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 IoT Initiative

Home	Agenda	FAQ	Sponsors	IoT Initiative

Internet of Things Festival
BOSTON • Saturday • Feb 22, 2014

The IoT Fest is one full day of free public celebration of creativity, technology, and the internet. Speakers, demonstrations and hands-on sessions at MIT will cover personal, commercial, and civil applications of IoT. Take this time to connect your real and digital worlds and celebrate what IoT can offer.

Creativity fused with technology and the internet - together we will make things.

DATE: Saturday, February 22, 2014
LOCATION: MIT Buidling E51, Cambridge, MA

News

JAN 14 — Welcoming Texas Instruments , Intel, Isis3D, O'Reilly, and Canonical as premiere sponsors!

JAN 14 — The TI University Program is offering a cool, online embedded processing course!

JAN 14 — Intel's Galileo Development Board is here today, and Edison was announced at CES.

JAN 14 — Isis3D will be creating and making things with their new Isis One 3D printer as part of the "Creator's Hut"

JAN 14 — O'Reilly helps you learn - check out "Getting Started with the Internet of Things: Connecting Sensors and Microcontrollers to the Cloud"

TEXAS INSTRUMENTS

CANONICAL

Isis3D

O'REILLY

intel

The parts of this talk

- Galileo
  - Quark
  - Arduino
- Linux
  - Linux InstallFest on 3/1/2014
  - http://blu.org/cgi-bin/calendar/2014-ifest51
- IoT (Internet of Things)
  - IoT Festival on 2/22/2014
  - http://www.iotfestival.com/

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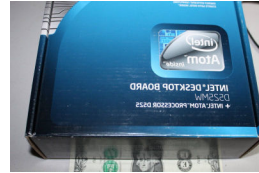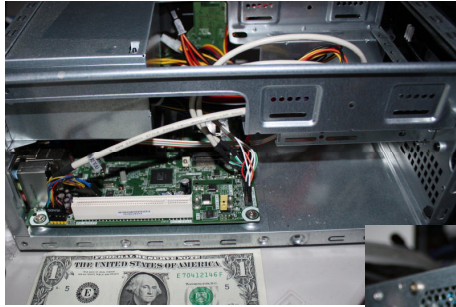
Source: http://www.cnn.com, 1/14/2014

Hardware Evolution

**"How the Nest thermostat was created"
CNN Money, 3/25/2013 (link)**

3
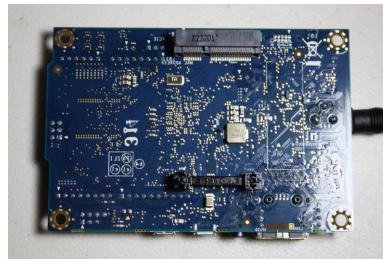
Atom

Next Unit of Computing (NUC)

Galileo

What's Next? Edison

- Galileo is not Edison
- Edison is in the future:
  - http://www.intel.com/content/www/us/en/do-it-yourself/edison.html

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
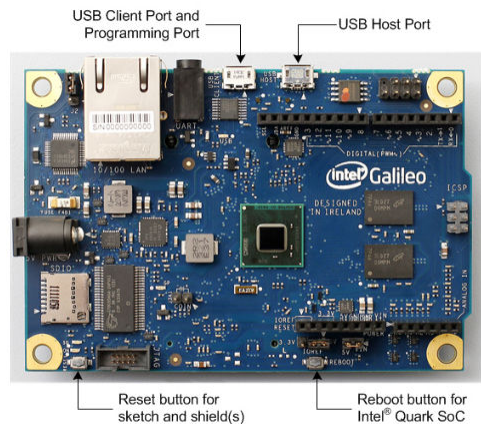
Matt's Top 10

- 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
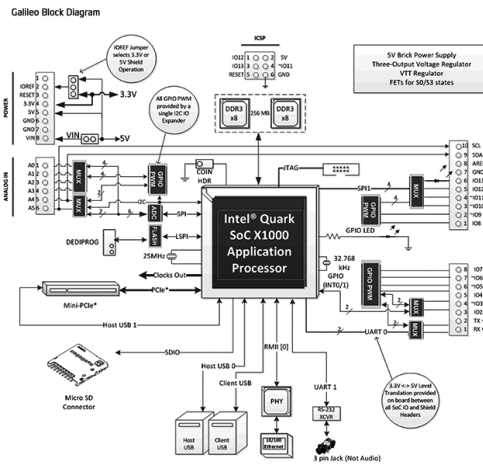Reset button for sketch

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
Source: http://www.intel.com/content/www/us/en/intelligent-systems/galileo/galileo-overview.html

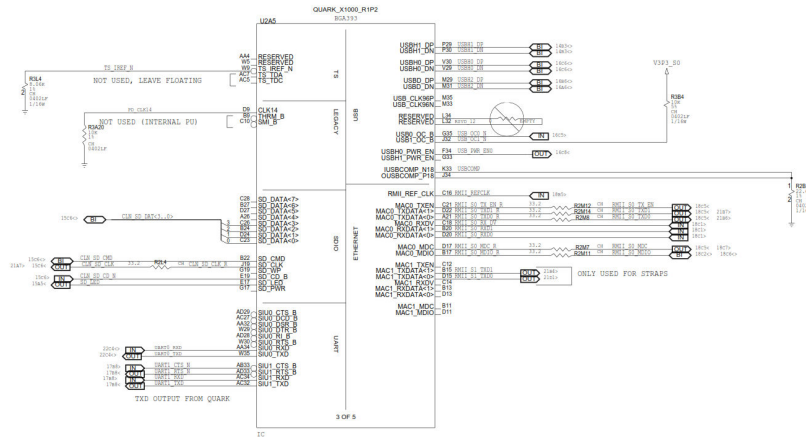# Intel Galileo Block Diagram

Source: http://www.intel.com/content/www/us/en/intelligent-systems/galileo/galileo-overview.html

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

Source: http://www.intel.com/content/www/us/en/do-it-yourself/where-to-buy.html as of 1/18/2014

Quark

Intel Quark SoC X1000 Block Diagram

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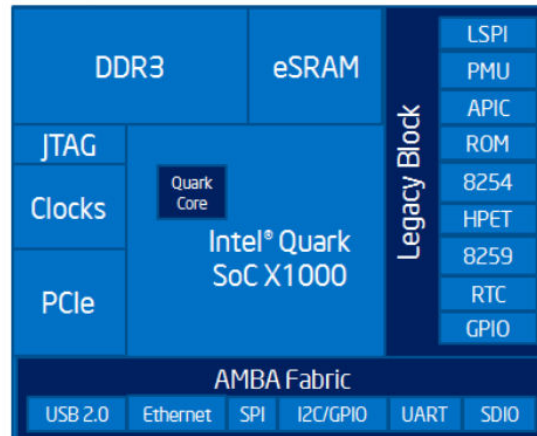
Quark Software Stack

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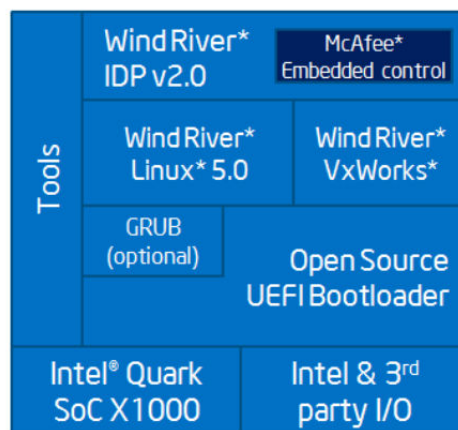
Quark as an SoC

□ 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

Source: http://ark.intel.com/products/79084/Intel-Quark-SoC-X1000-16K-Cache-400-MHz
and http://www.intel.com/content/www/us/en/intelligent-systems/galileo/galileo-overview.html

Intel® Quark SoC X1000

- 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

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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

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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

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!

Sources: http://arduino.cc/ and
http://en.wikipedia.org/wiki/Arduino

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
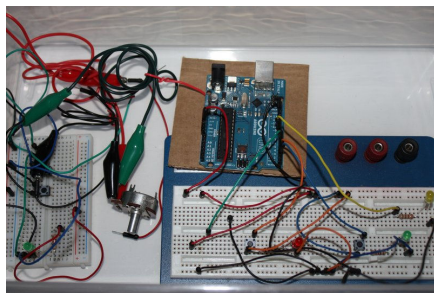
Arduino Shields

- After-market creations of Printed Circuit Boads
- 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
  - http://arduino.cc/en/ArduinoCertified/IntelGalileo
- Best Hardware Intro Video Ever
  - http://www.youtube.com/watch?v=20NXO6fT9Ek
- Link to other good Galileo Launch Videos
  - http://www.youtube.com/user/TheIntelJim/videos

Intel® Galileo Board Hardware Overview
channelintel 5,658 videos   10,718

Galileo Software Downloads

- Board Support Packages
- Linux 32 bit
- Linux 64 bit
- Linux Image for SD
- Little Linux Image
- Windows
- MacOSX
- …and more
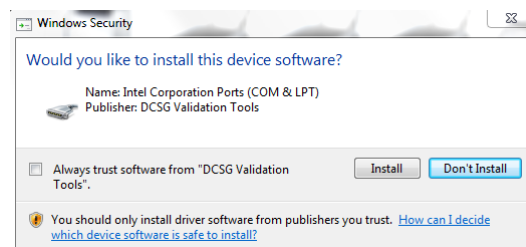 - https://downloadcenter.intel.com/Detail_Desc.aspx?DwnldID=23171
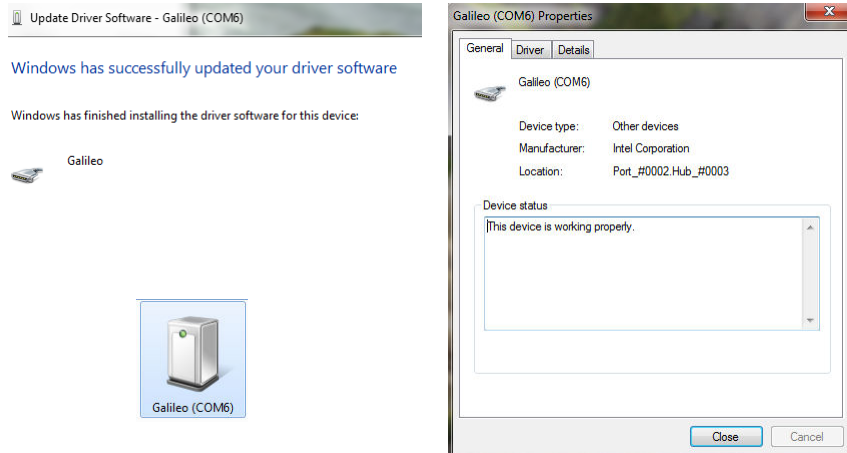
Installation and Operation

- 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)*
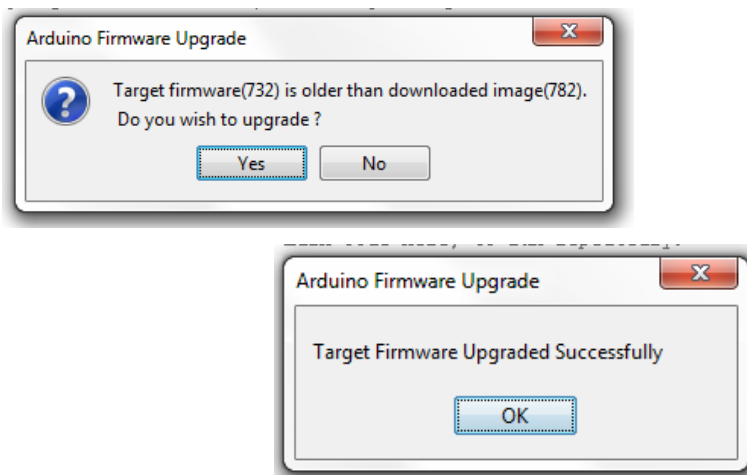 - *https://communities.intel.com/docs/DOC-21838*

Windows Device Driver

Driver Success!

Arduino Firmware Upgrade

Prototyping Apps

- Sensors / Components / Switches
  - Try iTeadStudio's electronic bricks!
  - http://imall.iteadstudio.com/prototyping/electronic-brick.html
- Breadboards, Standoffs
- Jumper Wire

Arduino Sketch

```
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);
  }
}
```
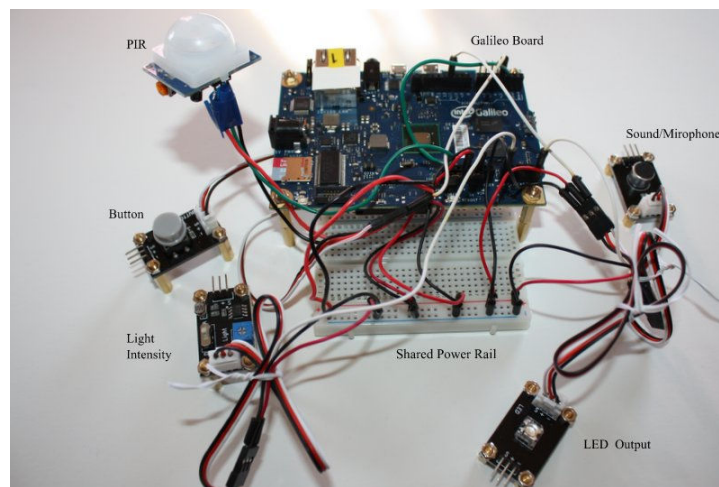
Demo!

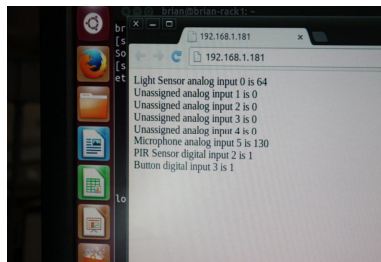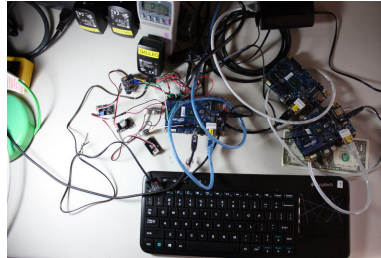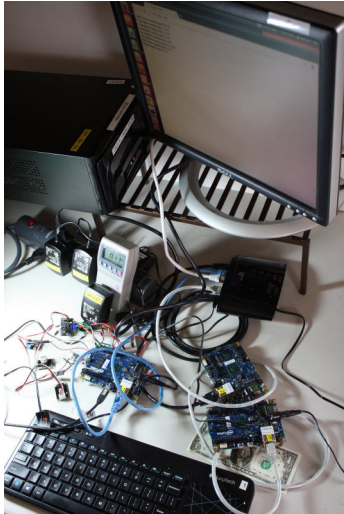---

Galileo Sensor Application

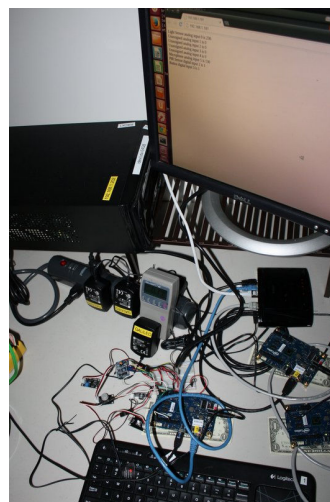# Galileo Development

Networked Galileo Configuration

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

Display shows sensor values in web browser

Network Router

Power Supplies and Energy Meter

Galileo #2 Runs Python
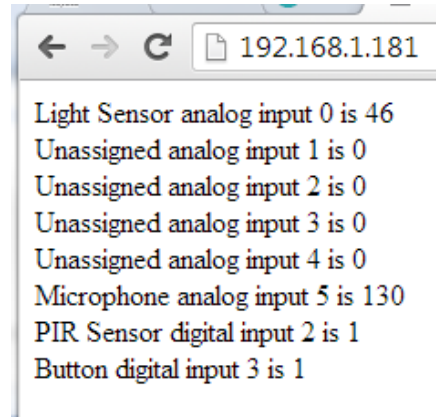
Galileo #1 Loaded with Sensors

Galileo #3 Experiments
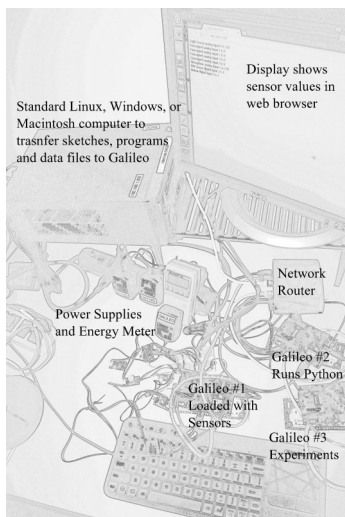
Tiny Web Server

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 throgh 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.

192.168.1.181

Light Sensor analog input 0 is 46
Unassigned analog input 1 is 0
Unassigned analog input 2 is 0
Unassigned analog input 3 is 0
Unassigned analog input 4 is 0
Microphone analog input 5 is 130
PIR Sensor digital input 2 is 1
Button digital input 3 is 1

Where to Buy Component Electronics

ITEAD STUDIO
make innovation easier
http://blog.iteadstudio.com/

adafruit
www.adafruit.com

Digi-Key CORPORATION
www.digikey.com

Newark element14
www.newark.com

TEXAS INSTRUMENTS
www.ti.com

MOUSER ELECTRONICS
www.mouser.com

sparkfun
www.sparkfun.com

MODERN DEVICE
www.moderndevice.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

Intel® Galileo

Sketch

Arduino I/O Adapter

I/O Driver

Linux Kernel
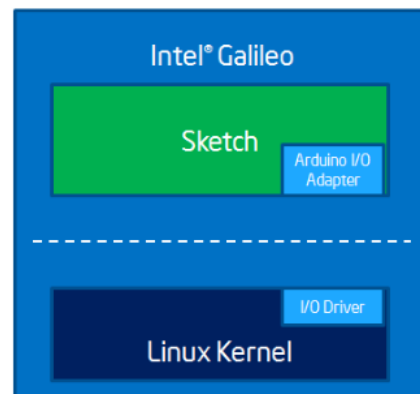
Source: Galileo Product Brief
https://communities.intel.com/docs/DOC-21836

Where do Arduino & Linux Meet?

```
/*
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

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

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Galileo I/O Mapping

Galileo I/O Mappings

Arduino IDE ID	GPIO Source	GPIO Pin	Linux	PWM Linux	Int	Dir	Muxed with	Initial Setup
IO0	Cypr	GPORT4_BIT6_PWM2	50	N/A	-	BI	UART0_RXD	I w/ pullup off
IO1	Cypr	GPORT4_BIT7_PWM0	51	N/A	-	BI	UART0_TXD	I w/ pullup off
IO2	SoC (Cypr)	GPIO<6> (GPORT0_BIT4_PWM7)	14 (32*)	-	0	BI	-	I w/ pullup off
IO3	SoC (Cypr)	GPIO<7> (GPORT0_BIT2_PWM3)	15 (18*)	3	1	BI	(PWM)	I w/ pullup off
IO4	Cypr	GPORT1_BIT4_PWM6	28		-	BI	-	I w/ pullup off
IO5	Cypr	GPORT0_BIT1_PWM5	17	5	-	BI	(PWM)	I w/ pullup off
IO6	Cypr	GPORT1_BIT0_PWM6	24	6	-	BI	(PWM)	I w/ pullup off
IO7	Cypr	GPORT1_BIT3_PWM0	27		-	BI	-	I w/ pullup off
IO8	Cypr	GPORT1_BIT2_PWM2	26		-	BI	-	I w/ pullup off
IO9	Cypr	GPORT0_BIT3_PWM1	19	1	-	BI	(PWM)	I w/ pullup off
IO10	Cypr	GPORT0_BIT0_PWM7	16	7	-	BI	(PWM) SPI1_SS_B	I w/ pullup off
IO11	Cypr	GPORT1_BIT1_PWM4	25	4	-	BI	(PWM) SPI1_MOSI	I w/ pullup off
IO12	Cypr	GPORT3_BIT2_PWM3	38		-	BI	SPI1_MISO	I w/ pullup off
IO13	Cypr	GPORT3_BIT3_PWM1	39		-	BI	SPI1_SCK	I w/ pullup off
IO14	Cypr	GPORT4_BIT0_PWM6	44		-	BI	AD7298:VIN0	I w/ pullup off
IO15	Cypr	GPORT4_BIT1_PWM4	45		-	BI	AD7298:VIN1	I w/ pullup off
IO16	Cypr	GPORT4_BIT2_PWM2	46		-	BI	AD7298:VIN2	I w/ pullup off
IO17	Cypr	GPORT4_BIT3_PWM0	47		-	BI	AD7298:VIN3	I w/ pullup off
IO18	Cypr	GPORT4_BIT4_PWM6	48		-	BI	AD7298:VIN4	I w/ pullup off
IO19	Cypr	GPORT4_BIT5_PWM4	49		-	BI	AD7298:VIN5	I w/ pullup off

* See Galileo I/O Function Muxing table below.

Galileo I/O Function Mapping

Galileo I/O Function Muxing

Mux Selector 0	Mux Selector 1	Cypress GPIO pin	Linux GPIO ID	Dir	Initial Setup
UART0_RXD	IO0	GPORT3_BIT4_PWM7	40	O	unknown
UART0_TXD	IO1	GPORT3_BIT5_PWM5	41	O	unknown
SPI1_SS_B	IO10	GPORT3_BIT6_PWM3	42	O	unknown
SPI1_MOSI	IO11	GPORT3_BIT7_PWM1	43	O	unknown
SPI1_MISO	IO12	GPORT5_BIT2_PWM3	54	O	unknown
SPI1_SCK	IO13	GPORT5_BIT3_PWM1	55	O	unknown
AD7298:VIN0	IO14	GPORT3_BIT1_PWM5	37	O	0
AD7298:VIN1	IO15	GPORT3_BIT2_PWM3	36	O	0
AD7298:VIN2	IO16	GPORT0_BIT7_PWM1	23	O	0
AD7298:VIN3	IO17	GPORT0_BIT6_PWM3	22	O	0
AD7298:VIN4	IO18	GPORT0_BIT5_PWM5	21	O	0
AD7298:VIN5	IO19	GPORT0_BIT4_PWM7	20	O	0
IO2 via SoC GPIO<6>	IO2 via Cypress GPORT0_BIT4_PWM7	GPORT1_BIT7_PWM0	31	O	unknown
IO3 via SoC GPIO<7>	IO3 via Cypress GPORT0_BIT2_PWM3	GPORT1_BIT6_PWM2	30	O	unknown
I2C	(AD7298:VIN4 or IO18) and (AD7298:VIN5 or IO19)	GPORT1_BIT5_PWM4	29	O	1

Galileo & Linux

- Default Linux
  - Poky
  - Yocto
  - https://www.yoctoproject.org/
  - http://www.yoctoproject.org/docs/current/kernel-dev/kernel-dev.html
- Bash Shell – ls, history, etc.
  - http://ss64.com/bash/
- Full Fat Linux
  - Debian, Whatever …
  - https://communities.intel.com/message/218148
- ROS Hydro
  - http://wiki.ros.org/IntelGalileo/How%20to%20install%20ROS%20Hydro%20on%20Intel%20Galileo
- GPIO Chunks
  - http://www.malinov.com/Home/sergey-s-blog/intelgalileo-programminggpiofromlinux
- 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

IoT Festival – 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. "

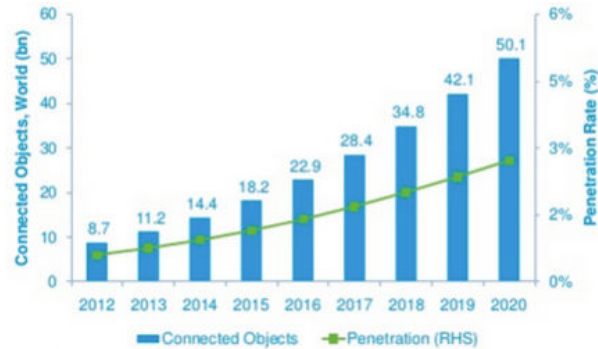 ▪ http://www.dailyfinance.com/2014/01/11/is-intel-on-the-cusp-of-the-next-tech-revolution/
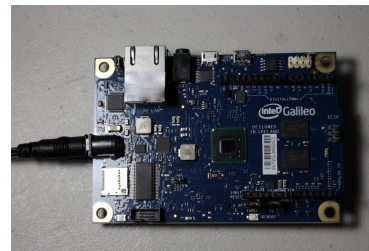
Wolsam's Hierarchy of IoT Economics

□ Complex System
  ▪ $$$$$$$
□ Equipment
  ▪ $$$$$
□ Gateway
  ▪ $$$$
□ Thing
  ▪ $$$
□ Tool
  ▪ $$
□ Part
  ▪ $

Source: Brian

The Market For IoT

Penetration of connected objects in total 'things' expected to reach 2.7% in 2020 from 0.6% in 2012

Source: Cisco

http://seekingalpha.com/article/1943631-intel-thinking-beyond-mobile

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."

Source:http://www.bizjournals.com/portland/blog/2014/01/are-you-an-internet-of-things-company.html, 1/15/2014

Thank You!

Questions?