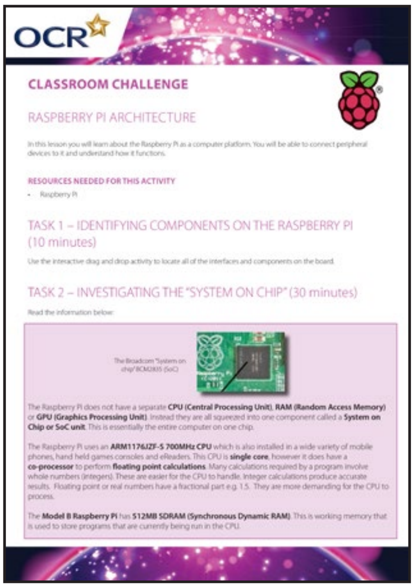
CLASSROOM CHALLENGE: INSTRUCTIONS AND ANSWERS FOR TEACHERS

RASPBERRY PI ARCHITECTURE

These instructions should accompany the OCR resource 'Raspberry Pi Architecture'.

This activity allows learners to investigate the architecture of the Raspberry Pi computer. The information is based on the second version of the model B (512MB RAM). It encourages them to think of computer system design in terms of the practical considerations whilst appreciating the fundamentals of computer components and peripheral devices.


CLASSROOM CHALLENGE

RASPBERRY PI ARCHITECTURE

In this lesson you will learn about the Raspberry Pi as a computer platform. You will be able to connect peripheral devices to it and understand how it functions.

RESOURCES NEEDED FOR THIS ACTIVITY

- Raspberry Pi

TASK 1 – IDENTIFYING COMPONENTS ON THE RASPBERRY PI (10 minutes)

Use the interactive drag and drop activity to locate all of the interfaces and components on the board.

TASK 2 – INVESTIGATING THE "SYSTEM ON CHIP" (30 minutes)

Read the information below:

The Broadcom "System on chip" BCM2835 (SoC)

The Raspberry Pi does not have a separate **CPU (Central Processing Unit)**, **RAM (Random Access Memory)** or **GPU (Graphics Processing Unit)**. Instead they are all squeezed into one component called a **System on Chip or SoC unit**. This is essentially the entire computer on one chip.

The Raspberry Pi uses an **ARM1176JZF-S 700MHz CPU** which is also installed in a wide variety of mobile phones, hand held games consoles and eReaders. This CPU is **single core**, however it does have a **co-processor** to perform **floating point calculations**. Many calculations required by a program involve whole numbers (integers). These are easier for the CPU to handle. Integer calculations produce accurate results. Floating point or real numbers have a fractional part e.g. 1.5. They are more demanding for the CPU to process.

The **Model B Raspberry Pi** has **512MB SDRAM (Synchronous Dynamic RAM)**. This is working memory that is used to store programs that are currently being run in the CPU.

Expected approximate duration:

Task 1 - 10 minutes

Task 2 - 30 minutes

Task 3 - 30 minutes

Useful teacher resources and reference material:

http://downloads.raspberrypi.org/Raspberry_Pi_Education_Manual.pdf
http://www.raspberrypi.org/wp-content/uploads/2012/12/quick-start-guide-v1.1.pdf
http://www.raspberrypi.org/phpBB3/viewforum.php?f=26

TASK 1 – IDENTIFYING COMPONENTS OF THE RASPBERRY PI (drag and drop activity)

Learners should be provided with a Raspberry Pi to refer to. This is a simple orientation exercise to identify physical components.

TASK 2 – INVESTIGATING THE "SYSTEM ON CHIP"

This activity allows learners to explore the technical architecture of the Raspberry Pi computer Broadcom "System on Chip". It is assumed that learners will already have investigated the architecture of a typical PC and a block diagram showing a Von Neumann computer layout. They should understand the purpose of registers, cache, RAM and the CPU. They will probably be familiar with the concept of PCs having a multi-core CPU so it may surprise them that the Raspberry Pi's ARM processor is single core. However, the addition of a floating point co-processor allows more complex calculations to be undertaken. This activity can also reinforce understanding of the Fetch Execute Cycle since the entire process is undertaken within the SoC. They should be able to understand technical data and be able to evaluate it. Although they will be aware that the computing power of the Raspberry Pi is more limited than a desktop PC, they should view it compared to small devices such as mobile phones, handheld games consoles and eReaders since a number of these use the same processor.

The SoC also houses the GPU which permits the Raspberry Pi to handle accelerated graphics.

MODEL ANSWERS TO QUESTIONS

1. The Raspberry Pi has a single core CPU that operates at 700MHz by default.
2. The ARM1176 processor has 32KB of level 1 cache and 128KB of level 2 cache memory. This stores recently used instructions very close to the CPU so that they can be quickly accessed if needed again rather than fetching them from RAM. Programs containing iterations (loops) would be an example of where instructions will be needed multiple times.
3. Using a System on Chip (SoC) rather than separate components saves space. This means that it can be installed in small devices such as a mobile phone. The Broadcom BCM 2835 SoC was installed in the Apple iPhone 3 and a number of mobile phones manufactured by Nokia and HTC. The components that make up the SoC will have been tested thoroughly so that they work together effectively. Another advantage is that system design is simplified as designers only need to install one component that is effectively "the computer".
4. The first instruction in the program is fetched from RAM and stored in the current instruction register in the CPU. In this program, the instruction will be ADD. The current memory address is stored in the memory address register. Data is read from RAM that will consist of the operands – the numbers to be added together. This is stored in the memory data read register. The lines in the program that are being executed are also copied into cache memory so that they are ready to be executed again rather than fetching them from memory. The numbers are added in the Arithmetic Logic Unit and the result loaded into the accumulator register.

TASK 3 – INPUT AND OUTPUT

Learners focus on components other than the computer in this activity. The Raspberry Pi could form a suitable base for the development of a mini - games console and this theme is developed within this task. Learners should be encouraged to think about practical peripherals whilst permitting them to think imaginatively and to design creatively.

They will appreciate some of the practical issues relating to computer system design such as lack of drivers for the installed operating system, attempting to power too many peripherals from the Raspberry Pi and using the correct interface. This is why they need to use a powered hub. A useful guide to currently verified peripherals for use with the Raspberry Pi with standard Debian Raspbian Wheezy operating system can be found at: http://elinux.org/RPi_VerifiedPeripherals

Current support for the CSI (Camera Serial Interface) and DSI (Display Serial Interface) is limited at the time of writing. It should be noted that the JTAG header is used for debugging of the processor and is not applicable for the connection of peripherals.

The GPIO (General Purpose Input Output) connector allows for a variety of external devices to be connected. This is discussed in another Classroom Challenge. However, it is strongly recommended that connection is made using an interface board to protect the Raspberry Pi's circuits and permit simple connection of a variety of different sensors and actuators. The Piface developed at the University of Manchester is an example product - http://pi.cs.man.ac.uk/interface.htm.

MODEL ANSWERS TO QUESTIONS

5. Example response:

Peripheral name	Input or output	Connection type	Purpose (why it is needed)	Example product
Mouse	Input	USB	So that the user can interact with the system and navigate using the GUI.	
Keyboard	Input	USB	So that the user can enter text to interact with programs and can type commands into the terminal.	*Suitable example products will be given.*
Speakers	Output	3.5mm stereo	This will allow sound to be heard.	
Monitor	Output	HDMI	The monitor will display graphics on the screen.	

6. Drivers are programs that allow peripheral hardware to communicate with the Raspberry Pi's operating system. The hardware device will not function without a driver.

7. One reason why a peripheral may not work is that an appropriate driver has not been installed. The connection between the Raspberry Pi and the peripheral may be faulty. The Raspberry Pi only supports two USB connections so needs a powered USB hub to be installed if more devices are needed. If an unpowered hub is used, devices connected to it may not work. The device itself may be faulty. In this case, a replacement device could be tested to see if this fixes the problem.

8. This is an extension activity to allow students to consider how the required input and output ports could be included into a case design that will also protect the internal hardware components. Whilst not a technical task, this will allow students to exercise their creativity and would be an engaging homework task that they could develop independently. There are many attempts already on the internet, students should aim to give unique features for theirs.