam at my school

I wasn't really taught programming/coding that was largely up to me



Raspberry Pi Foundation to the rescue!



“exists to promote the study of computer science and related topics, especially at school level, and to put the fun back into learning computing”

UK registered charity (1129409)

Not for profit! *Income* ***£31.5M*** *- Spending* ***£27.9M*** *(31 December 2018)*

Raspberry Pi Foundation - who are they

Today ~ 135 people but in Feb 2008 **Jack Lang** wrote the ●π manifesto - meanwhile, **Eben Upton** had been experimenting with low cost designs *(with Broadcom)* and **David Braben** was thinking about educational software to increase the flow of games programmers *(he wrote Elite!)*

The six trustees of the charity we really must thank are (Dr's): **Jack Lang**, **Eben Upton CBE**, **David Braben OBE**, **Prof Alan Mycroft**, **Rob Mullins** + **Pete Lomas FReng**

Raspberry Pi Foundation - who are they

PiPeople

Alan Mycroft
Eben Upton
Rob Mullins
Pete Lomas
Jack Lang
Dave Braben

Thanks also Liz Upton, Dom Cobley, James Adams, Gordon Hollingworth and many others

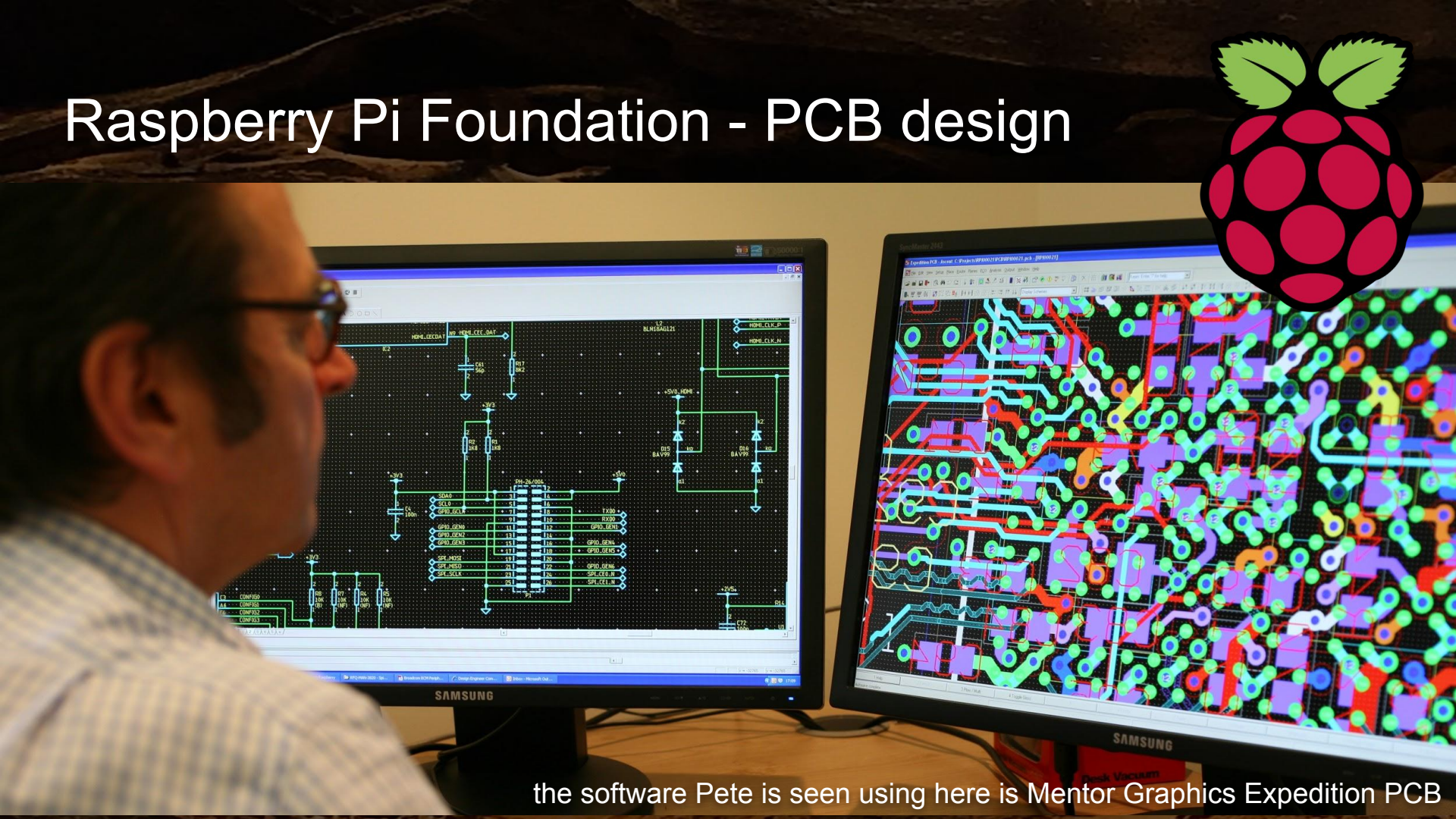
Raspberry Pi Foundation - Jack

I worked with Jack at ntl: (Virgin Media UK) he really is quite remarkable, witty and extremely knowledgeable

Lectures
Entrepreneurship
at Cambridge University

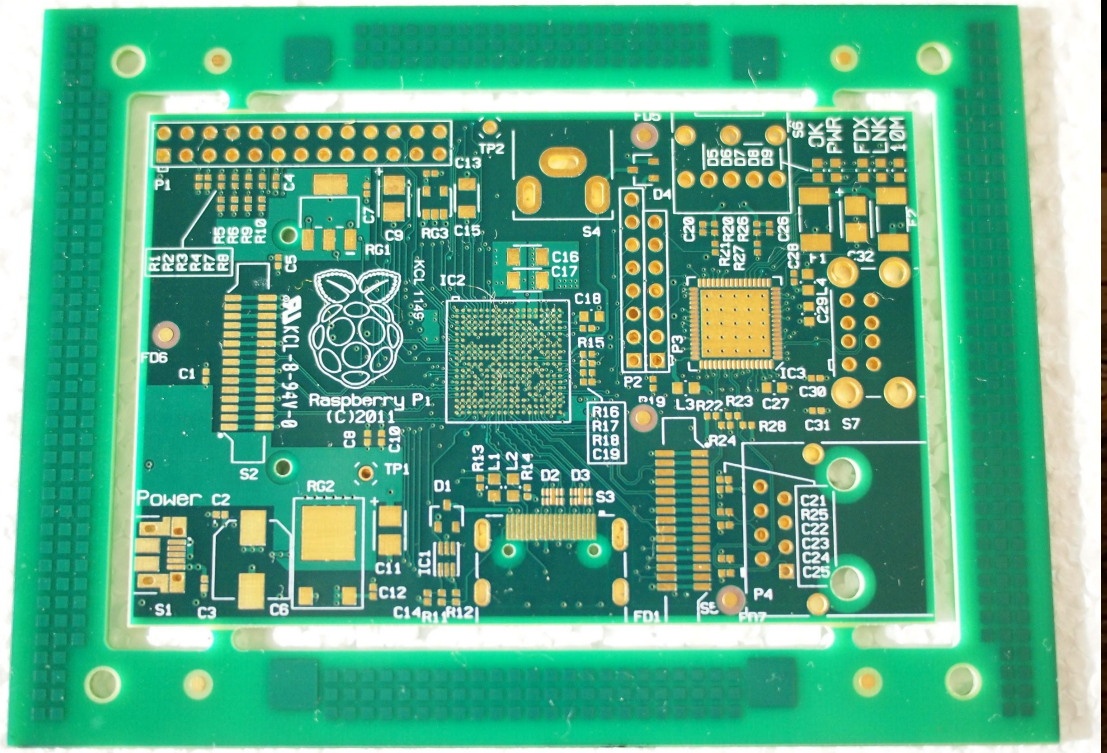
Knows bloody everyone
BBC Micro
Has a fireworks license!
Taught me to network

Raspberry Pi Foundation - PCB design



the software Pete is seen using here is Mentor Graphics Expedition PCB

Raspberry Pi Foundation - first PCB is born



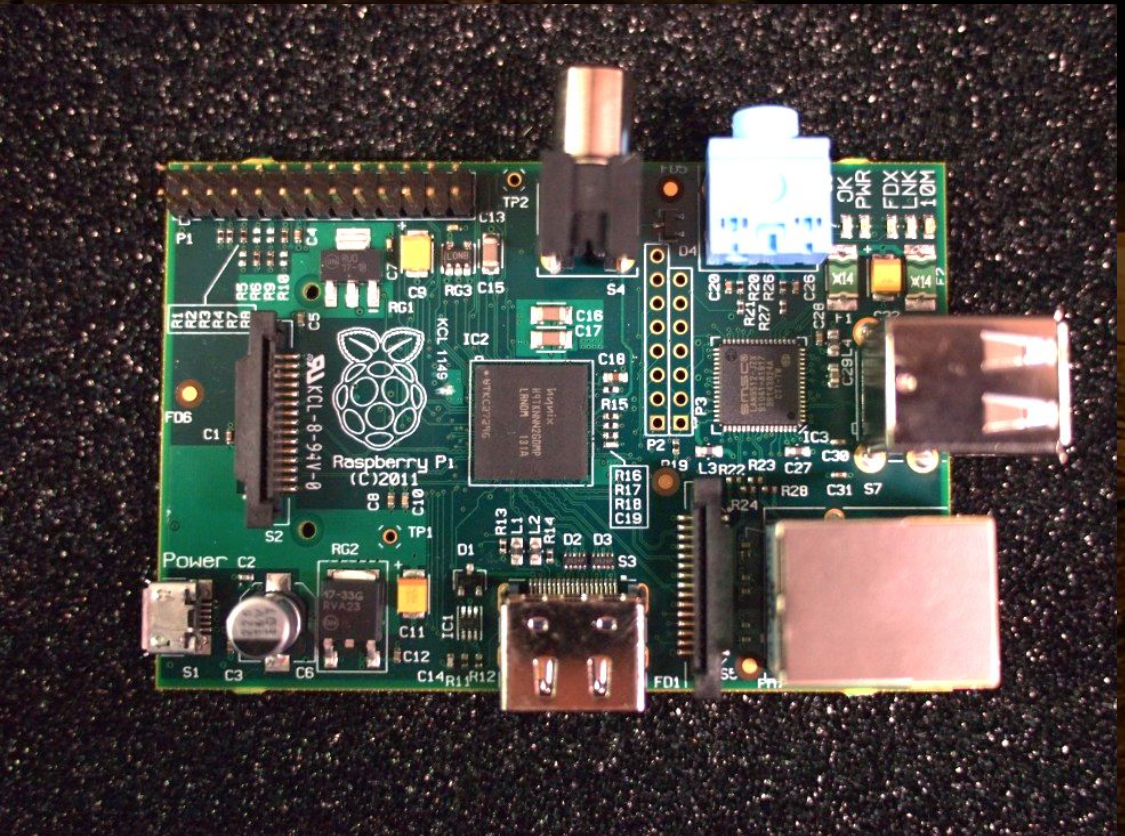
< A naked Pi

This photo is actually the **first ever** preproduction Raspberry Pi board!

1 of 25 (in Northcott UK)

(thanks Pete Lomas for the photo)

Raspberry Pi Foundation - first assembled

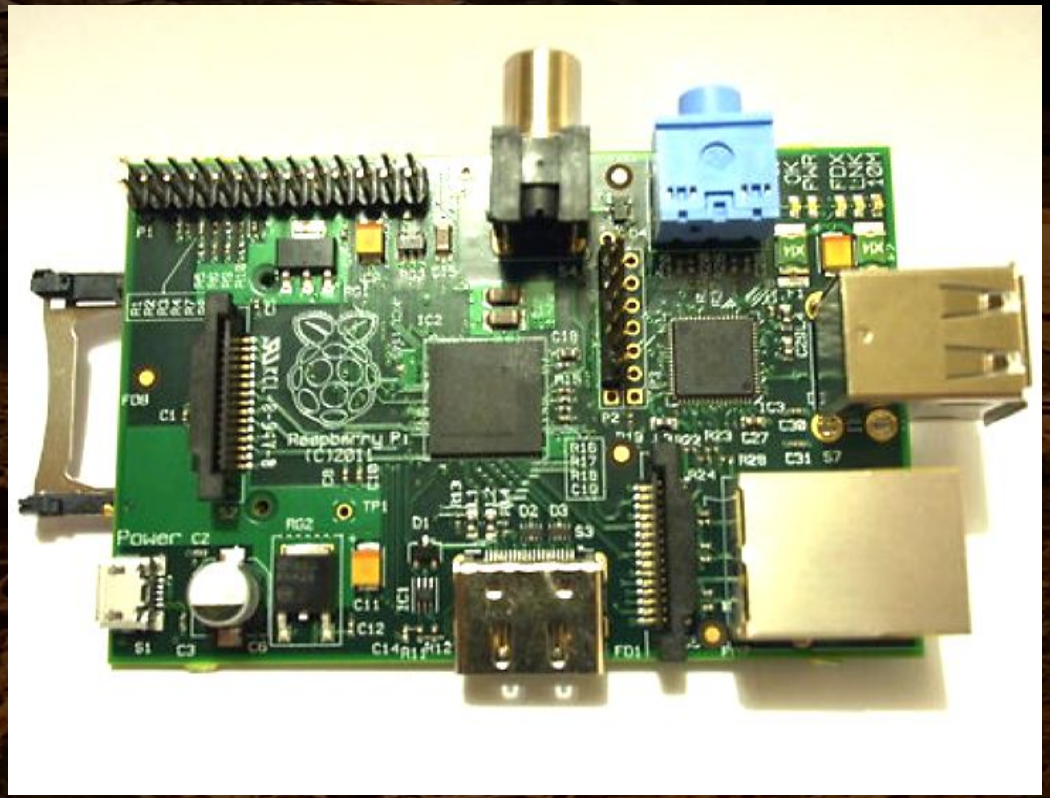


< less naked

The centre SoC and the RAM share same space (package-on-package)

No heat sink required
can get a little warm

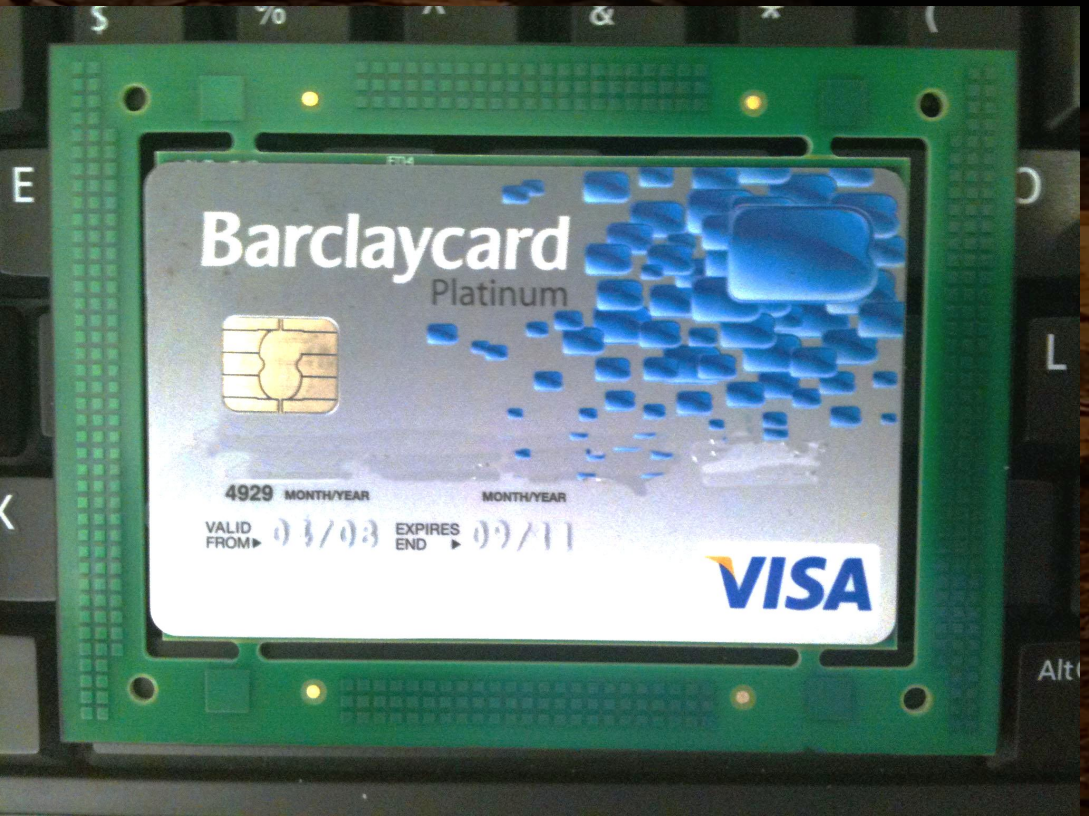
Raspberry Pi Foundation - first in test



< minor SD
card bodge to test

(delay in parts delivery - the production SD card and USB doesnt stick out like this)

Raspberry Pi Foundation - dimension test



Pete checking it actually *is* the size of credit card

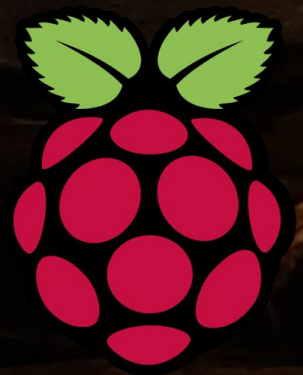
Minor solder blob mod, then off to China (via Hong Kong) for volume production

Raspberry Pi Foundation - first 2,000 units

The first 2,000 of 10,000 units that was going to be "*about enough*" (unpacking ceremony in Jack's garage)

US$50,000 investment

Raspberry Pi Foundation - eh oh!



"we accidently sold a million and it was all a bit embarrassing" *[Lang]*

BBC blog spikes interest, orders increased rapidly (> 350K = 700/s) - a separate company "Raspberry Pi Trading*" was set up 29th Feb 2012 to maintain the supply for such a demand

Fix put in place was to grant licenses RS and Premier Farnell (element14) to manufacture and distribute the Pi instead

** Raspberry Pi Trading, is fully owned by the Raspberry Pi Foundation, Eben is CEO*

Raspberry Pi Foundation - 29th Feb 2012

Orders on first day actually crashed the website!

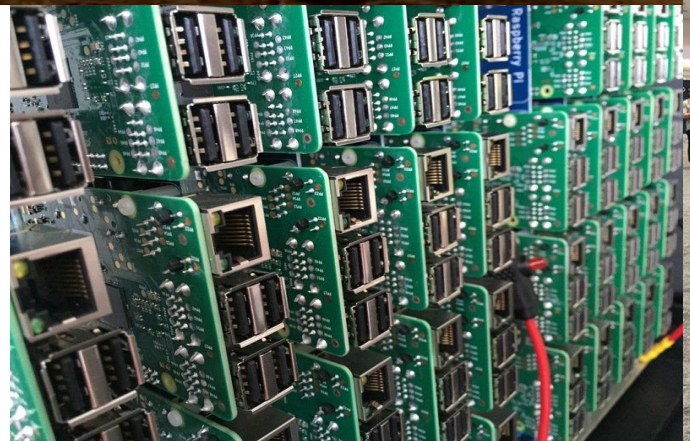
The "Buy" button sent would be purchasers to RS and Farnell, (at their request) to their own search page for RasPi

Turns out their search engines did not cache and so could not cope with 100,000/h search requests...

Sony (Wales) manufacturer 'made in UK' today

8 years later - more than 30 million units!

Making original estimates out by around 3000x



So who's buying them? Hobbyists of course... but also can be used in larger clusters - which makes super computing affordable - all sorts of things requiring high CPU/GPU computation / modelling more achievable

Raspberry Pi Foundation - Are you local?

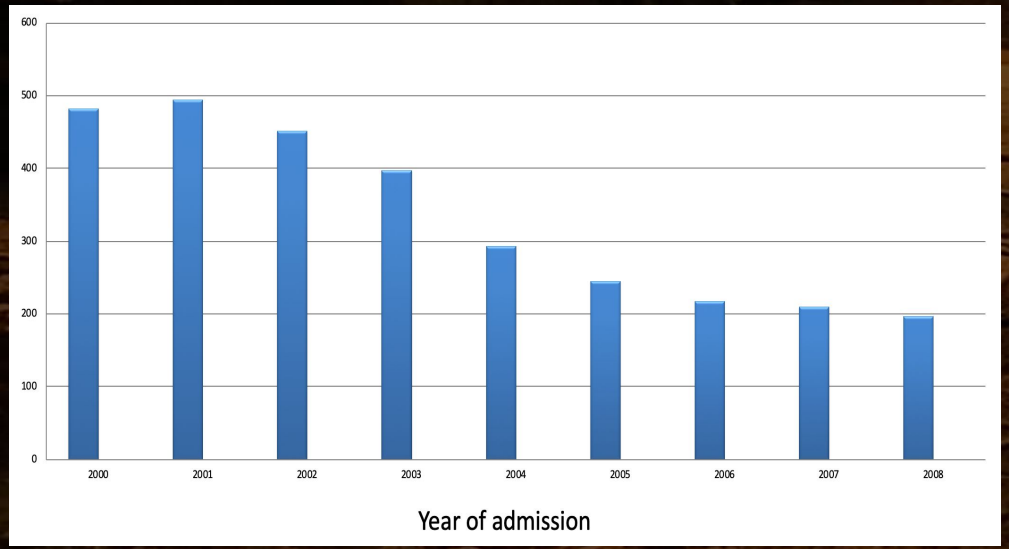
You'll find this special shop in downtown Cambridge

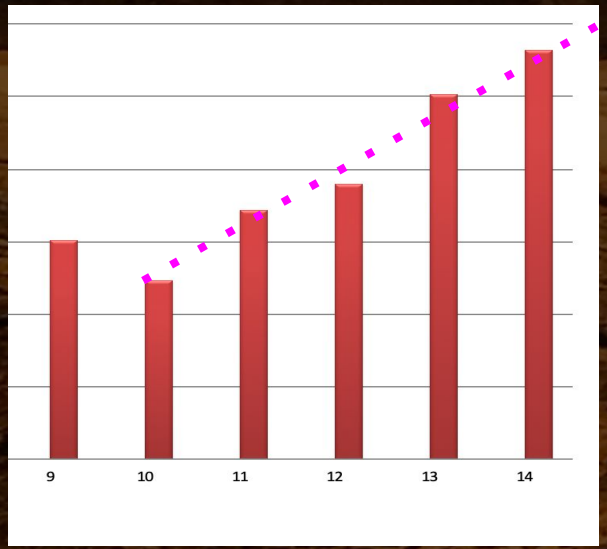
The Raspberry Pi Store - Grand Arcade Shopping Centre

Raspberry Pi Foundation - the best bit

What it's really about, CompSci students came back!

Cambridge had 1,307 applications in 2018 (vs only 197 in 2008)





Raspberry Pi Foundation - remote schools

Pi's are empowering various remote communities to become better educated in computer science

RACHEL-Pi are educational airdrops for areas with poor or no connectivity runs as hotspot/web server hosting Wikipedia etc

Get going with a Raspberry Pi (headless setup)

Copy the Raspbian Linux distribution .iso file to an SD card

```
$ sudo dd if=/dev/rdisk1 bs=1m | wget https://downloads.raspberrypi.org/raspbian_full_latest
```

You don’t technically need a keyboard, mouse or a monitor ;-)

```
$ touch /Volumes/boot/ssh
$ vi /Volumes/boot/wpa_supplicant.conf
country=AU
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1
network={
    ssid="YOUR_WIFI_NAME_BSSID"
    psk="YOUR_WIFI_PASSWORD"
}
$ sudo apt install realvnc-vnc-server realvnc-vnc-viewer
```

Set your expectations up realistically

The Raspberry Pi is *not* a PC, but is pretty powerful for its size

Cut down versions of Broadcom SoCs datasheets available
Broadcom BCM2711B0 quad-core A72 (v8-A) 64-bit 1.5GHz
4 Gigabyte LPDDR4 SDRAM - Underclock might be needed!!

Wi-Fi (5G 802.11ac + 2G 802.11b/g/n)
Bluetooth 5.0 with BLE (low energy)

(Power over Ethernet make sure your USB PSU power supply is 3A or higher)

4K Video capabilities (VideoCore VI @ 500MHz)

Always been good - earliest model comparable to first Xbox
Roku boxes (e.g. Telstra TV box) are in part Raspberry Pi too!

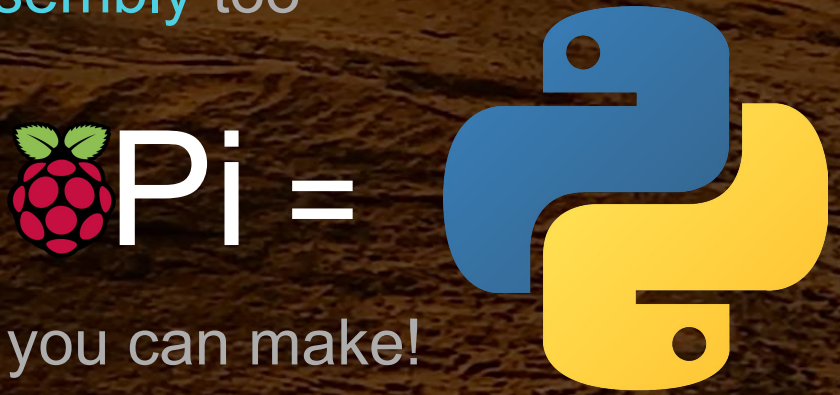
XBMC/Kodi runs! Netflix also (at least until the DRM kicks in)
Frame buffer today comes from latest Broadcom VideoCore 6

4K H.265 (HEVC) hardware decode * (60fps
HD H.264 hardware decode * (1080p60fps)
OpenGL 3.0 3D Graphics (and GLES2)
Supports dual 4K HDMI displays!

What can I do with *my* Raspberry Pi?

Sightly controversial comment - but - creating a website is kind of programming, but in traditional terms, really it's not

Yes of course, go learn React with JavaScript but also maybe also look into using WebAssembly too
Challenge yourself to maybe see how you might do it in C or Rust
And everyone *must* learn Python
Why? Like lego, can bind anything you can make!



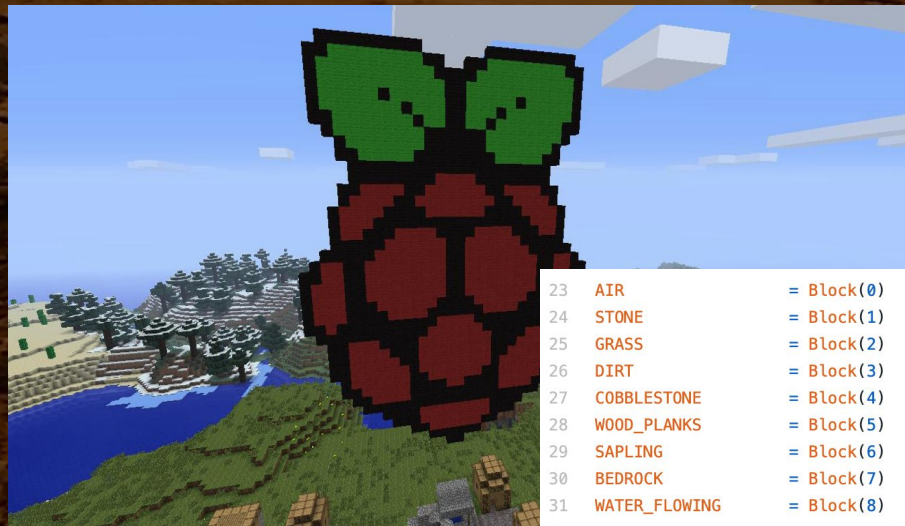
Maybe go write a Minecraft (Python) mod

https://projects.raspberrypi.org/en/projects/getting-started-with-minecraft-pi

```
from mcpi.minecraft import Minecraft
mc = Minecraft.create()

x, y, z = mc.player.getPos()

DIAMOND = 57
mc.setBlock(x + 1, y, z, DIAMOND)
```



Not just software - Connect it up to other hardware

By design the Raspberry Pi is very connectable! USB, Wi-Fi, Bluetooth, Ethernet...

... + 28x user GPIO supporting various interface signalling options, almost limitless

Up to 6x UART (serial port signalling, add yourself an RS232 port)
Up to 6x I^2C (Inter-Integrated Circuit serial bus connect to devices, including HDMI TVs)
Up to 5x SPI (Serial Peripheral Interface bus - all sort of microelectronics, LCDs, LEDs etc)
1x SDIO interface (add a second Secure Digital SD card reader)
1x DPI (Parallel RGB Display) 24-bit RGB24 (8 bits for red, green and blue) or RGB666 (6 bits per colour) or RGB565 (5 bits red, 6 green, and 5 blue)

Connect up to other hardware - GPIO

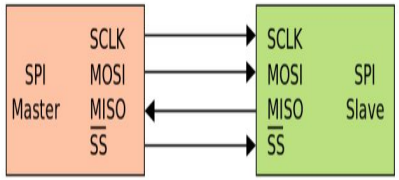
General Purpose In/Out pins - 28 of the 40 pin header at the top of the board are GPIO (can use regular IDC ribbon cable etc to attach to breadboard etc or make a 'hat' PCB)

3.3V high (true) GPIO00-08 def high
0V low (false) GPIO09-27 default low

GPIO02/03 fixed pull-up resistors
others are software configurable

```
import pigpio
pi = pigpio.pi()
pi.write(19, int('True'))
pi.stop()
```

Connect up to other hardware - SPI bus

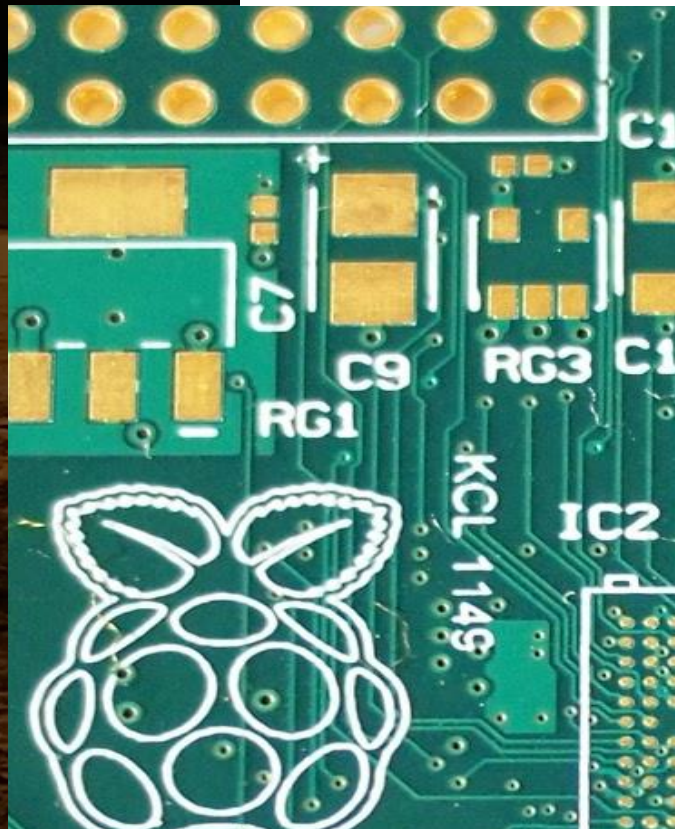


Serial Peripheral Interface (4 wire serial bus)
SPI allows Pi to act as 5 masters to multiple attached devices

Pin23 = SCLK (SCK serial clock from Raspberry Pi master device)
Pin19 = MOSI (SDO) Master Output Slave Input (Pi data output)
Pin21 = MISO (SDI) Master Input Slave Output (slave data output)
Pin24+26 = SPI CE0/CE1 = SS (shift select from Pi)

Software is off by default, run raspi-config to enable the devices
/dev/spidev0.0 and /dev/spidev0.1

```
import spidev
spi.open(0 bus, 1 device)
spi.xfer2([0x1234 some message])
```



Connect up to other hardware - I²C bus

Inter-Integrated Circuit - 2 wire addressable serial bus
Up to 6 buses - any number of addressable devices (inc HDMI)
(warning **3.3V not 5V** - be careful how/what you connect ;-)

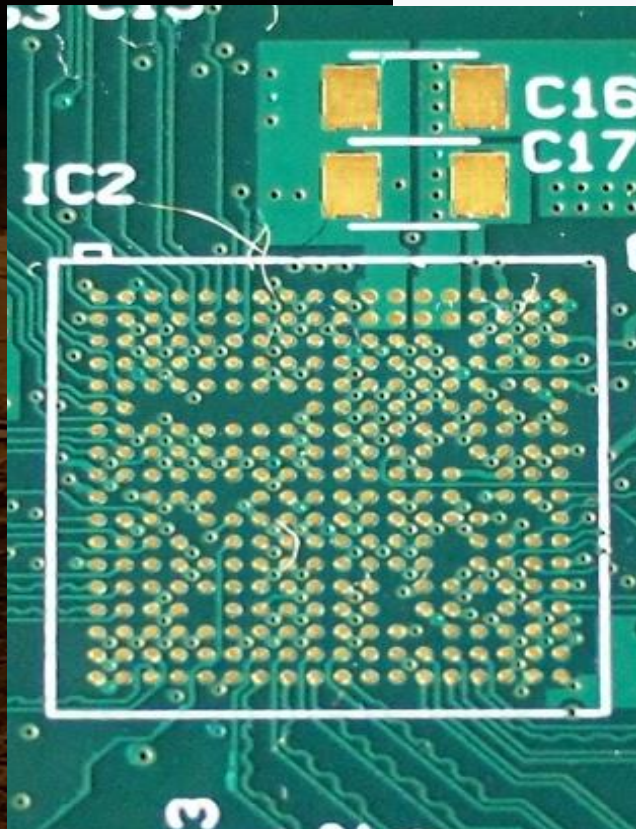
Pin3 = I²C SDA 0/1 (serial data)
Pin4 = I²C SCL 0/1 (serial clock line)

Pins 27 and 28 are I2C too but for EEPROM only

```
import smbus

channel = 1    # 1 is connected to the GPIO pins
addr = 0x60    # for your device
reg_write = 0x40  # Register addresses

bus = smbus.SMBus(channel)  # initialize
bus.write_i2c_block_data(addr, reg_write, msg)
```



Connect up to other hardware - PCIe

Peripheral Component Interconnect Express
(Raspberry Pi 4 only)

Refactoring the USB3 connector you can support regular PCIe boards found in most PC computers (so, high end gfx cards, but FPGAs boards too etc)

Various "multiplier boards" in the wild but it's a fiddly process to solder and you might lose that USB3 connectivity

Connect up to other hardware - USB2.0 / USB3.0

Universal Serial Bus - many USB devices out there with standard drivers, Pi4 has 2 x USB2 and 2 x USB3

Downstream current is 1.2A (aggregate on the 4 ports) - for some devices may need a bigger PSU

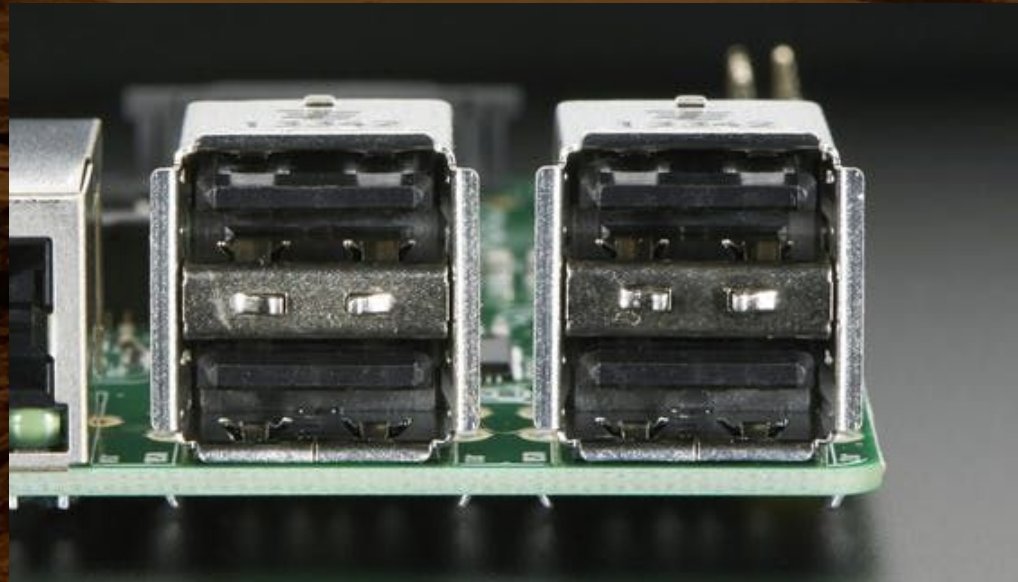
All transfer types: bulk (HDD), interrupt (mice/keyboard HID), isochronous and control endpoints

```
import usb

args["idVendor"] = 0x16c0 # uDMX
args["idProduct"] = 0x5dc # uDMX
device = usb.core.find(**args)

device.ctrl_transfer(type, req)
device.write(1, 'DMX_CH1=RGB')

lsusb
```



Connect up to other hardware - Bluetooth LE 5.0

Connect to BLE controllable devices, like Sphero

Sphero RVR / BOLT / SPRK+

Sphero Mini

BB-8 / BB-9E

R2-D2

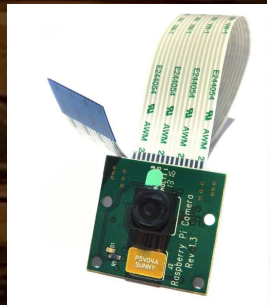
R2-Q5

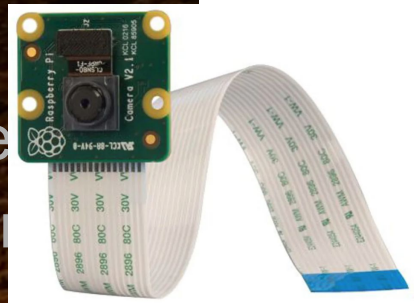
Connect up to other hardware - MIPI CSI (to MMAL)

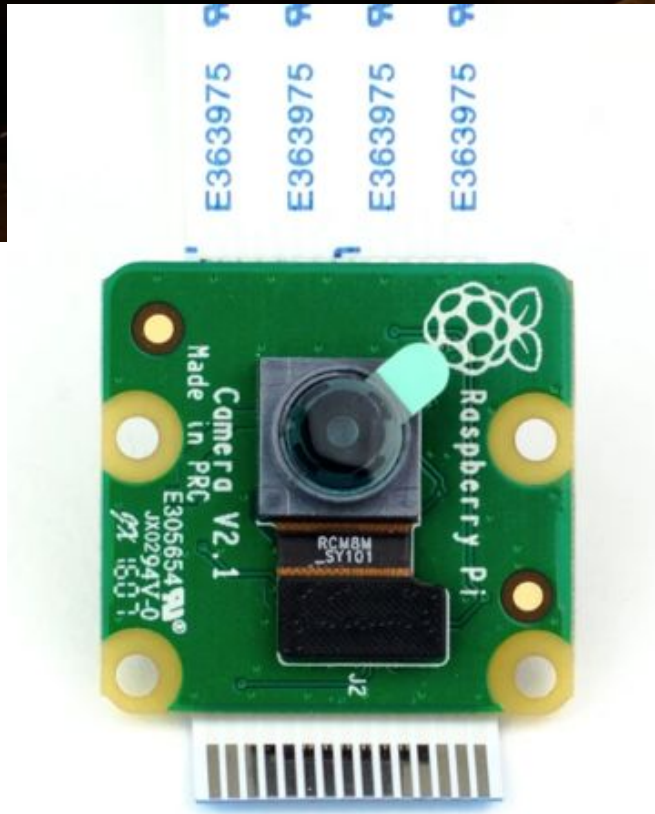
Several models - including slow motion!

Ribbon flex cable straight into the Raspberry Pi (all models)
Can be extended 2m
Requires an extra 200-250mA

Can capture at 1000fps!
Of course regular USB we
also work, but way less fu





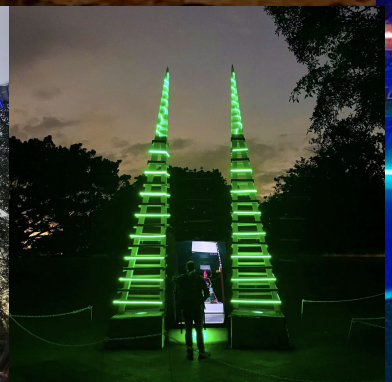


Then, perhaps give this a go?

This was Vivid Sydney - July 2019

2 x 2 x 6m towers! @ The RBG bar

= 4 x 10 x DMX LED relay boards +
2 x 4K TVs + 4 x webcams



Set up in The Royal Botanical Gardens
No time for fireworks! [*Fergal photo credit]*

or... could be useful?

BrewPi *[Elco Jacobs]*
A modern brewery controlle

The BrewPi Spark 3 is a
temperature controller
that can control your beer
fermentation with 0.1°C pre
It sends data to a Raspber
show a control panel with g
in your browser

Pyrmont Brewery

or... make yourself a wireless audio player!

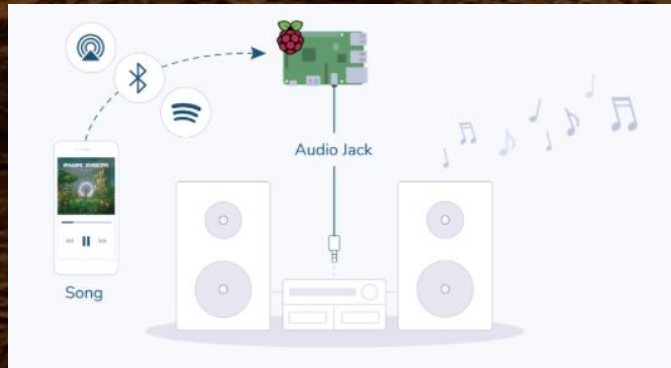
Ever wondered what might be playing the tunes in your local supermarket aisles?

There are actually a fair number of Pi's doing that right now

Check out Raspotify too (Spotify Connect) and SonicPi

Also balenaSound (Raspberry Pi as a Bluetooth audio receiver) at balena.io

Also NymphCast and AirPlay ShairPort



or... get your Pi streaming video

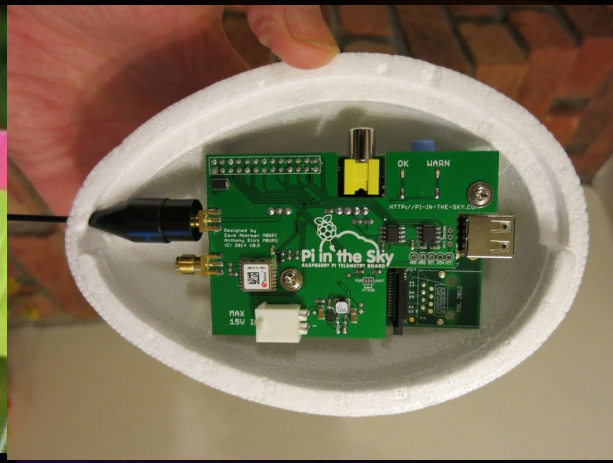
Mentioned earlier, the GPU/VideoCore is really *very* capable

Some big companies including Disney+ use Raspberry Pis as part of their development and test cycle (not prod devices)

The reasoning behind this is the Raspberry Pi is constrained and has similar hang ups to real world devices like Roku

Develop only on a Intel/PC? Sometimes that same code starts good, then flails and falls over on ARM/Pi - like Bambi on ice

or... go decide for yourself if the Earth is flat or round



or... go decide for yourself if the Earth is flat or round

(Pi in the Sky - photo credit Dave Akerman)

RTLS1

0.0 m/s 0.0 km/h
RATE VIH

239 m (12,101 m)
ALTITUDE (MAX)

2016-06-25 13:19:46
DATETIME (LOCAL)

51.76637, -2.81313
COORDINATES

105
AIR DIRECTION

2.9
AIR SPEED

0.23
CDA

117
COMPASS ACTUAL

41
COMPASS TARGET

0.0
CROSSWIND

4
FLIGHT MODE

0.3
GLIDE RATIO

81.7
HUMIDITY

-0.1
PITCH

8.4
PRED LANDING

51.76638
PRED LAT

-2.81264
PRED LONG

15
PRED TIME

986.0 Pa
PRESSURE

-0.4
ROLL

12
SATELLITES

50
SERVO LEFT

0
SERVO RIGHT

4000
SERVO TIME

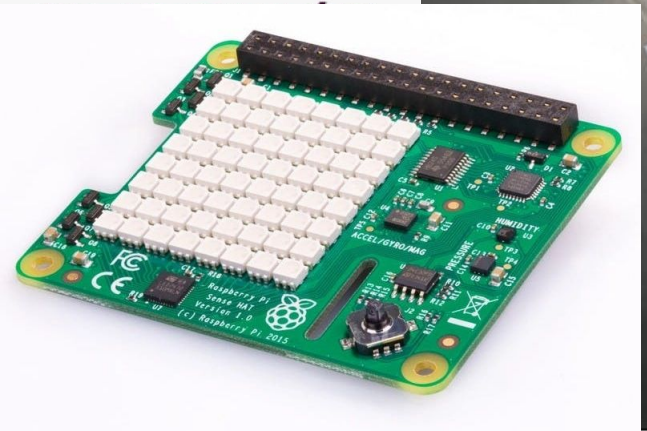
12.1°C
TEMPERATURE, EXTERNAL

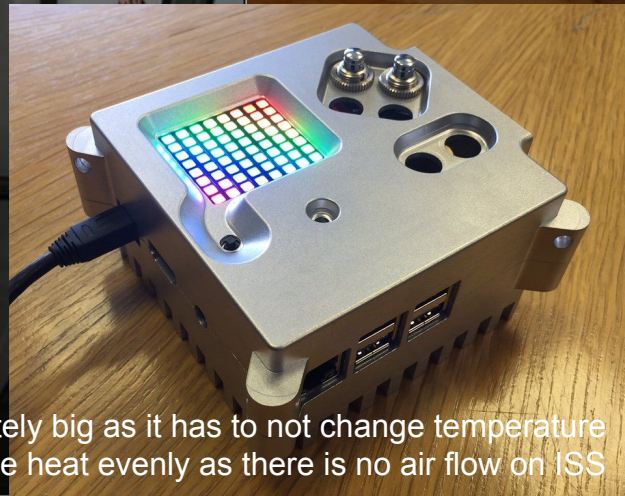
or... run *your* code a bit higher up! (400km! - Tim Peake ISS)

Your code in space! (RasPi + SenseHAT + Cams - photo credit ESA)

THE CODE OF
6800+
YOUNG PEOPLE
RAN IN SPACE

Two AstroPi's on the ISS!
Ed - life in space visible camera (no recording)
Izzy - (near Infrared only, no night vision)





The aluminium anodized case is deliberately big as it has to not change temperature too quickly or too much and also disperse heat evenly as there is no air flow on ISS

Aussie code in space! - *maybe* Australian schools too*

Positive but still early discussions with the Australian Space Agency

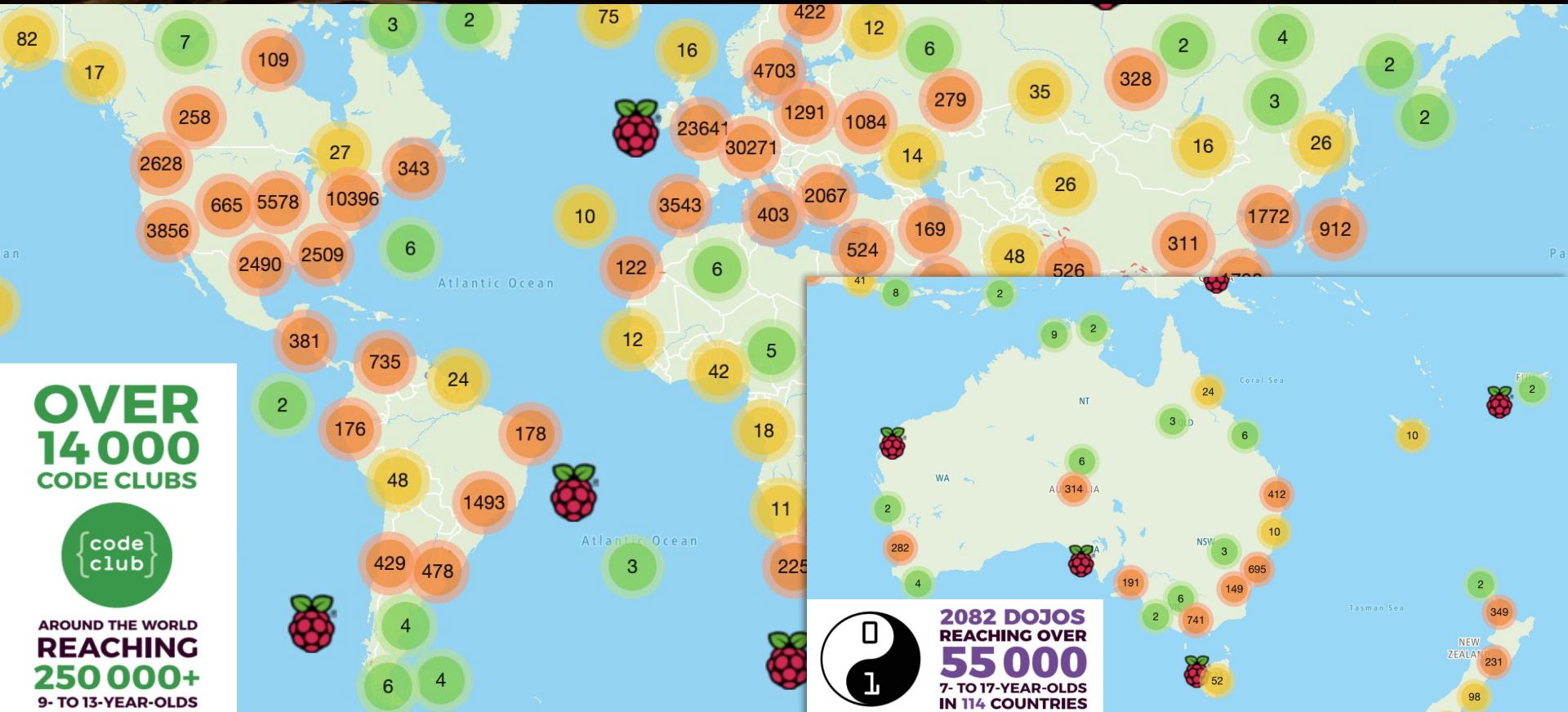
Ideas welcome of how this *might* work for Aussie kids
Could be up high, but plenty of ground work to cover here too

* AstroPi is open to schools in ESA Member States, Canada, Slovenia and Malta (+ officially authorised and/or ESA certified schools internationally)
We're part of EuroVision already!
Kind of the same thing right?! ;-)

Not the best use for a Pi

Bitcoin mining - a fairly wasteful use of our Earth’s fragile resources IMO - but some people are profiting from this

Who ya gonna call? (rastrack.co.uk map of registered Pi's - help is out there!)



Shallow dive into Linux device drivers (userland)

You can totally develop code on a Pi but typically how we do things is cross-compile from a more capable machine

Cross compiling for ARM - kernel flags - firmware repo armv7 vs aarch64 - arm-linux-gnueabihf-ld (early Pis hard float point)

```
brew install help2man bison crosstool-ng && ct-ng aarch64-rpi3-linux-gnu
KERNEL=kernel7 && make bcm2709_defconfig # crosstool-ng
make ARCH=arm CROSS_COMPILE=arm-linux-gnueabihf- menuconfig  #hard float
```

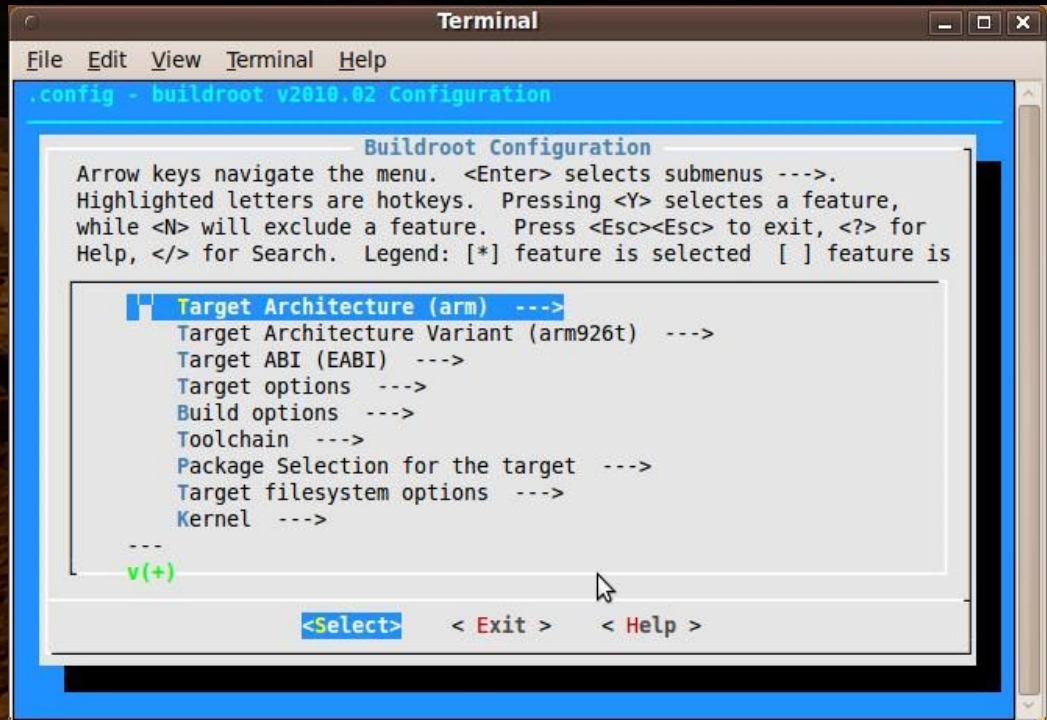
User space abstractions to framebuffer / DirectFB / Wayland
Broadcom provide support for OpenMAX - Open GLES / EGL
Audio too - SDL2 / PCM playback via Alsa

Buildroot (roll your own Raspberry Pi Linux distro)

Kernel - bcm2709_defconfig
BusyBox, OpenSSH
QtWebKit + userland

Raspberry Pi isn't so resource constrained to really need µClibc
glibc works fine

(and yes I did this ;-)



Google ChromeOS aarch64 (arm64-generic)

Make your own Chromebox!

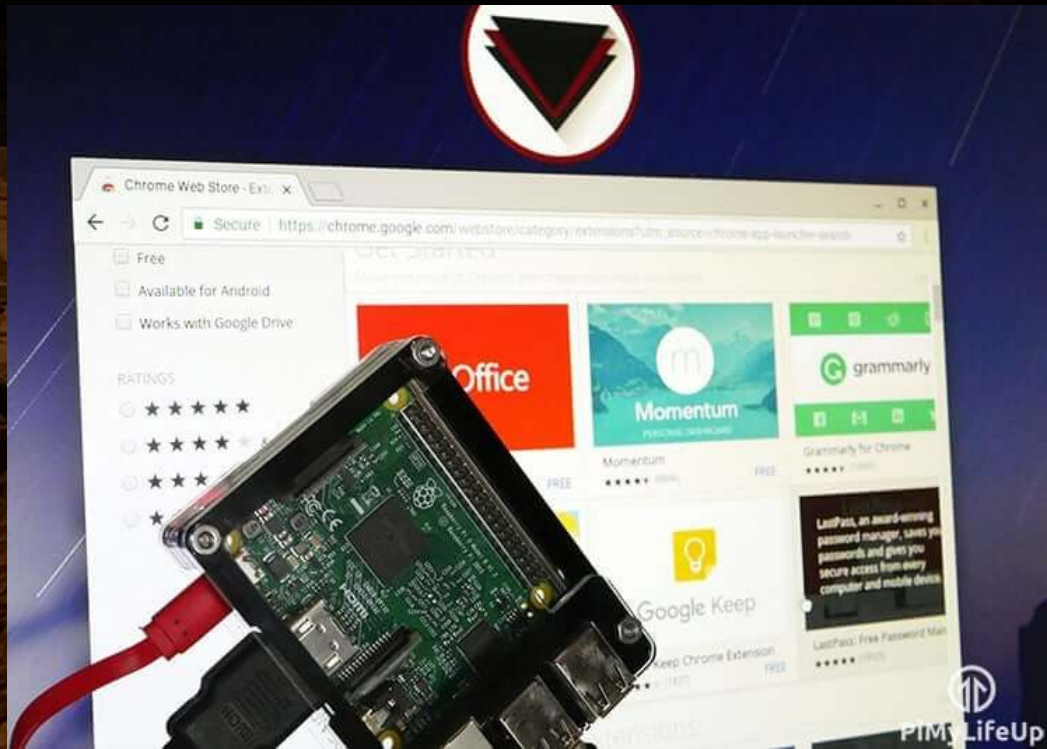
Chromium OS on a Pi

```
cros_sdk -- ./build_packages
    --board=rpi3

cros_sdk -- ./build_image --board=rpi3

cros flash usb:// rpi3/latest
```

Check out FydeOS



Microsoft Window 10 (IoT edition)

Working with WinCE in the 90s nostalgia, things come along

Number of ARM compiled apps remains fairly limited

But nothing stopping you compiling your own!

Mostly commercial use cases

Linux remains your friend

Remembering RiscOS (Acorn for ARM chipset)

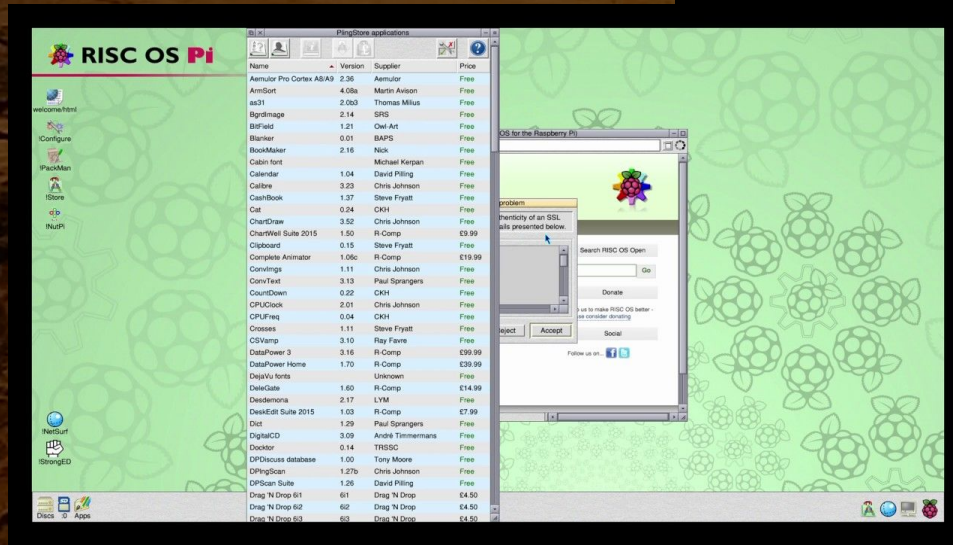
Many UK kids will have used RiscOS (possibly unknowingly)

BBC Basic V

I had my school buy the
full documentation set for me

(and yes I read them ;-)

Happy days, still a great OS!



Interesting quirks and tips

Depending on what you are doing, ever seen a rainbow in the corner of the screen? That tells you your Pi is hungry - give it some juice with a bigger PSU (3A for heavy video usage)

When things get slow on RPi.. "fstat" then look at I/O. Lots of activity on bus means you have run out of RAM and are likely page swapping from the SD card /swap partition *[Martin Gibson]*

Weird, I rebooted and same thing - residual power from *other* USB devices can keep some state alive over power cycles!

Thanks! + also a Raspberry Pi challenge for you...

I'm running a nano brewery, using Raspberry Pi's to control mash temperature and timing is fairly well documented

I'm after a way to **detect how full a keg is**, and also an auto **timed hop hopper** release system - ideas welcome!

These slides are here: http://bit.ly/39tZcMm

raspi@pyrmontbrewery.com

Come to the Jaycar Maker Hub (Central Park, Sydney)

This will be presented at the Raspberry Jam session at **2pm** on Pi Day! **14th March** - grab a free ticket on Eventbrite

RASPBERRY JAM