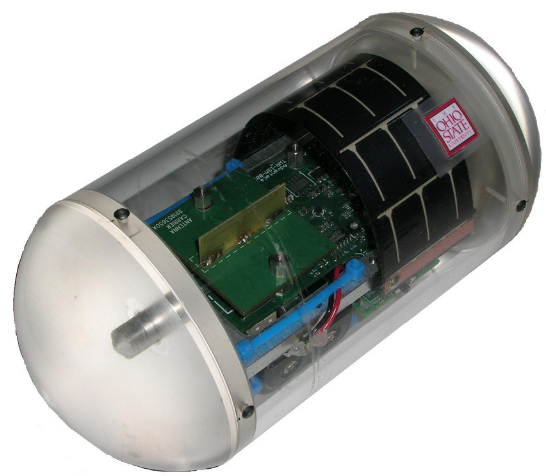
Printed Circuit Board Design Flow

A *design flow* is a rough guide for turning a *concept* into a real, live *working system*

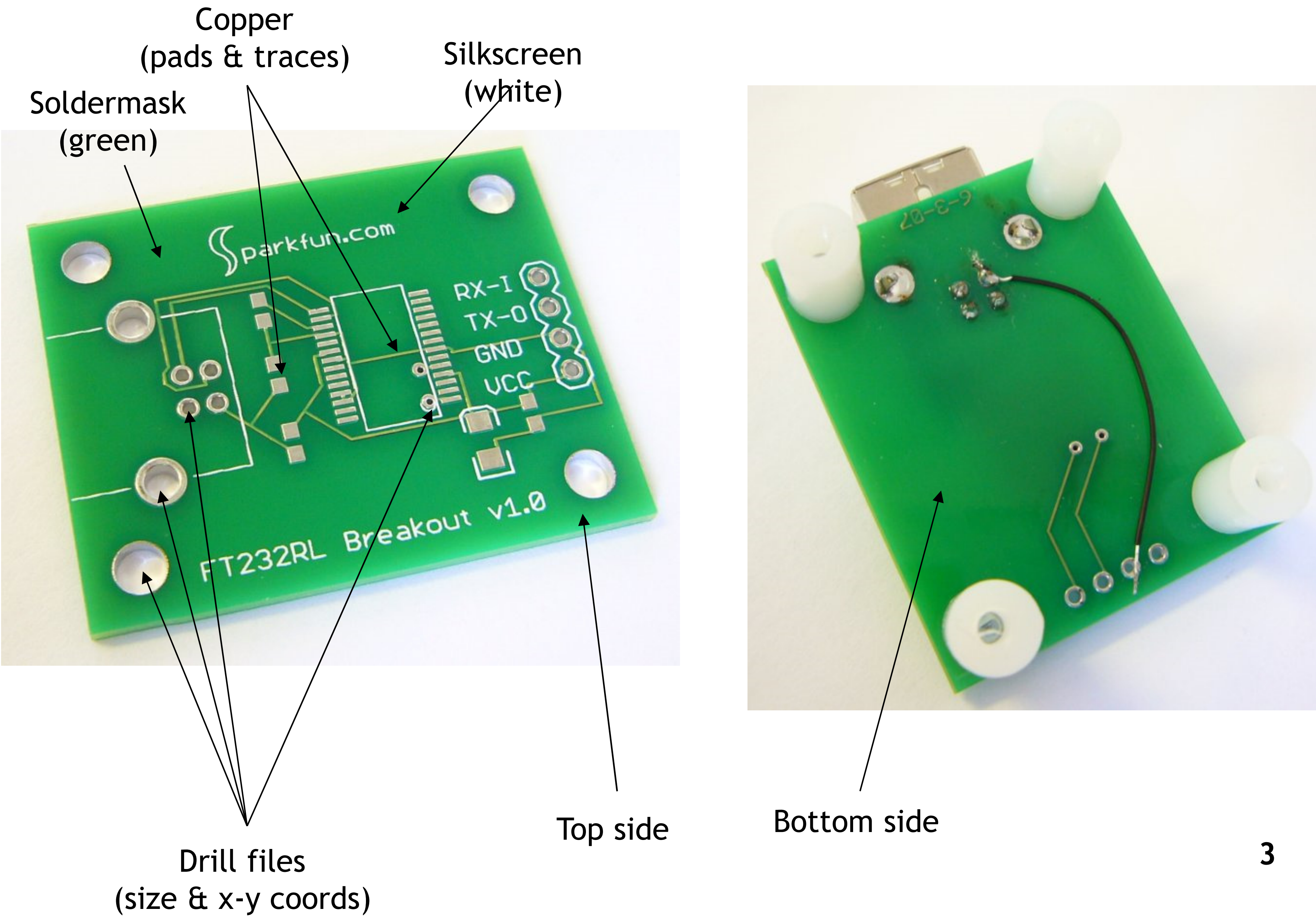
Inspiration
(Concept)

"An air-deployable motion sensor with 10 meter range and 6 month lifetime."

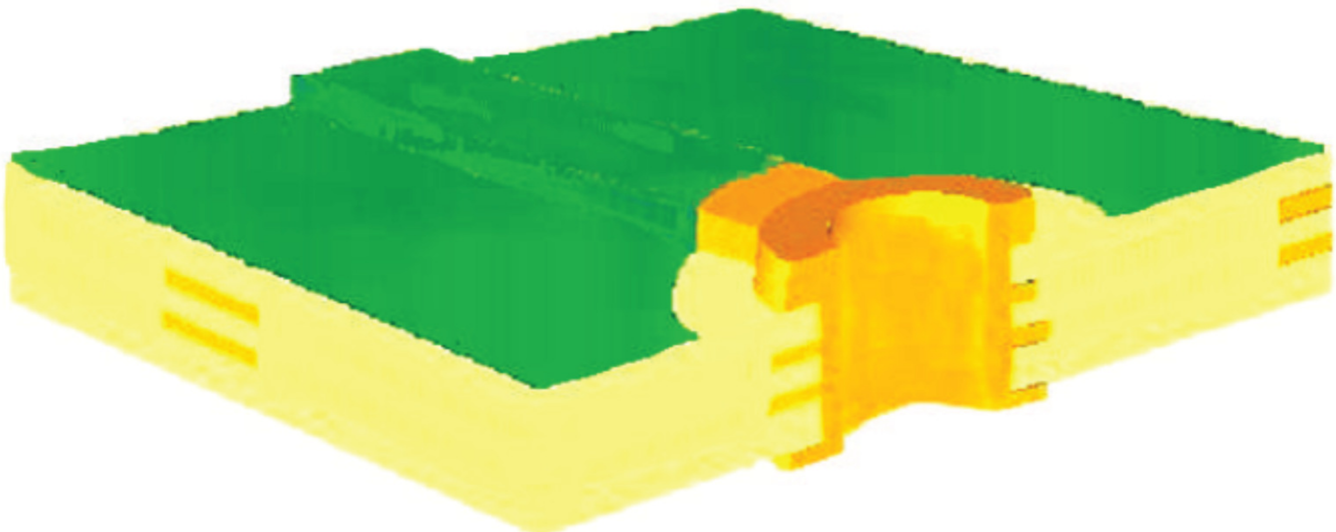
Implementation
(Working System)



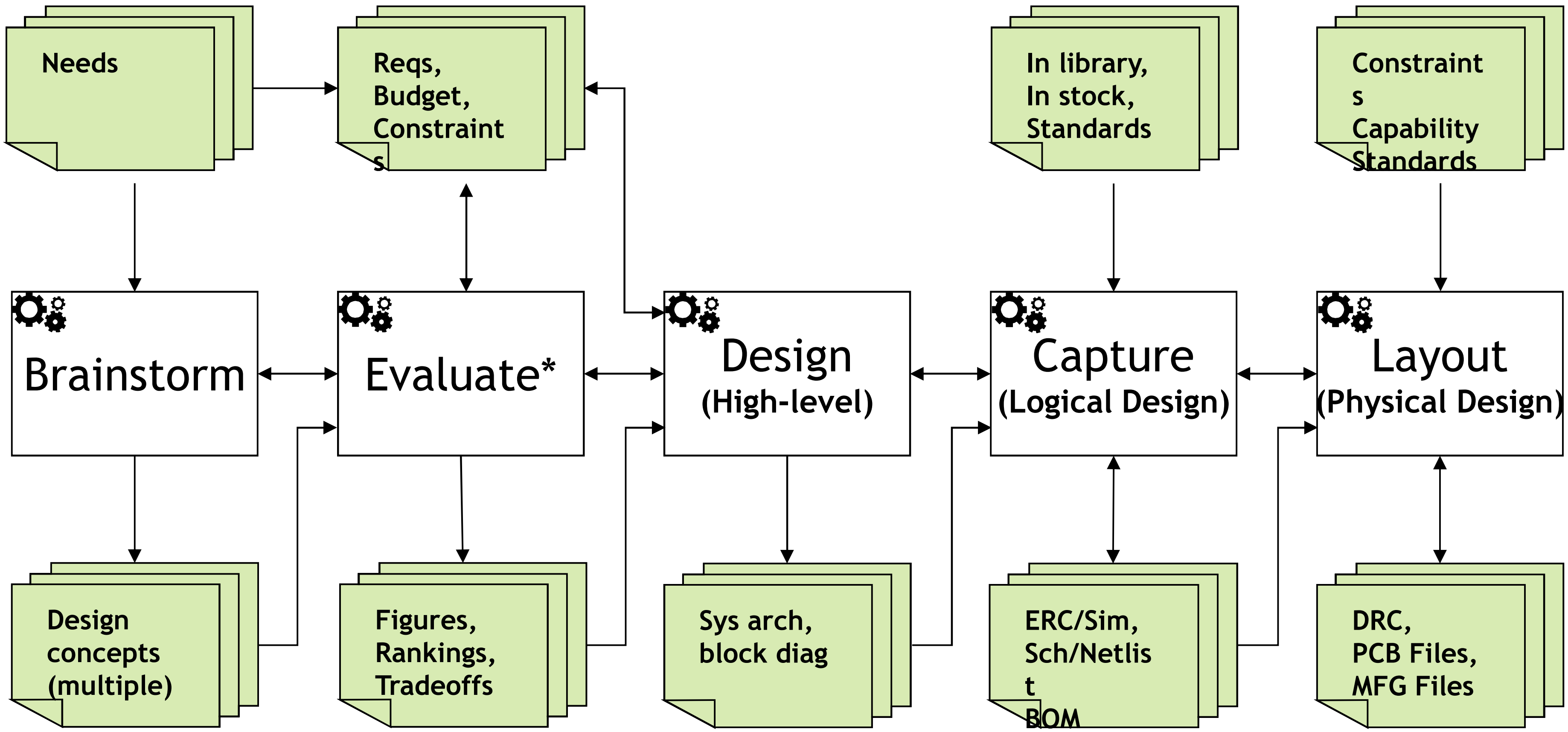
Starting with the end in mind: a printed circuit board



The cross-section of a PCB shows its layered construction



A practical PCB design flow that is *action-oriented* and *artifact-focused*



*evaluate through models, prototypes, and discussions

Brainstorming

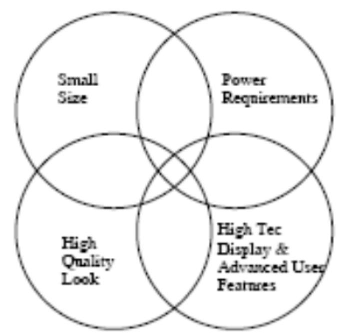
- Goal: generate as many ideas as possible!
- Use the “needs” as the rough guide
- Do not (yet) be limited by constraints or formal requirements
- Ideally, brainstorm in a group so diversity of perspectives emerge

Brainstorming example: energy metering in sensor networks

- Need: measure the *energy* consumed by a mote
- Brainstorm
- Resulting design concepts
  - Single-chip battery “fuel gauge”
  - High-side sense resistor + signal processing
  - Low-side sense resistor + signal processing
  - Pulse-frequency modulated switching regulator

Requirements and constraints address the myriad of important details that the system must satisfy

- Requirements address:
  - Functionality
  - Performance
  - Usability
  - Reliability
  - Maintainability
  - Budgetary
- Requirements may be at odds!



- Use correlation matrix to sort things out in this case

	Size	Battery capacity	Display/ Appearance	Range/ Performance
Size		++	++	-
Battery capacity			+	++
Display/ Appearance				--
Range/ Performance				

++ Highly correlated positive
\+ Moderately correlated positive
\- Moderately correlated negative
-- Highly correlated negative

Evaluation

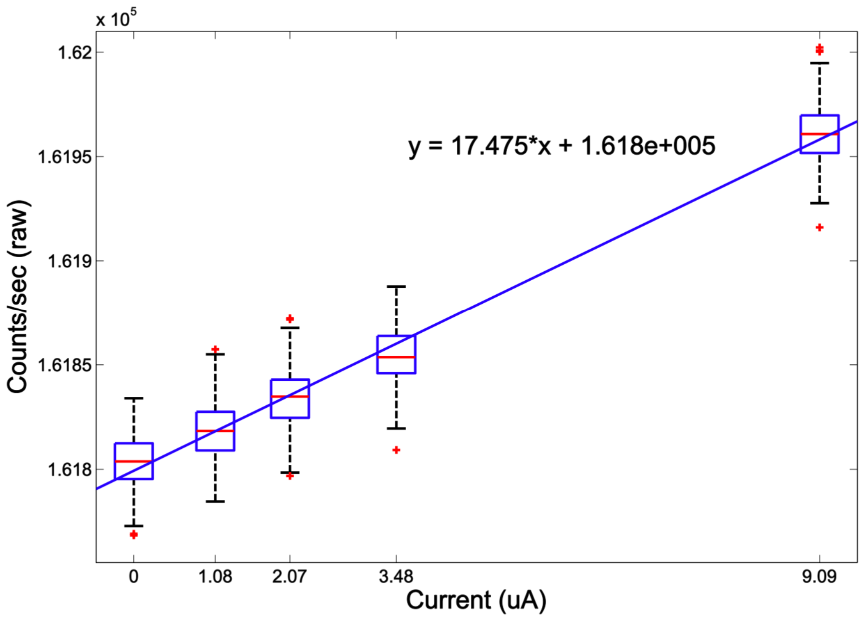
- Goal: identify best candidates to take forward
- Use requirements and constraints as the metric
- Get buy-in from stakeholders on decisions
- Also consider
  - Time-to-market
  - Economics
    - Non-recurring engineering (NRE) costs
    - Unit cost
  - Familiarity
  - Second-source options
- If none of the candidates pass, two options
  - Go back to brainstorming
  - Adjust the requirements (hard to change *needs* though)

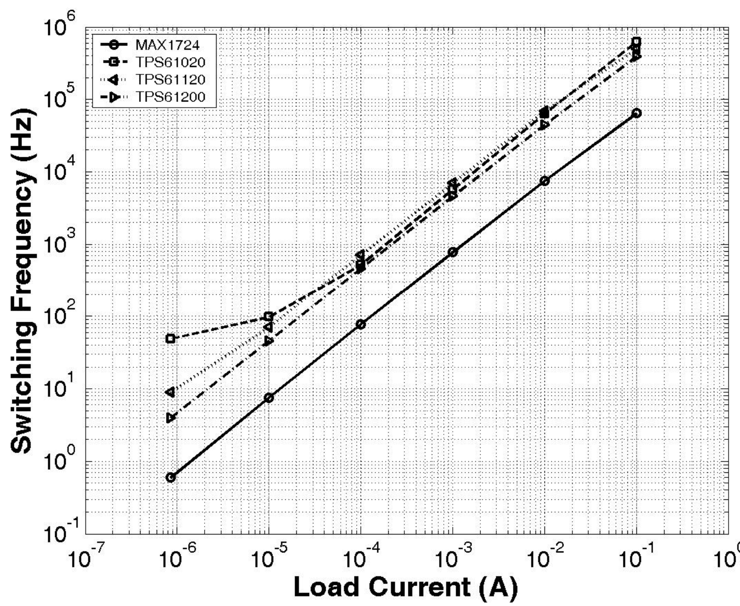
Evaluation example: energy metering in sensor networks

Requirements:	Low Cost	High Accu	Low Power	High Rez	Low Pert.
Design concepts					
Energy meter IC	N	Y	N	Y	Y
High-side sense resistor + signal processing	N	Y	N	Y	Y
Low-side sense resistor + signal processing	Y	Y	Y	Y	N
PFM switching regulator	Y	Y	Y	Y	Y

Evaluation example: energy metering in sensor networks

Accuracy / linearity are really important for an instrument





Sometimes a single experiment or figure says a lot

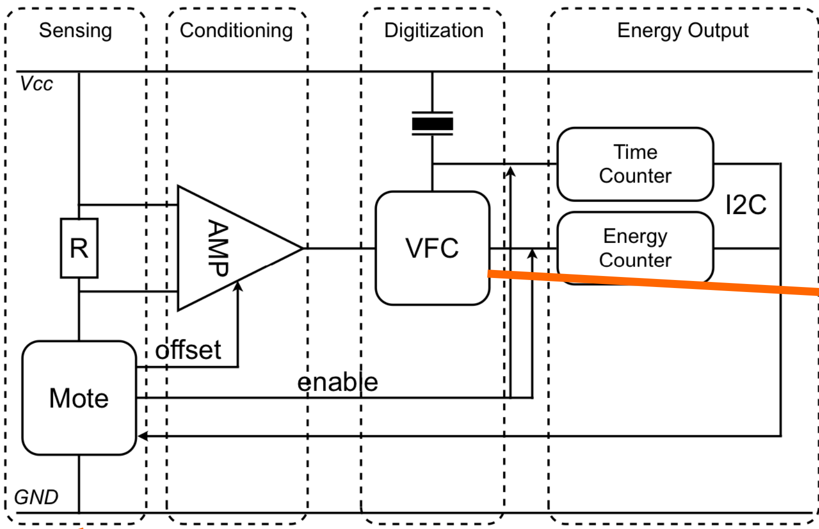
Design

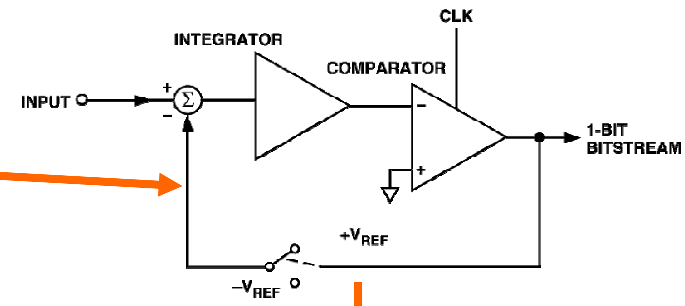
- Translate a concept into a block diagram
- Translate a block diagram into components
- Top-down
  - Start at a high-level and recursively decompose
  - Clearly define subsystem functionality
  - Clearly define subsystem interfaces
- Bottom-up
  - Start with building blocks and increasing integrate
  - Add "glue logic" between building blocks to create
- Combination
  - Good for complex designs with high-risk subsystems

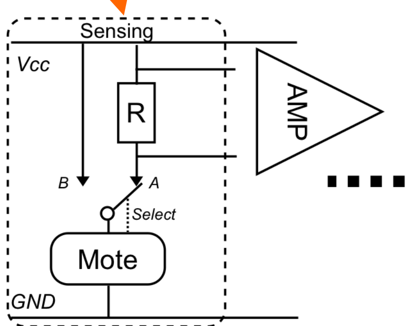
Design II

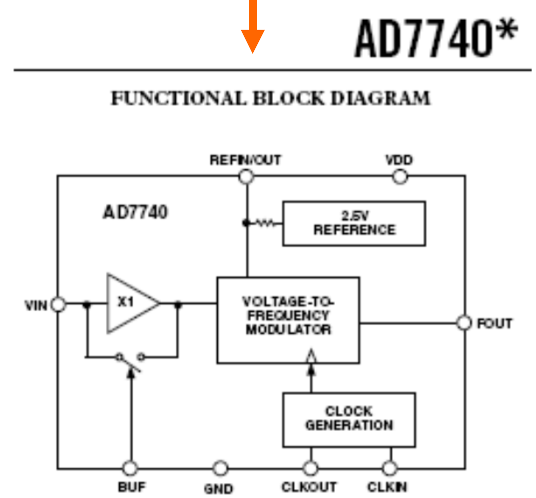
- Design can be difficult
- Many important decisions must be made
  - Analog or digital sensing?
  - 3.3V or 5.0V power supply?
  - Single-chip or discrete parts?
- Many tradeoffs must be analyzed
  - Higher resolution or lower power?
  - Higher bit-rate or longer range, given the same power?
- Decisions may be coupled and far-ranging
- One change can ripple through the entire design
  - Avoid such designs, if possible
  - Difficult in complex, highly-optimized designs

Design example: energy metering in sensor networks





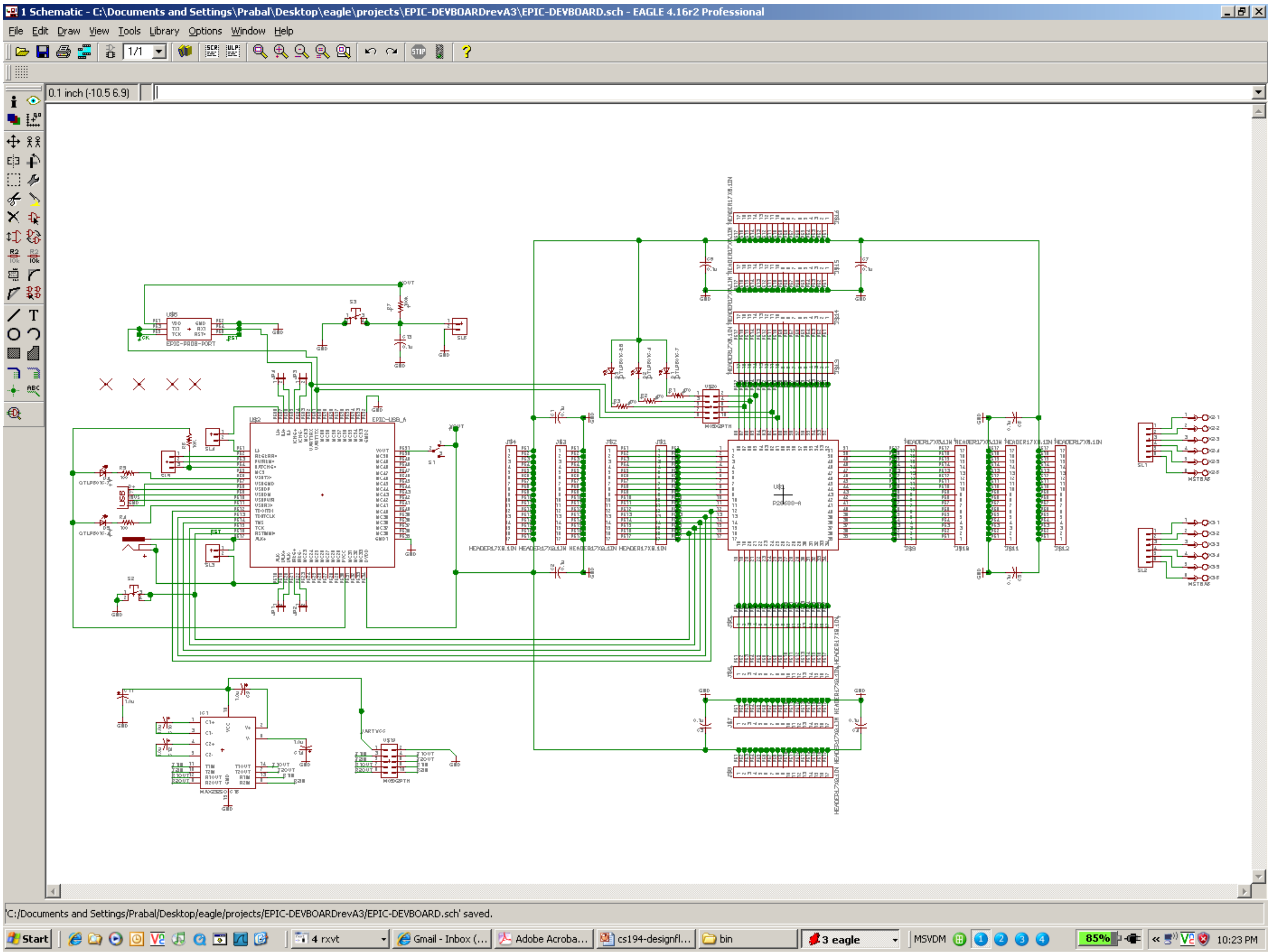




Schematic capture turns a block diagram into a detail design

- Parts selection
  - In library?
    - Yes: great, just use it! (BUT VERIFY FIRST!)
    - No: must create a schematic symbol.
  - In stock?
    - Yes: great, can use it!
    - No: pick a different park (VERIFY LEADTIME)
  - Under budget?
  - Right voltage? Beware: 1.8V, 3.3V, 5.0V
- Rough floorplanning
- Place the parts
- Connect the parts
- Layout guidelines (e.g. 50 ohm traces, etc.)

The schematic captures the logical circuit design



Layout is the process of transforming a schematic (netlist) into a set of Gerber and drill files suitable for manufacturing

- Input: schematic (or netlist)
- Uses: part libraries
- Outputs
  - Gerbers photoplots (top, bottom, middle layers)
    - Copper
    - Soldermask
    - Silkscreen
  - NC drill files
    - Aperture
    - X-Y locations
  - Manufacturing Drawings
    - Part name & locations
    - Pick & place file
- Actions
  - Create parts
  - Define board outline
  - Floorplanning
  - Define layers
  - Parts placement
  - Manual routing (ground/supply planes, RF signals, etc.)
  - Auto-routing (non-critical signals)
  - Design rule check (DRC)

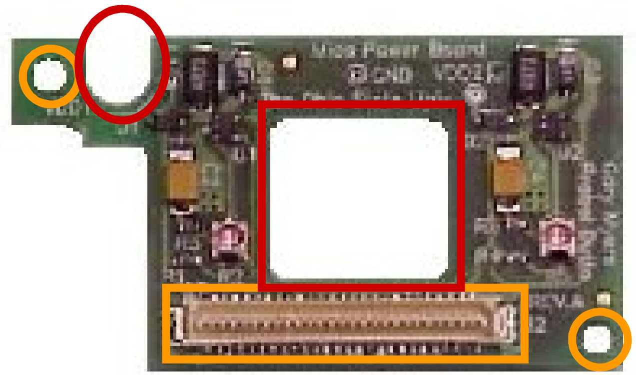
Layout constraints can affect the board size, component placement, and layer selection

- Constraints are requirements that limit the design space (this can be a very good thing)
- Examples
  - The humidity sensor must be exposed
  - The circuit must conform to a given footprint
  - The system must operate from a 3V power supply
- Some constraints are hard to satisfy yet easy to relax…*if* you communicate well with others. Passive/aggressive is always a bad a idea here!
- Advice: the requirement “make it as small as possible” is not a constraint. Rather, it is a recipe for a highly-coupled, painful design. ☹

Layout: board house *capabilities*, external *constraints*, and regulatory *standards* all affect the board layout

CAPABILITY

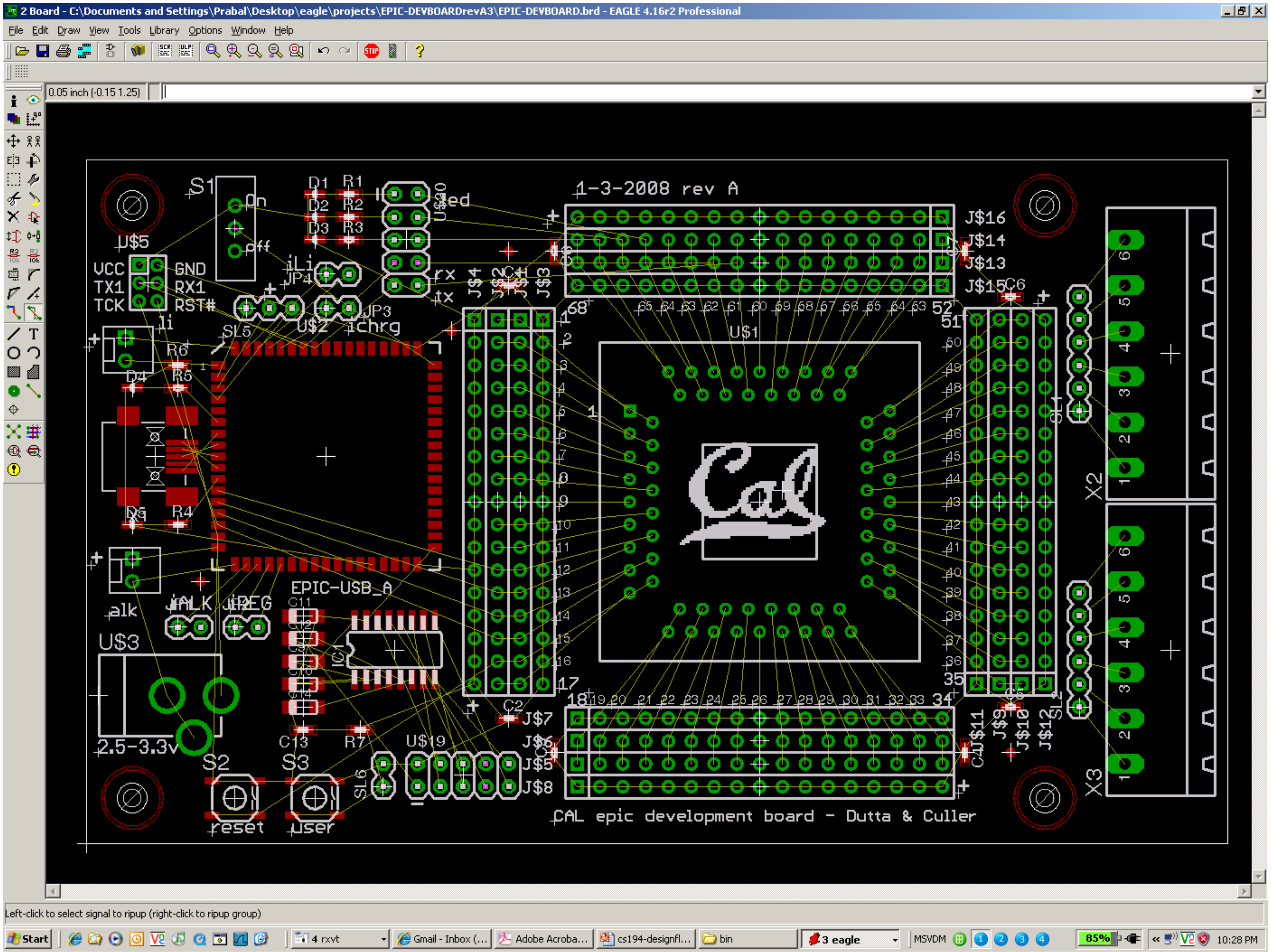
Materials	FR4, Rogers4003/4350, GETEK, High Tg FR4
Flammability	UL 94V-0
Minimum Line/Space	4/4 mils
Maximum Board Sizes	18" x 24"
Minimum Hole Size	8 mils(finished PTH)
Minimum Pad Size	18 mils
Copper Weight	1/2 oz, 1 oz , 2 oz, 3 oz, 4 oz
Maximum Layer Count	14 (in production)
Soldermask Color	Green, Yellow, Black, Blue, Red, White
Registration	+/- 5 mils(Max.)
Minimum Board Thickness	0.008" for 2-layer, 0.016" for 4-layer, 0.019" for 6-layer
Impedance Control	+/- 10%(in house TDR tester)
Surface Finish	HAL, Immersion Gold, Immersion Tin, ENTEK
Dimensional Tolerance	+/- 0.005"
Aspect Ratio	< 8 : 1
Annular Ring	0.002"
Blind/Bried Vias	Sequential Lamination
Electroplating Gold	up to 30u" plus



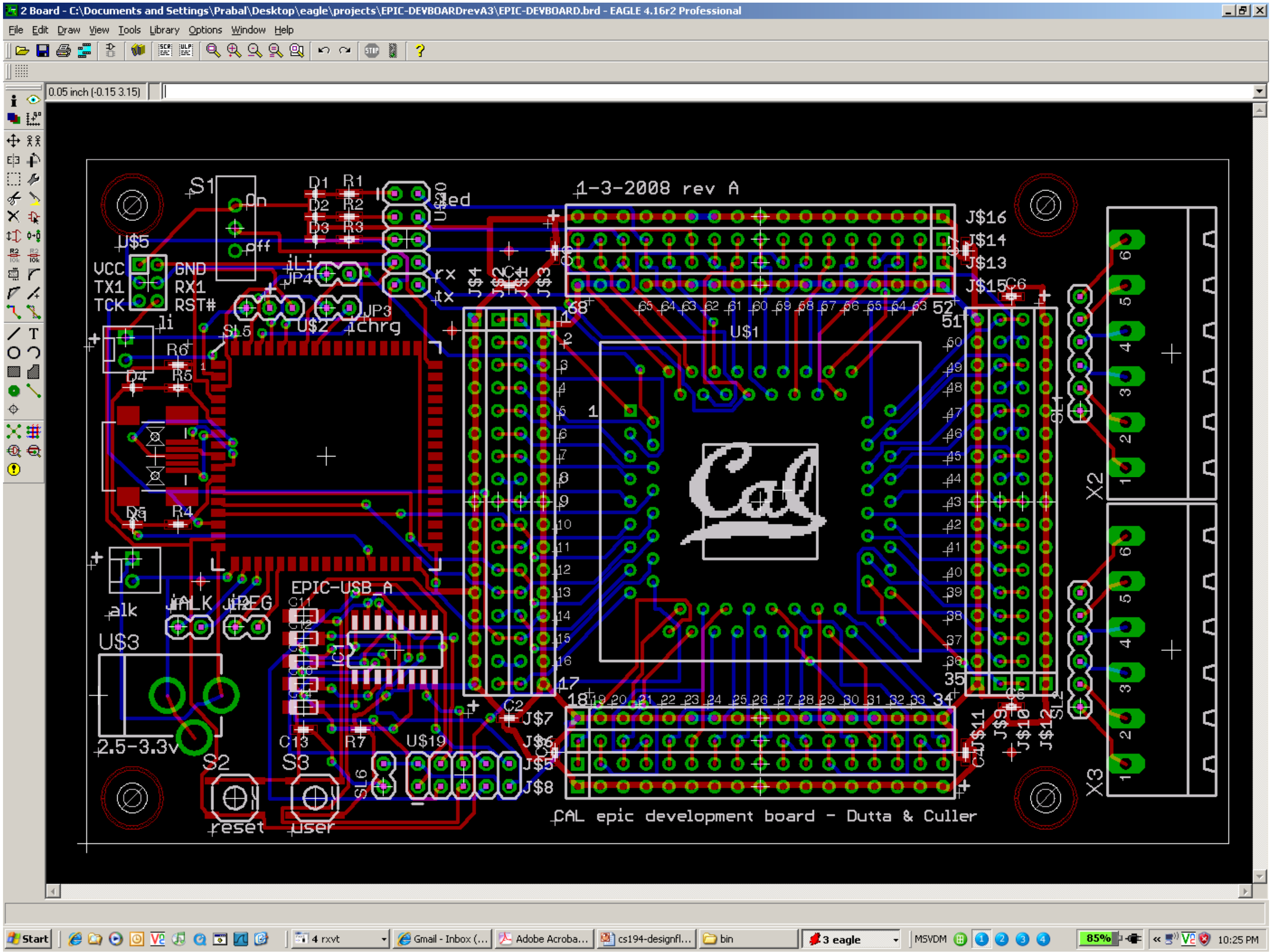
RoHS Restricted Materials

Material & Toxicological Profile (pdf)	Maximum Concer
Lead (Pb)	0.1% by weight
Mercury (Hg)	0.1% by weight
Cadmium (Cd)	0.01% by weight
Hexavalent Chromium (Cr-VI)	0.1% by weight
Polybrominated Biphenyls (PBB)	0.1% by weight
Polybrominated Diphenyl Ethers (PBDE)	0.1% by weight

Floorplanning captures the desired part locations



The auto-router places tracks on the board, saving time



Layout tips

- Teaching layout is a bit like teaching painting
- Suppy/Ground planes
  - Use a ground plane (or ground pour) if possible
  - Use a star topology for distributing power
  - Split analog and digital grounds if needed
  - Use thick power lines if no supply planes
  - Place bypass capacitors close to all ICs
- Layers
  - Two is cheap

Discussion? Questions?

There are lots of design flows in the literature but they are awfully general