Galileo, Linux and the Internet of Things

Brian DeLacey
1/15/2014
@ MIT BLU

http://blu.org/cgi-bin/calendar/2014-jan

IoT Festival – www.iotfestival.com
The parts of this talk

- **Galileo**
  - Quark
  - Arduino

- **Linux**
  - Linux InstallFest on 3/1/2014
  - [http://blu.org/cgi-bin/calendar/2014-ifest51](http://blu.org/cgi-bin/calendar/2014-ifest51)

- **IoT (Internet of Things)**
  - IoT Festival on 2/22/2014

Audience

- How many own a Galileo?
- How many own an Arduino?
- How many own a RPi, BBB, or other?
- Who writes code?
- Who does web development?
- Who does electronics / hardware?
- Who plans to “make” something this year?
- Who owns a thermostat?
Nice Nest

A $3 billion thermostat any idiot can install

CNN's Jarrett Bellini was assigned to buy a Nest, install it and report back. If he wasn't electrocuted in the process, that is. WATCH

More: Google's plot to take over your digital life • Today, the Nest -- tomorrow, the world! • How the Nest thermostat was created • Tony Fadell on why he sold Nest to Google • Wait a second -- Google owns WHAT?

Source: http://www.cnn.com, 1/14/2014

Hardware Evolution

“How the Nest thermostat was created”
CNN Money, 3/25/2013 (link)
Atom

Next Unit of Computing (NUC)
What’s Next? Edison

- Galileo is not Edison
- Edison is in the future:
Galileo

Introduction to Galileo

“The Intel® Galileo board is based on the Intel® Quark SoC X1000, a 32-bit Intel Pentium®-class system on a chip (SoC). It is the first board based on Intel® architecture designed to be hardware and software pin-compatible with shields designed for the Arduino Uno R3.

The Galileo board is also software-compatible with the Arduino Software Development Environment, which makes getting started a snap.”

Source: Intel® Galileo Product Brief
https://communities.intel.com/docs/DOC-21836
Galileo Development Board Layout

Matt’s Top 10

- Shield Compatibility
- Familiar IDE
- Ethernet Library Compatibility
- Real Time Clock (Battery not included)
- Works with PCI Express Mini Cards
- USB Host Port
- MicroSD Support
- TWI/I2C, SPI Support
- Serial Connectivity
- Linux on Board

Source: Matt Richardson, http://makezine.com/2013/10/03/10-great-intel-galileo-features/
Intel Galileo Board Characteristics

**Physical Characteristics**
- 10 cm long and 7 cm wide with the USB connectors
- UART jack
- Ethernet connector
- Four screw holes
- Reset button for sketch

**Processor Features**
- 400 MHz 32-bit Intel® with 512K on-die SRAM, 800 MTs Memory Speed
- TDP 1.9W – 2.2W (depending on VR), 15mm x 15mm
- Pentium® instruction set architecture (ISA) compatible processor
- Supports Arduino shields
- Integrated Real Time Clock (RTC), with optional 3V "coin cell" battery
- Operating temps from 0 to 70 degrees C (commercial) and more variants soon

**Storage Options**
- 8 MByte Legacy SPI Flash to store firmware (bootloader) and the latest sketch
- Between 256 KByte and 512 KByte dedicated for sketch storage
- 256 MByte DRAM
- Optional micro SD card offers up to 32GByte of storage
- USB storage works with any USB 2.0 compatible drive
- 11 KByte EEPROM programmed via the EEPROM library


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Intel Galileo Block Diagram

Check Out The Schematics

Source: Galileo Schematic - https://communities.intel.com/docs/DOC-21822

Galileo Documentation

- Index into Galileo Documentation
  - https://communities.intel.com/community/makers/documentation/galileodocuments
- Galileo Product Brief
  - https://communities.intel.com/docs/DOC-21836
- Galileo FAQ
  - https://communities.intel.com/message/207619
- PDF Overview
Where to buy?

- Adafruit
- Amazon
- Micro Center
- Mouser
- Newegg
- RS
- Fry's: In stores


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Quark
Intel Quark SoC X1000 Block Diagram

Source: Quark Product Brief
https://communities.intel.com/docs/DOC-21829

Quark Software Stack

Source: Quark Product Brief
https://communities.intel.com/docs/DOC-21829
Quark as an SoC

A typical SoC consists of:

- A microcontroller, microprocessor or DSP core(s). Some SoCs—called multiprocessor system on chip (MPSoc)—include more than one processor core.
- Memory blocks including a selection of ROM, RAM, EEPROM and flash memory.
- Timing sources including oscillators and phase-locked loops.
- Peripherals including counter-timers, real-time timers and power-on reset generators.
- External interfaces including industry standards such as USB, FireWire, Ethernet, USART, SPI.
- Analog interfaces including ADCs and DACs.
- Voltage regulators and power management circuits.

Source: http://en.wikipedia.org/wiki/System_on_a_chip

Intel® Quark SoC X1000 (1 of 2)

- Launch Date Q4’13
- Processor Number X1000
- # of Cores 1
- # of Threads 1
- Clock Speed 400 MHz
- Cache 16 KB
- 512 KBytes of on-die embedded SRAM
- Instruction Set 32-bit
- Lithography 32 nm
- Max TDP 2.2 W
- Max Memory Size (dependent on memory type) 2 GB
- Memory DDR3-800
- # of Mem Channels 1
- Max Memory Bandwidth 1.6 GB/s
- Physical Address Extensions 32-bit
- Pkg Size 15mm x 15mm
- Sockets FCBGA393

Intel® Quark SoC X1000 (2 of 2)

- PCI Support - PCI Express
- PCI Express Revision 2.0
- PCI Express Configurations x1
- Max # of PCI Express Lanes 2
- USB Revision 2.0
- # of USB Ports 3
- # of SATA Ports 0
- Integrated LAN 2
- General Purpose IO 16UART2
- AES New Instructions? No
- Secure Key? No

Source: http://ark.intel.com/products/79084/Intel-Quark-SoC-X1000-16K-Cache-400-MHz

Supports Idle States (C-states)

- ACPI compatible CPU sleep states supported
- Idle States (C-states) are used to save power when the processor is idle.
- C0 is the operational state, meaning that the CPU is doing useful work.
- C1 is the first idle state
- C2 the second, and so on, where more power saving actions are taken for numerically higher C-states.

Source: http://ark.intel.com/products/79084/Intel-Quark-SoC-X1000-16K-Cache-400-MHz
Supports Execute Disable Bit

- Execute Disable Bit is a hardware-based security feature that can reduce exposure to viruses and malicious-code attacks and prevent harmful software from executing and propagating on the server or network.

Source: http://ark.intel.com/products/79084/Intel-Quark-SoC-X1000-16K-Cache-400-MHz

Quark Documentation

- Index into Quark Documentation
  - https://communities.intel.com/community/makers/documentation/quarkdocuments
- Quark Product Brief
  - https://communities.intel.com/docs/DOC-21829
- Quark SoC x1000 Core Developer’s Manual (311 pages)
  - https://communities.intel.com/docs/DOC-21826
- Intel® Quark SoC X1000 Core – Hardware Reference Manual (143 pages)
  - https://communities.intel.com/docs/DOC-21825
- Quark Spec Update (20 pages)
  - https://communities.intel.com/docs/DOC-21827
- Quark Board Support Package (18 pages)
  - https://communities.intel.com/docs/DOC-21882
Arduino

- Fascinating History since 2005
- Low cost, single-board computer
- Built around a microcontroller (not an SoC)
- Open source hardware and software
- Major role in the “Maker Revolution”
  - Major influence on 3D Printer Developers
    - http://reprapbook.appspot.com/
- A de facto standard of Physical Computing
- “Hello, World” equivalent for an Arduino?
  - A sketch that makes an LED blink!

Arduino in Words

"Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software running on a computer (e.g. Flash, Processing, MaxMSP).

The boards can be built by hand or purchased preassembled; the software can be downloaded for free. The hardware reference designs (CAD files) are available under an open-source license, you are free to adapt them to your needs."

Sources: http://arduino.cc/

Arduino in Pictures
Arduino Shields

- After-market creations of Printed Circuit Boards
- Connect into pre-defined, standardized Arduino pin headers
- Offer enhanced functionality, e.g. GPS
  - Early Arduino boards lacked network connectivity
  - Ethernet shields became popular “add-ons”
  - Galileo offers neatly integrated and more affordable networked capabilities; this is a major step forward.
- Allows creative customization and application
- Widely available and have led to vibrant ecosystem of hardware/software vendors
- Compatibility considerations as hardware evolves

How do you “use” Galileo?
Getting Started

- Study the “Getting Started Guide” (14 pages)
  - https://communities.intel.com/docs/DOC-21838
- Arduino Site
- Best Hardware Intro Video Ever
  - http://www.youtube.com/watch?v=20NX3fT9Ek
- Link to other good Galileo Launch Videos
  - http://www.youtube.com/user/TheIntelJim/videos

Galileo Software Downloads

- Board Support Packages
- Linux 32 bit
- Linux 64 bit
- Linux Image for SD
- Little Linux Image
- Windows
- MacOSX
- ...and more
Installation and Operation

- Plug in the power cord
- Connect Micro USB cable
  - Micro-USB cable not supplied with purchase
  - Similar cable used by many cell phone chargers
- Install Drivers
  - Excellent online documentation for Windows, Mac and Linux; Look beyond the shipping box for docs!
  - Install Arduino IDE on a desktop or laptop
  - Create an Arduino sketch blink an LED
  - Create an Arduino sketch to assign an eth0 address
  - Install Intel’s SD card configuration if you want to do more (e.g. Run Python)
- Read available documentation to SSH into the Galileo from other, network-connected systems
- Study the “Getting Started Guide” (14 pages)
  - https://communities.intel.com/docs/DOC-21838

Windows Device Driver
Driver Success!

Arduino Firmware Upgrade
Prototyping Apps

- **Sensors / Components / Switches**
  - Try iTeadStudio’s electronic bricks!
- **Breadboards, Standoffs**
- **Jumper Wire**

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Arduino Sketch

```c
int motion_1 = 2;
int light_1 = 13;
void setup(){
  pinMode (motion_1,INPUT);
  pinMode (light_1, OUTPUT);
}

void loop (){,
  digitalWrite (light_1,LOW);
  delay(1000); //let the sensor settle down before reading
  int sensor_1 = digitalRead(motion_1);
  if (sensor_1 == HIGH){
    digitalWrite(light_1,HIGH);
    delay(500);
    digitalWrite(light_1,LOW);
    delay(500);
  }
}
```
Demo!

Galileo Sensor Application
Galileo Development

Networked Galileo Configuration

Standard Linux, Windows, or Macintosh computer to transfer sketches, programs, and data files to Galileo

Power Supplies and Energy Measurement

Galileo 55
Linked with Sensors

Displays shows sensor values in web browser
Tiny Web Server

A Tiny Web Server is running on the Galileo Dev Board. A number of sensors and circuits are also connected to Galileo.

The Galileo was given a static IP address through an Arduino sketch. It is connected to a network via ethernet. (WiFi is an option through PCI Express.)

An Arduino script starts a local web server on Galileo. The script reads and sets state of the analog and digital pins. Values for the pins are sent over a client connection, to a browser on the network.

Where to Buy Component Electronics

- Itead Studio
  - http://blog.iteadstudio.com/
  - www.iteadstudio.com

- Adafruit
  - www.adafruit.com

- Texas Instruments
  - www.ti.com

- Mouser Electronics
  - www.mouser.com

- Digi-Key
  - www.digikey.com

- Modern Device
  - www.moderndevice.com

- Element 14
  - www.element14.com

- Newark
  - www.newark.com
References For Creating Things

Linux

A follow-on presentation
February 19, 2014
Will Cover Linux on Galileo In-Depth
http://blu.org/cgi-bin/calendar/2014-feb
**Basic Shell / Linux Commands**

- top
- dmesg
- route
- history
- `more /etc/network/interfaces`
- lspci
- lsusb
- exit
- `uname –amnrspv`
- `cat /proc/meminfo`
- `cat /proc/cpuinfo`
- `cat /proc/version`
- `free`
- `df`
- `ls -a`
- `reboot`
- .....

**Arduino Sketches and the Linux Kernel**

- Arduino IDE runs on a desktop or laptop
- The IDE is used to create programs called sketches
- Sketches are transferred over the USB port to Galileo and then they run
- The Arduino I/O adaptor handles communication with the Linux Kernel

Source: Galileo Product Brief
https://communities.intel.com/docs/DOC-21836
Where do Arduino & Linux Meet?

```c
/*
  This example shows how to read the temperature of the Quark SoC
*/
char temp_raw[6];
int temp;
void setup() {
  Serial.begin(115200);
}
void loop() {
  temp = getQuarkTemp();
  Serial.print("The temperature of the Quark SoC is ");
  Serial.print(temp);
  Serial.println(" degrees celcius.");
  delay(1000);
}
int getQuarkTemp()
{
  FILE *fp;
  fp = fopen("/sys/class/thermal/thermal_zone0/temp", "r");
  fgets(temp_raw, 5, fp);
  fclose(fp);
  int temp = atoi(temp_raw);
  temp /= 100;
  return temp;
}
```

Arduino IDE examples calling Linux

GalileoLinuxExamples.zip

[Source: https://communities.intel.com/docs/DOC-22272](https://communities.intel.com/docs/DOC-22272)

Galileo Linux Examples

- Arduino IDE examples implementing Linux commands
- **Non-Persistent**
  - Linux_ADCTemperature
  - Linux_Serial
  - Linux_USBShell
  - Linux_QuarkTemperature
  - Linux_SystemTime
  - Linux_QuarkTouchSensor
  - Linux_TelnetShell

  *Examples just posted on January 15, 2014!*

- **Persistent**
  - Linux_PythonScript

[Source: https://communities.intel.com/docs/DOC-22272](https://communities.intel.com/docs/DOC-22272)
Galileo I/O Mapping

Galileo I/O Function Mapping
Galileo & Linux

- Default Linux
  - Poky
  - Yocto
  - [https://www.yoctoproject.org/](https://www.yoctoproject.org/)
  - [http://www.yoctoproject.org/docs/current/kernel-dev/kernel-dev.html](http://www.yoctoproject.org/docs/current/kernel-dev/kernel-dev.html)
- Bash Shell – ls, history, etc.
  - [http://ss64.com/bash/](http://ss64.com/bash/)
- Full Fat Linux
  - Debian, Whatever ...
  - [https://communities.intel.com/message/218148](https://communities.intel.com/message/218148)
- ROS Hydro
- GPIO Chunks
- More on this at the 2/19/2014 meeting

IoT

Internet of Things
Much more to follow
On 2/22/2014 at the
[www.iotfestival.com](http://www.iotfestival.com)
What’s driving IoT?

- Here are TEN attributes that are key:
  1. Small
  2. Smart
  3. Sensors
  4. Connected
  5. Processors
  6. Energy-Efficient
  7. Low-cost
  8. Reliable
  9. Creative
  10. Innovative
Embedded Silicon

“...embedding silicon into simple items around the house so that they can communicate with you and other devices is fascinating in its own right, and is poised to be a massive industry.”

http://www.dailyfinance.com/2014/01/11/is-intel-on-the-cusp-of-the-next-tech-revolution/

Wolsam’s Hierarchy of IoT Economics

- Complex System
  - $$$$$$$
- Equipment
  - $$$$$
- Gateway
  - $$$
- Thing
  - $$
- Tool
  - $$
- Part
  - $ 

Source: Brian
The Market For IoT


Investing in IoT

“Intel Capital topped the list of most active investors in the Internet of Things. Since 2012 Intel Capital has done 10 deals in this space, according to CB Insights. Deals include Redwood City, Calif.-based Arrayent...; San Jose, Calif.-based Gainspan...; San Francisco-based Basis Science...; and Kitchener, Ontario-based Thalmic Labs, which is developing a gesture controlled armband.”

Thank You!

Questions?