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Do You Like Coffee with Your Dessert? Java and Raspberry Pi

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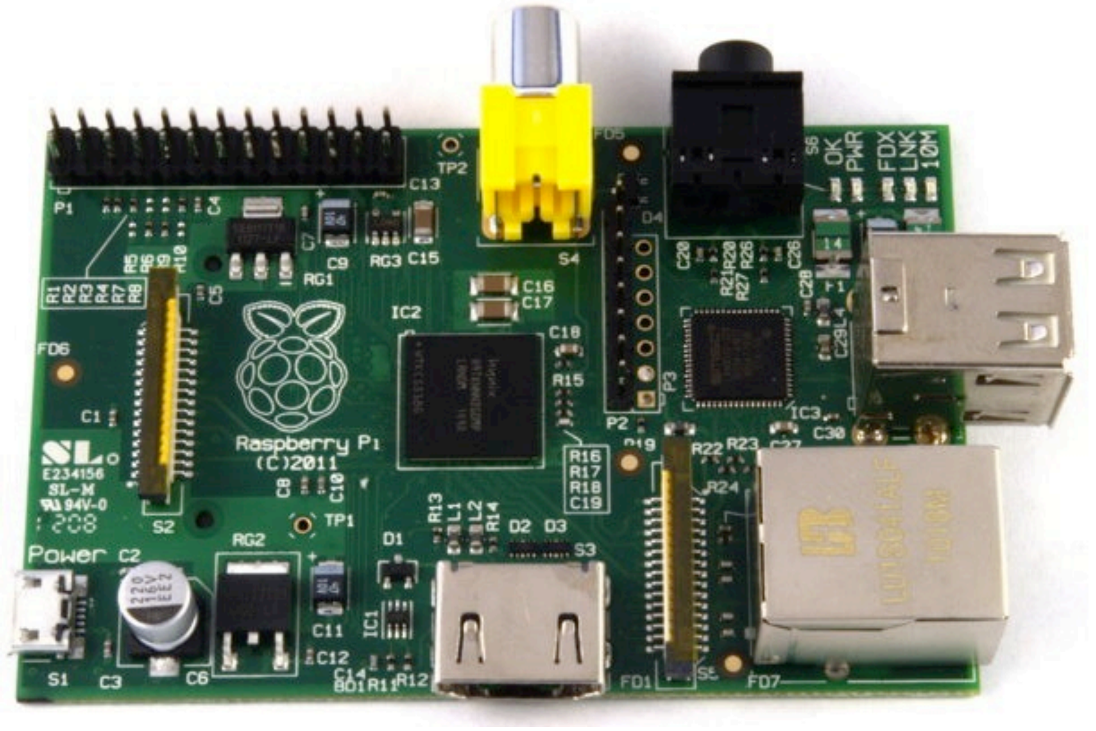
Program Agenda

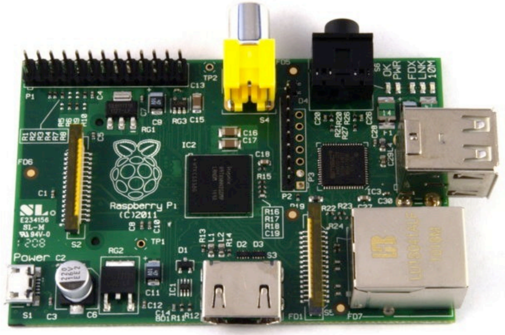
- The Raspberry Pi
- ARM Processors
- Java on ARM and the Raspberry Pi
- Using Java on the Raspberry Pi
- Demos

The Raspberry Pi



Rapberry Pi

History and Goals



- Project started in 2006
  - Goal to devise a computer to inspire children
  - Inspiration from the BBC Micro project from 1981
- Officially launched on Febuary 29th 2012
  - First production run was 10,000 boards
  - Both RS and Farnell's servers were stalled on the day of launch
  - RS reported over 100,000 pre-orders in one day
  - Current production is about 4,000 boards per day

Raspberry Pi
Specification

- CPU: ARM 11 core running at 700MHz
  - Broadcom SoC package
  - Can now be overclocked to 1GHz (without breaking the warranty!)
- Memory: 256Mb
- I/O:
  - HDMI and composite video
  - 2 x USB ports (Model B only)
  - Ethernet (Model B only)
  - Header pins for GPIO, UART, SPI and I2C

ARM Architecture

A Brief (But Interesting) History Lesson

- Acorn BBC Micro (6502 based)
  – Not powerful enough for Acorn's plans for a business computer
- Berkeley RISC Project
  – UNIX kernel only used 30% of instruction set of Motorola 68000
  – More registers, less instructions (Register windows)
  – One chip architecture to come from this was… SPARC
- Acorn RISC Machine (ARM)
  – 32-bit data, 26-bit address space, 27 registers
  – First machine was Acorn Archimedes
- Spin off from Acorn, Advanced RISC Machines

ARM Features

- 32-bit RISC Architecture
  - ARM accounts for 75% of embedded 32-bit CPUs today
  - 8 billion chips sold last year, more than 30 billion in total
    - zero manufactured by ARM
- Abstract architecture and microprocessor core designs
  - Raspberry Pi uses an ARM11 with the ARMv6 instruction set
- Low power consumption
  - Good for mobile devices
  - Raspberry Pi can be powered from 700mA 5V only PSU
  - Raspberry Pi does not require heatsink or fan

Current ARM Technology

- ARMv6
  - ARM 11, ARM Cortex-M
- ARMv7
  - ARM Cortex-A, ARM Cortex-M, ARM Cortex-R
- ARMv8 (Announced)
  - Will support 64-bit data and addressing
  - 32-bit instructions, 30 registers

Java On The ARM and Raspberry Pi

Java Specifics For ARM

Floating Point Operations

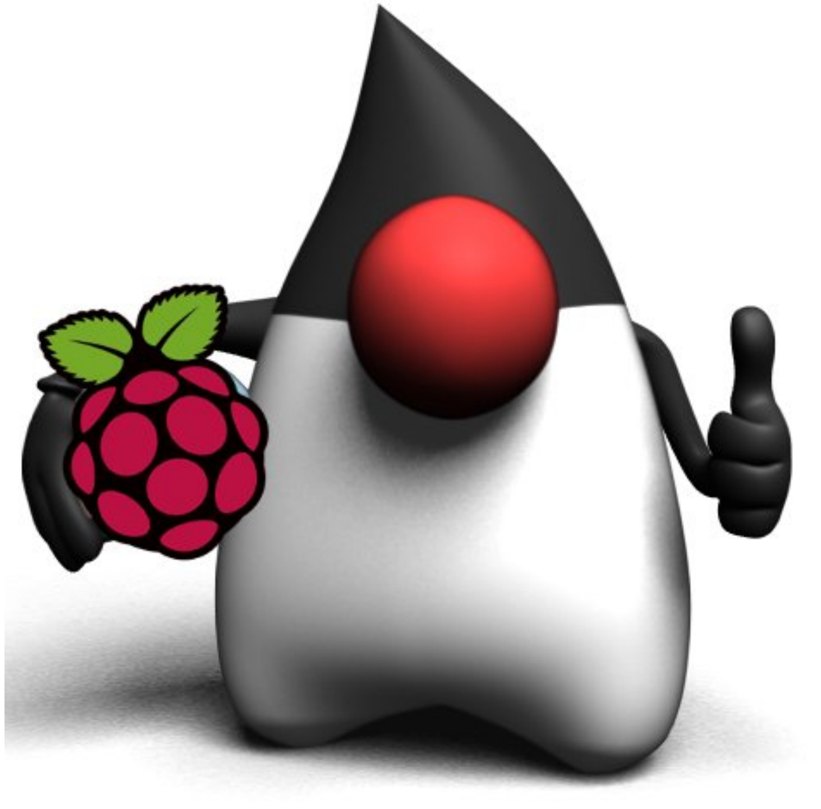
- Despite being an ARMv6 processor it does include an FPU
  - FPU only became standard as of ARMv7
- FPU (Hard Float, or HF) is much faster than a software library
- Linux distros and Oracle JVM for ARM assume no HF on ARMv6
  - Need special build of both
  - Raspbian distro build now available
  - Oracle JVM in the works, release date TBD

Beyond RISC

Performance Improvements

- DSP Enhancements
- Jazelle
- Thumb / Thumb2 / ThumbEE
- Floating Point (VFP)
- NEON
- Security Enhancements (TrustZone)

Using Java on the Raspberry Pi



Using Java on the Raspberry Pi

- Sound
- Vison
- Serial (TTL UART)
- USB
- GPIO

Making A Noise With Java

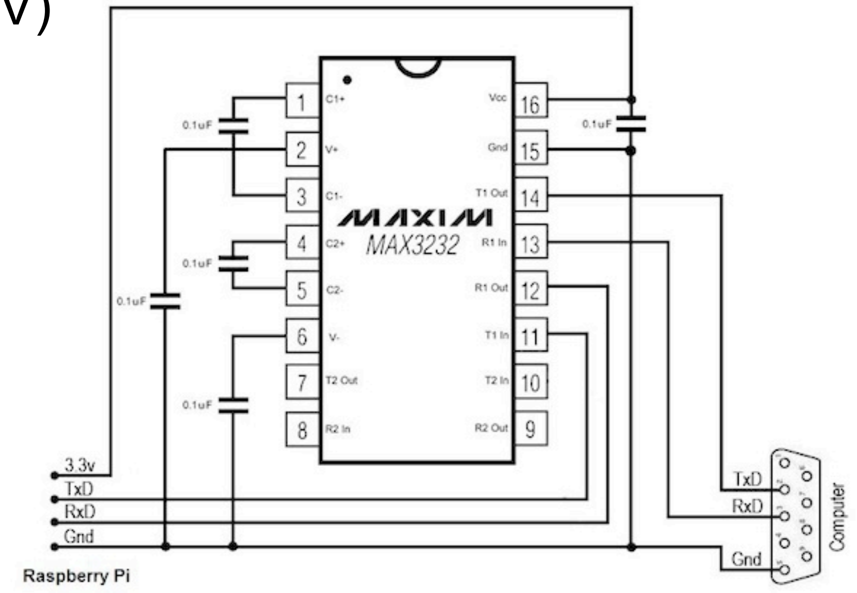
- Sound drivers now included in new distros
- Java Sound API
  - Remember to add audio to user's groups
  - Some bits work, others not so much
    - Playing (the right format) WAV file works
    - Using MIDI hangs trying to open a synthesizer
- FreeTTS text-to-speech
  - Should work once sound works properly

JavaFX on the Raspberry Pi

- Currently internal builds only
  - Will be released as technology preview soon
- Work involves optimal implementation of Prism graphics engine
- Configure with **`-Djavafx.platform`**
  - **`x11`** (X11, software rendering)
  - **`directfb`** (Not currently working due to need for 16/32 bit DirectFB
  - **`fb`** (Framebuffer with soft rendering)
  - **`eglfb`** (OpenGL rendering to framebuffer)

Using The Serial Port

- UART provides TTL level signals (3.3V)
- RS-232 uses 12V signals
- Use MAX3232 chip to convert
- Use this for access to serial console



USB Peripherals

Universal Serial Bus (But not as simple as serial)

- Easy devices are ones that appear as simple serial devices
  - `/dev/ttyUSB0`
- More complex devices need native code and libusb
  - `apt-get install libusb-1.0-0-dev`

Java and Serial Port/USB Serial Device

JavaComm API

- Install RXTX package
  - `apt-get install librxtx-java`
- How to solve the **`/dev/ttyS*`** only problem
  - `System.setProperty(“gnu.io.rxtx.SerialPorts”, “/dev/ttyUSB0”);`

The OWI Robot Arm

Cheap and cheerful

- Comes with USB interface
  - Windows only driver
  - Recognized as USB device by Linux
- Use native code for control and JNI
- Simple control protocol
  - 3 bytes (1 = arm, 2 = base, 3 = light)
  - Combining movements requires some bit twiddling
  - Can only stop all motors, not individually

Robot Arm Control

JNI Code

- Native C functions
  - Initialisation of arm using libusb and appropriate device
  - Separate function for each control element
  - Compile to shared library
- Use JNI to generate header file appropriate to Java code usage
  - e.g. **`native int arm_usb_init()`**
  - Implement appropriate stub to call library
  - Compile to shared library
  - JNI is not easy to reuse

Robot Arm Control

Java Code

- Java code is simple
  – Calibration required to determine time for specific movement

```
arm_gripper_move(OPEN);
uSleep(500);
arm_gripper_move(STOP);
uSleep(500);
arm_gripper_move(CLOSE);
uSleep(500);
arm_gripper_move(STOP);
```

Gamepad Controller

Manual dexterity

- Linux supports most of these out of the box
- Drivers create entries in `/dev/input`
- Java API through Jinput
  - Mature technology (not been touched since 2003)
  - Recompile code on RasPi
  - Needed to tweak build script for incomplete classpath
    - EVIOCGUSAGE disappeared
    - Rename `libjinput-linux.so` to `libjinput-linux64.so`
  - Devices do not have general read/write access
    - Possible (but frustratingly difficult) to use udev.rules to fix this

Gamepad Controller

Code

- Wrote library on top of JInput
  - JInput to generic, needed code to be more specific to gamepad

```
GamePadController gpc = new GamePadController();
gpc.addButtonListener(GamePadController.BUTTON_1, this);
gpc.addJoystickListener(GamePadController.JOYSTICK_LEFT, this);
new Thread(gpc).start();
```

Gamepad Controller

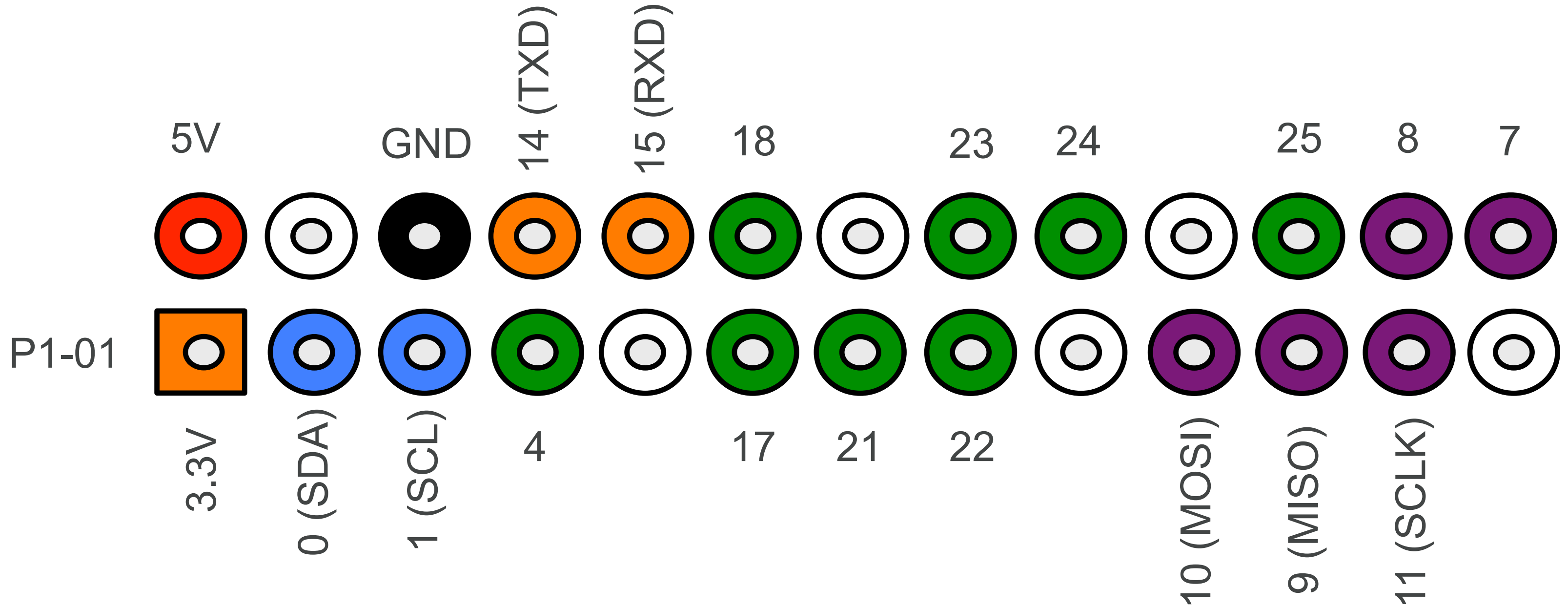
Code

```
public void buttonAction(ButtonEvent be) {
  if (be.getId() == GamePadController.BUTTON_1)
    robotArm.setGripperLight(true);
  ...
}

public void joystickAction(JoystickEvent jse) {
  if (jse.getId() == GamePadController.JOYSTICK_LEFT) {
    if ((position & JoystickEvent.POSITION_LEFT) != 0)
      robotArm.moveElbow(ArmController.UP);
  }
  ...
}
```

Using The GPIO Lines

P1 Connector Layout



P2 Connector: Pin 1 = 3.3V Pin 7,8 = GND

Using the GPIO Lines

Magic Incantations

```
#define BCM2708_PERI_BASE 0x20000000
#define GPIO_BASE (BCM2708_PERI_BASE + 0x200000)
#define BLOCK_SIZE (1024 * 4)
#define PAGE_SIZE (1024 * 4)

/* MMAP */
mem_fd = open("/dev/mem", O_RDWR | O_SYNC);
gpio_mem = malloc(BLOCK_SIZE + (PAGE_SIZE - 1));

gpio_map = (unsigned char *)mmap(
  (caddr_t)gpio_mem, BLOCK_SIZE, PROT_READ | PROT_WRITE,
  MAP_SHARED | MAP_FIXED, mem_fd, GPIO_BASE);

gpio = (volatile unsigned *)gpio_map;
```

Using the GPIO Lines

More Magic Incantations

```
/* Pin input */
*(gpio + (pin / 10)) &= ~(7 << ((pin % 10) * 3));

/* Pin output */
*(gpio + (pin / 10)) &= ~(7 << ((pin % 10) * 3));
*(gpio + (pin / 10)) |= (1 << ((pin % 10) * 3));

/* Pin high */
*(gpio + 7) = 1 << pin;

/* Pin low */
*(gpio + 10) = 1 << pin;
```

Hide The Magic Incantations With JNI

Simple Java Interface

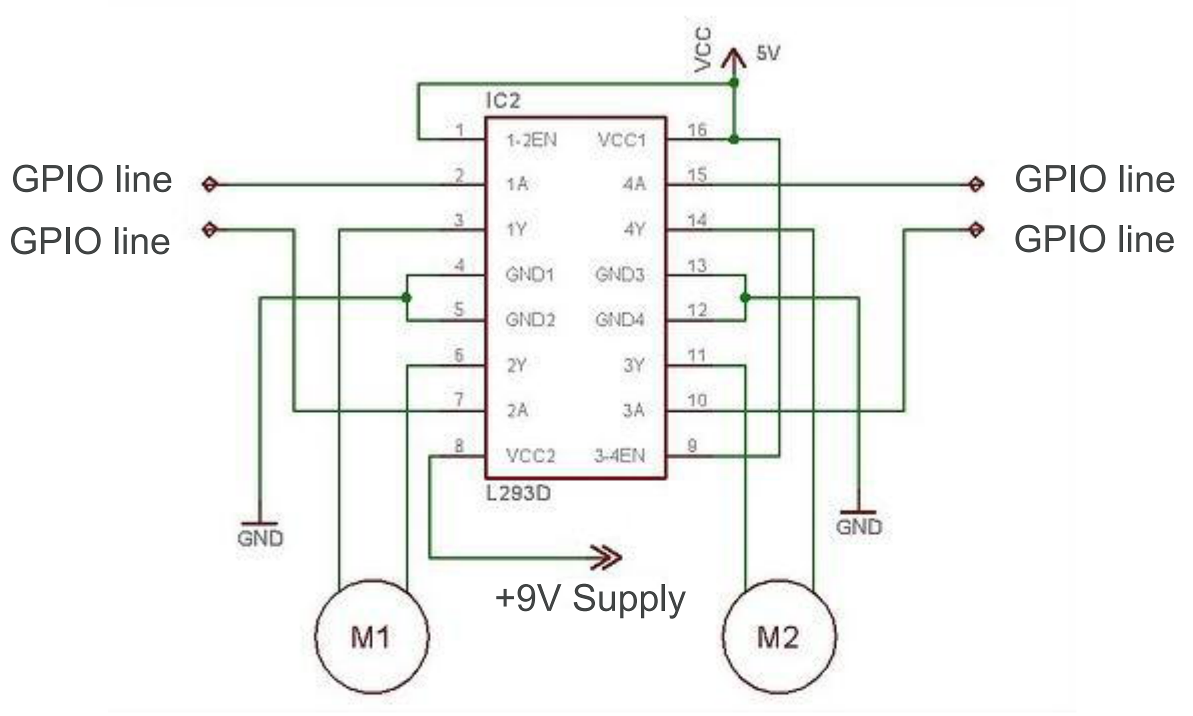
- Access to `/dev/mem` needs root access
  - Could solve this by writing our own device driver

```
gpio_init();
gpio_pin_output(MOTOR_PIN_CLKWISE);
gpio_pin_output(MOTOR_PIN_ACLKWISE);

/* Turn clockwise */
gpio_pin_low(MOTOR_PIN_ACLKWISE);
gpio_pin_high(MOTOR_PIN_CLKWISE);
```

GPIO Example: LEGO Motors

Using L293D Dual H-Bridge



How to Use SPI and I2C

Even more complex peripherals

- Drivers still experimental
  - Check Chris Boot's blog (www.bootc.net)
- Devices for SPI
  - `/dev/spidev-0.0` and `/dev/spidev-0.1`
- Devices for I2C
  - Run `i2c-dev`
  - `/dev/i2c-0`
- Not yet tried these with Java (Screen and JavaFX project next)

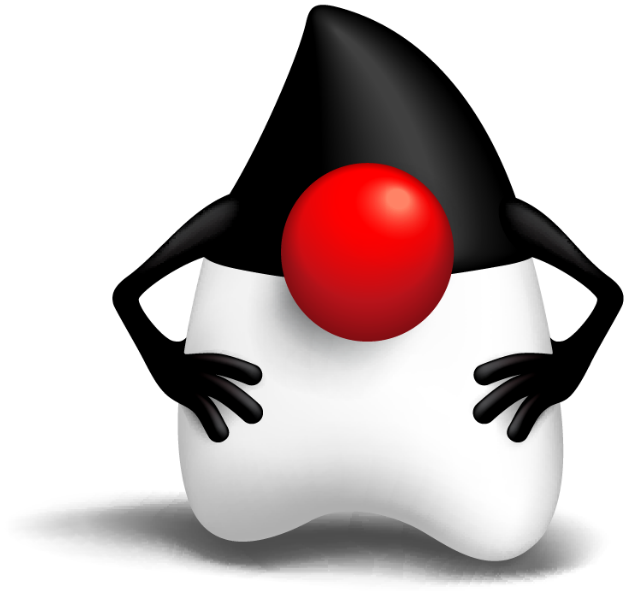
Conclusions

- Raspberry Pi is a very cool (and cheap) computer
  - Great for teaching
  - Great introduction to ARM
- Java works well and will get better
  - Once we have official HF support
- Opportunities are limitless!

Further Information

- java.oracle.com
- www.oracle.com/technetwork/java/embedded
- Raspberry Pi User Guide – Eben Upton, Gareth Halfacree
- www.raspberrypi.org

Demos



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