Raspberry Pi I Architecture

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What is a Raspberry Pi?

Raspberry Pi is a credit-card sized single-board computer designed and manufactured by the Raspberry Pi foundation in the United Kingdom.

Raspberry Pi has an ARMv6 700 MHz single-core processor, a VideoCore IV GPU and 512MB of RAM. it uses an SD card for its operating system and data storage.

The Raspberry Pi officially supports Raspbian, a lightweight linux OS based on Debian.

A Little History of the Raspberry Pi

Back in 2006, while Eben Upton, his colleagues at University of Cambridge, in conjunction with Pete Lomas and David Braben, formed the Raspberry Pi Foundation.

Early prototypes of the Raspberry Pi were based on the 8-bit Atmel ATMega644 in order to reduce cost. Following prototypes utilized an ARM processor similar to what was used in the release version of the Raspberry Pi.

History cont.

In 2012, the team started its first production run consisted of 10,000 Raspberry Pi unites manufactured by foundries in China and Taiwan.

Unfortunately, there was a manufacturing issue where the ethernet jack on the Raspberry Pi. This incident caused some minor shipping delays

It took the team six years of hardware development to create the Raspberry Pi makers and electronics enthusiasts adore today

Model B

In April 2012, the original Raspberry Pi, also known as the model B, was launched.

It offered an ARMv6 700 MHz single-core processor, a VideoCore IV GPU and 512MB of RAM, all packed in a credit card size board.

The model B supported 26-pin GPIO and a SD card slot for loading the operating system. Priced at $35 per unit.
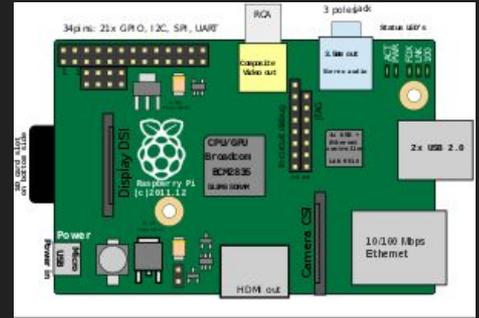
Model A

In February 2013, the Raspberry Pi model A was launched, It packed the same ARM single-core processor and the GPU as model B with half of the RAM capacity at 256MB.

Priced at $25 per unit, the model A could be regarded as the cheaper and less powerful version of model B.
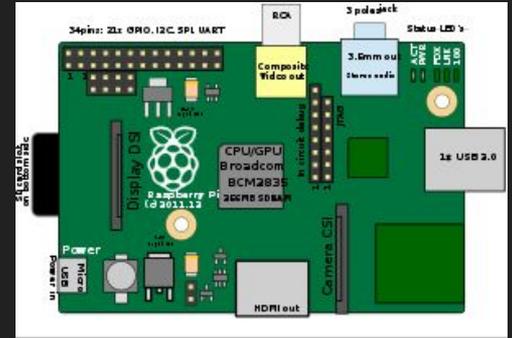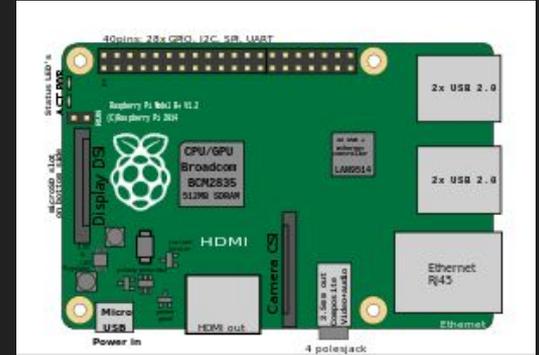
Model B+

In July 2014, the Raspberry Pi model B+ was launched, It was a worthy successor to the original Raspberry Pi.

Packing the same processing unit as its predecessor. The model B+ received two more USB ports, an updated 40-pin GPIO layout, and a micro-SD card slot for loading the operating system.

Priced at $30 per unit, the model B+ was cheaper and offered more connectivity than model B, Making it an Ideal choice for education.
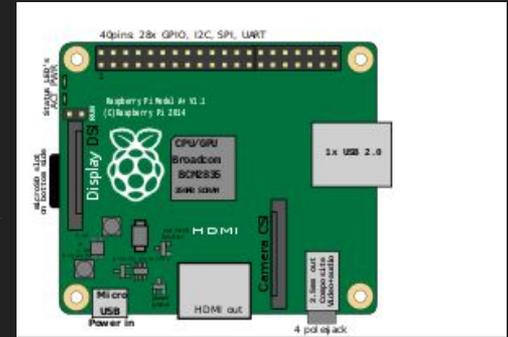
Model A+

In November 2014, the Raspberry Pi model A+ was launched, It offered improved specifications over the model A.

Packing the same processor as its predecessor, the model A+ upgraded RAM capacity from 256MB to 512MB. Smaller footprint, 40-pin GPIO, and micro-SD card.

Priced at $20 per unit, the model A+ was the smallest and cheapest single-board computer at that time.

Model Variants

Raspberry Pi:	Model A	Model B	Model B+	Model A+
Price:	$24.99	$39.99	$29.99	$19.99
Release Date	February, 2013	April. 2012	July, 2014	November, 2014
Chip:	Broadcom BCM2835			
Processor:	ARMv6 single core			
Processor Speed:	700 MHz			
Voltage and Power Draw:	600mA @ 5V			
GPU:	Dual Core VideoCore IV Multimedia Co-Processor			
Size:	85x56mm			65x56mm
Memory:	256 MB SDRAM	512 MB SDRAM		
Storage:	SD Card	SD Card	Micro SD Card	
GPIO:	26	26	40	
USB 2.0:	1	2	4	1
Ethernet:	None	10/100mb Ethernet RJ45 Jack		None
Audio:	Multi-Channel HD Audio over HDMI, Analog Stereo from 3.5mm Headphone Jack			

Raspberry Pi I Specifications Overview

- Model B
  - Processor: Broadcom BCM2835
  - CPU: ARM 1176JZFS (ARM 11 w/ v6 core, floating pt @ 700MHz)
  - GPU: Videocore IV GPU
  - RAM: 512 MB
  - USB: 2 USB 2.0
  - Network: Ethernet
  - Video out: HDMI
  - Audio out: 3.5 mm jack
  - SD Card Storage (Up to 32GB)
  - Micro USB power
  - Display Serial Interface Port (DSI)
 - Camera Serial Interface Port (CSI)
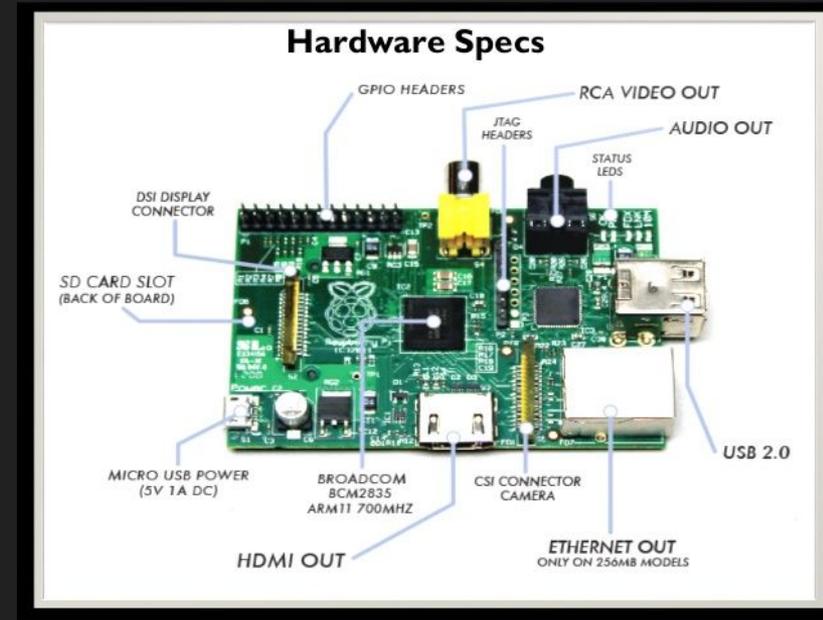
CPU Overview

- ARM11J6HZF-S
- ARMv6 Architecture
- 700 MHz Clock
- Single Core
- 32-bit RISC
- Branch Prediction with Return Stack
- 8 Pipeline Stages
- 33 general purpose 32 bit registers
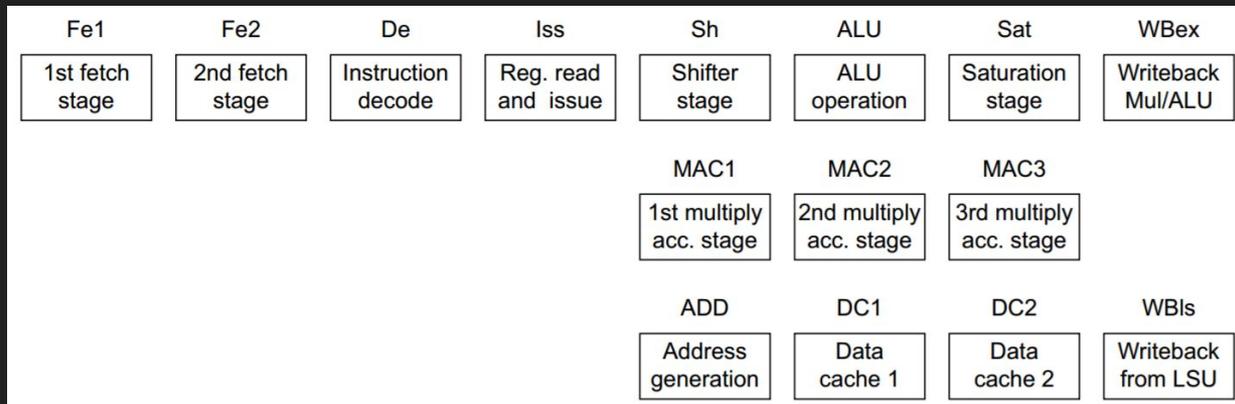- 7 dedicated 32 bit registers

CPU Main Components

- Integer Core
- Load Store Unit (LSU)
- Prefetch Unit
- Memory System
- AMBA AXI Interface
- Coprocessor Interface
- Debug
- Instruction Cycle and Interlocks
- Vector Floating-Point (VFP)
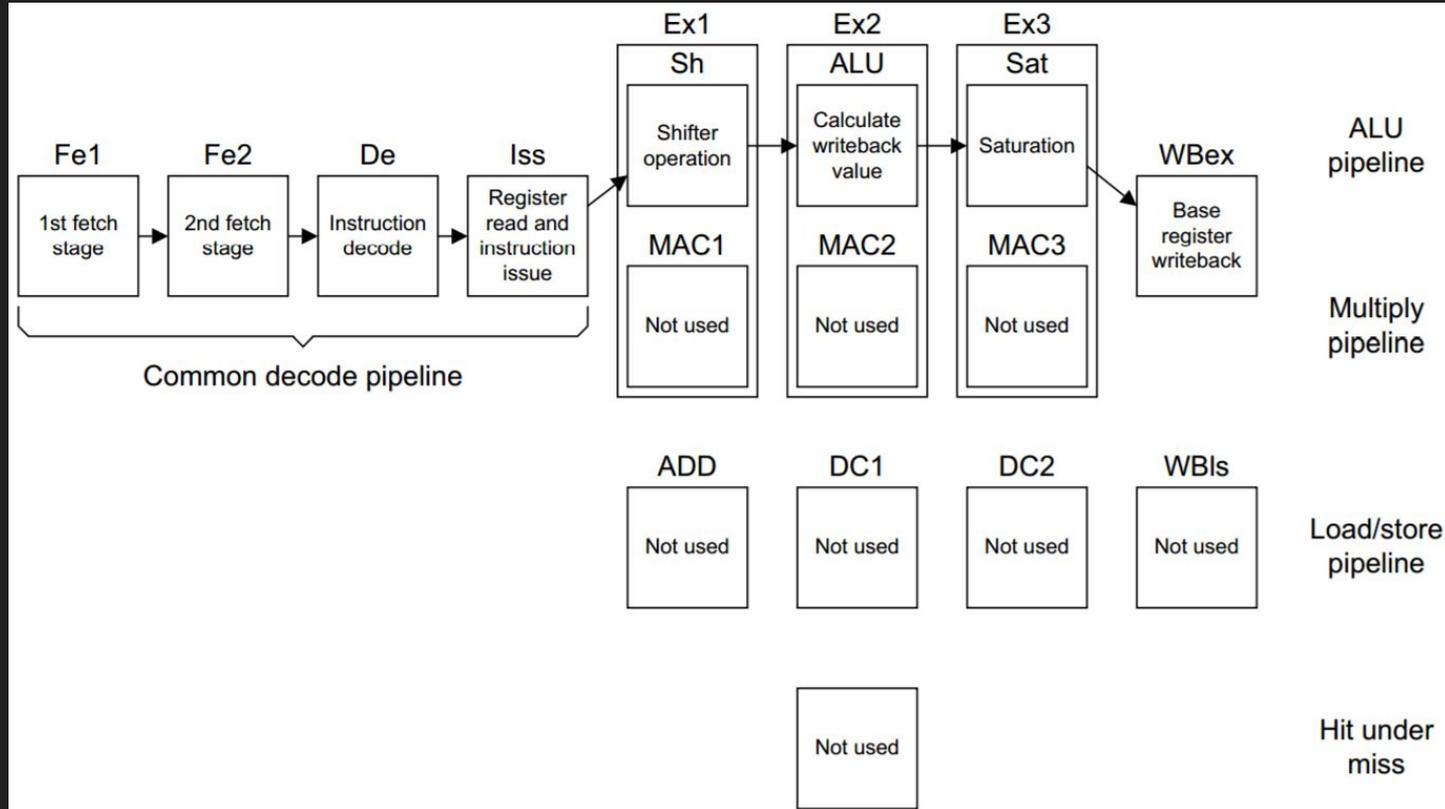- System Control
- Interrupt Handling
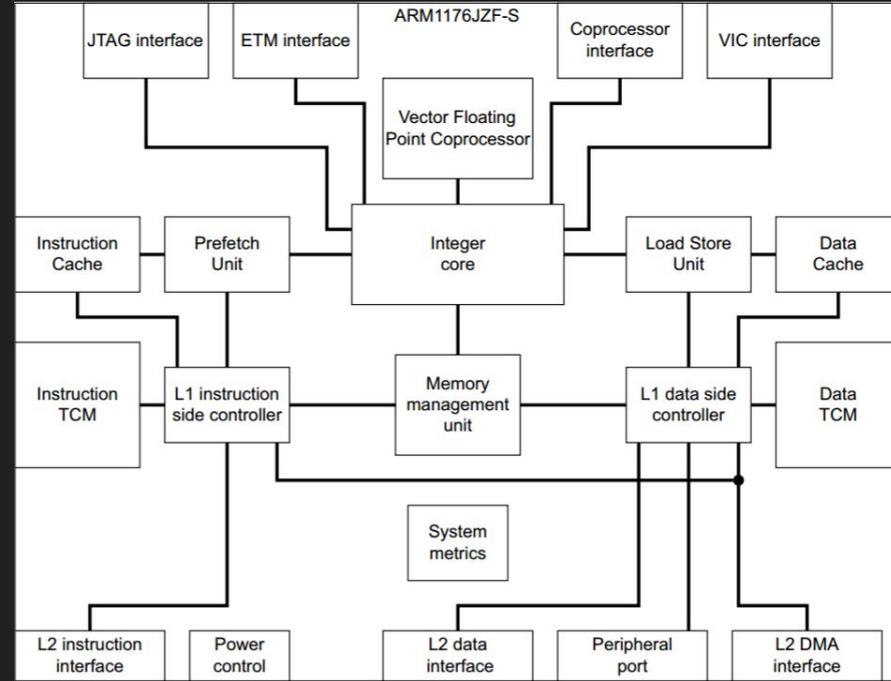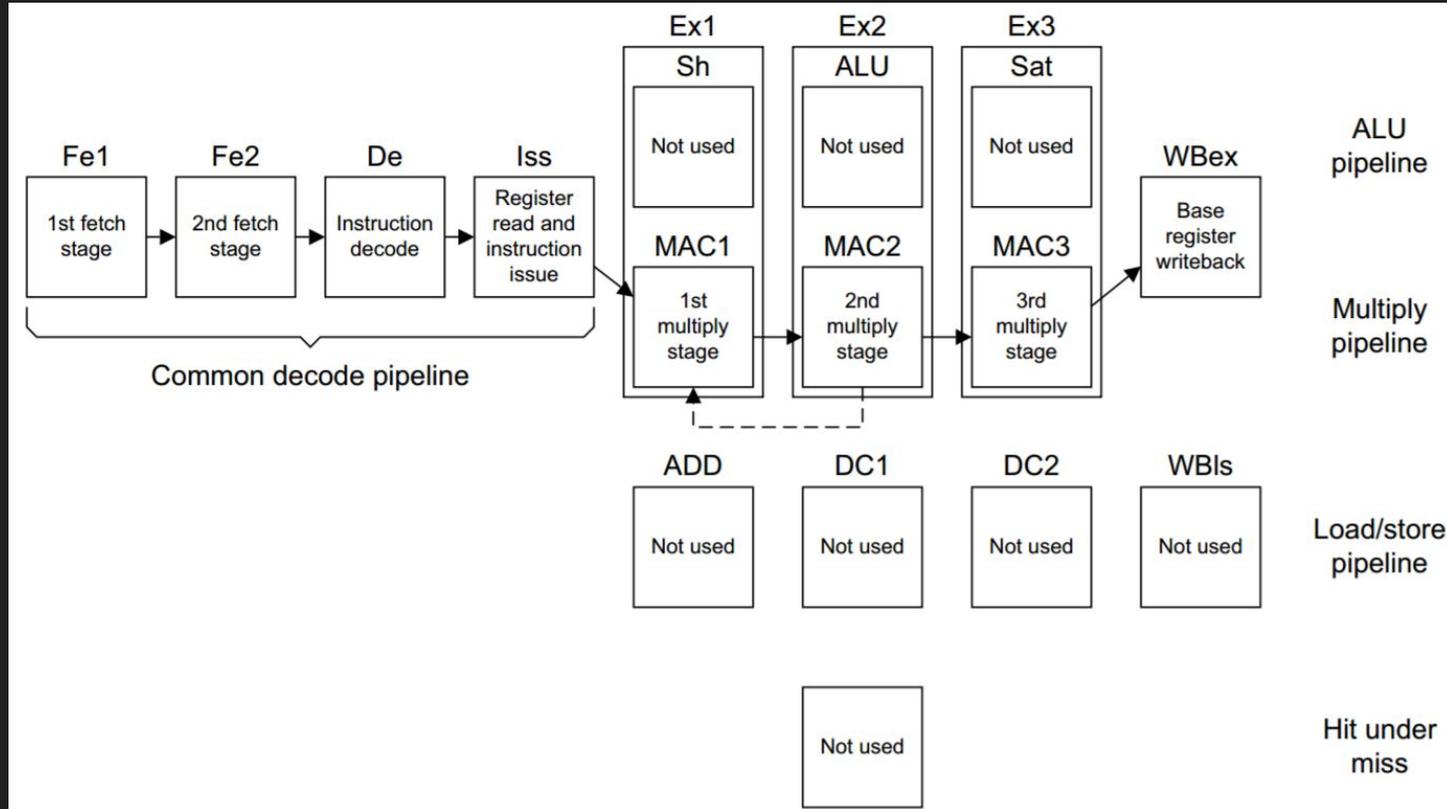
Pipelining Overview

- Two Fetch stages

- One Decode Stage

- One Issue Stage

- Four integer execution pipeline stages

| Fe1	Fe2	De	Iss	Sh	ALU	Sat	WBex
1st fetch stage	2nd fetch stage	Instruction decode	Reg. read and issue	Shifter stage	ALU operation	Saturation stage	Writeback Mul/ALU
				MAC1	MAC2	MAC3	
				1st multiply acc. stage	2nd multiply acc. stage	3rd multiply acc. stage	
				ADD	DC1	DC2	WBls
				Address generation	Data cache 1	Data cache 2	Writeback from LSU

Pipeline Flow for ALU Operations

Pipeline Flow for Multiplication Operations

Pipeline Flow for Load/Store Operations
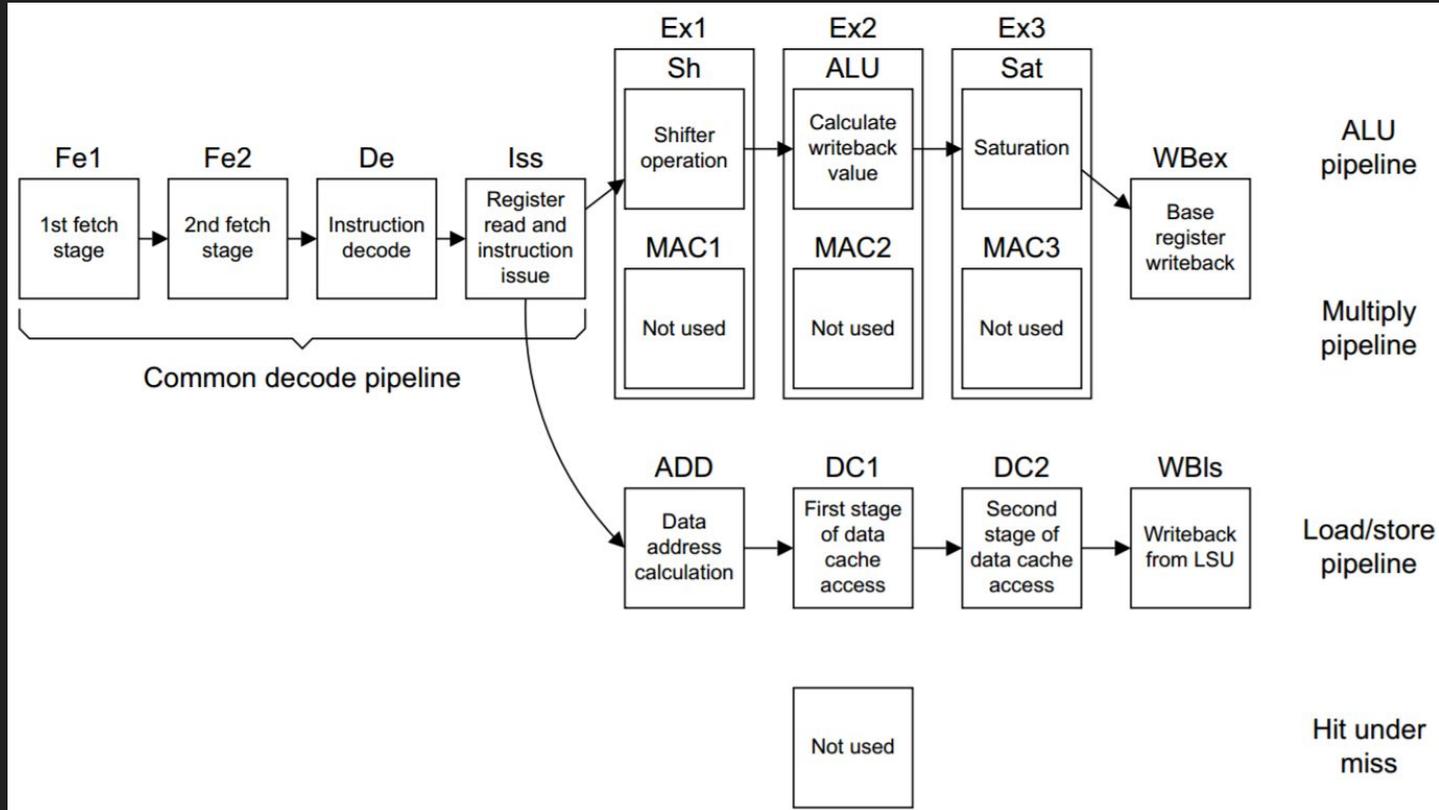
Cache Organization - One Level Memory System

- Four-way set associative with size configurable from 4 to 64KB
- Cache is Harvard implementation
- Cache replacement policies are Pseudo-Random or Round Robin, which is controlled by the RR bit in CP15 register c1
- MicroTLB determines if cache lines are write-back or write-through
- Contain both secure and non-secure data in cache lines
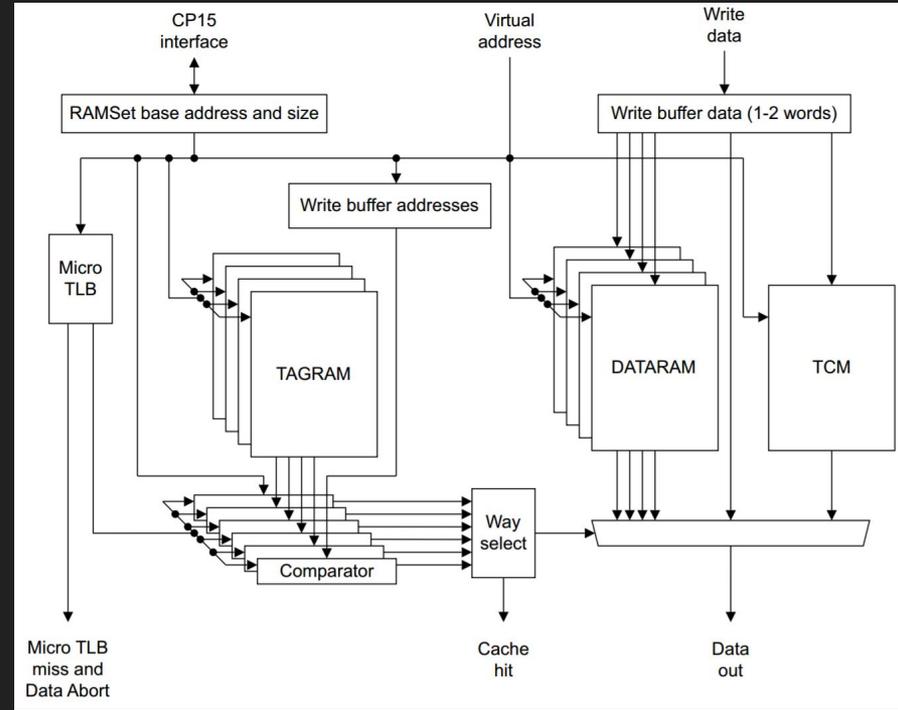
Program Flow Prediction

- Processor handles branches first time execution when no history is available for dynamic prediction for the prefetch unit
- Integer Core(IC)
  - Uses static branch prediction and return stack
- Prefetch Unit(PU)
  - Uses dynamic branch prediction
- When a branch is resolved, the PU receives information from the IC and either allocates space in the Branch Target Address Cache (BTAC) or updates an entry.
- Branches are resolved at or before the third execution stage

Dynamic Branch Prediction

- Uses a Branch Target Address Cache (BTAC) as the first line of branch prediction that hold virtual target addresses.
- Prediction history of a branch is stored as a two-bit value in the BTAC
- BTAC is a 128-entry direct-mapped cache structure
- Two bit values represent the following four states:
  - Strong predict branch taken
  - Weak predict branch taken
  - Strong predict branch not taken
  - Weak predict branch not taken
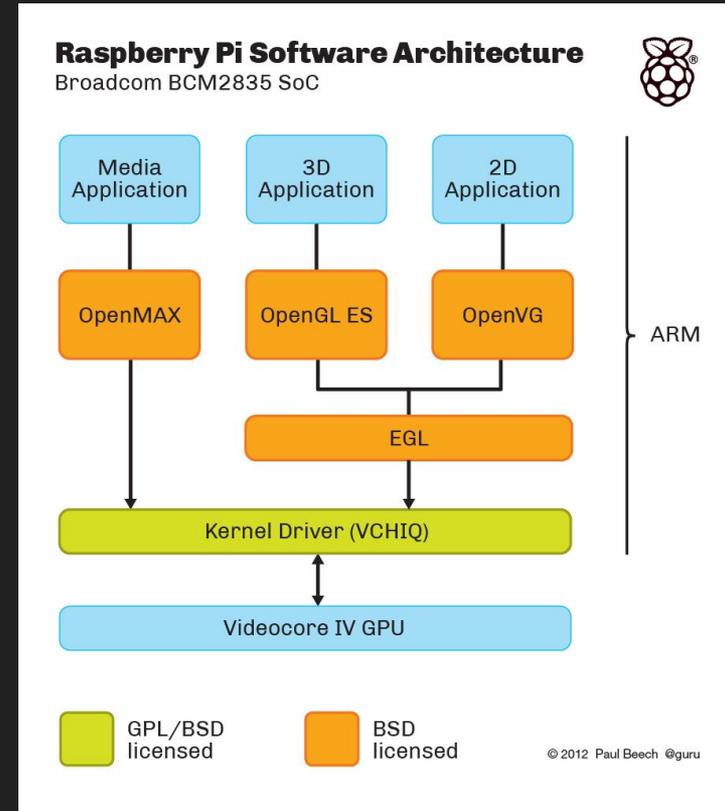
Static Branch Prediction

- Second level of branch prediction in processor is static branch prediction, which is based on the characteristics of the branch instruction.
- Uses no history information
- ARM1176JZF-S predicts all forward conditional branches not taken and all backward branches taken.
- Added to mitigate the trouble experienced by the miss when first encountering the branch by the predictor

Branch Folding

- Technique where the Branch instruction is removed from the pipeline and is stored in a buffer, which is executed on all dynamic predicted branches
- Can improve the Branch CPI to under 1
- Technique not done on the following:
  - BL and BLX instructions, to avoid losing the link. (Branch with link/exchange instruction set)
  - Predicted branches that lead directly to another branch
  - Branches that are have been cancelled when fetched

GPU Overview

- Broadcom Videocore IV GPU
  - Tile-based renderer (TBR) that use up to four cores
  - 40 nm technology
  - Integrated graphics card so shared memory
- Capable of Blu-Ray quality of 1080p with H.264 at 40Mb/s
- Graphics performance is similar to the Xbox 1
- 24 GFLOPS of general purpose computational power
- Has texture filtering and DMA infrastructure
- OpenGL ES 1.1, OpenGL ES 2.0, hardware accelerated OpenVG 1.1, Open EGL, and OpenMAX

Raspberry Pi Software Architecture
Broadcom BCM2835 SoC

Media Application — OpenMAX
3D Application — OpenGL ES
2D Application — OpenVG
EGL
Kernel Driver (VCHIQ)
Videocore IV GPU
ARM

GPL/BSD licensed
BSD licensed

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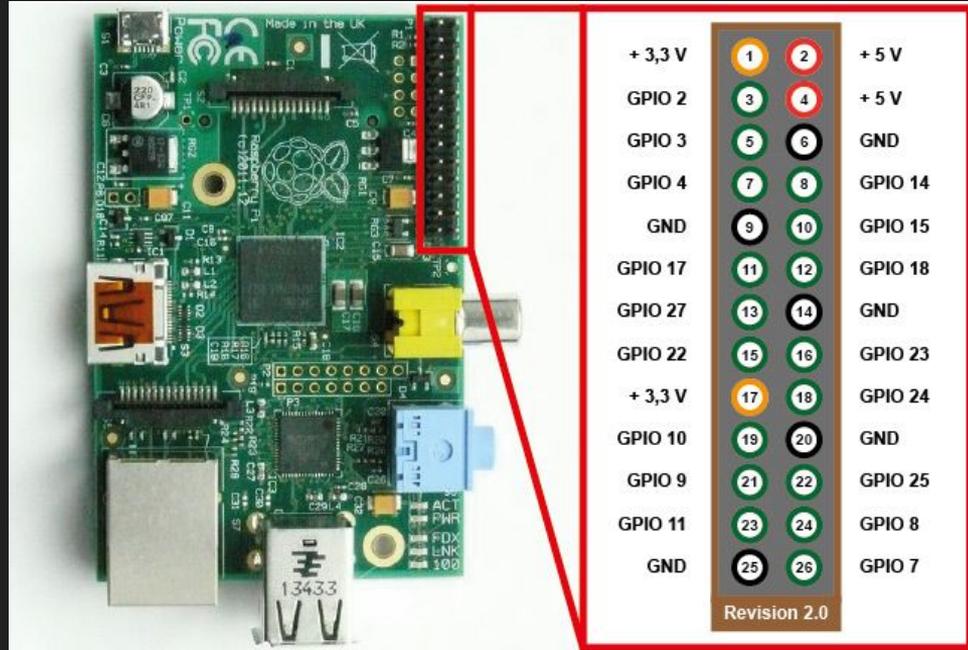# Model B I/O

2 x USB 2.0

1 x HDMI 1.2

1 x Ethernet Jack

26-pin GPIO

1 x micro USB for charging

1 x audio line-in

1 x audio line-out

Projects and Applications

Retro Gameboy with Raspberry Pi. Creator Warner Skoch started with the shell of an original Gameboy.

He managed to fit a model B and, a color LCD screen, and battery inside the chassis. Since the Raspberry Pi was a Linux computer, an emulator was installed.

Projects and Applications Cont.

Project magic mirror. Creator Michael Teeuw placed a LCD screen behind a transparent mirror and incorporated a Raspberry Pi for showing personalized messages, a clock, and even the upcoming weather.

When the display was off, the project worked as a stand mirror. Triggered by some keywords, the display would wake up and show useful information on the screen.

Sources/References

- ARM 1176JZF-S Technical Reference Manual:
  http://infocenter.arm.com/help/topic/com.arm.doc.ddi0301h/ddi0301h_arm1176jzfs_r0p7_trm.pdf
  http://infocenter.arm.com/help/index.jsp?topic=/com.arm.doc.ddi0301h/index.html
- Raspberry Pi Specs sheet:
  http://www.raspberry-projects.com/pi/pi-hardware/raspberry-pi-model-b/hardware-general-specifications
- GPU: https://www.notebookcheck.net/Broadcom-VideoCore-IV.116484.0.html
  http://elinux.org/Raspberry_Pi_VideoCore_APIs
- History and models: https://en.wikipedia.org/wiki/Raspberry_Pi

Questions?