THE DESIGN OF A CIRCUIT BOARD

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From Conception to Assembly

Overview of Process

- Development of Specifications
- Schematic Capture
- Layout and Component Definition
- Prototype Manufacturing
- Software Options
- +Demonstrations of gEDA and Rev. 1 Product

Development of Specification

- What do you want your board to do?
- How will it communicate with any desired peripherals or output devices?
- Choose core components and interfaces
- Complete at least a block-level schematic of the layout between onboard devices and their interfaces

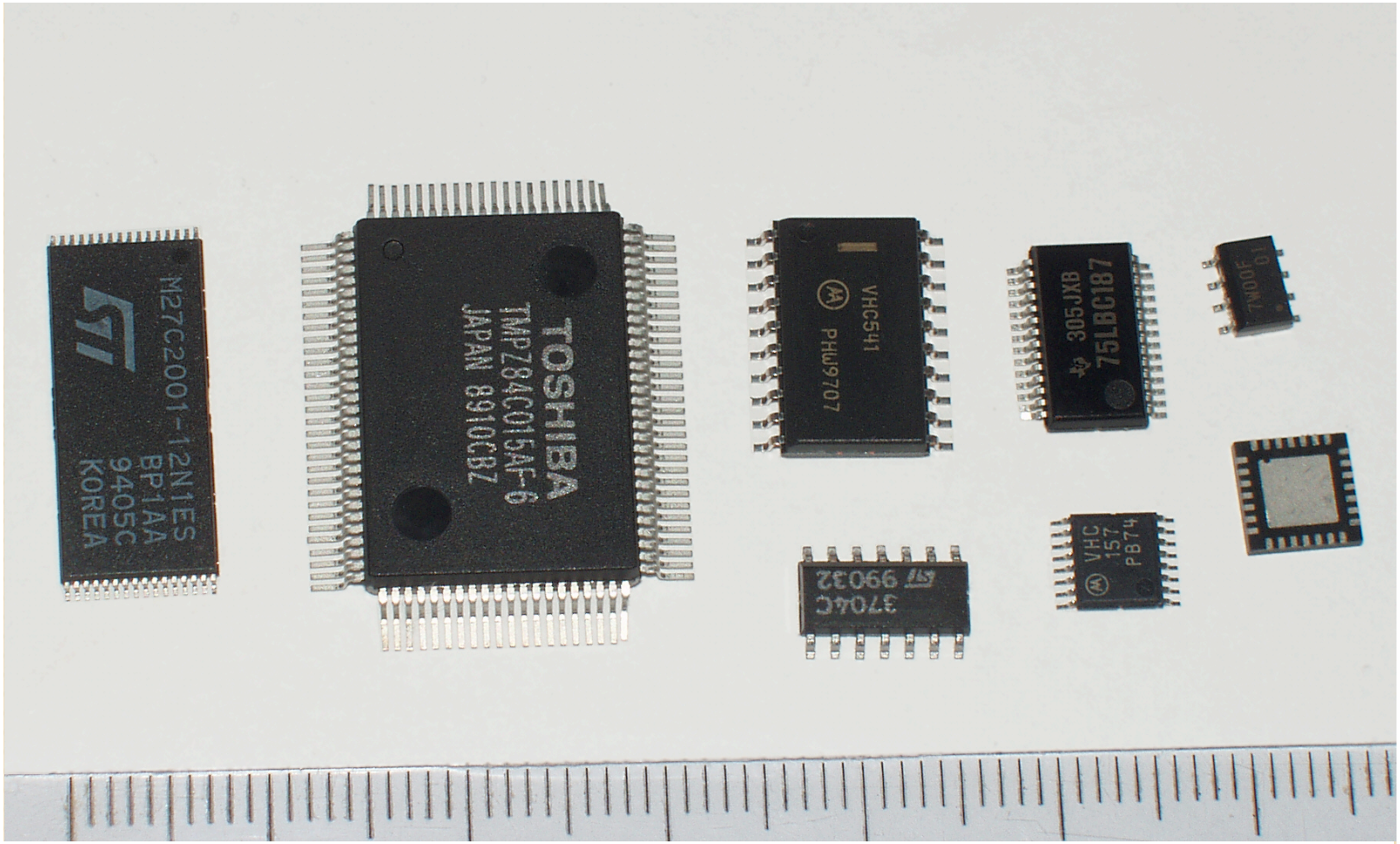
Schematic Capture

- Interconnection of components
- Need to have symbols to represent each component being used in the design
- Fulfillment of specifications
- Need to define initial power layout: supply, regulated rails, decoupling capacitors
- End: All connections made, Bill of Materials completed

Layout: Footprints and Form Factors

- Before the connections (netlist) from your schematic are useful, you have to know what the components your are using look like
- Need to look forward: some parts may be difficult or impossible to hand prototype
- Need accurate layouts: if something is critical and you didn't pay for it *with support*, you need to verify an existing design or DIY
- MIT Student: "To whoever uses the Sparkfun eagle library for a Nokia LCD footprint: the pins are reversed!"

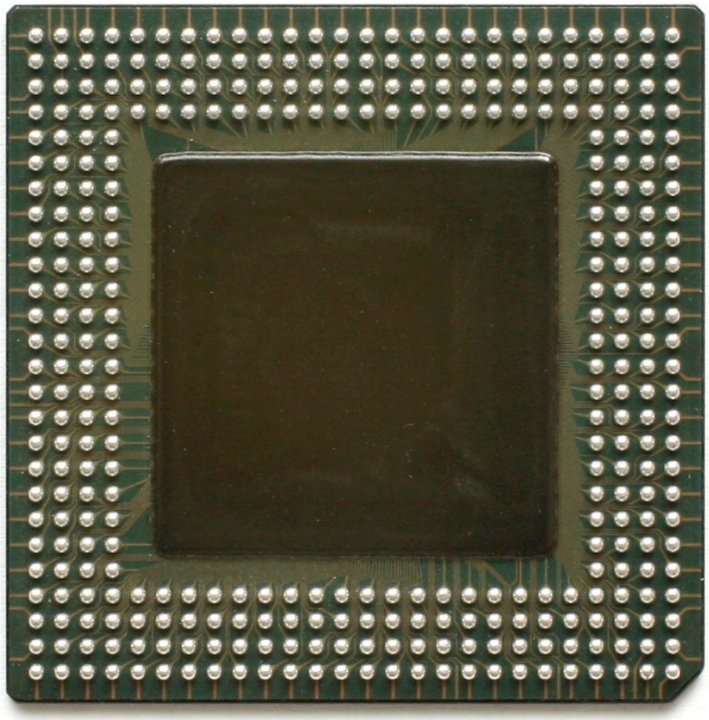
http://fab.cba.mit.edu/classes/MIT/863.09/people/gershon/final_project.html



Integrated Circuits: **TSSOP RQFP SO SSOP QFN**

Surface mount devices are the present. While some components may be through-hole, the logic of the board will likely be SMDs. All of these can be used in hand-assembled prototypes, though QFN requires special work.

https://commons.wikimedia.org/wiki/File:TSSOP_RQFP_SO_SSOP_QFN.jpg



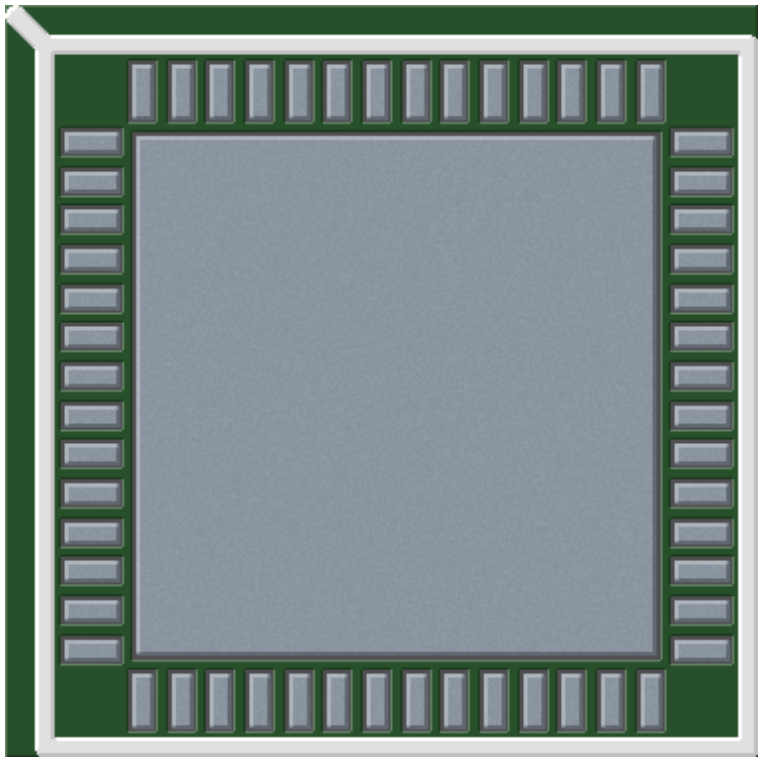
High Density Connections: Ball Grid Array

A soldering iron will no longer do. Assembling a board with a BGA part will require reflow in a temperature controlled oven. This part may also need to be machine-positioned to accurately place it on the board.

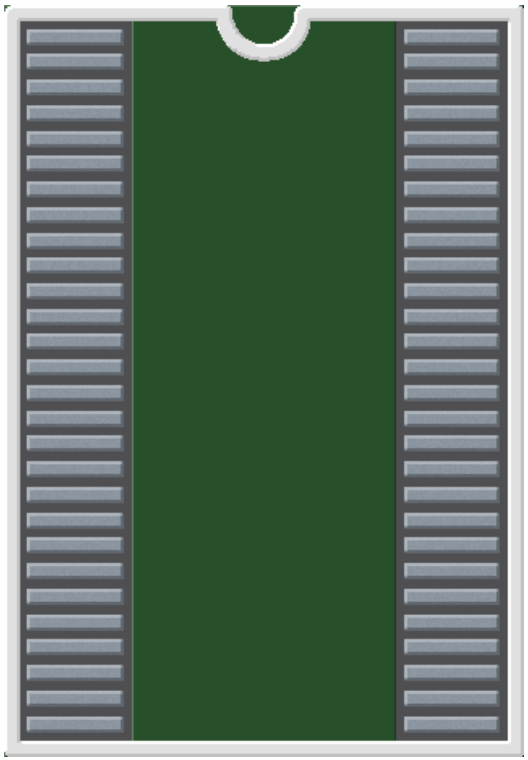
https://en.wikipedia.org/wiki/File:KI_Intel_Pentium_MMX_embedded_BGA_Bottom.jpg

Some Standardized Footprints

QFN56_8_EP



TSSOP56N



These are *probably* safe to work with for JEDEC standard part footprints.

Layout: Designing the Connections

- Implementing the connections between components
- Optimizing graph of the netlist with wires
- Greater density of connections requires more layers to efficiently complete the network
- Need to consider trace lengths and configurations
- Varying requirements for connections: low-resistance power, ground planes, integrity of high-frequency signals, matching

Layout: Complexity Options

- Everything determined by manufacturer
- Layers of board: 1, 2, 4, and higher
- Substrate material, thickness: FR4, ceramic
- Copper plating: 0.5, 1, 2, 3 oz/sq. ft
- Manufacturing parameters: trace size, copper spacing, annular ring width, drill sizes, board cutting/routing

Manufacturing a Prototype

- Cost is proportional to all of quality, speed, product complexity, and board features
- Without in-house manufacturing, a PCB will easily take >2 weeks to arrive for assembly
- Medium quality, fast, low complexity, bare minimum features: ThinkBox Router
- Complete: medium-high quality, 2+ weeks, low to medium complexity, standard features: Osh Park, Advanced Circuits

Hand Assembly of Board

- Through-hole only: solder with lab stump-tip irons
- SMD ~1mm/50mil: solder with a fine-tipped iron
- SMD smaller: solder with fine-tipped iron, viewing with a microscope
- Large-pad chips or BGA: good luck reflowing with a hot plate and a hot air source

The Gist of Production

- http://www.bunniestudios.com/blog/?p=2407
- Need to order tape-on-reel parts (1-5k per reel)
- 1x1.5 meter raw copperclad FR-4
- Massive drilling machines
- Long series of automated chemical tanks
- Boards from one place, assembly elsewhere
- Overall, not a simple task

Production of Boards: Etching Phase

Some video from the blog post on the production of Arduino boards. This shows off the automation and scale required.

Additional Assembly Options

- Better and faster than tweezer-placement
- Apply solder paste and adhesive to board
- Manual pick-and-place: load reel of components and control X,Y placement by hand
- Automated pick-and-place: load reels of components, panelized boards, and part positioning information
- Follow with small or large reflow oven to make connections

Software (Complete EDA)

- No good news here
- FOSS: gEDA (gschem, pcb, utilities), KiCAD
- Crippled Freeware: EAGLE Light Edition
- Enthusiastic hobbyist, Student Edition, something for support on a budget: ????
- Production Enterprise ($$$): Altium Designer, EAGLE

A Brief Demonstration

- gEDA: Building a really simple board