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A Review of Intel Galileo Development Board's Technology

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ABSTRACT
Intel Galileo, A Smart Arduino Based Development Board is cost-effective and efficient development board by Intel Corporation. Three variants- Gen 1, Gen 2 and Edison is already being launched in the market. Intel, being a market leader in development of Processor Technology is constantly researching and improving the Galileo Technology. The board can lay strong foundation for embedded system researchers to develop various DIY projects and build more energy efficient and cost effective products taking Galileo as the central controller. The aim of this research paper is to highlight Intel Galileo Development Board Technology- Its features, Board Components, Technology Available till date and Platform for programming various projects.
Keywords—Intel, Intel Galileo, Intel Galileo-Gen1, Intel Galileo Gen 2, Intel Edison, Development Board, Arduino, Intel XDK, Arduino IDE.

I.   INTRODUCTION

The world of Electronics and IoT (Internet of Things) is changing at a rapid pace and bringing new innovations and inventions in the area of Science, Medicine, Space, Transportation and Wearable Technology and in turn making the world SMART. Various manufactures have launched various development boards to facilitate programmers and researchers to make smart projects in the area of Smart Home Automation, Robotics, Drones and DIY Projects. In terms of development, researchers across the nook and corner of the world are making use of 8051, PIC, Arduino, AVR and ARM technology.

Taking into consideration the various Microcontroller Technologies and other hardware development boards, Intel Corporation, USA has launched their own development board: INTEL GALILEO [1] [2] [6]- which is regarded as "*Single Board Computer"* on 17 October, 2013. Intel Galileo is regarded as development board which is developed on the line of Arduino Certified development boards and is purely based on Intel x86 Architecture focusing mainly on Smart Home Projects, DIY Projects and providing base for various sensors interfacing.

Intel Corporation has integrated Intel Technology along with support for Arduino ready expansion boards i.e. Arduino Shield along with Arduino IDE [8] and libraries to facilitate smooth project development and easy to code interface for the programmers. In addition to this, to make the board smarter and gather more audience towards its future development, the board runs on Open Source Technology i.e. Linux Operating system along with Arduino Software Libraries and enabled re-usability of existing code called "sketches". Intel Galileo Board is live example of Platform Independence as this board can be programmed in OS X and Windows in addition to various flavors of Linux operating system. Basically overall the entire ecosystem of Arduino in terms of hardware and software is supported by Intel Galileo.

Brief Overview of Intel Galileo Technology
Intel Galileo Development board facilitates researchers, programmers and embedded system developers with a programmable control PCB. Intel Galileo board consists of Intel Quark SoC X1000 Application Processor which is a 32-bit Intel Pentium-class system. It is regarded as the first generation board based on Intel Architecture to be both hardware and software compliant with Arduino Shields designed for UNO R3. Arduino IDE can be used at front end for programming and sending code to the Board for easy interfacing. Till date, Intel Galileo Gen 1, Gen 2 and Intel Edison is launched by Intel Corporation to support development.

Organization of Paper
Section II provides details of Intel Galileo Technology- What is Intel Galileo Development Board, Board Components, Arduino Compatible Extension Pins, Features of Galileo board. Section III will cover comprehensive tabular based technical specifications comparison of various Intel Galileo Boards available till date. Section IV highlights Intel

XDK and Arduino IDE Software Environments and Section V includes conclusion and future scope.

OVERVIEW OF INTEL GALILEO TECHNOLOGY
In this section, overview of Intel Galileo Technology, Features and Technical Specifications is highlighted.

A. What is Intel Galileo Development Board? [3][4][1][12]
Intel Galileo is regarded as Arduino compatible- hardware development board enabling developers and researchers to develop interactive objects by reading information from the physical world, processing it and in turn taking action in the physical world.

Intel Galileo is a microcontroller board based on Intel Quark SoC X1000 Processor and is designed to be both hardware and software compliant with Arduino shields and especially designed for UNO R3.

Galileo consists of Digital Pins 0 to 13, Analog Inputs 0 to 5, power header, ICSP header, and UART port pins (0 and 1). This is also known as Arduino 1.0 pin out. Galileo is designed to facilitate shields operating at 3.3v or 5v. The operating voltage of Intel Galileo is 3.3v. But, with a jumper on board enables voltage translation to 5C at I/O pins.

Galileo board is also software compatible with Arduino IDE. In addition to this, the Galileo board has I/O ports and other features to expand native usage and capabilities beyond the Arduino shield ecosystem.

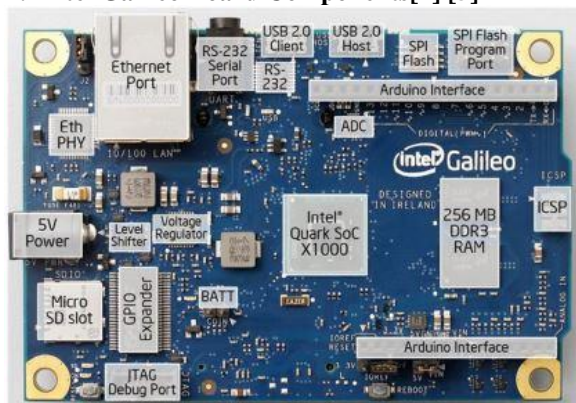**B. Intel Galileo Board Components[4] [5]**

Fig. 1 View of Intel Galileo Board

The following are the Board Components of Intel Galileo:
1. Processor- Intel Quark SoC X1000 (Codenamed: Clanton): Intel Quark SoC X1000 is a 32-bit low power consumption processor, x86 compatible with Pentium opcode instructions and implements various features like ACPI (Advanced Configuration and Power Interface)

and includes several interfaces which provides connections with external peripherals. Intel Quark Processor is basically regarded as the first processor compatible with IoT based wearable devices.
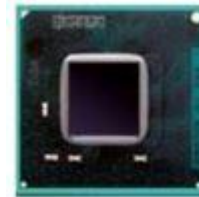

Fig.2 Intel Quark X1000 Processor

Technical Specifications: 400 MHz 32-bit Intel Pentium set Architecture (ISA)-Compatible processor; 16 KB L1 cache, 512 KB on-die embedded SRAM, RTC, 3V cell battery, ACPI compatible CPU sleep states supported.
2. Ethernet Port: 10/100 MBps Ethernet Port.
3. RS-232 serial port: 3-pin 3.5mm jack.
4. RS-232: RS-232 transceiver.
5. USB 2.0 client: Client connector; fully compliant USB 2.0 device controller and suitable for programming.
6. SPI Flash: 8MB Legacy SPI flash to store the firmware and the latest sketch.
7. SPI Flash Program Port: 7-pin header for Serial Peripheral Interface (SPI) programming. 4MHz to support Arduino UNO and programmable upto 25 MHz
8. Arduino Headers: SIP headers (Female Ports) for facilitating Arduino Shields.
9. ADC: Analog to Digital convertor.
10. ICSP: 6-pin in-circuit serial programming header to plug into existing shields.
11. RAM: 256 MB DRAM enabled by firmware by default.
12. JTAG debug port: 10-pin standard JTAG header for debugging.
13. GPIO expander: GPIO pulse width modulation provided by single I2C I/O expander.
14. Micro-SD slot: Supports upto 32 GB micro-SD card.
15. 5V DC power: Recommended power adapter is 5V at upto 3A.
16. Voltage Regulator: Generates a 3.3-volt supply. Max current draw to shield is 800mA.
17. Eth PHY: Ethernet physical later transceiver.
18. BATT: 3.3V battery terminal for internal Real Time Clock (RTC).

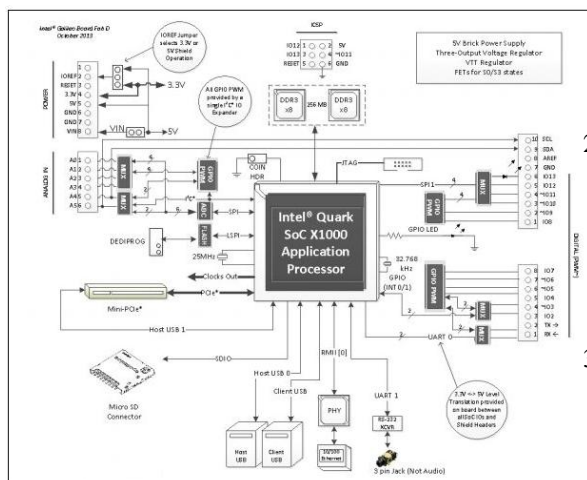The following diagram highlights Intel Galileo Connections:

Fig. 3 Intel Galileo Board Connection Diagram

C. Arduino Compatible Connection Pins [6] [9][10]

As, Intel Galileo board supports Arduino shields operating at 3.3V/5V. The pin layout of Intel Galileo board is as follows:

1. 14 Digital I/O Pins (IO2-IO13, TX, RX)
- 14 Digital Pins mainly used as input or output and make use of pinMode(), digitalWrite() and digitalRead() functions.
  o Pins operate at 3.3V/5V
  o 6 Digital pins can be used as Pulse Width Modulation (PWM) outputs and are labelled with ~ symbol.
  o RX & TX pins are used to control the programmable speed of UART port.
- SCL and SDA pins to control the I²C bus.
- AREF is unused.
- 6 Analog input pins (A0-A5):
  o Each pin provides 12 bits of resolution. By default, they measure from ground to 5 V.
- 7 Power Pins
  o IOREF: Allows an attached shield with proper configuration to adapt to the voltage provided by the board.
  o RESET button/pin: Bring this line LOW to reset the sketch.
  o 3.3 output pin: A 3.3 Volt supply generated by the on-board regulator.
  o 5V output pin: Pin outputs 5V from the external source.
  o GND: Ground pins.
  o VIN: Input voltage to the Galileo board.

D. Features of Intel Galileo Board/ Why Galileo?

The following are the Top 10 features of Intel Galileo Board and also highlights Why Galileo is Popular these days as compared to Arduino and other development boards:

1. Arduino Shield Compatibility: With the integration of expansion header on Galileo board,

the board becomes compatible for 3.3V / 5V shields designed for Uno R3. Galileo has 14 Digital I/O pins, 6 Analog Pins, Serial port and ICSP header.

2. Compatible with Arduino IDE: All the Galileo boards available till date can be programmed using Arduino IDE software and even firmware update can be done using Arduino IDE software. Ethernet Advantage: With Ethernet Port availability, board can be easily connected to Internet and facilitates almost each and every protocol like HTTP, FTP etc. available till date.

3. Real Time Clock: Galileo has onboard RTC so that proper connectivity via Internet can be there. For maintaining RTC, a 3.0 V cell batter is provided on board. Compatible with PCI Express Mini Cards: Galileo has an expansion slot for PCI express mini cards which gives the developers and programmers to connect various external cards like Wi-Fi, Bluetooth, GSM and even external HDD for expandable storage.

4. USB Host: With USB 2.0, all USB 2.0 devices like Keyboard, Mouse, HDD etc. can be connected to Galileo board. Micro SD Card Slot: Upto 32GB micro-SD card support, Galileo also supports installation of Linux operating system and other apps. SD card slot is accessible via Arduino SD card library.

5. TWI/I2C/SPI Support: Various components like TWI/I2C/SPI components can be connected to Galileo. Serial Connectivity: Serial port is used for connecting linux command line from the computer.

6. Onboard Linux: As Galileo is having 8MB flash memory onboard, a very light distribution of Linux can be installed and various other tools like ALSA-Sound Tool, V4L2- Video Input, SSH, Python, node.js, openCV can be installed.

II. TECHNICAL SPECIFICATIONS COMPARISON OF VARIOUS INTEL GALILEO BOARDS [1] [4][10][11]

In this section, a tabular comprehensive technical specification comparison would be covered of various Intel Galileo Boards:
Till Date, Intel Corporation has launched 3 models of Intel Galileo Boards:
1. Intel Galileo Development Board- Generation 1
2. Intel Galileo Development Board- Generation 2

Intel Edison Board.

The Table will give comprehensive comparison of Technical Specifications of 3 boards mentioned above.

III. INTEL XDK AND ARDUINO IDE DEVELOPMENT ENVIRONMENT

To facilitate development in Intel Galileo Board, Arduino IDE environment and Arduino Libraries and also Intel XD- Cross Platform Development Environment is available.

E. Intel XDK- Development Kit [10][13]

Intel XDK is a cross-platform development kit created by Intel to develop native apps for mobile phones, tablets using various web technologies like HTML5, CSS and JavaScript. Intel XDK is available for cross-platform operating systems supporting Windows, Linux and even OS X. Apps being developed using Intel XDK can be compiled online via Cordova platform which in turn does the work for making apps-platform independent.
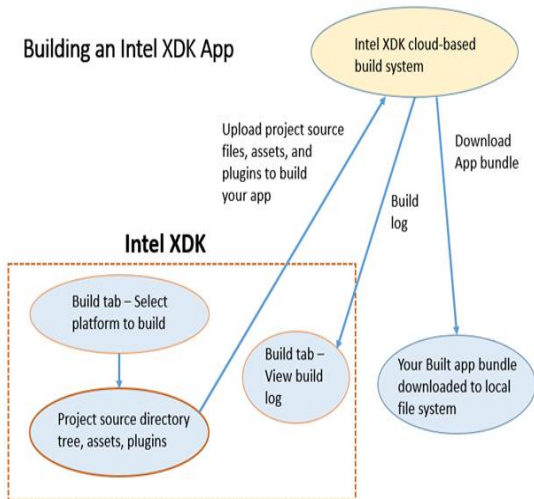

Fig. 4. Overview of Intel XDK Platform Operating Procedure

The latest version of Intel XDK is v2727 available on November, 2015.

Fig. 5 GUI Interface of Intel XDK

The following are the Top features of Intel XDK:
1.   Automatic Code Generation
2.   Code Completion
3.   Emulator
4.   Device Testing via Intel App Preview Mobile App
5.   Cordova and Third Party Plugins Support
6.   Drag and Drop UI Layout Builder
7.   Expanded Device AP Support
8.   One Click Store Deployment
9.   Remote Server Compiling
10.   Support for Android, iOS, Windows 8/10, Chrome OS, Firefox OS, Tizen OS

Arduino IDE Environment[8]

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.

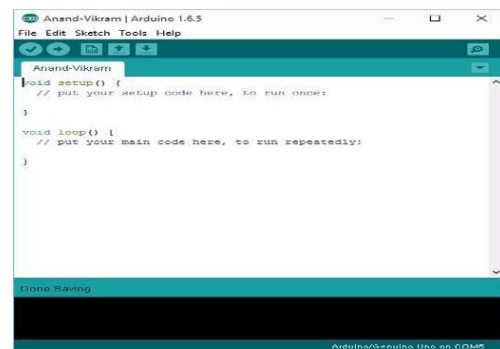The following figure will highlight the screenshot of Arduino IDE.

Fig. 6 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] 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. 7. 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.

IV. CONCLUSION

In this paper, a comprehensive review of Intel Galileo- Arduino Based Development board is being carried out. Intel Galileo supports all Libraries of Arduino and can be used for making various sorts of DIY project in terms of Smart Home Automation, Robotics, Drones and even can used for successful implementation of Smart Cities projects. The paper would become a strong base for researchers to take up this board and make projects by combining Intel and Arduino Technology.

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Sr. No	Basis of Difference	Intel Galileo (Generation 1)	Intel Galileo (Generation 2)	Intel Edison
	Dimensions	10x7 cm	123.8 mm (L) x 72.0 mm (W)	35.5 x 25.0 x 3.9 mm
	Processor	400 MHz 32-bit Intel Pentium Instruction set- 16 KB L1 Cache, 512 KB SRAM, ACPI Compatible and Integrated RTC.	Intel Quark SoC X1000	22 nm Intel SoC featuring dual-core, dual-threaded Intel Atom CPU at 500 MHz and 32-bit Intel Quark Microcontroller at 100 MHz
	RAM	256 MB DRAM	256 MB DDR3	1 GB LPDDR3 POP Memory (2 Channel 32bits@800MT/Sec)
	Power	5V	7 to 15 V	3.3 to 4.5v
	Ports	10/100 MB Ethernet RJ45 Port, USB 2.0 Port, USB 2.0 Host Port, mPCIe Slot with USB 2.0 Host support	USB 2.0 Host Port, USB 2.0 Client Port, UART, mPCIe Slot with USB 2.0 Host Support	1 USB 2.0 OTG Controller
	Flash Storage	8 MB SPI Flash; microSD card support upto 32 GB	8 KB EEPROM; 8MB NOR Flash, Upto 32-GB microSD card support	4 GB eMMC
	External Interfaces	UART, ICSP, SPI, I^2C, TWI	6-pin 2 UART, 6-pin ICSP, 10-pin JTAG, 1 SPI, 1 I^2C, 6 PWM with 12-bit resolution.	2 UART, 2 I^2C, 1 SPI, 1 I2S
	Pins	14 Digital I/O, 6 Analog	20 Digital I/O, 6 Analog Inputs	12 GPIO
	Firmware Cum Software	Arduino IDE/ Linux Operating System	Arduino IDE/Linux Operating System	Arduino IDE, Eclipse with C/C++, Python Support, Intel XDK supporting Node.JS and HTML 5, Yocto Linux v 1.6
	Price	$70	$75	$100
	Diagram			

Table 1: Comprehensive Tabular Comparison of Various Intel Galileo Boards Available Till Date