Introduction – 64 Studio Ltd

- GNU/Linux multimedia software/hardware consultancy
- Created first amd64 distro for media production in 2005
- Custom Debian and Ubuntu-based distros for x86 & ARM
- Linux kernel driver debug & development (soundcards!)
- Best audio latency from commodity hardware
- Tools must be available to all

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Introduction – Daniel James

- Director of 64 Studio Ltd
- Co-founded company in 2005 with Free Ekanayaka
- LinuxUser & Developer magazine 1999-2007
- Author of 'Crafting Digital Media' and 'Airtime for Broadcasters', audio journalism
- Heard Opteron might be good for audio workstations...

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Introduction – Chris Obbard

- Chief Engineer at 64 Studio Ltd

- Electronic Design Engineer with focus on digital systems & software (C, Bash, Python, Javascript)

- Designed many embedded systems from small processors running 100 lines of C... to massive realtime multi-core systems

- Hacking on Linux for around 10 years

- Interested in projects upstreaming SoC support
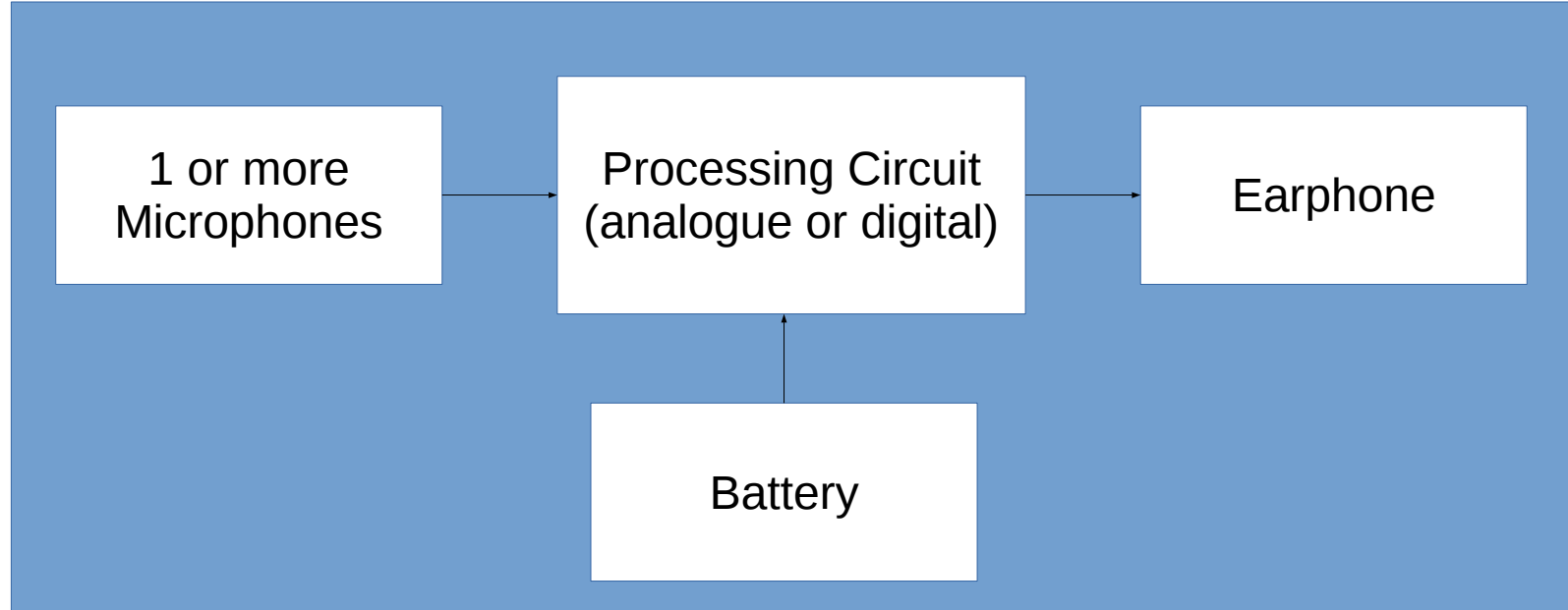
Hearing aids
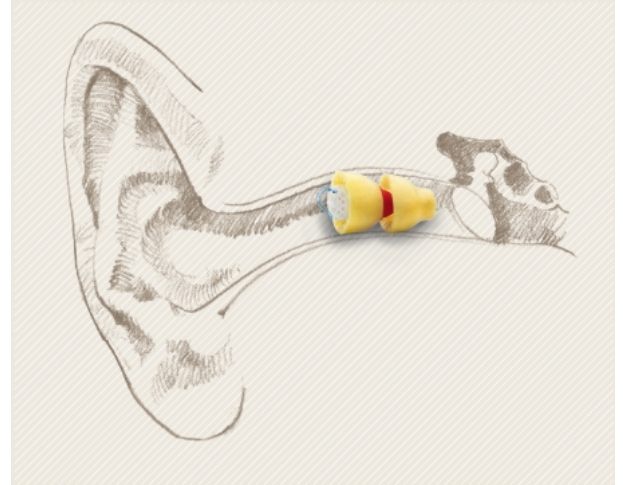
Hearing aids

- Purpose: sound audible to people with hearing loss
- Causes: exposure to loud noise, disease, inherited
- Prices range from £500 for basic set to >£5,000
- Hearing aid may have to be calibrated to individuals
- £1.11 spent on hearing research per person in the UK, compared to sight loss at £11.35 per person*
- Hearing aids might slow the onset of dementia*

* https://www.telegraph.co.uk/science/2018/10/11/hearing-aids-slow-dementia-75-new-study-finds/

Hearing aid – simplified diagram

Hearing aids – Analogue

- Not sold any more!

- May be expensive, bulky, old...

- Filter response complicated to change on-the-fly

- Mobile phones and new ways of living demand upgrades to functionality

Hearing aids – Digital

- Most use DSPs or PLCs – not economic for small companies
- May not be software upgradable or be able to modify algorithms
- Initial cost for digital hearing aids may be higher
- Latency between microphone inputs to earpiece output can increase with algorithm complexity
- Power consumption may be higher
- Added extras like Bluetooth handsfree or modifying parameters with phone
- All things the project aims to solve!

openMHA – Master Hearing Aid

- Open Source Platform for hearing aid algorithm research
- C++ Software for Linux, Windows, macOS
- Realtime for hearing latency
- Includes multiple hearing aid algorithms
- Support for "Beamforming" with multiple microphones
- Every research group needs a standard base to test & develop their algorithms
- Established: developed since 2006

http://www.openmha.org/publication/2016/10/26/for-the-patients-benefit.html

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PC-based Hardware

- PC or Laptop
- External audio interface
- External hearing aid preamplifier
- Mains power required?
- Lots of processing power!

http://batandcat.com/uploads/3/5/0/4/35048951/aas_2018_openmha_platform_hk.pdf

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SBC-based Hardware

- because of mobile phones....
- SBCs are cheap
- Low power
- May be easy to acquire today, but not next year
- Lots of hardware peripherals
- Linux support... Peripherals require drivers

Choosing SBC

- USB audio has too much overhead, natural plan to use I^{2}S/PCM

- Raspberry Pi only supports two channels of I^{2}S audio input/output

- Home Theatre has introduced eight & sixteen channel PCM modules in some modern SBCs

BeagleBone Black

- Beaglebone Black is a good balance of required features!

- Easy to get hold of, reasonably priced and not too much extra on the board

- Simple path from Development kit to Custom Board

- Open Source Hardware

- Lots of support from American company Texas Instruments!

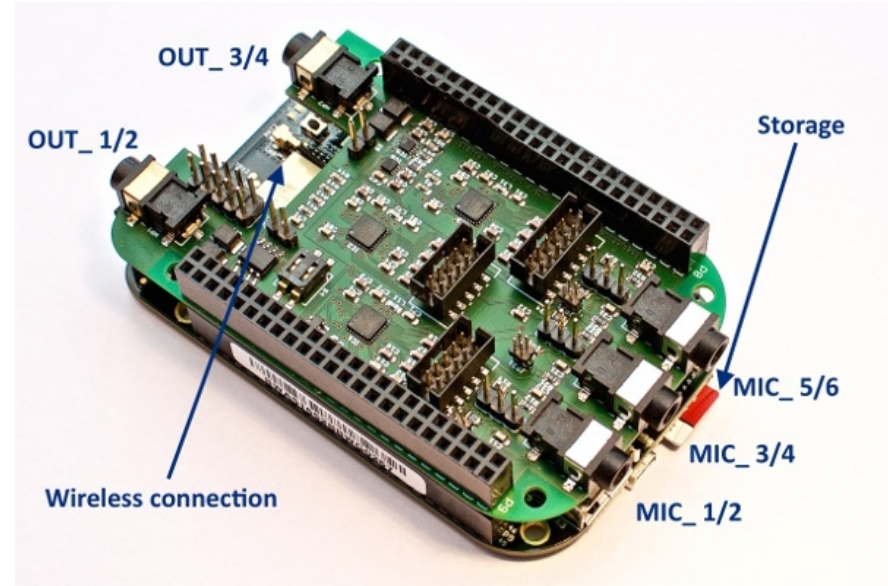- Single-core 1 GHz may be limiting...

...lots of development...
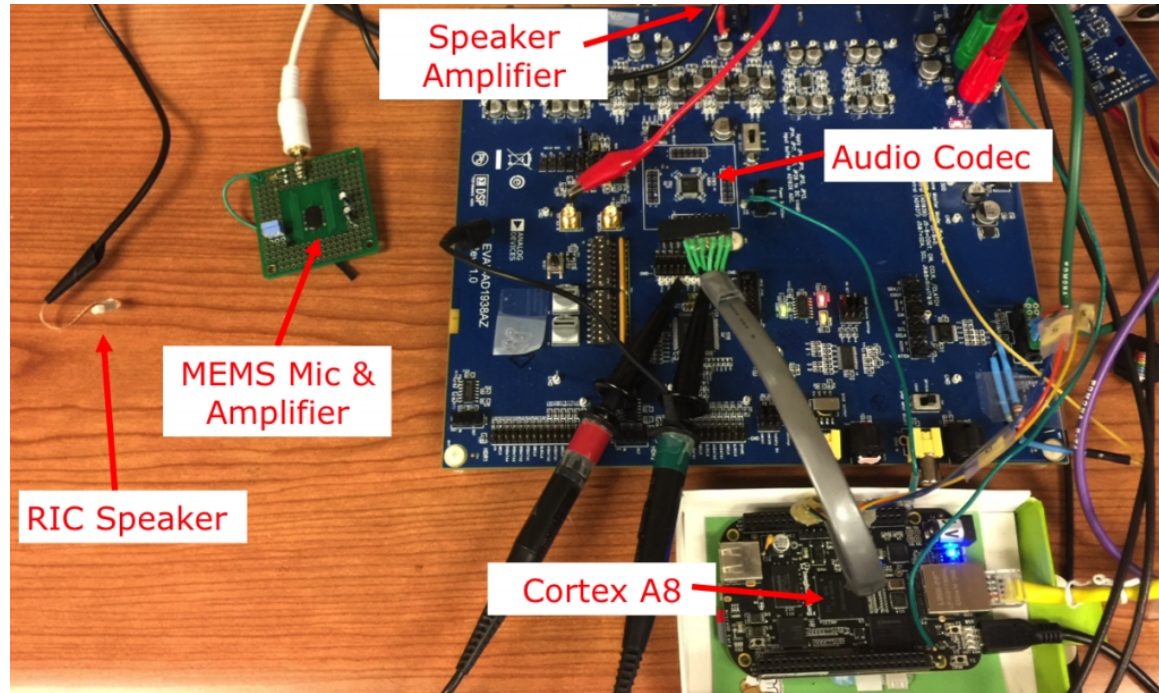
cape4all

- Designed to be used with external hearing aids & preamps
- 3x stereo microphone inputs
- 2x stereo headphone outputs
- External microSD storage
- Bluetooth connection
- Wifi connection
- Battery connections
- Open Source hardware!

OUT_ 3/4
OUT_ 1/2
Storage
MIC_ 5/6
MIC_ 3/4
MIC_ 1/2
Wireless connection

https://opensource.com/article/18/7/open-hearing-aid-platform

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BSP Image

- Added Beaglebone image generation scripts to PDK
- PDK is our tool for making custom Linux distros
- Looked at Beaglebone SD card layout... and copied it!
- Created small u-boot script
- Mainline Linux & u-boot packaged into debs
- Debootstrap a minimal Debian environment
- Just added some basic ALSA/JACKD2 tools for testing
- ... our custom packages came later ...

https://github.com/64studio/pdk
https://github.com/64studio/pdk-mediagen

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Linux driver

- On the board are 3x I^{2}S codecs communicating in TDM mode to the BeagleBone Black

- A sub-500 line glue-logic Linux driver was created

- Describes the clock-path and other hardware descriptions to the kernel

- Result: audio in & out on all channels!

- Tested using standard ALSA & JACK tools

Realtime Performance

- jack_iodelay: simple application reads from audio input to audio output

- Mainline Linux 4.14

  - ~17ms latency at ~70% CPU usage

- TI Linux Kernel 4.14 w/ PREEMPT_RT & threadirqs

  - ~4ms latency at ~21% CPU usage

  - What a result!!!!

Realtime Performance

- TI Linux Kernel has patches waiting to go upstream
- Pre-PREEMPT_RT-patched branch
- "McASP" audio serial port & DMA drivers significantly better for our application
- Vendor configuration may be better suited
- TI applications engineer helped explain default configuration options
- BUT some vendor support is not as good
- (Allwinner...)

Realtime Performance

- Realtime != fast
- Realtime = deadline **must** be met
- Normally deadline is a "life or death" situation...
- If our deadline not met, buffer overflow or underrun
- Bad news! May damage equipment (e.g channel skip on subwoofer)
- But not *that* bad.

Realtime Performance

- Patience is required...

- 1) try *cyclictest* from *rt-tests* to make sure the system really, really is realtime capable :-)

- 2) find IRQ of soundcard DMA (*/proc/interrupts*)

- 3) get the IRQ process ID (*ps | grep irq/??*)

- 4) change soundcard DMA priority to around 95

- 5) change program priority to around 90

- 6) ...profit...!

Mahalia

- Customer does development on Ubuntu & Debian so naturally wanted a Debian-based distro

- Used PDK to:

- ... pull packages from Debian

- ... insert scripts to setup soundcard settings & priority

- ... install openMHA & configuration files

- ... install Kernel & u-boot

- ... other system tweaks

https://github.com/64studio/pdk
https://github.com/64studio/pdk-mediagen

Mahalia

- OpenMHA & JACK server starts on boot ready to process
- Wi-Fi hotspot (with BeagleBone serial number appended)
- Bluetooth Low Energy Peripheral (serial appended)
- Can be flashed to SD card or internal eMMC
- Instructions to build Mahalia distro to be released soon!

https://github.com/mahalia-bone/mahalia-utils

Future

- Supporting electronics getting smaller & cheaper
- Custom board with processor, codecs & amps included
- Beaglebone is only single-core at 1000 MHz
- Allwinner processors are fast & gaining much better mainline support for peripherals... perfect candidate?
- Get it out there and help universities to improve products for hearing loss :-)

Questions?
Comments?
Suggestions?