A Review of Arduino Board's, Lilypad's & Arduino Shields

Anand Nayyar

Assistant Professor, Department of Computer App. & IT
KCL Institute of Management and Technology, Jalandhar
Email Id: anand_nayyar@yahoo.co.in

Er. Vikram Puri

Member of ACM, theIRED, IAENG
Jalandhar, Punjab
Email Id: vikrampuri@acm.org

Abstract – The word "Open Source" is everywhere with Linux Technology and GNU foundation. In addition to open source software's and operating systems, Open Source Hardware is also progressing and becoming center point of attraction for researchers across the nook and corner of the world. The most widely adopted Open Source hardware available right now is "Arduino". Arduino has various products like boards, Lilypad's and shields. The aim of this research paper is to explore the world of Arduino technology in terms of Boards, Lilypad's and Shields covering in depth regarding-Technical Specifications, features and real-world applications. Arduino technology has enabled various manufactures and research enthusiasts to come out with their own customized boards and shields as per their research requirements and area of implementations. Arduino Open Source community is also providing platform for researchers to come up with innovative research applications and market ready products in terms of Home Automation, Robotics, Wireless Connectivity, Drones and many others.

Keywords – Arduino; Arduino Shield; ATMega; Arduino Boards; IoT; Arduino Lilypad

I. INTRODUCTION

Arduino [4] [5], an open source platform which provides strong base for hardware and software. Arduino Project was started in 2005 by some research students at Interaction Design Institute in Ivrea, Italy. The name "Arduino" was coined from a bar in Ivrea. The bar was named on "Arduin of Ivrea" who was margrace of Ivrea and king of Italy from 1002 to 1014 [1]. The motive behind development of Arduino was to provide a platform to Hobbyists and Embedded Systems Professionals and Open Source Hardware Developers to create devices and projects by integrating various types of Sensors and Actuators. Since then, various Do-it-Yourself (DIY) kits were launched commercially all over, because of its open source nature various manufacturers have got the power to manufacture their own Arduino customized boards. With the establishment of Adafruit industries in 2011, Arduino became so much popular that since then till 2015 almost 10,00,000 boards are sold globally.

Fig.1 Arduino Open Source Community Logo

Till date, various Arduino boards like Arduino 101, Zero, Due, Yun, Leonardo, Uno, Mega2560, Ethernet, FIO, Nano, LilyPad, Pro, Mega ADK, Esplora, Micro, Mini pro are launched with different specifications in terms of hardware and user based applications.

In addition to standard boards and other manufacturer compatible boards, various shields are also launched which serves specific purpose for Wireless, Sensors, GSM, Bluetooth, Prototyping, USB Functionality and many more. The aim behind the development of this paper is to enlighten in detail regarding Arduino Technology, Arduino Standard Boards and Arduino shields. This paper would provide platform for researchers to study detailed description of Arduino Technology and choose specific boards and shields as per their desired research area and interest.

Organization of Paper

Section II will give detailed overview of Technical Specification of Arduino Standard Board of Arduino USA along with brief description of Arduino IDE Software, Section III will highlight various Standard Arduino Boards and Lilypad's, Section IV will highlight various Standard Arduino Shields, Section V will comprise of Conclusion and Future scope.

II. Arduino Board Technology-Overview, Hardware and Software IDE

A. Basic Overview [2]

Arduino is basically not a "MicroController" but regarded as "Open Source Hardware Movement" and was founded by Massimo Banzi and David Cuartielles, Tom Igoe, Gianluca Martino and David Mellis in 2005. Arduino has easy to learn language and libraries based on C++ Language and IDE environment for proper programming interface. Arduino is regarded as Platform Independent Hardware and can operate on Windows, Linux and MAC operating System.

B. Hardware Specifications

Arduino, an open source hardware board is based on ATMega328 Microcontroller based on 8-, 16- and 32-bit AVR Technology. ATMega328 is basically AVR 8-bit RISC controller based on Dual Inline Package (DIP) technology; has 20 MHz clock oscillator, 32kB flash, 1kB SRAM, 23 I/O Programmable Pins, 6 Channel 10-Bit ADC and 6 PWM outputs.
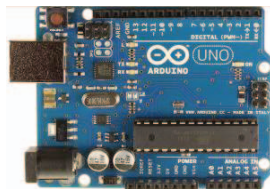

Fig. 2. Arduino Standard Board

The following Table I gives a detailed description of Technical Specifications of Arduino Board:

TABLE I: TECHNICAL SPECIFICATIONS OF ARDUINO BOARD

Parameter	Specification
Input Voltage	7-12v (DC Jack) 5v (USB)
Max Output Current	40 mA Per Pin
Processor	ATmega328P
Oscillator	16 MHz
Analog Pins	6
Digital Pins	14
PWM Pins	6
Other Specifications	4 LED's (TX, RX, Pin 13, Power Indicator), Reset Switch
Flash	32 kB

C. Arduino Software (IDE)- Integrated Development Environment [3]

Arduino Integrated Development Environment (IDE) is platform independent base for Arduino hardware and can run on multiple operating system platforms. It is basically a cross platform application based on Java Technology and has foundation of Processing Programming language and Wiring Projects. Arduino IDE is a strong platform for all researchers, programmers and other industry project development professionals to develop projects on Arduino Controllers and other sensors.

The following figure will highlight the screenshot of Arduino IDE.
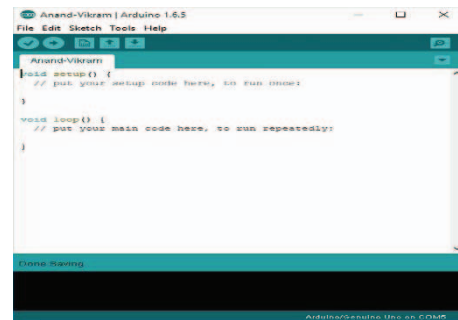

Fig. 3 Arduino IDE Screenshot

Arduino IDE is open source software which is available free of cost to download and test on the following link:

https://www.arduino.cc/en/Main/Software

The latest software which is available till date is Arduino 1.6.5.

Arduino IDE is bundled with software library called "Wiring" to facilitate easy I/O operations. The entire program structure can be written main functions:

1. setup(): This function is used for initialization of settings and executes atleast once at execution of program.

2. loop(): This function is executed iteratively till powering off the main board.

After writing the program on the Sketch, the program is to be compiled by clicking [button]. After successful compilation, the program is uploaded to the board by clicking the "Upload Button" [button]. On clicking of the upload button, the code is written to a Temporary File which includes extra include header at top and simple main () function at bottom.

The following source code is an example of Arduino LED Blink Code:

```
void setup() {
    // initialize digital pin 13 as an output.
    pinMode(13, OUTPUT);
}

// the loop function runs over and over again forever
void loop() {
    digitalWrite(13, HIGH);   // turn the LED on (HIGH is the voltage level)
    delay(1000);              // wait for a second
    digitalWrite(13, LOW);    // turn the LED off by making the voltage LOW
    delay(1000);              // wait for a second
}
```

Fig. 4. LED Blink Code of Arduino Board

Arduino IDE makes use of GNU toolchain (Programming Tools under GNU Project) along with AVR Lib.c for facilitation of program code compilation and uploading the final version to board for execution.

Why Arduino [4] [5]?

In this section, we will elaborate some of the unique features which justify the adaptability towards Arduino and why Arduino boards are unique in nature.

The following are the unique features of Arduino Boards:

1. Platform Independent: Arduino Boards are compatible towards cross-platforms whether Windows, Linux (All Flavors) and even MAC OS operating systems as compared to other boards which are mostly operational on Windows Operating system.

2. Cost-Effectiveness: Arduino technology is also cheap as compared to other microcontrollers. The basic board which is nice for all sorts of development for projects for students, hobbyists and microcontroller enthusiast cost less than $50 which gives it strong reason for world-wide acceptance.

3. Easy to Program: Arduino Technology offers simple and easy programming environment via Arduino Software (IDE) which is very easy to understand, flexible, robust for all sorts of users. Various in-built examples are also in IDE software which can be used as such for various interactions with board.

4. Open Source Hardware: As belonging to the open source hardware category, Arduino technology is utilized by various manufactures and they have come up with their own custom made boards.

5. Open Source Software: Arduino speaks C++, so various C++ libraries can be taken to next level to AVR and can be directly embedded into main programs.

   III. Arduino Standards Boards and Lilypad Boards [3]

Section III will give a comprehensive review of Arduino Boards and Lilypad's available till date along with their respective technical specifications.

What is Arduino Board?

Arduino Boards are development boards for interfacing of different peripherals, sensors and wireless communication devices for providing platform for R&D based products and projects development.

Categories of Arduino Boards & Lilypad's

Arduino Boards belong to different categories. The following Table II highlights the Arduino Board's categories:

TABLE II: CATEGORIES OF ARDUINO BOARD

Category	Board Names
Entry Level	Arduino Uno; Arduino Pro; Arduino 101;
Enhanced Features	Arduino Mega 2560; Arduino Zero; Arduino Due
Internet of Things (IoT)	Arduino Yun
Wearable	Arduino Gemma; Lilypad Arduino USB, Lilypad Arduino Main Board; Lilypad Arduino Simple; Lilypad Arduino Simple Snap

Arduino Boards divided into different categories as follows:

1. Entry Level Boards :

Entry Level Boards are most easy to use and program and helpful to even novice users in getting abreast with electronics and primary IDE environment. These boards can also be categorized under Starter kit category of Arduino Technology.

   a. Arduino Uno: Arduino Uno is regarded as start point board for Electronics and coding because of its robust nature.

Technical Specifications: Arduino Uno is based on ATmega328. Consists of 14 digital Input/output pins, 6 analog pins and 6 PWM outputs. Can simply connect to the PC through USB.
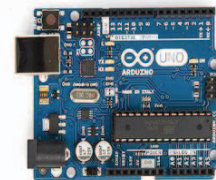

Fig. 5 Arduino Uno

   b. Arduino Pro: Arduino Pro is designed for semi-permanent installation in objects or exhibitions.

Technical Specifications: Arduino Pro is based on ATmega168 or ATmega328. Consists of 14 digital Input/output pins, 6 analog pins and 6 PWM outputs. It can connect through FTDI cable or Breakout Board to provide communication and power.
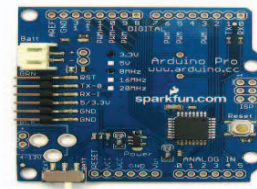
Fig.6. Arduino Pro

c. Arduino 101: Arduino 101 is basically designed to control projects via Smartphones using Bluetooth.

Technical Specifications: Arduino 101 is based on Intel Curie Technology. Contains two tiny cores an X86 and ARC. Consists of 14 digital Input/output, 6 analog pins and 4 PWM output. Has inbuilt Bluetooth and 6- axis Accelometer/gyroscope.
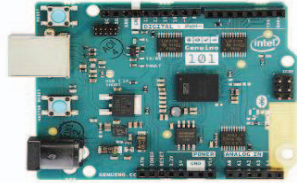

Fig.7. Arduino 101

2. Enhanced Features Boards

Enhanced features boards are designed for complex project development and has more features and performance as compared to entry level boards.

Enhanced feature boards are as follows:

a. Arduino Mega 2560: Arduino Mega 2560 is designed for developing Arduino based robots and doing 3D printing technology based research.

Technical Specifications: Arduino Mega 2560 is based on ATmega2560. Consists of 54 digital Input/ Output pins, 16 analog inputs, 4 UART (Universal Asynchronous Receiver and Transmitter). Can simply connect to PC via USB port.
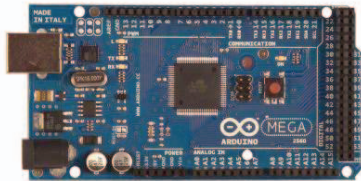

Fig.8. Arduino Mega 2560

b. Arduino Zero: Arduino Zero is designed for developing various projects in areas of IoT, Automation, Robotics and Wearable technology.

Technical Specifications: Arduino Zero is based on Atmel SAMD21 having 32-bit ARM Cortex M0+core. Consists of 20 digital Input/output, 6 analog pins, 1 analog output pin and all PWM outputs except PIN 2 and PIN7. Can connect to PC via Micro-USB port.
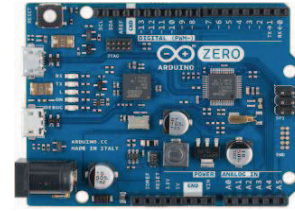

Fig. 9. Arduino Zero

c. Arduino Due: Arduino Due is designed for large and complex industrial, robotics, automation, sensor communication based projects.

Technical Specifications: Arduino Due is based on AtemelSAM3X8E ARM Cortex-M3. Consists of 54 digital Input/output pins, 12 analog pins, 4 UART, 2 DAC(Digital to analog convertor), SPI(serial peripheral interface) Header, JTAG(Joint Test Action Group) header, erase and reset switch. Can Connect to PC via Micro-USB port.
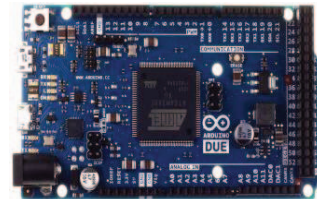

Fig. 10. Arduino Due

3. Internet of things (IoT) Boards

Internet of Things (IoT) boards are designed for interfacing with IoT products.

The IoT Boards are as follows:

a) Arduino Yun: Arduino Yun is designed for developing IoT based projects and has uniqueness to combine Linux Technology for more stable and secure development and interfacing.

Technical Specifications: Arduino Yun is based on the Atmega32u4 and Atheros AR9331. Consists of 20 digital Input/output pins, 12 analog inputs, 7 PWM outputs, 3 reset switches. Contains connectivity options of Ethernet and Wi-Fi. Can connect to PC via Micro USB port.

Fig.11. Arduino Yun

4. Wearable Boards

Wearable Boards are designed for developing projects based on Wearable gadgets and gizmos.

The wearable boards are as follows:

    a) Arduino Gemma: Arduino Gemma is designed for projects based on wearable technology.

Technical Specifications: Arduino Gemma is based on ATtiny85. Consists of 3 digital Input/ Output, 1 analog input and 2 PWM output, 1 JST (Japan Solderless Terminal) connector and 1 reset switch. Can connect to PC via Micro USB port.
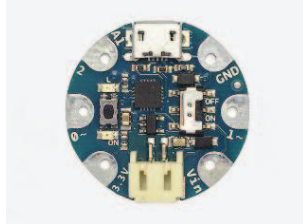

Fig.12. Arduino Gemma

    b) LilyPad Arduino USB: LilyPad Arduino USB is designed for E-Textiles and Wearable devices project development.

Technical Specifications: Lilypad Arduino USB is based on ATmega32U4. Consists of 9 digital Input/ Output, 4 analog input and 1 PWM output, 1 JST (Japan Solderless Terminal) connector and 1 reset switch. Can connect to PC via Micro USB port.
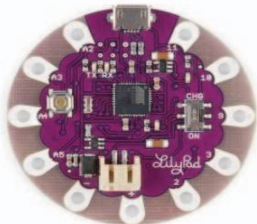

Fig. 13. Arduino LilyPad USB

5. LilyPad Arduino Main Board: Arduino LilyPad Main Board comprise of sensors and actuators with conductive thread for usage in E-Textiles and wearable products development.

Technical Specifications: Lilypad Arduino Main Board is based on ATmega168V or ATmega328V. Consists of 14 digital Input/output, 6 analog input and 6 PWM outputs. Can connect through FTDI cable or Breakout Board to provide communication and power.
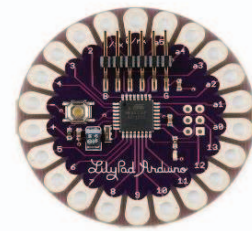

Fig. 14. LilyPad Arduino Main Board

6. LilyPad Arduino Simple: LilyPad Arduino simple is designed for simple IoT based products and research level development of IoT.

Technical Specifications: Lilypad Arduino Simple is based on ATmega328. Consists of 9 Input/ Output pins, 4 analog inputs, 5 PWM outputs, 1 JST (Japan Solderless Technology). Can connect through FTDI cable or Breakout Board to provide communication and power.
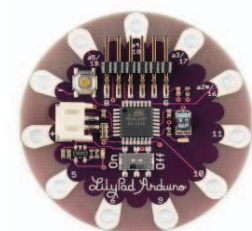

Fig.15. LilyPad Arduino Simple

7. LilyPad Arduino Simple Snap: LilyPad Arduino Simple Snap is designed for R & D purpose of E-Textiles projects.

Technical Specifications: Lilypad Arduino Simple Snap is based on ATmega328. Consists of 9 Input/ Output pins, 4 analog inputs and 5 PWM outputs. Can connect through FTDI cable or Breakout Board to provide communication and power.
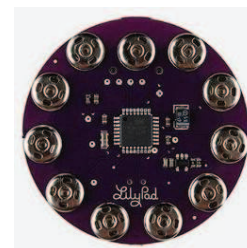

Fig.16. Arduino LilyPad Simple Snap

IV. Arduino Shields

Section IV gives a comprehensive review of various Arduino Shields along with their respective technical specifications and Tabular explanation of features of each and every shield.

What is Arduino Shield?

Arduino Shields are basically add-on circuit boards attached over the top of Arduino PCB to provide enhanced capabilities and platform for researchers with varied functionalities via additional hardware. As, Arduino is open source hardware platform for all sorts of users from beginner to advanced level. But if, beginner user feels uncomfortable with as such Arduino usage, Arduino Shields come to rescue in this situation. Arduino shields are especially designed for beginners to overcome the complexity of soldering components and attaching additional hardware resources for their respective projects. Shields combine all sorts of hardware customized as per user project requirements in one stack giving plug and play advantage.

In this section, the 4 Standard Arduino Shields would be discussed with their respective definitions, technical specifications and real-world applications.

Types of Arduino Shields

Various Arduino Shields are available till date by various manufacturers in market.

A. Motor Shield

Motor Shield (Entry Level Shield) is based on L298 to drive DC Motors, Stepper Motors, Relays and inductive loads such as solenoids.

TABLE III: TECHNICAL SPECIFICATIONS OF MOTOR SHEILD

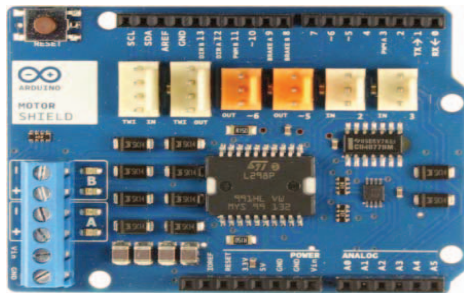| Parameters	Values
Operating Voltage	5V to 12V
Max Current	4A
Max Motor Control	2 DC Motors; 1 Stepper Motor

Applications: Robotics, Relay Connections.

Fig. 17. Arduino Motor Shield

B. Prototype Shield

Prototype Shield (Enhanced Feature Shield) is designed for developing custom circuits as per user project requirements. Enables soldering of components or breadboard placing.

Equipped with extra connections for I/O pins for mounting IC's.

TABLE IV: TECHNICAL SPECIFICATIONS OF PROTOTYPE SHEILD

Parameters	Values
Voltage on Board	5V, 3.3V & GND
Max Current	As per type of Arduino Board Attached
Extra Features	1 Reset Switch, 14-Pin SMD, 1.0 Arduino Pinout, 1 ICSP Connector, 20 Pin Through Hole.

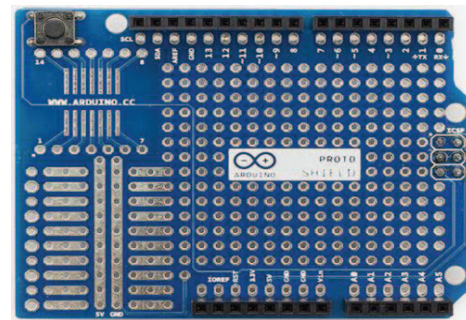Applications: Designing all sorts of Circuits, Any Sensor Interfacing and Breadboard Attachment.

Fig.18. Arduino Prototype Shield

C. Ethernet Shield

Ethernet Shield (Internet of Thing (IoT)) shield facilitates online connectivity to Arduino board. Shield makes used of Wiznet W5100 Ethernet chip capable for both TCP and UDP packet transmission and supports upto 4 simultaneous socket connections. Ethernet shield is equipped with micro-SD card slot for facilitating user for storage of files and card can be accessed via SD Library.

TABLE V: TECHNICAL SPECIFICATIONS OF ETHERNET SHEILD

Parameters	Values
Operating Voltage	5V
Connection Speed	10/100 MBps
Ethernet Controller	W5100 with 16K Buffer memory
Extra Features	Power Over Ethernet, SD Card Slot (SD and SDHC), Reset

Applications: IoT, Web Server Deployment, P2P Connectivity, Internet Connectivity (Project Specific)
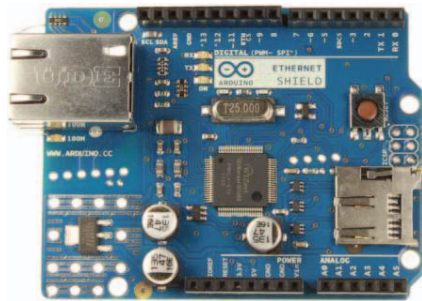

Fig. 19. Arduino Ethernet Shield

D. GSM Shield

Arduino GSM Shield provides Internet facility via GPRS network to Arduino boards along with Calling and SMS utility through GPRS enabled SIM card. GSM shield is equipped with Radio Modem (M10) by Quectel operating at frequencies: GSM850MHz, GSM900MHz, DCS1800MHz, and PCS1900MHz. The shield is enabled with GSM Library. The shield also supports TCP/UDP/HTTP protocols via GPRS connectivity at speed of 85.6 kbps.

TABLE VI: TECHNICAL SPECIFICATIONS OF GSM SHEILD

Parameters	Values
Operating Voltage	5V
Max Current	700 mAh – 1000 mAh
Protocols Supported	TCP, UDP, HTTP
LED's	ON, STATUS, NET

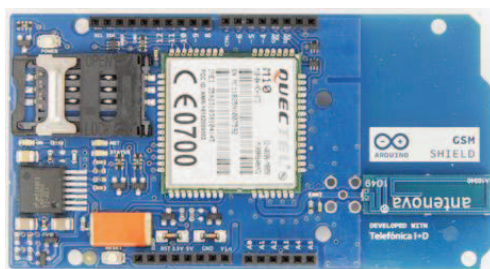Applications: Security, IoT, GPS Tracking System

Fig. 20. Arduino GSM Shield

E. Wi-Fi Shield 101

Arduino Wi-Fi Shield is made for IoT based applications with crypt-authentication as security feature. Wi-Fi shield has in-built library for connecting to Arduino board to Internet via IEEE 802.11 standard. The shield is based on Atmel SmartConnect-WINC1500 module which supports 802.11 b/g/n upto the speed of 72Mbps.

TABLE VII: TECHNICAL SPECIFICATIONS OF WIFI SHEILD

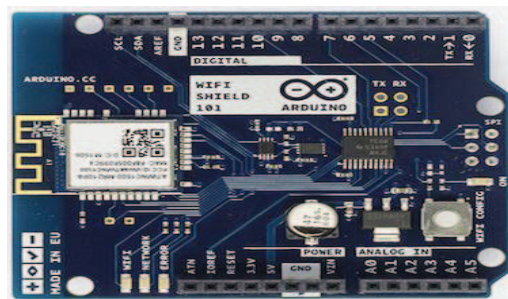| Parameters	Values
Operating Voltage	3.3V, 5V
Encryption Standards Supported	WEP, WPA2
Security Feature	CrrptoAuthentication
Interfacing Port	SPI
LED's	ON, WIFI, ERROR, NETWORK

Applications: IoT, Robotics, WLAN, Home Automation

Fig. 21. Arduino Wi-Fi Shield

V. CONCLUSION AND FUTURE SCOPE

In this Research Paper, a comprehensive review of standard Arduino boards, Lilypad's and Arduino Shields along with their technical specifications cum real-world applications is enlighted. This paper will assist researchers to explore Arduino technology and to choose specific Arduino boards, Lilypad's and Arduino shields as per their research interests. This research paper will act as strong platform for researchers, embedded system professionals and hobbyists to develop their own customized and feature-rich boards cum shields in future for developing projects and implementable market-ready products.

In future, our research would be on the development of IoT enabled devices using Lilypad, Sensor Network based on Arduino and Lilypad technology and also in near future, research would be to propose own customized built Arduino Shield integrating various sensors (Temperature, Humidity, Event, Gyro/Accelerometer) to launch market ready Arduino Based Out-of- Box Shield.

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