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Raspberry Pi- A Small, Powerful, Cost Effective and Efficient Form Factor Computer: A Review

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Abstract*—Raspberry Pi, an efficient and cost effective credit card sized computer comes under light of sun by United Kingdom-Raspberry Pi foundation with the aim to enlighten and empower computer science teaching in schools and other developing countries. Since its inception, various open source communities have contributed tons towards open source apps, operating systems and various other small form factor computers similar to Raspberry Pi. Till date, researchers, hobbyists and other embedded systems enthusiast across the planet are making amazing projects using Pi which looks unbelievable and have out-of-the-box implementation. Raspberry Pi since its launch is regularly under constant development cum improvement both in terms of hardware and software which in-turn making Pi a "Full Fledged Computer" with possibility to be considered for almost all computing intensive tasks. The aim of this research paper is to enlighten regarding what is Raspberry Pi, Why Raspberry Pi is Required, Generations of Raspberry Pi, operating systems available till date in Pi and other hardware available for project development. This paper will lay foundation for various open source communities across planet to become aware and use this credit card sized computer for making projects ranging from day to day activities to scientific and complex applications development.

***Keywords*—Raspberry Pi, Embedded Systems, Linux, IoT, Small Form Factor Computer, Raspbian, Open Source.**

I. INTRODUCTION

A. History of Raspberry Pi

Raspberry Pi- A name which is now not a new technical buzzword for researchers in the area of Computer Science, Electronics & Embedded Systems engineering worldwide. Till date, 5 million pieces of various generations of Raspberry Pi ranging from Model A to Model B and even the latest Raspberry Pi Zero (Going Out of Stock in First week of Launch) have been sold and thousands of projects ranging from Robotics, Super Computer development, Gaming Consoles, Portable Tablets, Server based Implementations on lines of Linux and Cloud Computing, Drones and even Astro Pi has been proposed and implemented all over the world.

The foundation seed for development for Raspberry Pi journey started in 2006, when researchers named: Eben Upton, Rob Mullins, Jack Lang and Alan Mycroft at University of Cambridge's Computer Laboratory became stunned to see the decline in the skill level of A Level students and students applying for computer science. The main idea behind their stepping stone development was to give kids tiny and affordable computer in the period where computers were expensive and programming practice among kids was not supported by parents of children in U.K.

The team lead by Eben Upton developed several versions of working prototypes from year 2006 to 2008 and the final released version was named as "***RASPBERRY Pi".***

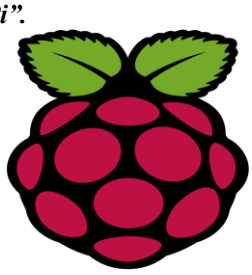

Fig. 1 Raspberry Pi Logo

In 2008, the processors used in mobile devices were becoming cheaper and powerful and have full potential to support and run multimedia and all sorts of programming. The project seemed to be of high potential to the team, so the members Eben Upton, Rob, Jack and Alan got the project joint-ventured by Pete Lomas, MD of Norcott Technologies (Hardware Design and Manufacture Company) and David Braben (Co-Author of Seminal BBC Micro Game Elite) to make Raspberry Pi Foundation.

The Raspberry Pi was officially created in year 2012 (February 2012) and the developing stone was laid by Raspberry Pi Foundation and within 3 years, the model B entered mass level production with Element 14 and RS Electronics and within 2 years of official launch of Pi, 2 million pieces are sold till date.

Raspberry Pi, a complete PC in itself started a new movement of Portable and Low powerful computers. And taking Raspberry Pi into consideration various replica boards like Intel Galileo, Dwengo, Beaglebone, ORCID etc. have come up with their boards providing somewhat same or little bit more configuration as compared to Pi.

Raspberry Pi Foundation Hall of Fame

Raspberry Pi Hall of fame comprise of following members:

A. Eben Upton: Eben Christopher Upton is currently working as Technical Director and ASIC architect at Broadcom. He is the man who was actually regarded as founder and former trustee of Raspberry Pi Foundation and currently acting as CEO of Raspberry Pi trading company. The main role performed by Eben Upton is development of overall software and hardware architecture of Raspberry Pi device.

Fig. 2 Eben Upton

B. Paul Beech: Paul beech was the man behind the design of current logo of Raspberry Pi foundation and is currently working on drawing diagrams, posters and website development of Official Raspberry Pi. He is regarded as one of the founder member of Pimoroni, who make Pibow, PiHub, Pibrella and other useful doo-hickeys to make raspberry pi more fun learning and interactive.

Fig. 3 Paul Beech

C. Alex Bradbury: Alex Bradbury, Ph.D from University of Cambridge has been working as volunteer for Raspberry Pi foundation even before its official inception. Alex does the work of repositories maintenance which comprise of custom versions of Raspbian Operating system and even has Co-Authored a Popular book titled “Learning Python with Raspberry Pi”.

Fig. 4 Alex Bradbury

D. Dom Cobley: Dom Cobley (Engineer at Broadcom) has done various successful contributions to make Raspberry Pi into a Media Streaming device. Dom Cobley has contributed: VideoCore firmware for Pi; Kernel maintenance and even developed XBMC (Xtreme Box Media Center) as developer for enabling media streaming (Video and Audio) via Raspberry Pi.

Fig. 5 Dom Cobley

E. Peter Green: Peter Green was responsible for Raspbian variant of Debian and maintains Raspbian repository. Currently, Peter is involved in developing Raspbian version based on Debian Jessie (Debian 8) in stable form.

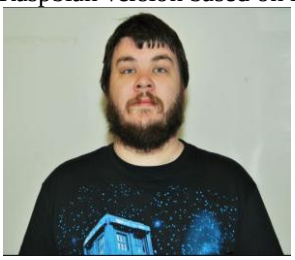

Fig. 6 Peter Green

F. James Hughes: James Hughes was also one of the first's volunteers of Raspberry Pi foundation since 2011. He is now the lead developer of Camera Board Software; Pi Forum's Moderator and works tirelessly on maintaining raspberry pi website and Twitter page.

Fig. 7 James Hughes

G. Rob Mullins: Rob Mullins was one of the Co-Founders of Raspberry Pi foundation along with Eben Upton and served as trustee for foundation till 2014. He is currently working as Senior Lecturer in Computer Laboratory at University of Cambridge. His area of expertise focusses on Computer Architecture and VLSI- On-chip Interconnection networks, chip-multi-processors and novel parallel processing fabrics.

Fig. 8 Rob Mullins

H. Mike Thompson: Mike Thompson worked in collaboration with Peter green on Raspbian Operating system for raspberry Pi.

Fig. 9 Mike Thompson

I. Gert Van Loo: Gert is an engineer at Broadcom and was the person behind the development of original hardware design of Alpha boards in 2011 which later became "Raspberry Pi". He also developed Gertboard and Gertduino expansion boards for Pi.

In addition to the above persons which were primarily responsible for bringing Raspberry Pi under light of sun. The project was not at all possible without the following supporters:

Fig. 11 Raspberry Pi Foundation Supporters

Introduction to Raspberry Pi

The Raspberry Pi- a credit card sized single board computer developed by Raspberry Pi Foundation, United Kingdom. The board is a miniature marvel, packs extreme computing power and capable to develop amazing projects. The computer costs ranging from $5 to $35 and is perfect to perform all sort of computing tasks and interfacing various sorts of devices via GPIO.

The Raspberry Pi board contains Broadcom based ARM Processor, Graphics Chip, RAM, GPIO and other connectors for external devices. The operating procedure of Raspberry Pi is very similar as compared to PC and requires additional hardware like Keyboard, Mouse, Display Unit, Power Supply, SD Card with OS Installed (Acting like Hard Disk) for operation. Raspberry Pi also facilitates USB ports, Ethernet for Internet/Network-Peer to Peer Connectivity.

Like any other computer, where Operating system acts as backbone for operation. Raspberry Pi, facilitates open source operating system's based on Linux. Till date more than 30 operating systems based on different flavors of Linux is being launched. Raspberry Pi foundation has also launched various accessories like Camera, Gertboard and Compute Model Kit for deploying add-on hardware modules.

Road Map of Paper

The paper is organized as follows: Section II titled "Meet Raspberry Pi" will discuss: Components that make up Raspberry Pi, Why Raspberry Pi, Pros and Cons of Pi and Is Raspberry Pi- Open Source or Commercial? Section III will comprise of discussion regarding various generations and models available till date of Raspberry Pi from Model A to Raspberry Pi Zero; Section IV will enlists all available operating systems for Raspberry Pi; Section V will comprise of various add-on hardware components for Pi; Section VI will lead to conclusion and future scope.

II. MEET RASPBERRY PI: A HIGH PERFOMANCE MACHINE WITH DYNAMIC POSSIBILITIES AND INFINITE OUTCOMES

In this section, various components of Raspberry Pi, Why we need Raspberry Pi, Various pros and cons of Raspberry pi and Is Raspberry-Open Source or Commercial? Would be discussed.

A. Components of Raspberry Pi- Computer

Raspberry Pi comprise of following components:

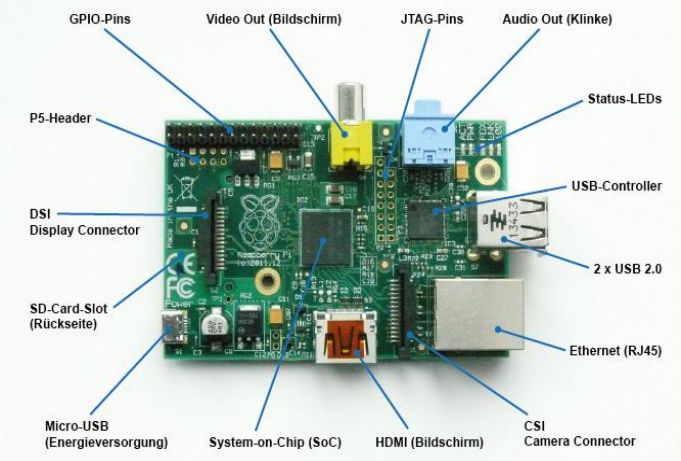

Fig. 12 Raspberry Pi (Components Explanation)

1. Micro-USB Power Supply: Raspberry Pi requires 5 volts (V) +/- 5% per USB 2.0 standard. Talking of various models of Raspberry Pi: Model B: 700mA at 3.5 watts (W); Model A: 500mA at 2.5 watts. The power port on PCB of Raspberry Pi is Micro-USB type B interface, so a Pi compatible power supply uses standard USB A connector on one side and MicroUSB B connector on other side.

Raspberry Pi Standard USB Type B charger.

2. SD Card Slot: Secure Digital Card slot (SD Card) slot is a solid-state removable storage device which is required to run operating systems on Raspberry Pi as Raspberry Pi doesn't have any onboard memory and data storage functionality. Raspberry Pi supports both SDHC (Secure Digital High Capacity) and SDXC (Secure Digital eXtended Capacity). The best suited card for proper running of all sorts of operating systems without any hiccup is Class 10 with speed @ 10MB/sec.

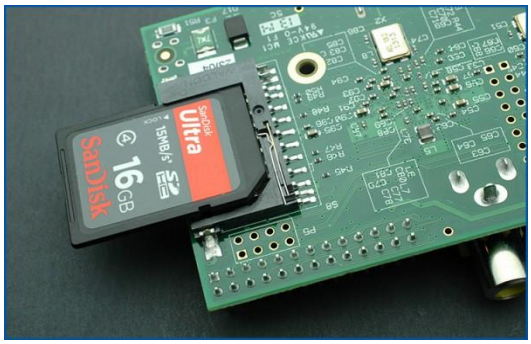

Fig. 13 SD-Card with 16 GB Capacity Class 10

3. USB Ports & Ethernet Port: Raspberry Pi Model B comprise of 2 USB 2.0 ports whereas Model B+ comprise of 4 USB 2.0 ports. USB ports enable the connectivity of external peripherals like Keyboard, Mouse, USB-Hub, Wi-Fi dongle etc.

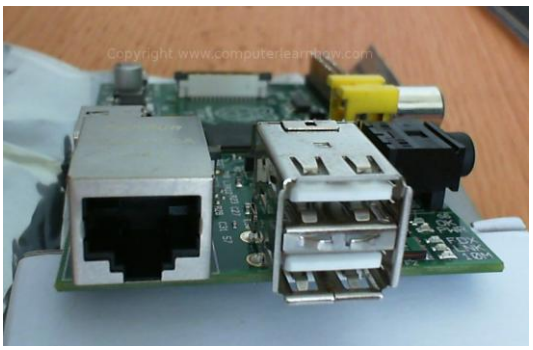

Fig. 14 USB Ports and Ethernet Port of Raspberry Pi

Ethernet Port: In order to enable Internet connection online and to update the software's or to install latest packages from online repositories, Raspberry Pi supports Ethernet Connection. Raspberry Pi (Every Model) comprise of RJ45 Ethernet Jack which supports CAT5/6 cables. It enables Raspberry Pi to be connected to Wireless Router, ADSL Model or any other Internet connectivity sharing device.

4. HDMI (High Definition Multimedia Interface): HDMI Port enables Raspberry Pi to be connected to HDTV via HDMI cable. Raspberry Pi supports maximum resolution of 1920x1200. With the help of HDMI Full HD MPEG-4 can be streamed via HDMI.

Fig. 15 HDMI Port of Raspberry Pi

5. Video Out (RCA Cable): In addition to HDMI Connectivity which facilitates HD connection, Raspberry Pi also has provision to be connected to standard monitor or TV using RCA video cable. RCA cable is less expensive as compared to HDMI but along with RCA cable, the user has to buy 3.5mm stereo cable for audio facilitation.

Fig. 16 RCA Cable Jack of Raspberry Pi

6. Status Led's: Raspberry Pi comprise of 5 main LED's performing the following functions:
   a. ACT: (Color-Green): The main function of ACT LED is to show card status. Normally flashing during any SD Card activity performed by end user.
   b. PWR: (Color-Red): The main function of PWR led is power. This led is continuously ON when raspberry Pi is switched on and keep on till switched off.
   c. FDX: (Color-Orange): The main function of FDX led is full duplex. This Led is powered on when Ethernet connection is of Full Duplex type.
   d. LNK: (Color- Orange): The function performed by LNK led is Link. This LED is powered on when Ethernet connection is established and packet transfer starts taking place.
   e. 100: (Color-Orange): The 100 Led objective is to show 100 Mbps connection. When any connection is established at Ethernet port, this LED only gets on when connection is of 100 Mbps speed and gets powered off when connection is at 10 Mbps.

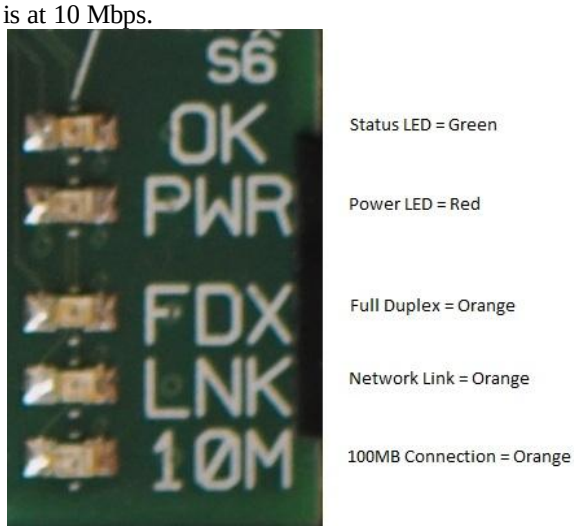

Fig. 17 Raspberry Pi LED's cum LED functioning

7. GPIO (General Purpose Input Output): GPIO facilitates connecting all sorts of peripheral devices to Raspberry Pi. Raspberry Pi has onboard GPIO with 40 pins, 26 of which are used as digital inputs or outputs. More importantly, 9 of the 14 new GPIO pins are dedicated inputs/outputs, it also facilitates the onboard UART, I2C, SPI Bus and still large amount of free GPIO pins are there for add-on attachments.

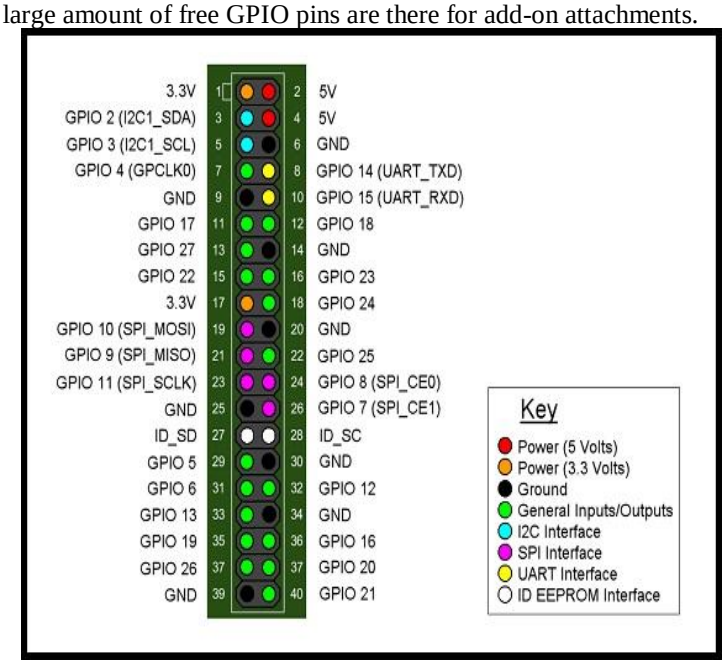

Fig. 18 GPIO PINS of Raspberry Pi

8. CSI Camera Connector: Raspberry Pi has a Mobile Industry Processor Interface (MIPI) Camera Serial Interface Type 2 (CSI-2). CSI-2 facilitates connection of small camera to Broadcom BCM 2835 processor. The function of this interface is to standardize the attachment of camera modules to the processors for the mobile phone industry. MIPI CSI-2 version 1.01 supports upto 4 data lanes, and each lane carries 1 Gbps bandwidth. The D-PHY specification defines the physical hardware layer interface between camera and processor to facilitate fast exchange of data.

Fig. 19 CSI Camera Connector

9. DSI Display Connector: Raspberry Pi connector S2 is a display serial interface (DSI) for connecting LCD panel using a 15-pin ribbon cable. The Mobile Industry Processor Interface (MIPI) inside the Broadcom BCM2835 IC feeds graphics data directly to the display panel through this connector.

DSI Connector Pinout

Socket S2 Pin	Function
1	Ground
2	Data Lane 1 N
3	Data Lane 1 P
4	Ground
5	Clock N
6	Clock P
7	Ground
8	Data Lane 0 N
9	Data Lane 0 P
10	Ground
11	PJV
12	PJV
13	Ground
14	+3.3 V
15	+3.3 V

Fig. 20 DSI Connector Pinout

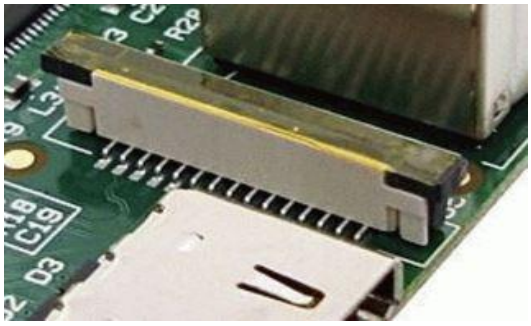

Fig. 21 DSI Connector of Raspberry Pi.

10. System On Chip (SoC): Raspberry Pi (System on Chip) SoC is ARM Based by Broadcom Technologies. The ARM processor runs from 700 Mhz to 1 Ghz. The SoC also facilitates videocore 4 GPU, and is capable for fast 3D core, openGL and supports Blueray and H.264 video playback.

Fig. 22 System on Chip (SoC)

B. Pros & Cons of Raspberry Pi

The following are the Pros/Advantages of Raspberry Pi usage:

1. Raspberry Pi is regarded as a small, powerful and efficient cum compact form factor computer and is very cheap to acquire. Various SME's can use Raspberry Pi to do small and medium level tasks like Running as Web Server, Database Server, and Media Server. So, in turn lots of money on purchase of various servers can be saved.
2. Raspberry Pi can act as single platform for extensive programming experience. Various Programming languages are supported by Pi and users can install the respective compiler for proper execution of code. Python, the main programming language which is used by Pi, is less complex and easy to understand. It provides better code development, less lines and provides automatic memory management function.
3. As the product supports open source operating system and open source apps. So, tons of operating systems in various flavors of Linux and millions of apps in that Linux operating system are available at simple disposal of Raspberry Pi.
4. Raspberry Pi supports add on hardware like Camera, Component Moduler Kit, Gertboard and HAT board which facilitates to connect thousands of third party hardware like Buttons, LED's and user can perform various operations on Pi.
5. The product is energy efficient and provides greener ethical alternative to small businesses. This small credit card sized product is easy to recycle and saves lots of money on cooling solutions.

Cons

The following are the Limitations/Cons of Raspberry Pi:

1. It cannot act as full-fledged computer because the Ethernet Port and Processing CPU is not so fast to process multitasking computing cycles.
2. Not compatible with fully functional Windows Operating System.
3. The product is limited to SME's and not very highly useful and provides huge options of facilities to larger organizations/enterprises.
4. Doesn't have Real Time Clock (RTC) with battery backup. Time can only be work arounded using NTP Server and most of the operating systems does this task automatically.
5. Doesn't support Bluetooth, Wi-Fi out of box and even various USB Based dongles are also not supported for wireless connectivity.
6. Doesn't have built-in ADC Convertor. External charger is used for ADC purpose.

C. Is Raspberry Pi- Open Source or Commercial?

What is meant by Open Source and GPL?

Open Source may be defined as Hardware or Software which is manufactured and given free of cost along with its respective License to Distribute and Intellectual Property Rights (IPR). Linux, being an open source operating system allows the end users to download, modify, improve and even release own customized distributed version to any person in the world.

Open source technology also brings enhancement in security and defenses against all sorts of vulnerabilities and backdoors as open source community can detect and correct the security loopholes and in turn makes the overall system to work hack-proof and stable.

Open source software is released under GNU (GNU's not UNIX) General Public License coined as "GPL" which gives the power to the end user to download and use the GPL software as per their own requirements.

Is Raspberry Pi Open Source?

The Question: Is Raspberry Pi Open Source is although very difficult to answer. Yet we can say, it is right now "***A MYSTRY"*** As, running Pi requires backbone of Linux operating system which is open source and free to use. But taking into consideration the Raspberry Pi's hardware- CPU which is from Broadcom Company i.e. BCM2835 System on a Chip (SoC), the Intellectual Property rights of Broadcom SoC is not open source.

But in 2012, Broadcom distributed the source code of ARM11 code for Pi to the open world, to facilitate the users to write their own GPU code of various video drivers and improve the processing and video capabilities of PI graphics processing. But it doesn't mean, that the source code for all hardware core is open to the end user. Which in turn makes the question: Is Raspberry Pi really an Open Source Hardware? More complex to answer.

So, in a nutshell, Calling Raspberry Pi as open source hardware right now? Can't be declared as the proper answer to this is still yet to be answered because software is open source, some cores of hardware is open source but some IPR of hardware is Confidential from Broadcom.

III. GENERATIONS OF RASPBERRY PI

In this section, various Generations of Raspberry Pi starting from Raspberry Pi Model A to Raspberry Pi Model B+ and latest released Raspberry Pi Zero along with their detailed technical specifications would be discussed.

Raspberry Pi- Model A

Raspberry Model A is regarded as First Generation of Raspberry Pi's models released till date. Under Raspberry Pi Model A two models were released: Raspberry Pi 1 Model A and Raspberry Pi 1 Model A+.

A. Raspberry Pi: Model A [3]

Raspberry Pi Model A is regarded as Lower-spec variant of Raspberry Pi. The model was especially used for embedded projects as this model of Pi because this model misses important hardware ports. Model A was lighter and consumes less power as compared to Model B.

Model A is now outdated and is also not available readily in the market nowadays.

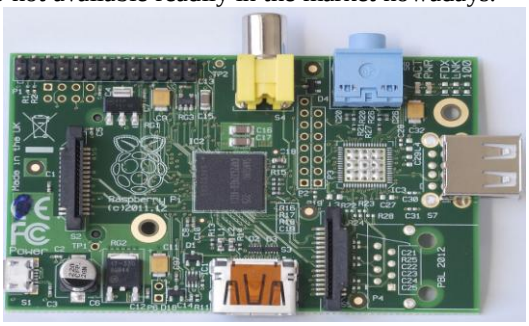

Fig. 23 Raspberry Pi 1 Model A

The following Table 1 defines the Technical Specification of Raspberry Pi 1 Model A:

Technical Specifications

Hardware Parameters	Description
SoC	Broadcom BCM2835
CPU	700 MHz Single Core ARM 1176JZF-S
GPU	Broadcom VideoCore IV @ 250 MHz
RAM	256 MB
Onboard Ports	1 USB; 1 HDMI (Ver 1.4); 3.5mm Sound Jack;
Video Input	15-pin MIPI camera interface (CSI) Connector
Audio Input	2 Boards via I^2S
Onboard Storage	SD/MMC/SDIO Card slot
Ethernet	No
GPIO	8 GPIO including UART, I^2C, SPI Bus with two chip selects, I^2S audio, +3.3 V, +5V, GND.
Adapter Rating	5V; 300 mA
Launch Date	February 2013
Price	$25

B. Raspberry Pi: Model A+ [4]

Raspberry Pi 1 Model A+ was the successor and well updated model to Model A of Raspberry Pi in terms of smaller size and less power consumption. Various enhanced improvements are being done in Model A+ in terms of additional GPIO pins, MicroSD card support and better audio reproduction. Raspberry Pi Model A+ was also capable of running various operating systems and provide strong backbone for various projects of space programs and media center operations.

Model A+ is also discontinued from the market nowadays because of the availability of more upper generation models.

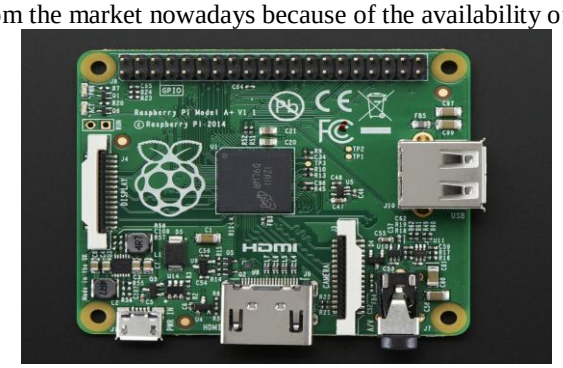

Fig. 24 Raspberry Pi 1 Model A+

The following Table 2 defines the Technical Specification of Raspberry Pi 1 Model A+:

Technical Specifications

Hardware Parameters	Description
SoC	Broadcom BCM2835
CPU	700 MHz Single Core ARM 1176JZF-S
GPU	Broadcom VideoCore IV @ 250 MHz
RAM	256 MB
Onboard Ports	1 USB; 1 HDMI (Ver 1.4); 3.5mm Sound Jack;

Video Input	15-pin MIPI camera interface (CSI) Connector
Audio Input	2 Boards via I^2S
Onboard Storage	MicroSD Card Slot
Ethernet	No
GPIO	17 GPIO including UART, I^2C, SPI Bus with two chip selects, I^2S audio, +3.3 V, +5V, GND, HAT ID Bus
Adapter Rating	5V; 200 mA
Launch Date	November 2014
Price	$20

C. Raspberry Pi: Model B [5]

Raspberry Pi 1 Model B was regarded as higher specification variant of Pi 1 Model A with good performance in working because of high RAM, additional USB port slots and Ethernet Port. Raspberry Pi 1 Model B laid the stepping stone of computing as Hobby in kids towards education, programming and home projects.

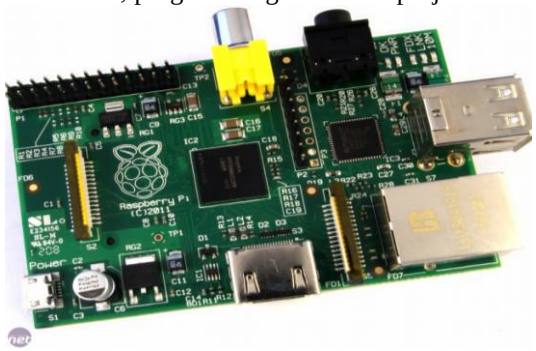

Fig. 25 Raspberry Pi 1 Model B

The following Table 3 defines the Technical Specification of Raspberry Pi 1 Model B:

Technical Specifications

Hardware Parameters	Description
SoC	Broadcom BCM2835
CPU	700 MHz Single Core ARM 1176JZF-S
GPU	Broadcom VideoCore IV @ 250 MHz
RAM	512 MB
Onboard Ports	2 USB; 1 HDMI (Ver 1.4); 3.5mm Sound Jack;
Video Input	15-pin MIPI camera interface (CSI) Connector
Audio Input	2 Boards via I^2S
Onboard Storage	SD/MMC/SDIO Card
Ethernet	10/100 Mbps
GPIO	8 GPIO including UART, I^2C, SPI Bus with two chip selects, I^2S audio, +3.3 V, +5V, GND, Additional 4 GPIO on P5 pad.
Adapter Rating	5V; 700 mA
Launch Date	June 2012
Price	$35

D. Raspberry Pi: Model B+ [6]

Raspberry Pi 1 Model B+ was regarded as the last cum final version under Raspberry Pi 1 models category. Model B+ replaced Model B and was equipped with more enriched hardware features like more GPIO, more USB ports, better MicroSD card, low power consumption as compared to all Raspberry 1 generations models and better audio output.

Fig. 26 Raspberry Pi 1 Model B+

The following Table 4 defines the Technical Specification of Raspberry Pi 1 Model B:

Technical Specifications

Hardware Parameters	Description
SoC	Broadcom BCM2835
CPU	700 MHz Single Core ARM 1176JZF-S
GPU	Broadcom VideoCore IV @ 250 MHz
RAM	512 MB
Onboard Ports	4 USB; 1 HDMI (Ver 1.4); 3.5mm Sound Jack;
Video Input	15-pin MIPI camera interface (CSI) Connector
Audio Input	2 Boards via I^2S
Onboard Storage	MicroSD slot
Ethernet	10/100 Mbps
GPIO	17 GPIO including UART, I^2C, SPI Bus with two chip selects, I^2S audio, +3.3 V, +5V, GND, HAT ID bus
Adapter Rating	5V; 600 mA
Launch Date	July 2014
Price	$25

Raspberry Pi 2 Model B

Raspberry Pi Model B generations were launched after Model A generations with better features, powerful hardware and better operating systems support.

A. Raspberry Pi 2: Model B [7]

Raspberry Pi 2 Model B is regarded as second generation Raspberry Pi. It replaced the Raspberry Pi 1 Model B+ models in terms of powerful CPU, RAM, GPIO and additional hardware connectivity support.

Fig. 27 Raspberry Pi 2 Model B

The following Table 5 defines the Technical Specification of Raspberry Pi 1 Model B:

Technical Specifications

Hardware Parameters	Description
SoC	Broadcom BCM2836
CPU	900 MHz Quad-Core ARM Cortex-A7
GPU	Broadcom VideoCore IV @ 250 MHz
RAM	1 GB
Onboard Ports	4 USB; 1 HDMI (Ver 1.4); 3.5mm Sound Jack;
Video Input	15-pin MIPI camera interface (CSI) Connector
Audio Input	2 Boards via I^2S
Onboard Storage	MicroSD slot
Ethernet	10/100 Mbps
GPIO	17 GPIO including UART, I^2C, SPI Bus with two chip selects, I^2S audio, +3.3 V, +5V, GND, HAT ID bus
Adapter Rating	5V; 800 mA
Launch Date	February 2015
Price	$35

Raspberry Pi- Zero [8] [9]

Raspberry Pi ZERO is the latest addition to Raspberry Pi Family. It is the low cost and least expensive board costing about $5. Raspberry Pi Zero, being compatible to run Raspbian and all other applications being supported by other Pi's. The size is almost half of A+ model and utilities are double in number.

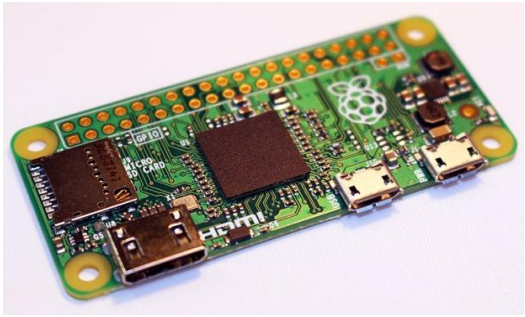

Fig. 28 Raspberry Pi Zero

The following Table 6 defines the Technical Specification of Raspberry Pi 1 Model B:

Technical Specifications

Hardware Parameters	Description
SoC	Broadcom BCM2835
CPU	1 GHz ARM1176JZF-S Single Core
GPU	Broadcom VideoCore IV @ 250 MHz
RAM	512 MB
Onboard Ports	Micro-USB; Mini- HDMI (Ver 1.4); Audio via PWN on GPIO.
Video Input	N/A
Audio Input	2 Boards via I^2S
Onboard Storage	MicroSD slot
Ethernet	N/A
GPIO	40 GPIO Pins
Adapter Rating	5V; 160 mA
Launch Date	November 2015
Price	$5

IV. RASPBERRY PI- OPERATIONS SYSTEMS

Operating System is regarded as the most crucial software for computer hardware to work and to provide interface between the computer hardware and programs running.

Raspberry Pi has tons of operating system which are based on Linux and are free and open source.

Linux and Raspberry Pi

Linus Torvalds, the man behind the development of Linux operating system provided Linux as platform for community development. Raspberry Pi foundation decided to integrate official Linux distribution which is optimized for Raspberry Pi known as Raspbian Pi.

Kernel and Firmware

Operating system being represented as "Outer Body" of system, Kernel is regarded as "Brain" of the overall system. Kernel is basically a component of operating systems which functions with installed hardware devices. Kernel is also termed as "Firmware" because it is software that is semi-permanently written on Partition 1 of SD card.

In this section, an overview of various operating systems which can be installed and supported by Raspberry Pi would be discussed.

The Operating Systems can be divided into two Categories available for Raspberry Pi:

A. Official Available Operating Systems:

1. Raspbian Operating System [10]: Raspbian operating system, based on Debian is optimized for Raspberry Pi hardware. Raspbian consists of set of programs and utilities which makes the Pi run. Bundled with more than 35000 packages, supports easy install on Pi.
   Raspbian Pi, being the basic operating system for Pi is optimized for best performance, stability and is also under active development by open source community for on-going development.
   Download: https://www.raspbian.org/RaspbianImages
   Latest Version: Raspbian Jessie; Kernel Version: 4.1

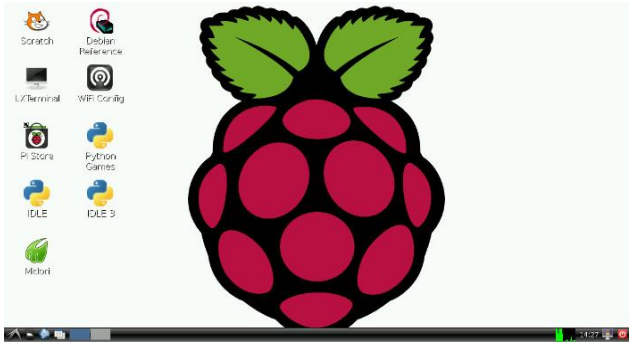

Fig. 29 GUI Interface of Raspbian OS.

2. Arch Linux ARM [11, 12]: Arch Linux ARM is regarded as Linux distribution especially tailored cum developed for ARM computers. Arch Linux ARM is regarded as simple in operation and provides full control to end users. It facilitates a lightweight base structure to customize the system as per user requirements, and only because of this Arch Linux ARM provides no GUI interface.
   Like Raspbian, Arch is also under regular development and updates are on-going.
   Download: https://www.archlinux.org/download/
   Latest Version: 2015.12.1

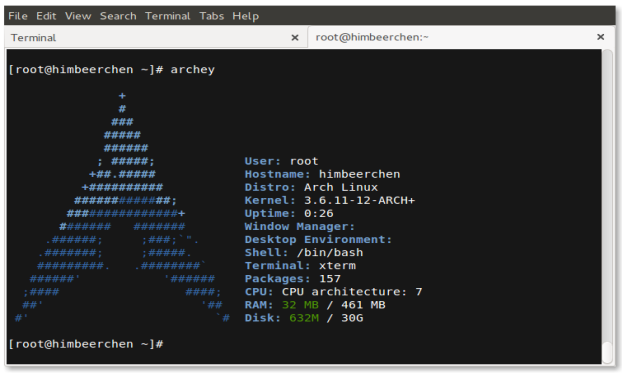

Fig. 30 CUI Interface of ARCH Linux for Raspberry Pi.

3. OpenELEC (Open Embedded Linux Entertainment Center) [13]: OpenELEC, a Linux based distribution especially designed for managing HTPC's and this distribution is based on KODI (XBMC-Media Player).
   OpenELEC supports XBMC Frodo 12.1. OpenELEC is basically designed for faster system boot and can easily turn any blank PC into full fledged media streaming machine in less than 15 minutes. OpenELEC operating system is fully optimized to varios architectures like Atom, ION, Intel, Fusion, Raspberry Pi etc.
   Download: http://openelec.tv/
   Latest Version: 3.0.0

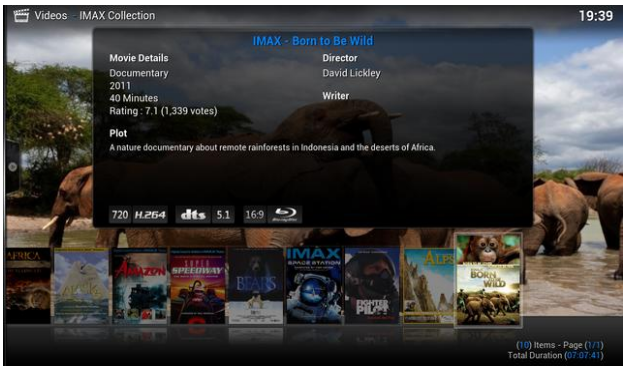

Fig. 31 GUI Interface of OpenELEC Raspberry Pi

4. Pidora [14]: Pidora Operating system is also known as "Raspberry Pi Fedora Remix". Pidora is a Linux software distribution especially designed for Raspberry Pi. It comprise of software packages from Fedora Project which are especially tailored/modified to run on Pi. Pidora being combination of Fedora software, also provides platform to open source community to contribute their apps in this operating system.
   Download: http://pidora.ca/
   Latest Version: Pidora 2014

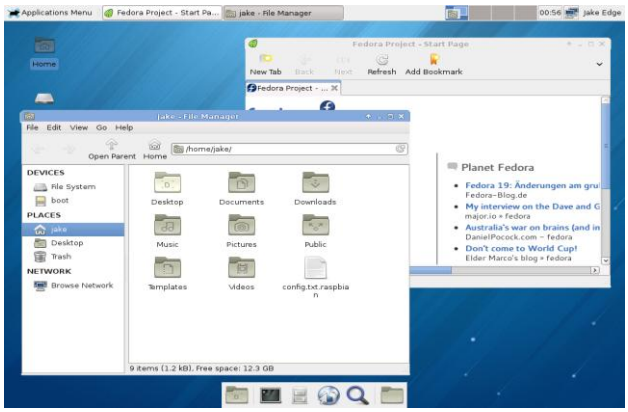

Fig. 32 GUI Interface of Pidora Operating System

5. Puppy Linux [15]: Puppy Linux is regarded as Lightweight distribution that focusses on simple use via low memory usage. Puppy Linux is also customized for Raspberry Pi with wide collection of application suites. Like, other distributions, open source community developers and even penetration testers are working all across the globe for improving the stability, performance and efficiency of the system and community releases regular apps and updates cum bug fixes for operating system.
   Download: http://puppylinux.org/main/Download%20Latest%20Release.htm
   Latest Version: Slacko Puppy 6.3

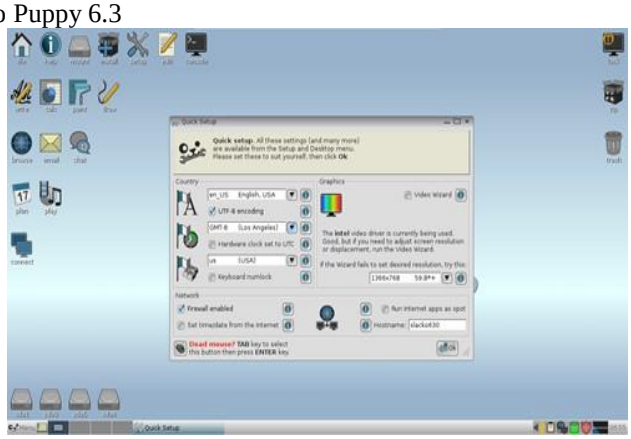

Fig. 33 GUI Interface for Puppy Linux for Raspberry Pi

6. RISC OS [16, 17]: RISC OS is especially designed for ARM processor by ARM Team. RISC OS is very fast, compact and efficient OS as it is not related to windows and Linux. It provides a complete desktop system and collection of applications for running Raspberry Pi.
   Download: https://www.riscosopen.org/content/downloads/raspberry-pi
   Latest Version: RISC OS 14

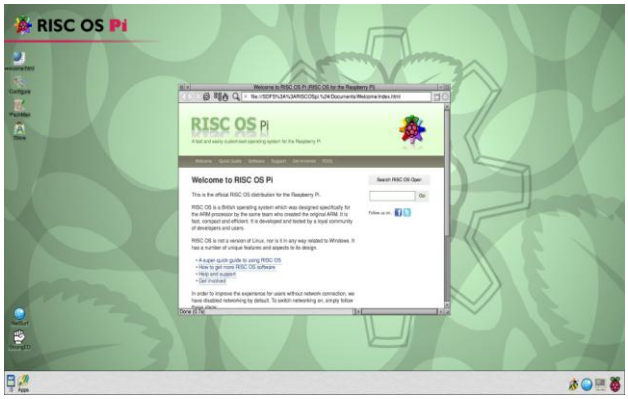

Fig. 34 GUI Interface of RISC OS for Raspberry Pi

7. OSMC (Open Source Media Center) [18]: Open Source Media Center is a free and open source media player based Linux distribution having more than 30000 packages. OSMC is free and open source and takes few minutes to install. OSMC has very active community releasing updates and new packages every month. "OSMC has a Saying: Play Anything from Anywhere".
   Download: https://osmc.tv/download/
   Version: 2015.11.1

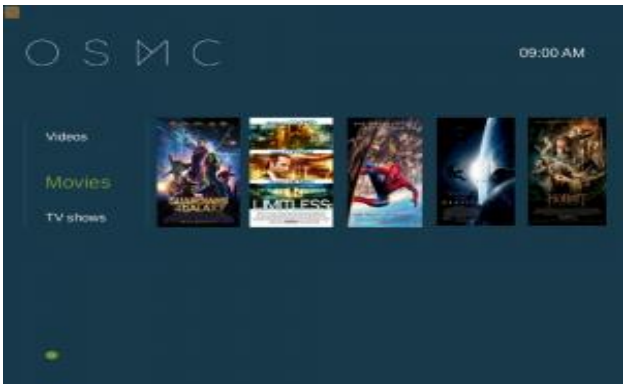

Fig. 35 GUI Interface of OSMC for Raspberry Pi

8. Ubuntu Mate: Ubuntu Mate is tailored version of Ubuntu 15.10 especially designed for Raspberry Pi and released on October 22, 2015. With Ubuntu mate, extensive software repositories as available in Ubuntu is readily available for Pi. Ubuntu Mate provides a full-fledged desktop environment to run all sorts of Graphical Applications and other normal Ubuntu works. Ubuntu Mate is product outcome from Raspberry Jams in order to make better "out of the box" GPIO support.
   Download: https://ubuntu-mate.org/wily/
   Latest Version: Ubuntu Mate 15.10

Fig. 36 GUI Interface for Ubuntu Mate 15.10

9. Window 10 IoT Core [20]: Windows 10 IoT Core is a platform for developing IoT based applications for Raspberry Pi by Microsoft. Windows 10 IoT core brings the power of Windows to Raspberry Pi and enables easy to integrate the rich experience with devices as natural user interface, searching, and online storage and even cloud computing.
   Download: http://ms-iot.github.io/content/en-US/Downloads.htm
   Latest Version: Windows 10

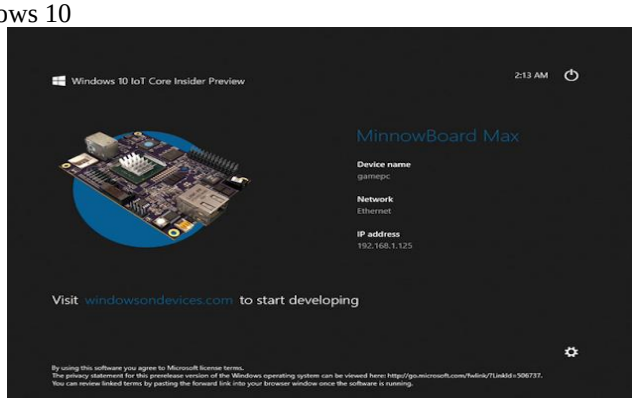

Fig. 37 Windows 10 IoT Core

B. Misc. Operating Systems

The following is the list of other operating systems which can also be downloaded and installed on Raspberry Pi:

1. Q4OS [21]: Fast and powerful operating systems focusing on security, reliability, long term stability and conservative integration of verified new features for raspberry pi.
2. Xbian [22]: Xbian is a small, fast and lightweight media center distribution for Raspberry Pi. Based on minor Debian providing fastest kodi solution for various small form factor computer.

3. openSUSE [23]: Formaly known as SUSE linux and SuSE Linux professional provides a good platform for open source tools for software developers and administrators in addition to user-friendly desktop and feature rich server GUI interface.
4. FreeBSD [24]: FreeBSD supported Raspberry Pi since November 2012 and has similarities like Linux. FreeBSD maintains a complete operating system i.e. Project delivers kernel, device drivers, userland utilities and documentation.
5. Kali Linux [25]: Kali Linux, a Debian based linux especially designed for Digital Forensics and Penetration Testing also supports Raspberry Pi. It is equipped with more than 600 testing programs, GUI interface and other ethical hacking programs.
6. SailPi [26]: SailPi operating system is based on Sailfish OS version 2.0.0.10. This operating system has stronger OS core, supports various architectures like Intel Atom including Pi, provides good security features and good multitasking and enhanced user interface.

V. RASPBERRY PI- ADD ON HARDWAREACCESSORIES

In this section, various add on accessories which are available for raspberry pi to work as add-on utilities are listed.

A. Raspberry Pi Camera Module [27]

Raspberry Pi Camera Module is equipped to take HD video as well as still photos. Provides good utility for beginners and also offer widen scope for projects for advanced users.

Specifications: Raspberry Pi Camera has Effective Resolution of 5 Mega-Pixel and supports video recording at: 1080@30fps, 720p@60fps and Vga@90fps. It comes along with 15cm ribbon cable to be connected via CSI port of Raspberry Pi.

Raspberry Pi works with all generations of Raspberry Pi models. The camera can be accessed via MMAL and V4L APIs and other third party software's like Picamera Python Library.

Fig. 38 Raspberry Pi Camera Module

B. Gertboard [28,29]

Gertboard is an add-on GPIO expansion board for Raspberry Pi. Gertboard is equipped with wide range of components like Buttons, LEDs, A/D and D/A Converters, Motor Controller and Atmel Atmegs 328p AVR microcontroller which can be programmed using Arduino IDE software.

The following are the Specifications of Gertboard:

- Full access to all GPIO Pins
- Full access to all ATmega pins.
- 12 Digital buffers
- 12 LED's
- 3 Buttons
- SPI 2 channel D/A convertor and A/D convertor
- 4 amp capacity DC motor
- 6 Open-collector outputs.

Fig. 39 Gerboard for Raspberry Pi

Compute Module Development Kit[30]

The Compute Module Development Kits is basically a prototyping kit to make Raspberry Pi more flexible and ready for industrial applications.

Specifications: It contains Raspberry Pi-BCM2835 Prcessor with 512 MB RAM, 4GB eMMC flash device. The board consists of 120 GPIO pins, HDMI port, USB port, Two Camera Ports, Two Display Ports.

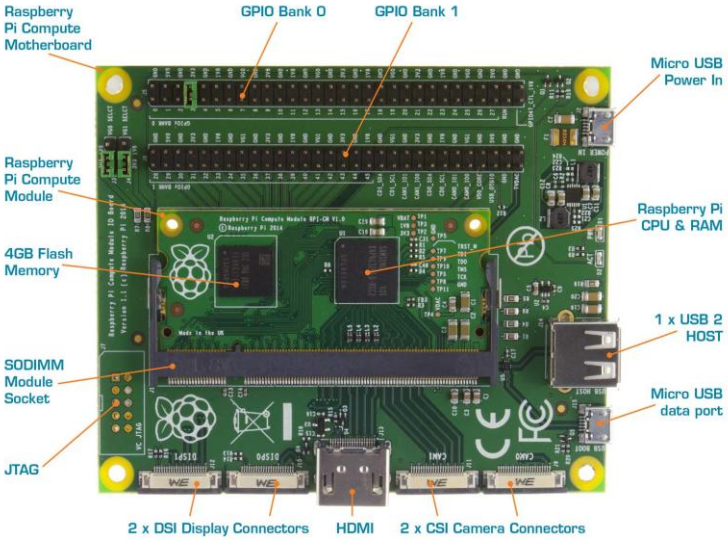

Fig. 40 Compute Module Development Kit for Raspberry Pi

C. Raspberry Pi Touch Display[31]

Raspberry Pi has another very important add on accessory called Pi Touch Display. It gives raspberry Pi users ability to create all-in-one projects such as making tablets, photo frames, gaming consoles, and other embedded projects.

Specifications: 7" Touchscreen Monitor, Resolution: 800x480, Power from GPIO, Connectivity via DSI port.

Fig. 41 7" Raspberry Pi Touch Screen

D. Sense Hat for Raspberry Pi [32]

Sense Hat for Raspberry Pi is an add-on-board for Raspberry Pi especially designed for Astro Pi. Sense Hat is also planned to be deployed to International Space Station in December 2015.

Specifications: 8x8 RGB LED Matrix. 5 Button Joystick, Sensors: Gyroscope, Accelerometer, Magnetometer, Temperature, Barometric Pressure, Humidity.

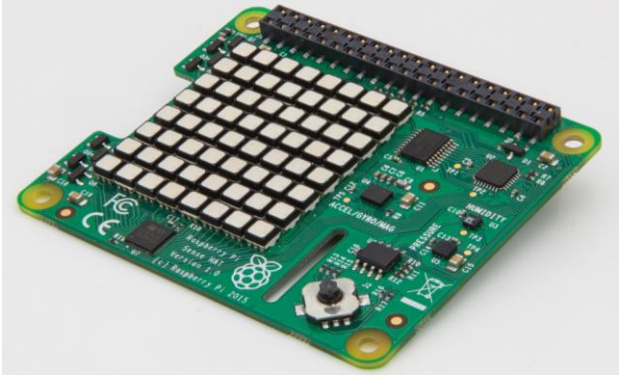

Fig. 42 Sense Hat for Raspberry Pi

VI. CONCLUSION

In this paper, a comprehensive review of Raspberry Pi- A $25 small and compact credit card sized computer is being done. Raspberry Pi, being a small form factor device has unlimited possibilities of project development in area of embedded systems and daily routing out of box projects. Raspberry Pi is helpful both for computer science students to learn programming, Linux Administration and do Server Administration implementations of Emails, Cloud and other Web Servers. For embedded systems, various interfacing like Sensors, LED's etc. can be interfaced via GPIO. This paper will be an eye-opener for all, to use this device and explore for unlimited possibilities.

VII. FUTURE SCOPE

In future, the focus would be to develop own Sensor Network Kit, Robotics as well as Raspberry Pi Embedded Systems project using Raspberry Pi B/B+/Zero model.

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