Experiment No. 1

Objectives: Getting information and study of IOT microcontrollers (Arduino and **RaspberryPi)**

PART A: Study on Arduino Board.

1.1 Introduction to Arduino Uno Board

Arduino Uno is a microcontroller board based on the 8-bit ATmega328P microcontroller. Along with ATmega328P, it also contains other components, such as crystal oscillator, serial communication, voltage regulator, etc. to support the microcontroller. Arduino Uno has 14 digital input/output pins (6 of which can be used as PWM outputs), 6 analog input pins, USB connection, power barrel jack, ICSP connector and reset button. It is an open-source platform, means the boards and software are readily available and anyone can modify and optimize the boards for better functionality.

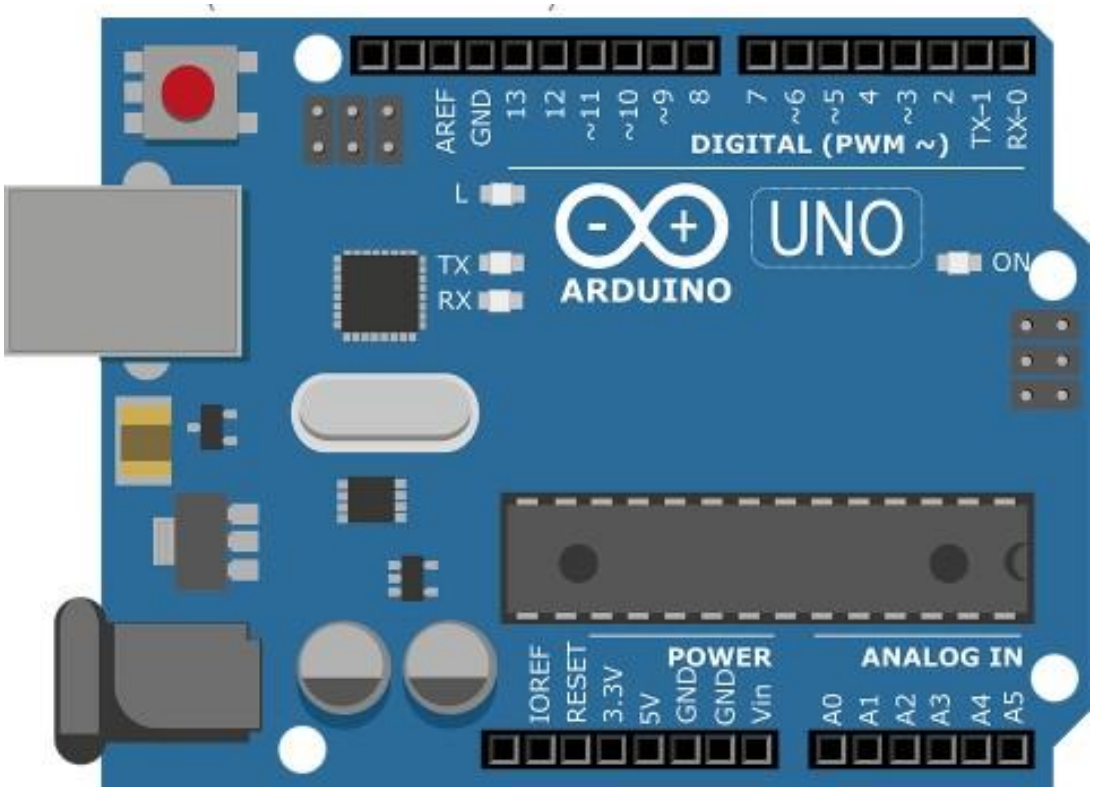


Figure 1. IC of Arduino UNO (ATmega328p).

The software used for Arduino devices is called IDE (Integrated Development Environment) which is free to use and required some basic skills to learn it. It can be programmed using C and C++ language. Some people get confused between Microcontroller and Arduino. While former is just an on system 40 pin chip that comes with a built-in microprocessor and later is a board that comes with the microcontroller in the base of the board, bootloader and allows easy access to input-output pins and makes uploading or burning of the program very easy.

	Pin Category	Pin Name	Details
I.	Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source. 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: ground pins.
ii	Reset	Reset	Resets the microcontroller.
iii	Analog Pins	A0 – A5	Used to provide analog input in the range of 0-5V
iv	Input/Output Pins	Digital Pins 0 - 13	Can be used as input or output pins.
v	Serial	0(Rx), 1(Tx)	Used to receive and transmit TTL serial data.
vi	External Interrupts	2, 3	To trigger an interrupt.
vii	PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
viii	SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
ix	Inbuilt LED	13	To turn on the inbuilt LED.
x	TWI	A4 (SDA), A5 (SCA)	Used for TWI communication.
xi	AREF	AREF	To provide reference voltage for input voltage.

1.2 Table 3 shows the Arduino Uno Technical Specifications

i	Microcontroller	ATmega328P – 8 bit AVR family microcontroller
ii	Operating Voltage	5V
iii	Recommended Input Voltage	7-12V
iv	Input Voltage Limits	6-20V
v	Analog Input Pins	6 (A0 – A5)
vi	Digital I/O Pins	14 (Out of which 6 provide PWM output)
vii	DC Current on I/O Pins	40 mA
viii	DC Current on 3.3V Pin	50 mA
ix	Flash Memory	32 KB (0.5 KB is used for Bootloader)

1.4 Arduino Uno to ATmega328 Pin Mapping

When ATmega328 chip is used in place of Arduino Uno, or vice versa, the image below shows the pin mapping between the two.

1.5 How to use Arduino Board

(i).Digital Pins

The 14 digital input/output pins can be used as input or output pins by using pinMode(), digitalRead() and digitalWrite() functions in arduino programming. Each pin operates at 5V and can provide or receive a maximum of 40mA current, and has an internal pull-up resistor of 20-50 KOhms which are disconnected by default. Out of these 14 pins, some pins have specific functions as listed below:

- Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. On the Arduino Diecimila, these pins are connected to the corresponding pins of the FTDI USB-to-TTL Serial chip. On the Arduino BT, they are connected to the corresponding pins of the WT11 Bluetooth module. On the Arduino Mini and LilyPad Arduino, they are intended for use with an external TTL serial module (e.g. the Mini-USB Adapter).

- External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- PWM: 3, 5, 6, 9, 10, and 11. provide 8-bit PWM output with the analogWrite() function. On boards with an ATmega8, PWM output is available only on pins 9, 10, and 11.
- BT Reset: 7. (Arduino BT-only) Connected to the reset line of the bluetooth module.
- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.
- LED: 13. On the Diecimila and LilyPad, there is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

(ii).Analog Pins

In addition to the specific functions listed below, the analog input pins support 10-bit analog-to- digital conversion (ADC) using the analogRead() function. Most of the analog inputs can also be used as digital pins: analog input 0 as digital pin 14 through analog input 5 as digital pin 19. Analog inputs 6 and 7 (present on the Mini and BT) cannot be used as digital pins.

- I2C: 4 (SDA) and 5 (SCL). Support I2C (TWI) communication using the Wire library (documentation on the Wiring website).

(iii).Power Pins

- VIN (sometimes labelled "9V"). The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin..
- 5V. The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.

- 3V3. (Diecimila-only) A 3.3 volt supply generated by the on-board FTDI chip.
- GND. Ground pins.

(iv).Other Pins

- AREF. Reference voltage for the analog inputs. Used with analogReference().
- Reset. (Diecimila-only) Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

1.6 Architecture and basic working of CPU of ATmega328

1. The data is uploaded in serial via the port (being uploaded from the computer's Arduino IDE). The data is decoded and then the instructions are sent to instruction register and it decodes the instructions on the same clock pulse.
2. On the next clock pulse the next set of instructions are loaded in instruction register.
3. In general purpose registers the registers are of 8-bit but there are 3 16-bit registers also.

a. 8-bit registers are used to store data for normal calculations and results.

b. 16-bit registers are used to store data of timer counter in 2 different register. Eg. X-low & X-high. They are fast, and are used to store specific hardware functions.

4. EEPROM stores data permanently even if the power is cut out. Programming inside a EEPROM is slow.
5. Interrupt Unit checks whether there is an interrupt for the execution of instruction to be executed in ISR (Interrupt Service Routine).
6. Serial Peripheral Interface (SPI) is an interface bus commonly used to send data between microcontrollers and small peripherals such as Camera, Display, SD cards, etc. It uses separate clock and data lines, along with a select line to choose the device you wish to talk to.
7. Watchdog timer is used to detect and recover from MCU malfunctioning.
8. Analog comparator compares the input values on the positive and negative pin, when the value of positive pin is higher the output is set.
9. Status and control is used to control the flow of execution of commands by checking other blocks inside the CPU at regular intervals
10 .ALU (Arithmetic and Logical unit)The high performance AVR ALU operates in direct connection with all the 32 general purpose working registers. Within a single clock cycle, arithmetic operations b/w general purpose registers are executed. The ALU operations are divided into 3 main categories – arithmetic, logical and bit-function.
11. I/O pins The digital inputs and outputs (digital I/O) on the Arduino are what allow you to connect the Arduino sensors, actuators, and other ICs. Learning how to use them will allow you to use the Arduino to do some really useful things, such as reading switch inputs, lighting indicators, and controlling relay outputs.

1.7 Communication in Arduino board

Arduino can be used to communicate with a computer, another Arduino board or other microcontrollers. The ATmega328P microcontroller provides UART TTL (5V) serial communication which can be done using digital pin 0 (Rx) and digital pin 1 (Tx). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The ATmega16U2 firmware uses the standard USB COM drivers, and no external driver is needed.

1.8 Software and programing on Arduino board

1.8.1 Software

Arduino IDE (Integrated Development Environment) is required to program the Arduino Uno board https://www.arduino.cc/en/software.

1.8.2 Programming Arduino

Once arduino IDE is installed on the computer, connect the board with computer using USB cable. Now open the arduino IDE and choose the correct board by selecting Tools>Boards>Arduino/Genuino Uno, and choose the correct Port by selecting Tools>Port. Arduino Uno is programmed using Arduino programming language based on Wiring. To get it started with Arduino Uno board and blink the built-in LED, load the example code by selecting Files>Examples>Basics>Blink. Once the example code (also shown below) is loaded into your IDE, click on the 'upload' button given on the top bar. Once the upload is finished, you should see
the Arduino's built-in LED blinking. Below is the example code for blinking:

```
void setup() {
pinMode(LED_BUILTIN, OUTPUT);
}
void loop() {
   digitalWrite(LED_BUILTIN, HIGH);
         making the voltage LOW delay(1000);   // wait for a second
}
```

PART B: Study on Raspberry Pi.

2.1 Introduction to Raspberry Pi

Raspberry Pi is a series of small single-board computers developed in the United Kingdom by the Raspberry Pi Foundation in association with Broadcom. The Raspberry Pi project originally leaned towards the promotion of teaching basic computer science in schools and in developing countries. Created by the Raspberry Pi Foundation, the Raspberry Pi is an open-source, Linux based, credit card sized computer board. The original model became more popular than anticipated, selling outside its target market for uses such as robotics. It is widely used in many areas, such as for weather monitoring because of its low cost, modularity, and open design. It is typically used by computer and electronic hobbyists, due to its adoption of HDMI and USB devices.

2.1.1 Generations of Raspberry Pi

Several generations of Raspberry Pis have been released.

- The first generation (Raspberry Pi Model B) was released in February 2012, followed by the simpler and cheaper Model A. These first generation boards feature ARM11 processors, are approximately credit-card sized and represent the standard mainline form- factor.
- The Raspberry Pi 2 was released in February 2015 and initially featured a 900 MHz 32- bit quad-core ARM Cortex-A7 processor with 1 GiB RAM. Later versions featured a 1.2 GHz 64-bit quad-core ARM Cortex-A53 processor.
- Raspberry Pi 3 Model B was released in February 2016 with a 1.2 GHz 64-bit quad core ARM Cortex-A53 processor, on-board 802.11n Wi-Fi, Bluetooth and USB boot capabilities.[30] On Pi Day 2018, the Raspberry Pi 3 Model B+ was launched with a faster 1.4 GHz processor, a three-times faster gigabit Ethernet (throughput limited to ca. 300 Mbit/s by the internal USB 2.0 connection), and 2.4 / 5 GHz dual-band 802.11ac Wi- Fi (100 Mbit/s).

- Raspberry Pi 4 Model B was released in June 2019[2] with a 1.5 GHz 64-bit quad core ARM Cortex-A72 processor, on-board 802.11ac Wi-Fi, Bluetooth 5, full gigabit Ethernet (throughput not limited), two USB 2.0 ports, two USB 3.0 ports, and dual- monitor support via a pair of micro HDMI (HDMI Type D) ports for up to 4K resolution. The Pi 4 is also powered via a USB-C port, enabling additional power to be provided to downstream peripherals, when used with an appropriate PSU.
- Raspberry Pi 400 was released in November 2020. It features a custom board that is
- derived from the existing Raspberry Pi 4, specifically remodelled with a keyboard attached. A robust cooling solution similar to the one found in a Commodore 64 allows the Raspberry Pi 400's Broadcom BCM2711C0 processor to be clocked at 1.8 GHz, which is slightly higher than the Raspberry Pi 4. The keyboard-computer features 4 GiB of LPDDR4 RAM.
- Raspberry Pi Pico was released in January 2021 with a retail price of $4.[37] It was Raspberry Pi's first board based upon a single microcontroller chip; the RP2040, which was designed by Raspberry Pi in the UK.[38] The Pico has 264 KiB of RAM and 2 MiB of flash memory. It is programmable in MicroPython, Circuit Python, and C.

2.2 The Raspberry Pi 3 Model B

The Raspberry Pi 3 Model B builds upon the features of its predecessors with a new, faster processor on board to increase its speed. It also features WiFi and Bluetooth Low Energy capabilities to enhance the functionality and the ability to power more powerful devices over the USB ports.

- Quad Core 1.2GHz Broadcom BCM2837 64bit CPU,1GB RAM
- BCM43438 WiFi and Bluetooth Low Energy (BLE) on board
- 40-pin Extended GPIO
- 4x USB 2 ports
- 4 Pole stereo output and composite video port, Full size HDMI
- CSI camera port for connecting a Raspberry Pi camera
- DSI display port for connecting a Raspberry Pi touchscreen display
- Micro SD port for loading your operating system and storing data

- Upgraded switched Micro USB power source up to 2.5A.

2.3 The IC of Raspberry Pi 3 Model B

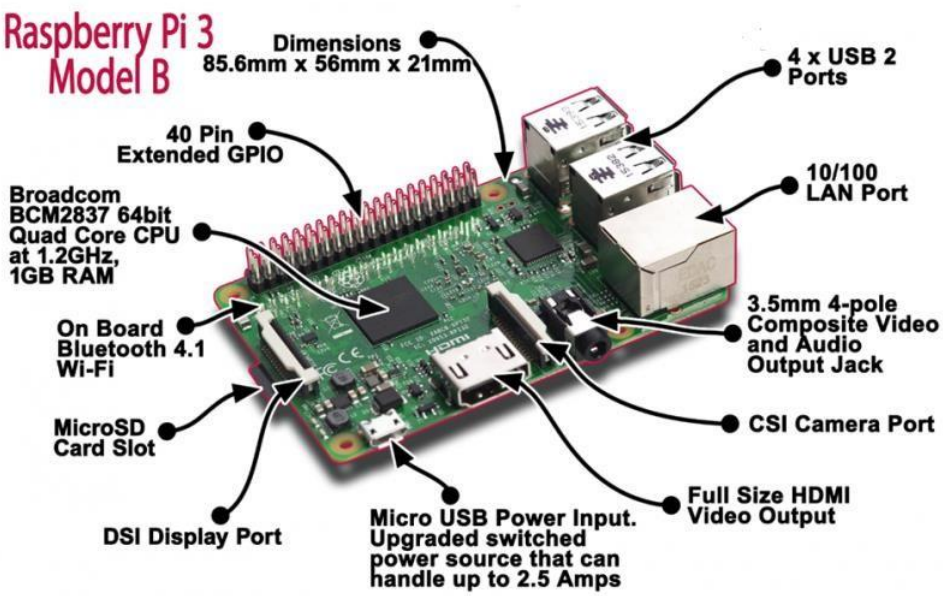
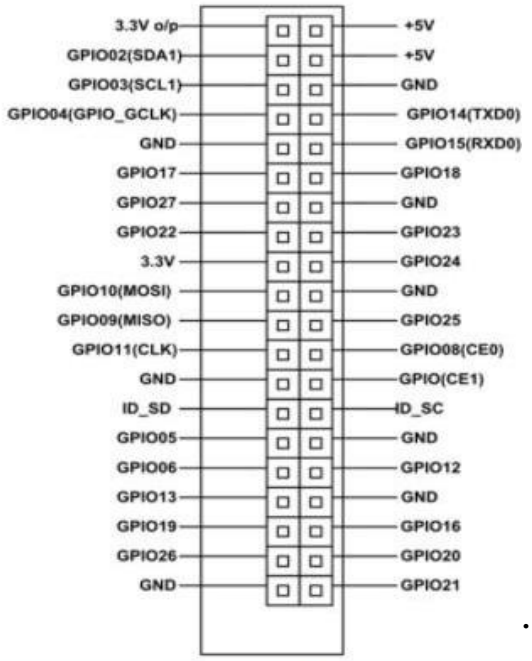


Figure 5. Raspberry Pi 3 Model B

Raspberry Pi 3 Model B+



Raspberry Pi 3 Pinout

PIN GROUP	PIN NAME	DESCRIPTION
POWER SOURCE	+5V, +3.3V, GND and Vin	+5V -power output +3.3V -power output GND – GROUND pin
COMMUNICATION INTERFACE	UART Interface(RXD, TXD) [(GPIO15,GPIO14)]	UART (Universal Asynchronous Receiver Transmitter) used for interfacing sensors and other devices.

SPI Interface	(MOSI, MISO, CLK, CE) x 2 [SPI0-(GPIO10, GPIO9, GPIO11, GPIO8)] [SPI1--(GPIO20,GPIO19, GPIO21, GPIO7)]	SPI (Serial Peripheral Interface) used for communicating with other boards or peripherals.
TWI Interface	(SDA, SCL) x 2 [(GPIO2, GPIO3)] [(ID_SD,ID_SC)]	TWI (Two Wire Interface) Interface can be used to connect peripherals.
INPUT OUTPUT PINS	26 I/O	Although these some pins have multiple functions they can be considered as I/O pins.
PWM	Hardware PWM available on GPIO12, GPIO13, GPIO18, GPIO19	These 4 channels can provide PWM (Pulse Width Modulation) outputs. *Software PWM available on all pins
EXTERNAL INTERRUPTS	All I/O	In the board all I/O pins can be used as Interrupts.

2.1 Table 4 shows Technical Specifications Raspberry Pi 3

Name	Description
Microprocessor	Broadcom BCM2837 64bit Quad Core Processor
Processor Operating Voltage	3.3V
Raw Voltage input	5V, 2A power source
Maximum current through each I/O pin	16mA
Maximum total current drawn from all I/O pins	54mA
Flash Memory (Operating System)	16Gbytes SSD memory card
Internal RAM	1Gbytes DDR2
Clock Frequency	1.2GHz
GPU	Dual Core Video Core IV® Multimedia Co-Processor. Provides Open GLES 2.0, hardware-accelerated Open VG, and 1080p30 H.264 high- profile decode.
Ethernet	10/100 Ethernet
Wireless Connectivity	BCM43143 (802.11 b/g/n Wireless LAN and Bluetooth 4.1)
Operating Temperature	-40ºC to +85ºC

2.2 Table 4 shows Board Connectors of Raspberry Pi 3

2.3 How to Use RASPBERRY PI 3

As mentioned earlier PI is simply a **COMPUTER ON A SINGLE BOARD** so it cannot be usedlike ARDUINO development boards. For the PI to start working we need to first install OPERATING SYSTEM. This feature is similar to our PC. The PI has dedicated OS for it; any other OS will not work.

We will discuss the programming of PI in step by step below.

1. Take the 16GB micro SD card and dedicate it specifically for PI OS.
2. Choose and Download OS software. [https://www.raspberrypi.org/downloads/] (‘NOOBS’recommended for beginners)
3. Format the SD card and install OS on to the SD memory card using convenient methods.
4. Take the SD card after OS installation and insert it in PI board.
5. Connect monitor, keyboard and mouse
6. Power the board with micro USB connector
7. Once the power is tuned ON the PI will run on the OS installed in the memory card andwill start from boot.
8. Once all drivers are checked the PI will ask for authorization, this is set by default and canbe changed.
9. After authorization you will reach desktop where all application program developmentstarts.

On the PI you can download application programs required for your use and can directly install asyou do for your PC. After that you can work on developing required program and get the PI run the developed programs.

2.4 Programming Languages on RASPBERRY PI 3

Python is the recommended programming language — particularly if you are new to programming or want to refresh your programming knowledge. Scratch is a great interactive programming language for children who want to learn to code through creating games, stories and animations. Other programming languages you can get on your Pi include C, C++, Java and Ruby

2.5 Detailed description of components:

1) System Timer: The System Timer peripheral provides four 32-bit timer channels and a single64-bit free running counter. Each channel has an output compare register, which is compared against the 32 least significant bits of the free running counter values.

2) The Processor: At the heart of the Raspberry Pi is the same processor you would have found in the iPhone 3G and the Kindle 2, so you can think of the capabilities of the Raspberry

Pi as comparable to those powerful little devices. This chip is a 32 bit, 700 MHz System on a Chip, which is built on the ARM11 architecture.

3) Interrupt controller: The interrupt controller can be programmed to interrupt the processor when any of the status bits are set. The GPIO peripheral has three dedicated interrupt lines. Each GPIO bank can generate an independent interrupt. The third line generates a single interrupt whenever any bit is set.

4) General Purpose Input/Output (GPIO): 3.3 volt logic via 26 pin header (NOT 5 volt or shorttolerant) Pins can be configured to be input/output. General Purpose Input/Output (GPIO) is a

generic pin on a chip whose behavior can be controlled by the user at run time. True GPIO (GeneralPurpose Input Output) pins that you can use to turn LEDs on and off etc. I2C interface pins that allow you to connect hardware modules with just two control pins. SPI interface with SPI devices,a similar concept to I2C but uses a different standard.

5) PCM / I2S Audio: The PCM audio interface is an APB peripheral providing input and output of telephony or high quality serial audio streams. It supports many classic PCM formats includingI2S. The PCM audio interface has 4 interface signals; PCM_CLK - bit clock. PCM_FS - frame sync signal. PCM_DIN - serial data input. PCM_DOUT - serial data output. PCM is a serial formatwith a single bit data_in and out.

6) DMA Controller: The BCM2835 DMA Controller provides a total of 16 DMA channels. Eachchannel operates independently from the others and is internally arbitrated onto one of the 3 systembusses.

7) UART: The BCM2835 device has two UARTS. On mini UART and PL011 UART. The PL011UART is a Universal Asynchronous Receiver/Transmitter. This is the ARM UART (PL011) implementation. The UART performs serial-to-parallel conversion on data characters received from an external peripheral device or modem, and parallel-to-serial conversion on data charactersreceived from the Advanced Peripheral Bus (APB).

8) Pulse Width Modulator: PWM controller incorporates the following features:

• Two independent output bit-streams, clocked at a fixed frequency.

• Bit-streams configured individually to output either PWM or a serialized version of a 32-bitword.

• PWM outputs have variable input and output resolutions.

• Serialize mode configured to load data to and/or read data from a FIFO storage block, that canstore up to eight 32-bit words.

• Both modes clocked by clk_pwm which is nominally 100MHz, but can be varied by clockmanager.

9) CPU

- ARM 1176JZF-S (armv6k) 700MHz
- RISC Architecture and low power draw.

10) MEMORY

- RAM:- 512MB (Model B rev.2), 256 MB (Model A, Model B rev.1)
- SD Card:- At least 4GB SD card is needed, and it should be a Class 4 card. Class 4 cards are capable of transferring at least 4MB/sec.

11) Two USB 2.0 ports in RPi: Dual USB sockets on RPi model B, single on model A.It can beexpandable via regular or powered hubs. On the Model B there are two USB 2.0 ports, but only one on the Model A. Some of the early Raspberry Pi boards were limited in the amount of currentthat they could provide. Some USB devices can draw up 500mA. The original Pi board supported100mA or so, but the newer revisions are up to the full USB 2.0 spec.

12) Ethernet port: The model B has a standard RJ45 Ethernet port. The Model A does not, but can be connected to a wired network by a USB Ethernet adapter (the port on the Model B is actuallyan onboard USB to Ethernet adapter). WiFi connectivity via a USB dongle is another option.

13) HDMI connector: The HDMI port provides digital video and audio output. 14 different videoresolutions are supported, and the HDMI signal can be converted to DVI (used by many monitors),composite (analog video signal usually carried over a yellow RCA connector), or SCART (a European standard for connecting audio-visual equipment) with external adapters.

14) Video: ● HDMI or (digital) DVI via cheap adaptor/cable, Composite NTSC/PAL via RCA

,Wide range of resolutions , NO VGA without an add-on, nontrivial converter (Adafruit).

15) Audio: Via HDMI or from stereo jack , Support Maturity appears to be lagging

16) Networking : 10/100mbps via RJ45 on model B , Wireless via USB add-on supported.