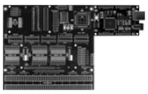
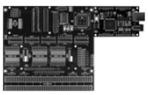


EEL3744

Menu

- Elements of Microcomputer
- Components of a Microcontroller
- Microprocessor Applications
- Autonomous Mobile Agents
- History of the Microprocessor
- Instruction Set Processors
- GCPU
- Other Embedded Computer Systems



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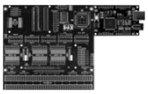
Elements of Microcomputer

- Microprocessor
- RAM (Random Access Memory)
- ROM (Read Only Memory)
  > PROM, EPROM, EEPROM
- I/O Devices
- Interface Components



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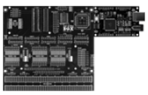
Components of Microcontroller

(a single chip microcomputer)

- CPU (Central Processing Unit)
- ALU (Arithmetic Logic Unit)
- Address/Data/Control Bus
- RAM/ROM
- I/O lines and Buffers
- Registers
- Timers & Clock circuitry
- A/D & D/A



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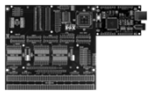
Microprocessor Applications

- Cars
  > Engine, Pollution controls, Anti-lock brakes, Instrument panels, etc.
- Portable Devices
  > Pagers, Cellular phones, Multi-meters, etc.
- Peripheral Computer Devices
  > Keyboard, Modems, Printers, etc.
- Others: Microwave ovens, Security Systems, TVs, etc.
- Autonomous Mobile Agents



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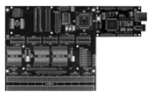
Autonomous Mobile Agents

- Later in the semester I'll show you many of the robots that we have built in IMDL or MIL since 1994
  - > Many were built by undergraduates
  - > Some are now MIL group projects



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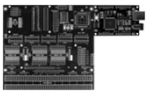
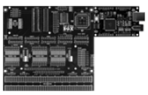
Microprocessor (μP) History

- When we say μP, we are talking about the brains of the computer. But of course a brain without significant memory or a body is not very useful, so the bulk of a computer are all the other components necessary to communicate with and challenge the brain.



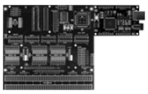
EEL3744
Microprocessor (μP) History

- 1968
  > Attempted the first single chip computer (Viatron)
- 1969
  > Intel got into the act developing calculators for BusiCom
- 1970
  > HP calculator $300.
  > 4KB of Magnetic Core Memory cost about $18,000 in today's dollars.



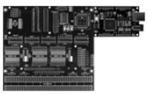
EEL3744
Microprocessor (μP) History

- 1971-1972
  > Intel 4004 4-bit μP
  > Intel then decided one of the best ways to start the spread of μP was to put them in cash registers. They were right!
- 1973
  > Intel's 8008 and the 8008A were introduced, both 8-bit processors.



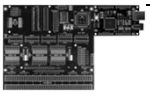
EEL3744
Microprocessor (μP) History

- 1974-1975
  > Motorola got into the game with an 8-bit processor, the 6800.
- 1974-1978
  > Z-80, 6502, 8085 (used to teach 3701 with this), 8088 (8-bit bus/16-bit μP), 8086 (16-bit μP), and 68000 (16-bit).
- 1979
  > Motorola 6805



EEL3744
Microprocessor (μP) History

- 1980-1982
  > Motorola 68020, 68030 (32-bit)
  > Intel 80186, 80286 (16-bit) and separate coprocessors & memory management chips
- 1983-1986
  > Motorola 68040 (32-bit)
  > Intel 80386 (32-bit)
- 1987
  > Intel 80486



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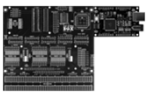
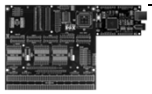
Microprocessor (μP) History

- 1989 – 2000
  - > Intel 80586 (Pentium), 80686 (Pentium Pro), with MMX, Pentium II, [non-Intel 80786], Pentium III, Pentium 4, Core Duo, Athlon
- 2000-2010
  - > Athlon 64, Pentium M, Xeon, Atom, Core I7
- Early 80's: microcontroller (μC) were introduced:
  - > Intel started with 8048
    - – Then the 8049, 8050, 8051 and the 8096 (in Peatman)
  - > Motorola moved the 6800 line into a μC with 68HC11's in 1985.
  - > In 1997, Motorola introduced the 68HC12, a 16-bit μC
  - > All Motorola's chips above 6800 will execute the 6800 instructions.
- Late 80's: VLSI PALs, PLAs, **DSPs**, etc.
- 90's: CPLD, FPGA, ASIC's

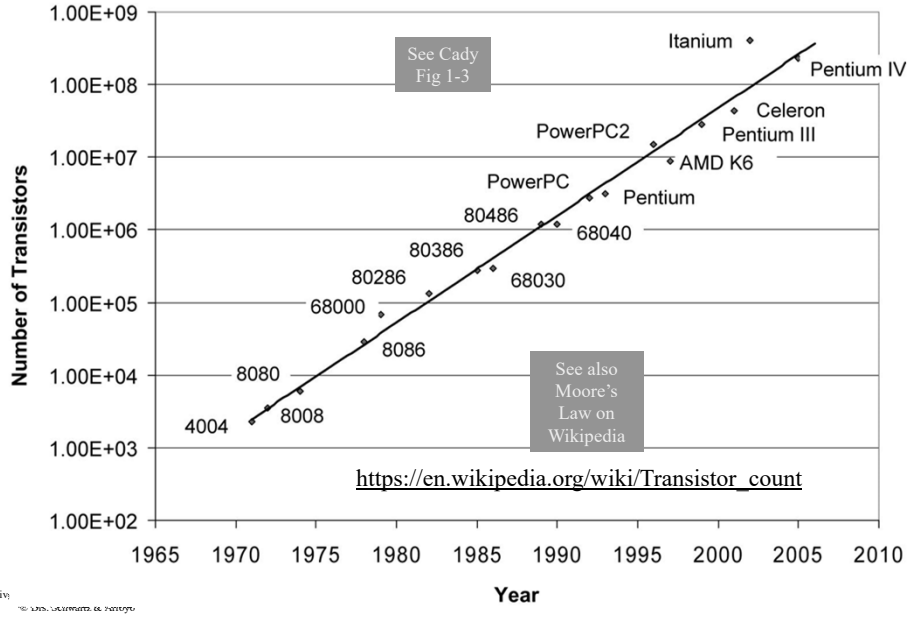


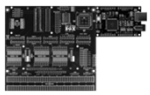
EEL3744
Microprocessor (μP) History

- During all this growth, the costs of μP (and μC) remains relatively constant, but the functionality grew
  - > Now we have **real-time** control, fast and low power chips
  - > μP's are entire computers on a chip
  - > μC's are μP's with RAM, ROM, I/O (plus interface logic and control module), timers, A/D, D/A, etc.
  - > μP's and μC's have built-in extensibility, i.e., can expand their function with additional chips for more: RAM, ROM, Ports (I/O lines)

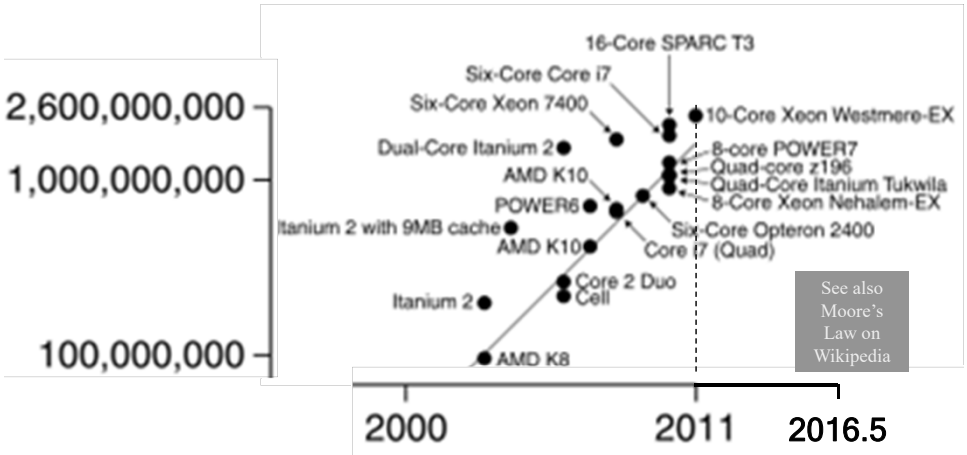


EEL3744 # of Transistors in µPs



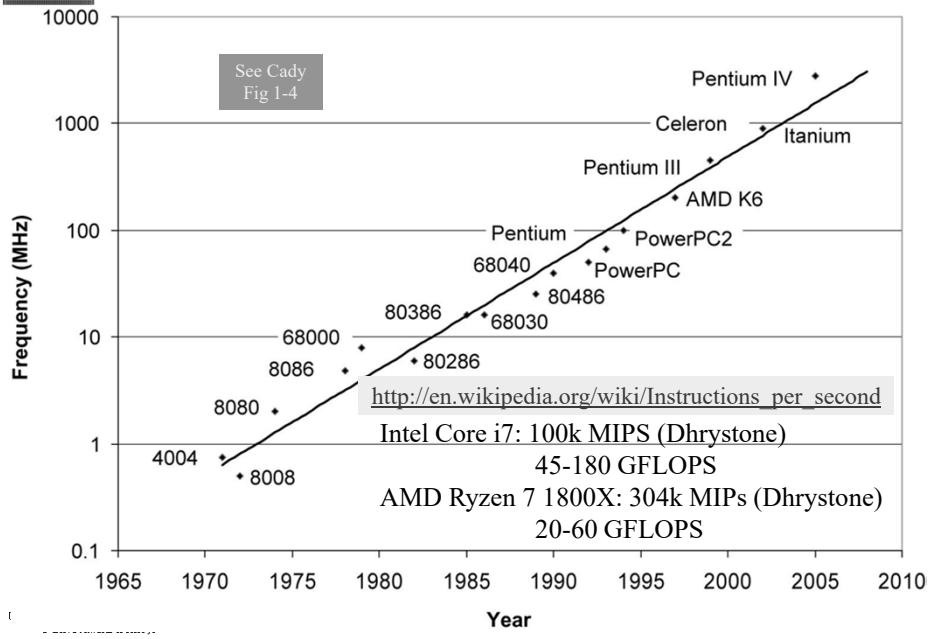


EEL3744 # of Transistors in µPs



http://en.wikipedia.org/wiki/Moore%27s_law

EEL3744 μP Speeds



http://en.wikipedia.org/wiki/Instructions_per_second

Intel Core i7: 100k MIPS (Dhrystone)
45-180 GFLOPS
AMD Ryzen 7 1800X: 304k MIPs (Dhrystone)
20-60 GFLOPS

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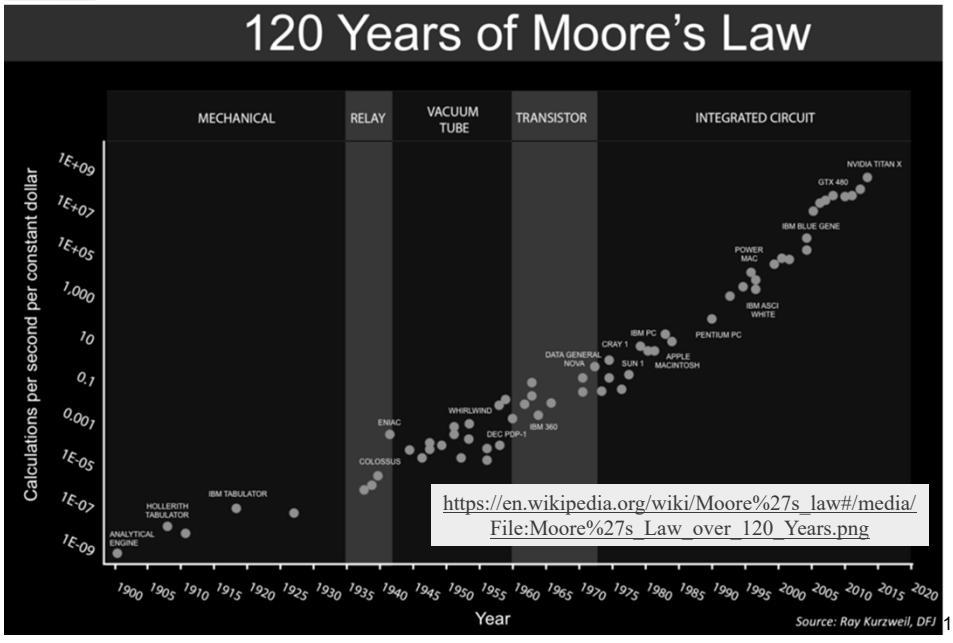
EEL3744 Calculations/sec/Constant $



https://en.wikipedia.org/wiki/Moore%27s_law#/media/File:Moore%27s_Law_over_120_Years.png

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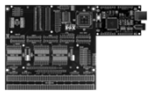

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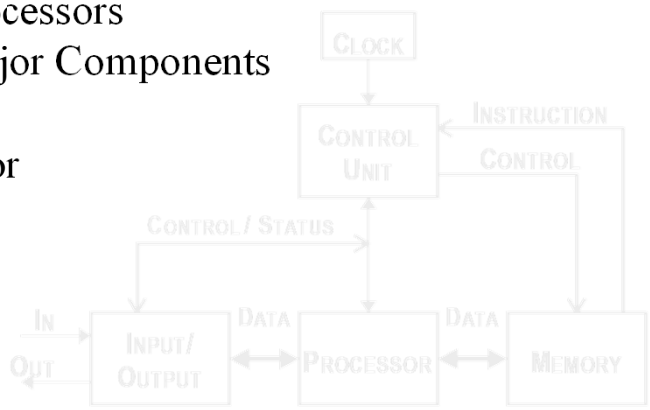
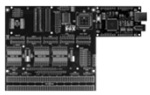
Instruction Set Processors

Instruction Processors
Functional/Major Components
- The Clock
- The Processor
- Control Unit



Von Neumann (aka Princeton) Architecture



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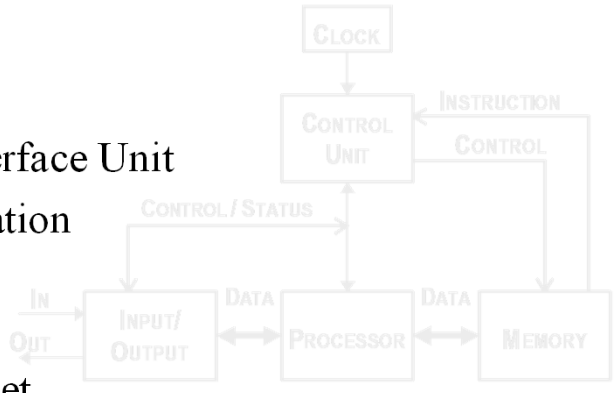
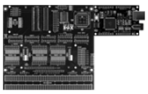
Instruction Set Processors

- The Memory
  - > Binary-Coded Instructions
    - – Program
    - – Software
  - > Data Numbers
- Input/Output Interface Unit
- Instruction Operation
  - > Fetch Cycle
  - > Execute Cycle
- The Instruction Set



Von Neumann Architecture



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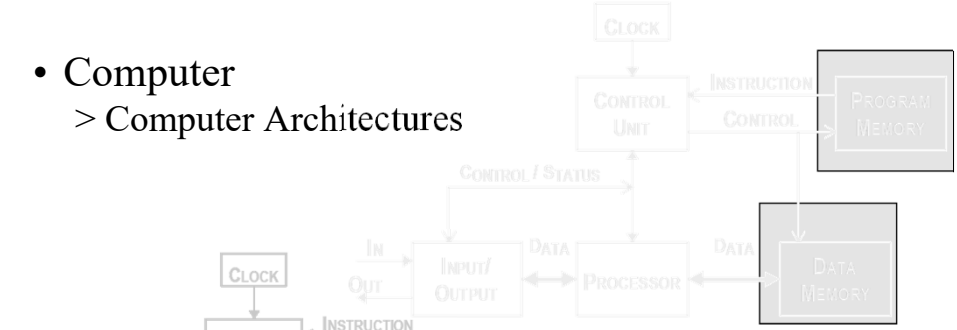
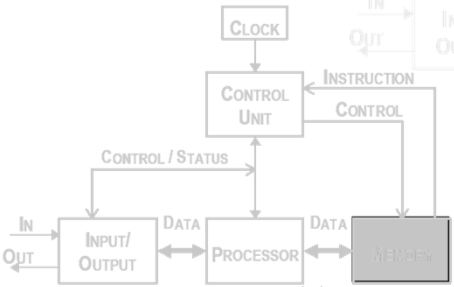
Instruction Set Processors

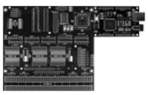
- Computer
  - > Computer Architectures



Harvard Architecture



Von Neumann Architecture



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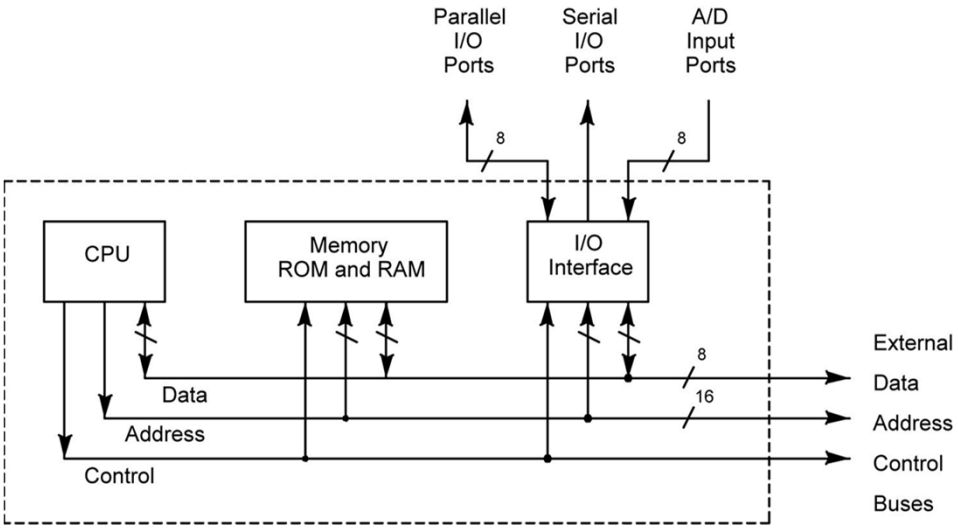
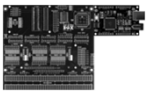
See Cady ch01, slide 2

Von Neumann Computer Architecture





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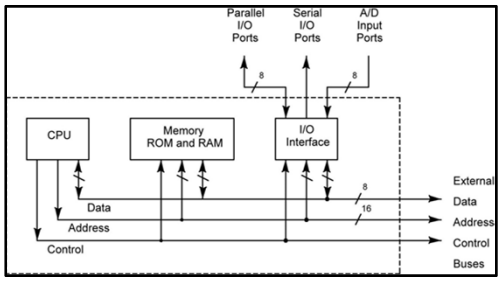
Von Neuman



Harvard Computer Architecture

See Cady ch01, slide 3

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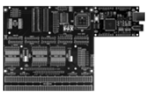

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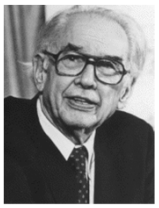
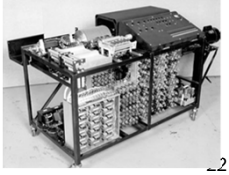
Atansoff - Berry Computer (ABC)

- John Atansoff and Clifford Berry are recognized as having created the **first** electronic digital computing device in 19**37**
  - > Atansoff graduated from the **University of Florida** (with an **EE** degree) in 19**25** (0x25 = 37)



- The ABC concepts were borrowed, without permission, to build ENIAC in the 1940s
  - > A 1973 lawsuit established that Atanasoff was indeed the "**father of the digital computer**"
  - > "It was at an evening of **scotch and 100 mph car rides**," John Atanasoff told reporters, "when the concept came, for an electronically operated machine, that would use **base-two** (**binary**) numbers instead of the traditional base-10 numbers, condensers for memory, and a regenerative process to preclude loss of memory from electrical failure."



University of Florida, EEL 3744 – File **02**
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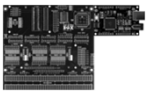

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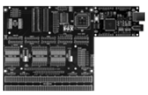
Why Assembly Language?

- Why should you learn assembly language?
  - > Sometimes, assembly is the best solution for a particular program where efficiency (speed or storage) matter!
  - > See http://techcrunch.com/2014/01/04/snappylabs/
- We will start the course using assembly language and then migrate to C
  - > There is **no expectation** that you know how to program in C today



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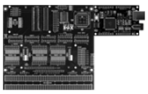
GCPU

- The GCPU is very much like the 68HC11 and 68HC12 and also the Atmel AVR and Atmel XMEGA microcontrollers
  - > But you already know how the GCPU works!
  - > The instruction sets are all similar, but **English ≠ Spanish ≠ Chinese** …
- See website



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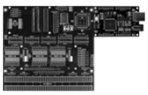
Atmel AVRs (see Wikipedia)

- There 6 basic families of Atmel AVRs

tinyAVR: the ATtiny series
- > 0.5–16 kB program memory
- > 6–32-pin package
- > Limited peripheral set

megaAVR: the ATmega series
- > 4–512 kB program memory
- > 28–100-pin package
- > Extended instruction set (multiply instructions and instructions for handling larger program memories)
- > Extensive peripheral set



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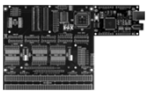
Atmel AVRs (see Wikipedia)

XMEGA: the ATxmega series
- > 16–384 kB program memory
- > 44–64–100-pin package (A4, A3, A1)
- > Extended performance features, such as DMA, "Event System," and cryptography support
- > Extensive peripheral set with DACs

Application-specific AVR
- > megaAVRs with special features not found on the other members of the AVR family, such as LCD controller, USB controller, advanced PWM, CAN, etc.



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Atmel AVRs (see Wikipedia)

FPSLIC (AVR with FPGA)

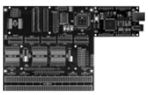
> FPGA 5K to 40K gates
> SRAM for the AVR program code, unlike all other AVRs
> AVR core can run at up to 50 MHz

32-bit AVRs

> AVR32
  – They include SIMD and DSP instructions, along with other audio and video processing features
  – Intended to compete with the ARM based processors
  – Instruction set is similar to other RISC cores, but is not compatible with the original AVR or any of the various ARM cores

Atmel also makes ARMs

> Called SAM or the SMART line (**S**mart **A**tmel **M**icrocontroller)
  – Often used for IoT



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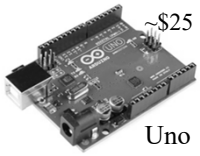
The Arduino Revolution



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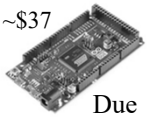
Uno

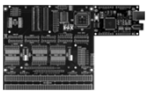
- **Arduino** is a single-board microcontroller designed to make the process of using electronics in multidisciplinary projects more accessible (i.e., for the hobbyist [non-engineer])
  > The hardware consists of a simple **open source hardware** board designed around an 8-bit Atmel AVR microcontroller, though a new model has been designed around a 32-bit Atmel ARM (i.e., the Arduino Duo)



~$37

Due

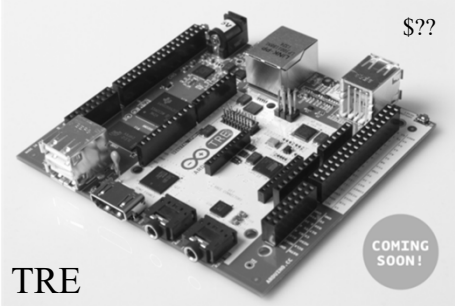
  > The software consists of a standard programming language compiler and a boot loader that executes on the microcontroller
  > See http://www.arduino.cc/ . Prices from $25 to $100
- **Arduido Shields** can be plugged on top of the Arduino PCB, extending its capabilities



EEL3744 The Arduino TRE (coming soon)

- **Arduino TRE** features
  - > Atmel ATmega32u4 @ 16 MHz
    - – Memory: 32 KB flash 2.5 KB SRAM; 1 KB EEPROM
    - – 14 digital I/O (5 V)
    - – 6 analog inputs (plus 6 from digital I/O)
    - – 7 PWM channels
  - > TI Sitara AM3359AZCZ100 (ARM Cortex-A8) @ 1 GHz
    - – Memory: 512 MB DDR3L RAM
    - – MicroSD card
    - – Ethernet 10/100
    - – 1 USB 2.0 device port
    - – 4 USB 2.0 host ports
    - – HDMI (1920x1080) video
    - – HDMI, stereo analog audio I/O
    - – 23 digital I/O (3.3 V)
    - – 4 PWM channels
    - – LCD expansion connector

http://www.arduino.cc/



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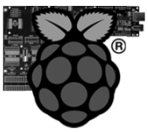


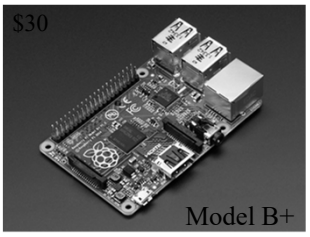
EEL3744 Raspberry Pi

Model A

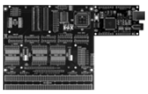
- Similar to the Arduino family of PCBs, the Raspberry Pi family is based around a single board computer

https://www.raspberrypi.org

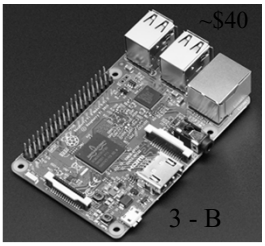
  - > Instead of an 8-bit microcontroller on the early Arduinos, the Raspberry Pis are built around **ARM** processors and can run Linux (as well as …)
- RP is an entry-level single board computer with
  - > USB keyboard and mouse inputs, Ethernet port, SD card slot
  - > TV port, PC monitor port
  - > Audio ports, LEDs, GPIO
  - > OS: Linux (3 varieties) + others



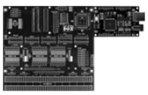
Model B+



EEL3744 Raspberry Pi



- **CPU:** 4× ARM Cortex-A53, 1.2GHz
- **GPU:** Broadcom VideoCore IV
- **RAM:** 1GB LPDDR2 (900 MHz)
- **Networking:** 10/100 Ethernet, 2.4GHz 802.11n wireless
- **Bluetooth:** Bluetooth 4.1 Classic, Bluetooth Low Energy
- **Storage:** microSD
- **GPIO:** 40-pin header, populated
- **Ports:** HDMI, 3.5mm analogue audio-video jack, 4× USB 2.0, Ethernet, Camera Serial Interface (CSI), Display Serial Interface (DSI)



EEL3744 TI LaunchPads

- MSP430/MSP432 LaunchPad Development Kits
  - > Like Arduino shields, TI LaunchPads have an assortment of BoosterPacks including
    - – Sensor Hub
    - – LCD
    - – RFID
    - – Touch Screen
    - – Capacitive Touch
    - – Wi-Fi
    - – Etc.

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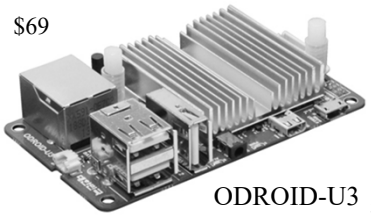
ODROID

www.hardkernel.com (now a **XU4** is available)

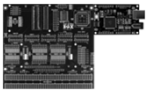
- Although the ODROID is less well known then the Raspberry Pi, it is more powerful
- ODROID-U3 includes the following:
  - > 1.7GHz Quad-Core processor and 2GByte RAM
  - > 10/100Mbps Ethernet with RJ-45 LAN Jack
  - > Audio codec with headphone jack on board
  - > XUbuntu 13.10 or Android 4.x Operating System
  - > Supports 1080p via micro HDMI cable
  - > 3 USB 2.0 host ports
  - > MicroSD Card Slot
  - > 83 x 48 mm
  - > 48g (w/ heat sink); 30g w/o

Same ARM as Samsung Galaxy s3

$69



ODROID-U3



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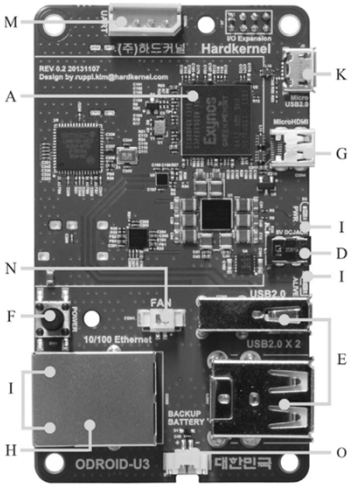
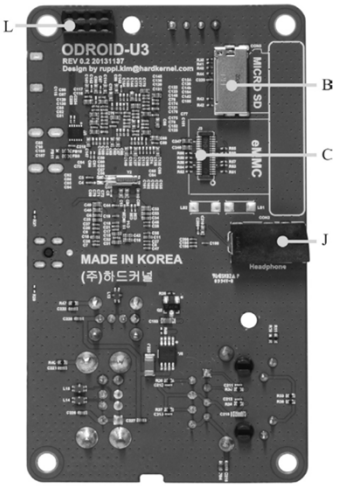
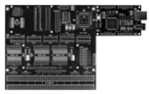
ODROID-U3: Under the Hood





- A – ARM µP
- B – SD card Slot
- C – eMMC Slot
- D – Power Jack
- E – USB Port
- F – Power Button
- G – HDMI Conn.
- H – Ethernet Port
- I – Status LEDs
- J – Analog Audio
- K – µ USB Conn.
- L – GPIO
- M – Serial Port
- N – PWM out for cooling fan
- O – RTC Batt. Conn.



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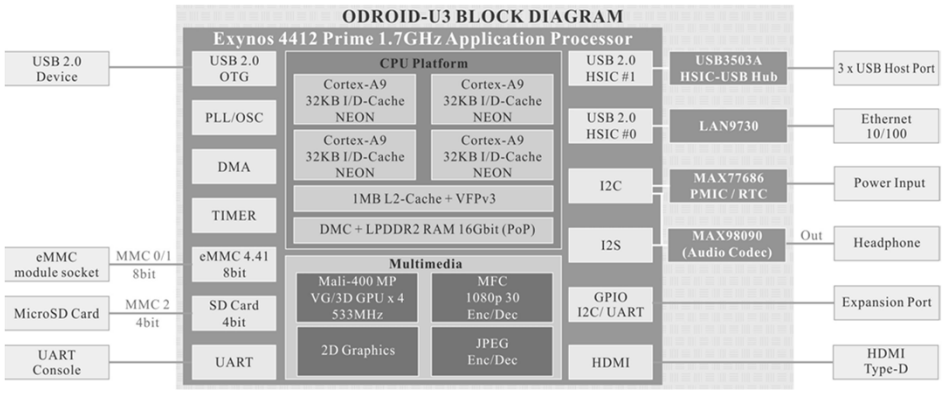
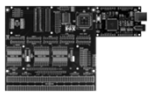
ODROID-U3 Block Diagram





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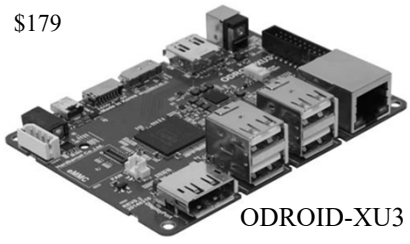
ODROID-XU3

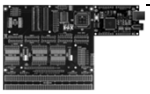
- Samsung Exynos5422 Cortex™-A15 2.0Ghz quad core and Cortex™-A7 quad core CPUs
- Can run multiple Linux flavors, e.g., $179
  - > Ubuntu 14.04 and Android 4.4
- 2Gbyte LPDDR3 RAM at 933MHz
- eMMC5.0 HS400 Flash Storage
- 1 USB 3.0 Host
- 1 USB 3.0 OTG
- 4 USB 2.0 Host
- HDMI 1.4a
- DisplayPort 1.1
- Integrated power consumption monitoring tool



ODROID-XU3

www.ameridroid.com

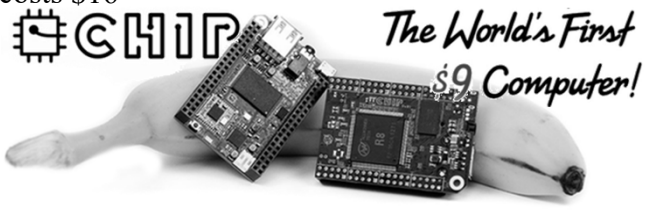
www.hardkernel.com

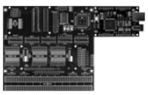


EEL3744 CHIP (now available!)

- SoC – Allwinner R8 Cortex A8 processor @ 1 GHz
  - > With Mali-400 GPU
- 80 GPIO
- 512 MB RAM, 4GB NAND flash
- Connectivity – 802.11 b/g/n Wi-Fi + Bluetooth 4.0
- Video Output – Composite video and audio
  - > HDMI and VGA available via adapters
- USB – 1x USB host port, 1x micro USB OTG port
- Two expansion headers
- Power – 5V via micro USB OTG or battery
- CHIP Pro costs $16

https://getchip.com/





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The End!