Electrical Engineering and Computer Sciences

EECS 16A

First Lecture Plan

- Introductions
- Administrative Details (grading, etc.)
- Overview of 16A's subject matter mosaic
- Introduction to the technology ecosystem

- Intro to imaging

Introduce Faculty

- Babak Ayazifar

  ayazifar@eecs.berkeley.edu

  517 Cory
- **No surprise visits, please!**
  – For one-on-one matters,
    - make appointment by e-mail;
    - provide your availability; and
    - we'll pick a mutually-convenient slot to meet.

Introduce Faculty

- Vladimir Stojanović

  vlada@eecs.berkeley.edu

  513 Cory
- Story…
- Other contributors to 16 (besides Babak/Vladimir):
  - Elad Alon, Anant Sahai, Ali Niknejad, Claire Tomlin, Gireeja Ranade, Michel Maharbiz, Laura Waller, Miki Lustig, Vivek Subramanian, Thomas Courtade

Introduce TAs

- 28 TAs
- Many are returning 16A staff members

Head TA

- Email: head-ta-ee16a@berkeley.edu

Email Harrison with:

- Questions not for piazza
- Conflicts
- Emergencies

And we have even more!

- An army of Academic Interns…
  - Former 16A students just like you …

Important Web Sites

- EECS 16A

  http://inst.eecs.berkeley.edu/~ee16a/fa16/

- Piazza

  http://piazza.com/

Course Policies

- Illnesses
- Religious Holidays (please let us know in advance)
- Disabled Students Program (DSP) Accommodations
- No Distraction Policy
- Grading
- Class Participation
- Labs and Discussion
- HW Cycle
- Piazza
- Extra Credit
- HW Parties & Tips for Success

Grading

- **No curve**: In theory, each of you can get an A
- Breakdown
  - 33% Cumulative Final
  - 34% Midterms
    - September 19th, 2016 at 8-10pm (Known Problem: CS 70 exam at this time)
    - November 3rd, 2016 at 8-10pm
  - 15% Labs (Attendance Mandatory; drop lowest ONE)
  - 15% HWs (drop lowest TWO)
  - 3% Effort, Participation, Altruism

Interlocking Weekly Homework Cycles (Chronologically Ordered)

- HW ***N*** released this Tuesday afternoon
- HW ***N-1*** self-grades due this Friday, at noon
- HW ***N*** HW Party this Friday
- HW ***N*** due Tuesday of next week, at noon
  (**No late submissions!**)
- HW ***N*** solutions released Tuesday next week, noon+
- HW ***N+1*** released Tuesday next week, afternoon
- HW ***N*** self-grades due on Friday next week, at noon

- Midterm weeks, redoing midterm is a part of HW.
- HW has mechanics, proofs, word problems, and coding.

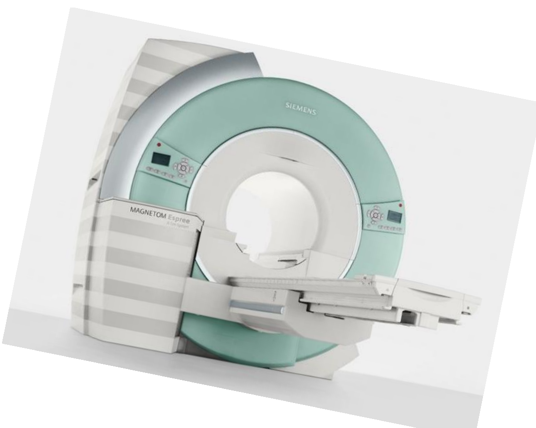
Tips for Success in 16A:

- Focus on understanding, get enough sleep, and keep up!
- Suggested cycle (reading, lecture, discussion):
  - Skim the readings in the posted notes **before** lecture
  - Attend lecture; participate, discuss w/ classmates
  - Read notes actively, mark what is challenging
  - Attend discussion, participate, discuss w/ classmates
  - Reread notes carefully, aim for full mastery
  - **Strongly-recommended** textbook, *Introduction to Linear Algebra*, **5th Edition**, by Gilbert Strang

Tips for Success in 16A: Marathon not Sprint (Continued)

- Suggested cycle (HW)
  - Parse the HW
  - Try HW on your own
  - **Collaborate** in a study group and attend HW Party
  - Ask/Lurk and help others on Piazza
  - Write up HW on your own (a must!)
  - Study solutions carefully and reflect on what you understand; keep track of various methods of tackling problems
- Do extra problems, and attend bonus sections that we offer.
- Study with others as well as alone.
- Seek and offer help.
- Keep a log of what you study (Babak will say more as we proceed)

Content Introduction



- **All of these extract information from the real world and interact with it; we will be learning how to design and understand these devices & systems!**

16A: Information Devices and Systems

- **Imaging/Tomography (~4 wks)**
  - Topics: Basics of linear algebraic thinking and graphs
  - Lab: Single-pixel imager
- **Touchscreens (5 wks)**
  - Topics: Basics of linear circuits and design
  - Lab: Home-made R and C touchscreens
- **Locationing and Google PageRank (5 wks)**
  - Topics: Linear-algebraic optimization, eigenvalues/eigenvectors
  - Lab: Acoustic "GPS"

Some detailed topics for 16A

- Vectors and vector spaces
- Inner products, projection, orthogonality
- Matrices and linear transformations
- Rank and solving systems of linear equations
- Graphs, flows, and matrices
- How to do design and synthesis
- KCL, KVL, Ohm's Law
- Equivalence, modeling, and abstraction
- Capacitance and charge
- Gain and feedback
- Correlation and interference
- Linear regression and optimization
- Determinants, eigenvalues and eigenvectors
- Diagonalization

EECS Upper Divs: What 16AB feed

16AB
~~20~~
70
61B
61A
61C
~~40~~
16AB

Modeling and Algorithms	**170, 126, 188, 127**	**189, 120, *121*, 123, 174, 144, 172**
General Software	162, 161, 169	160, *168*, 149
General Hardware	105, 140, 151	130, 143, 145L

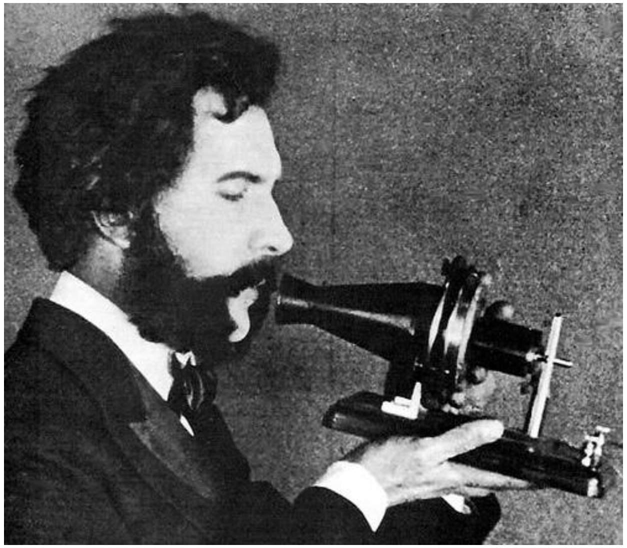
Specific Domains	
121, 122, *168* Comm+Net	176, 145B CompBio, Imaging
191 Quantum	128, 106, 192 Control + Robotics
184 Graphics	186 Databases
164 Compilers	152 Computers
145MO Bio	147 MEMS
117 Antennas	142 Comm ICs
118 Optics	113, 137AB, 134 Power+SolarEnergy

How Did We Get From This…

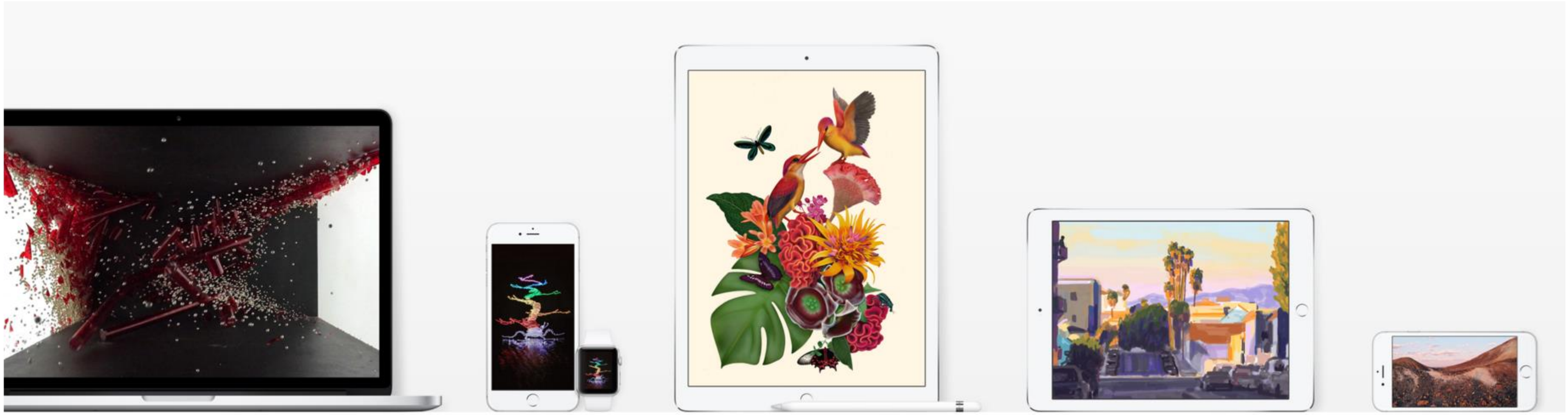
1837

1866

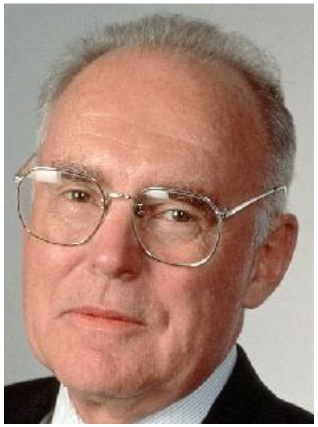
1876



To This?



Moore's Law

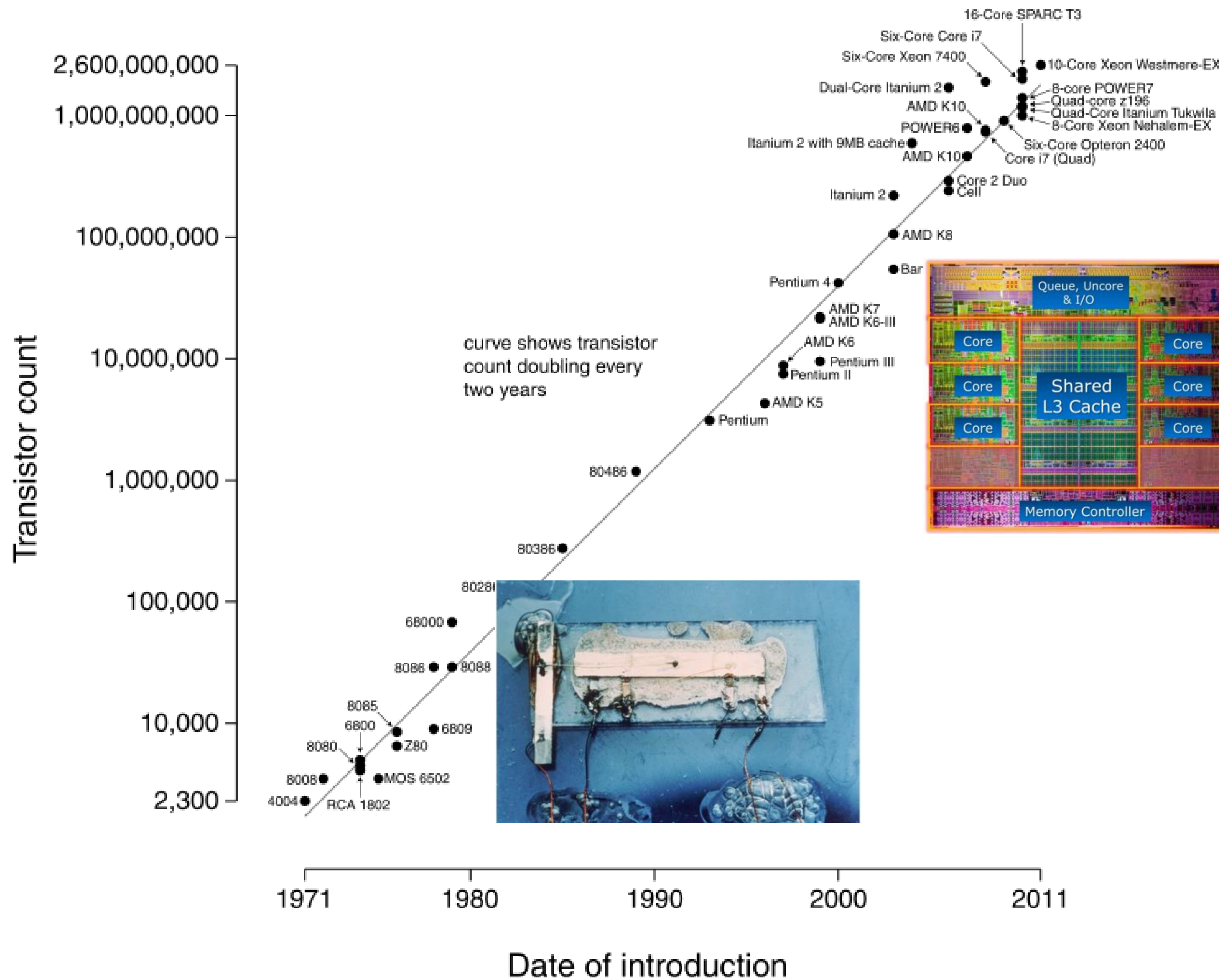


Gordon Moore

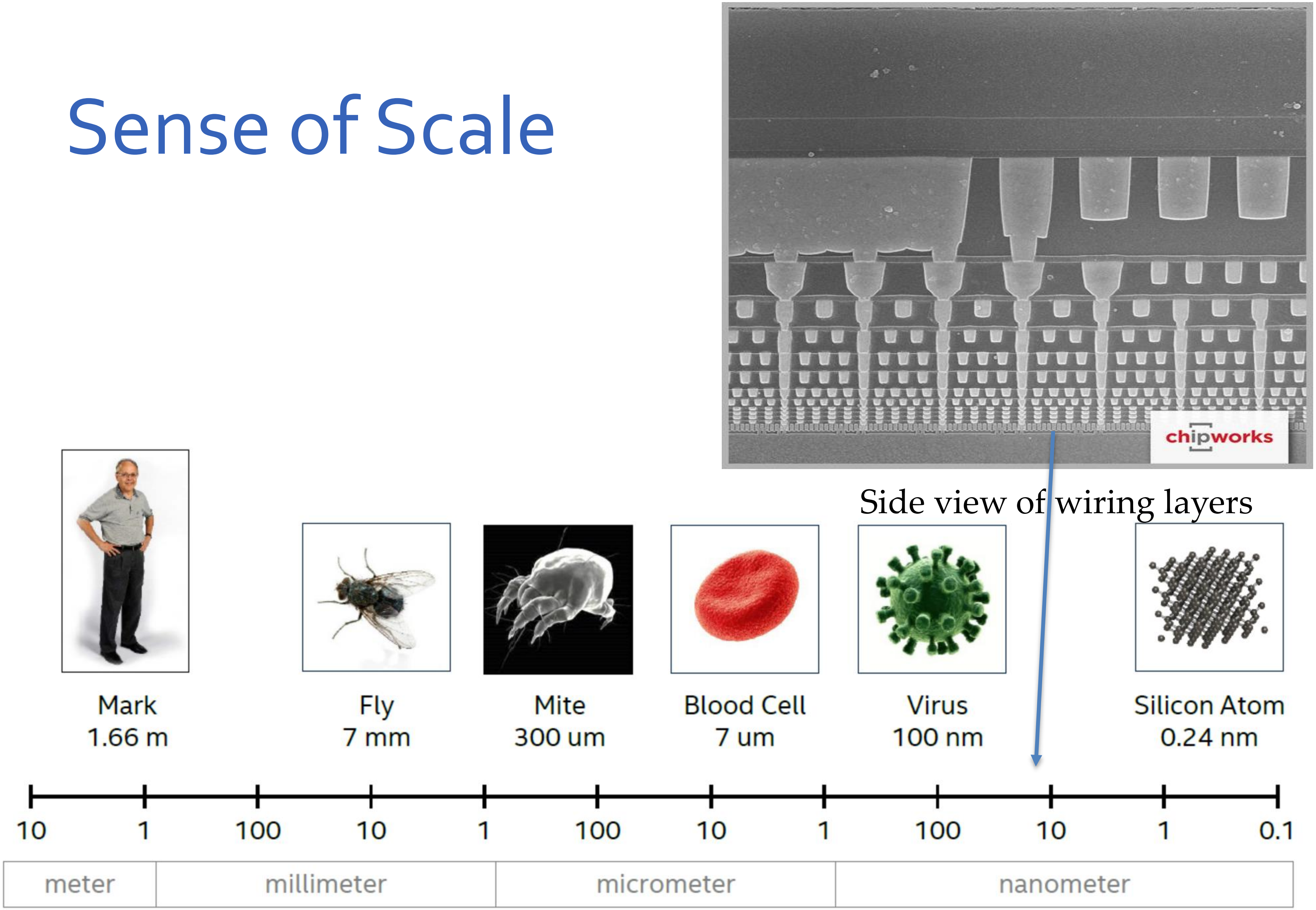
Intel Cofounder

B.S. Cal 1950!

Microprocessor Transistor Counts 1971-2011 & Moore's Law

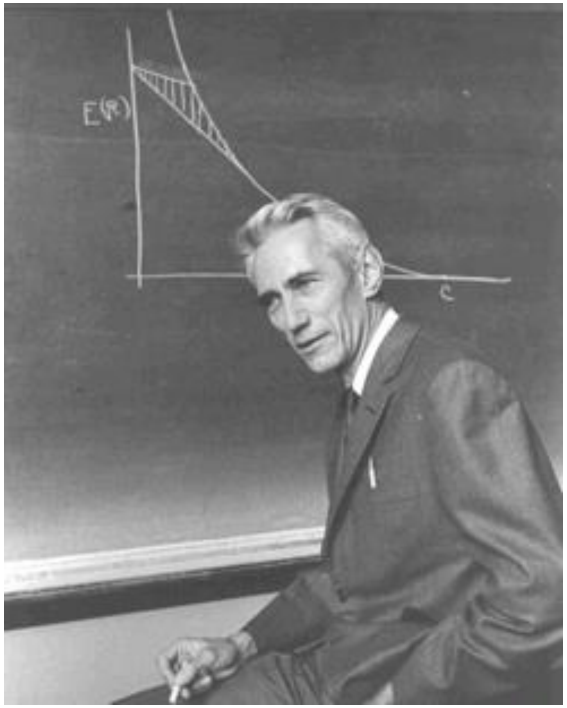


Sense of Scale



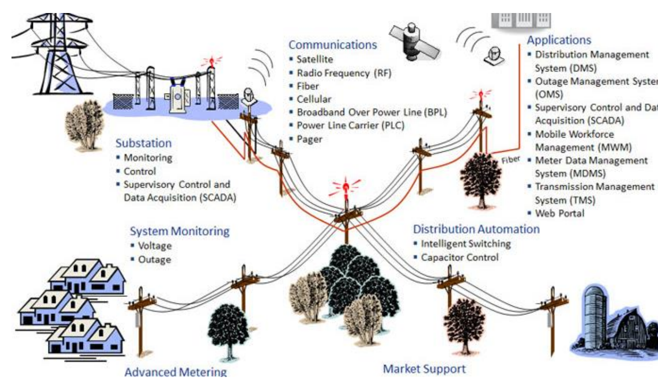
Source: Mark Bohr, IDF14

That's Just One Piece of the Puzzle…



1940's

Where This is Used:



Whom We're Training You to Be

2016

An example system: iPad Air 2

- Runs apps, but:
  - How is it charged / discharged?
  - What makes the display tick?
  - How does the Wi-Fi work?
  - How does it sense touch on the touch screen?
  - How does it sense motion?
  - How do the "brains" operate?

... and how can I learn stuff, so I can work on such cool technology?

Inside an iPad Air 2

Physical world interaction: camera

Communication: Antenna

Display / touch screen

"Brains": the main board

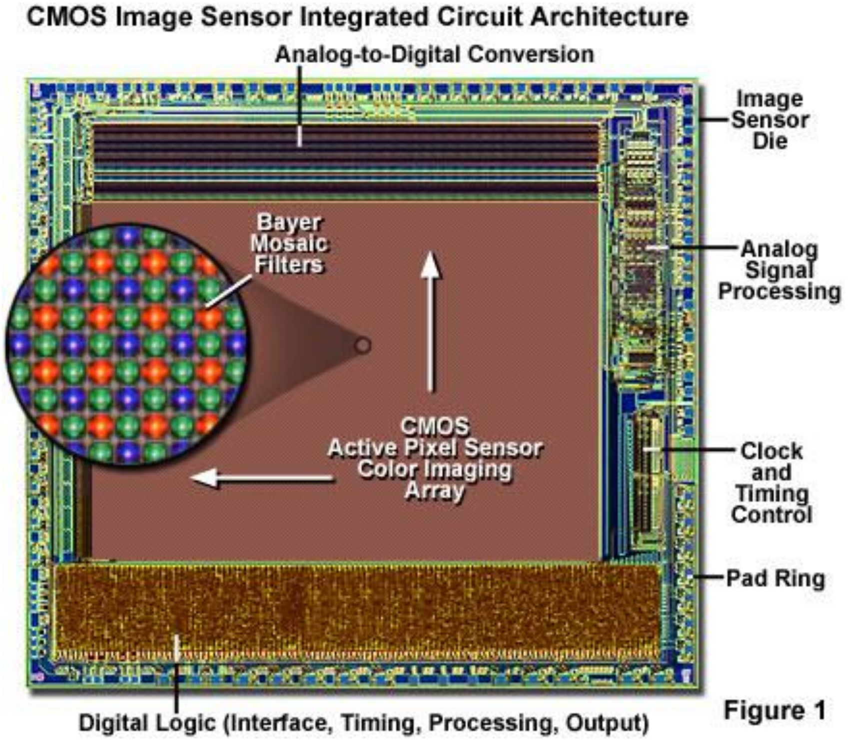
Energy: Battery

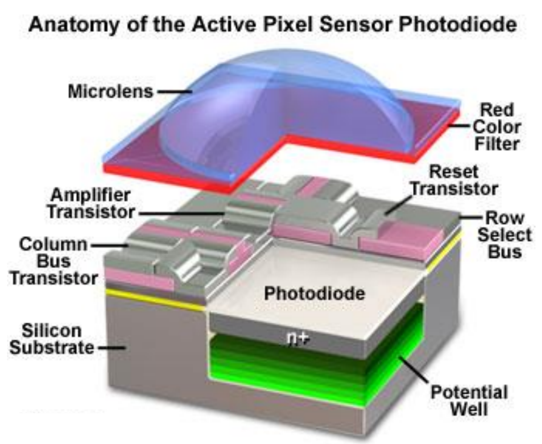
User interface device: home button

Physical world interaction: speakers

The Camera

Goal: Convert light into electrical signals





Get color spatial distribution by using an array of "light" detectors, each under a color filter

Cameras: "Mathematical" Guts

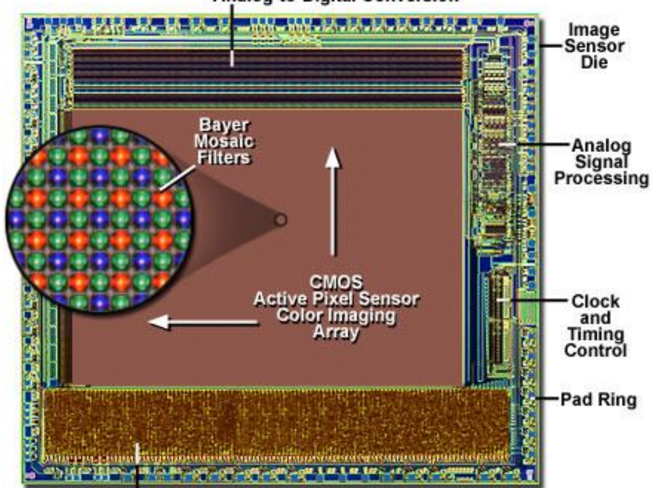


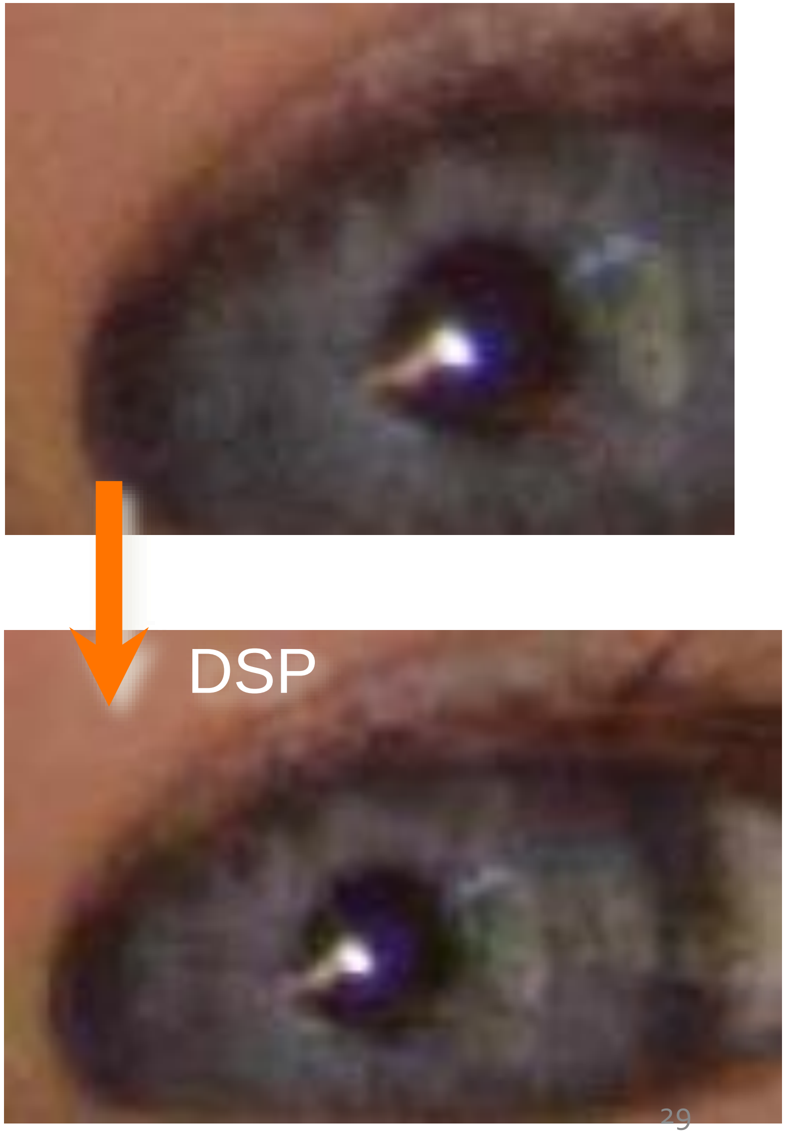
Figure 1

Focus/exposure Control → preprocessing → white-balancing → demosaic → Color transform → Post-processing → Compression

Cameras: Compression

- Compression of 40x without perceptual loss of quality.

- Example of slight overcompression: difference enables x60 compression!



Imaging

- **Everyone knows about cameras…**

- **What else might you be interested in “imaging”?**

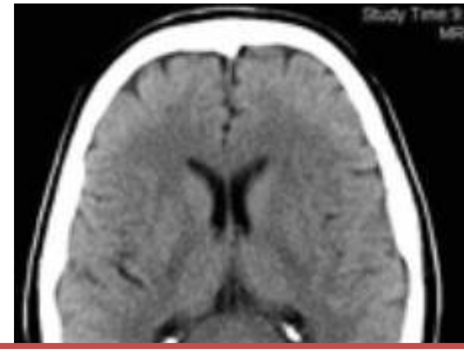
Medical Imaging ca. 1895

- **Need to find a way to see inside without "light"**

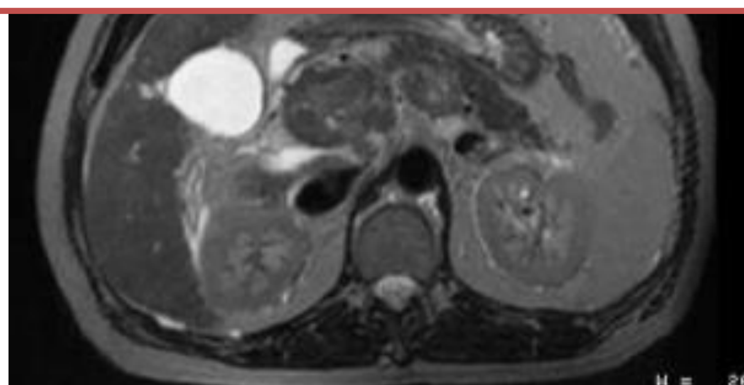
Medical Imaging Today

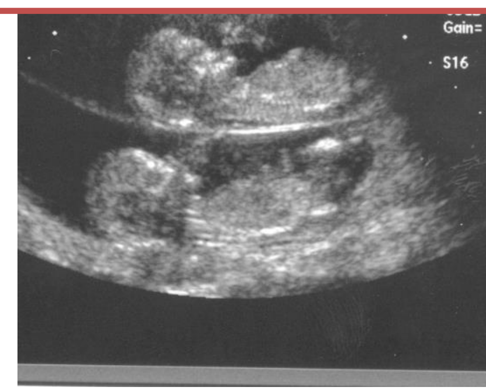
X-Ray

CT

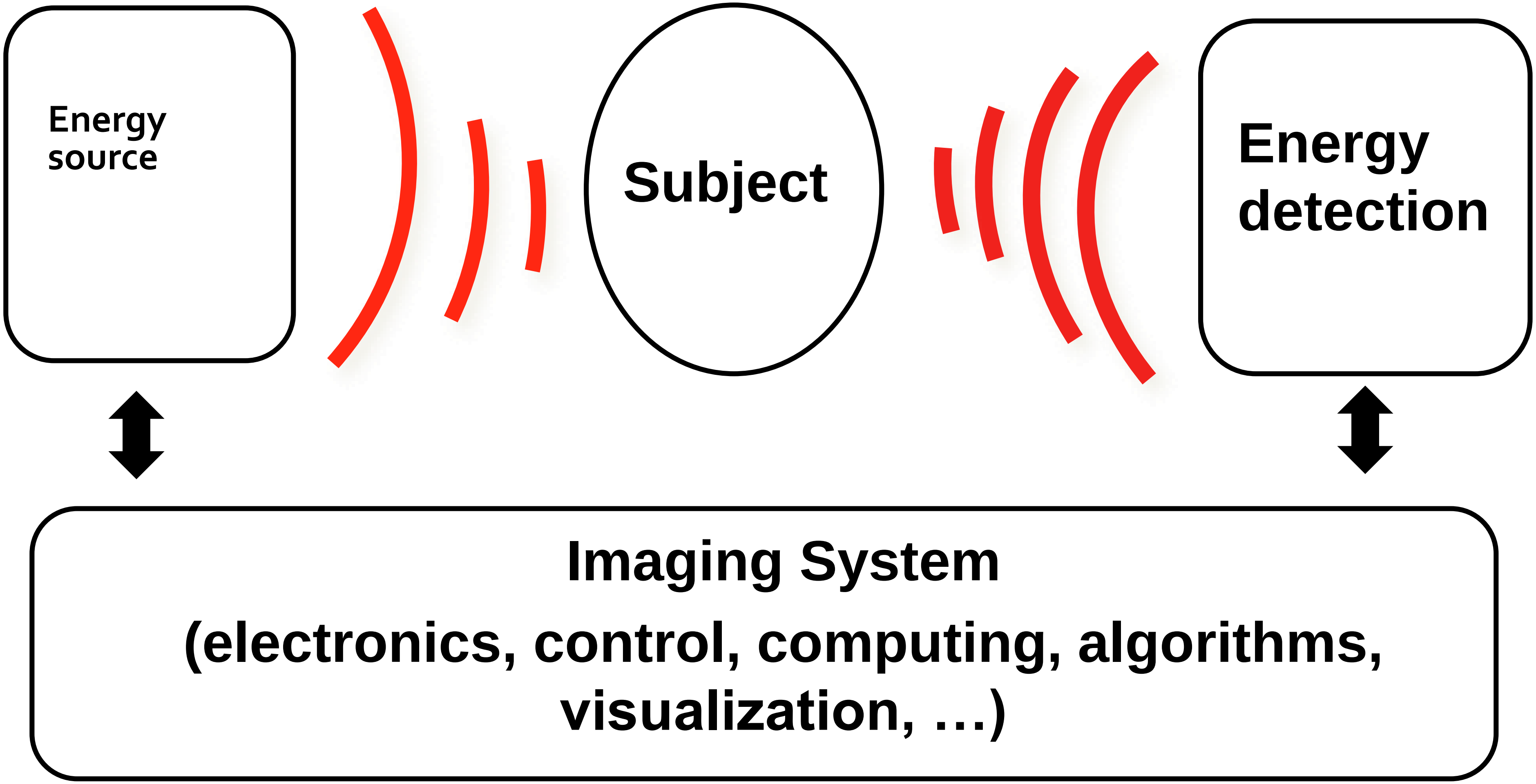


All of these were enabled/dramatically advanced by the mathematical and hardware design techniques you will learn in this class!





Imaging In General



Simplest Imaging System

- **What is the absolute smallest number of components you need to make an imaging system?**

Simple Imager Example

Simple Imager Example

Actual Imager: Your Cellphone Camera

- **What is the source of light?**

- **Does it use any moving components?**

- **How does it figure out which point is which?**

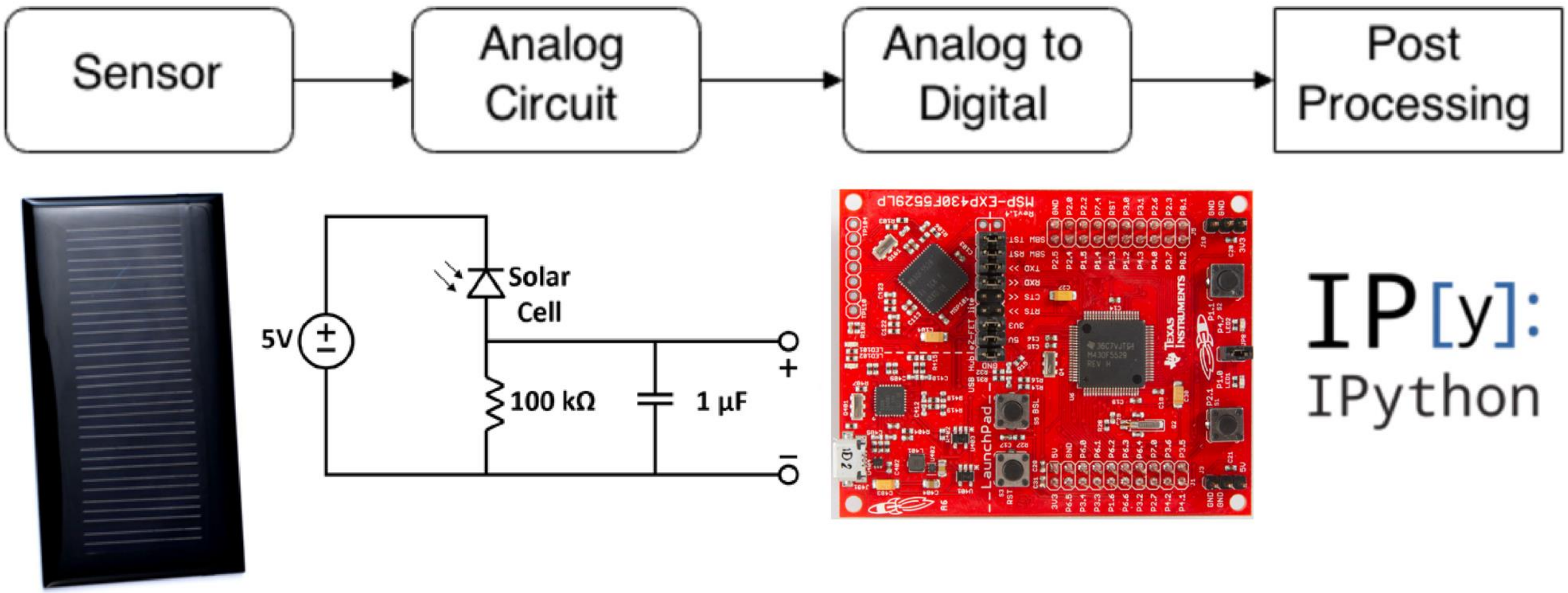
Another Example: Ultrasound Imaging

- **Sound waves travel into body and an echo signal is recorded. This echo is due to changes in material properties (fat, muscle, fluid, …)**

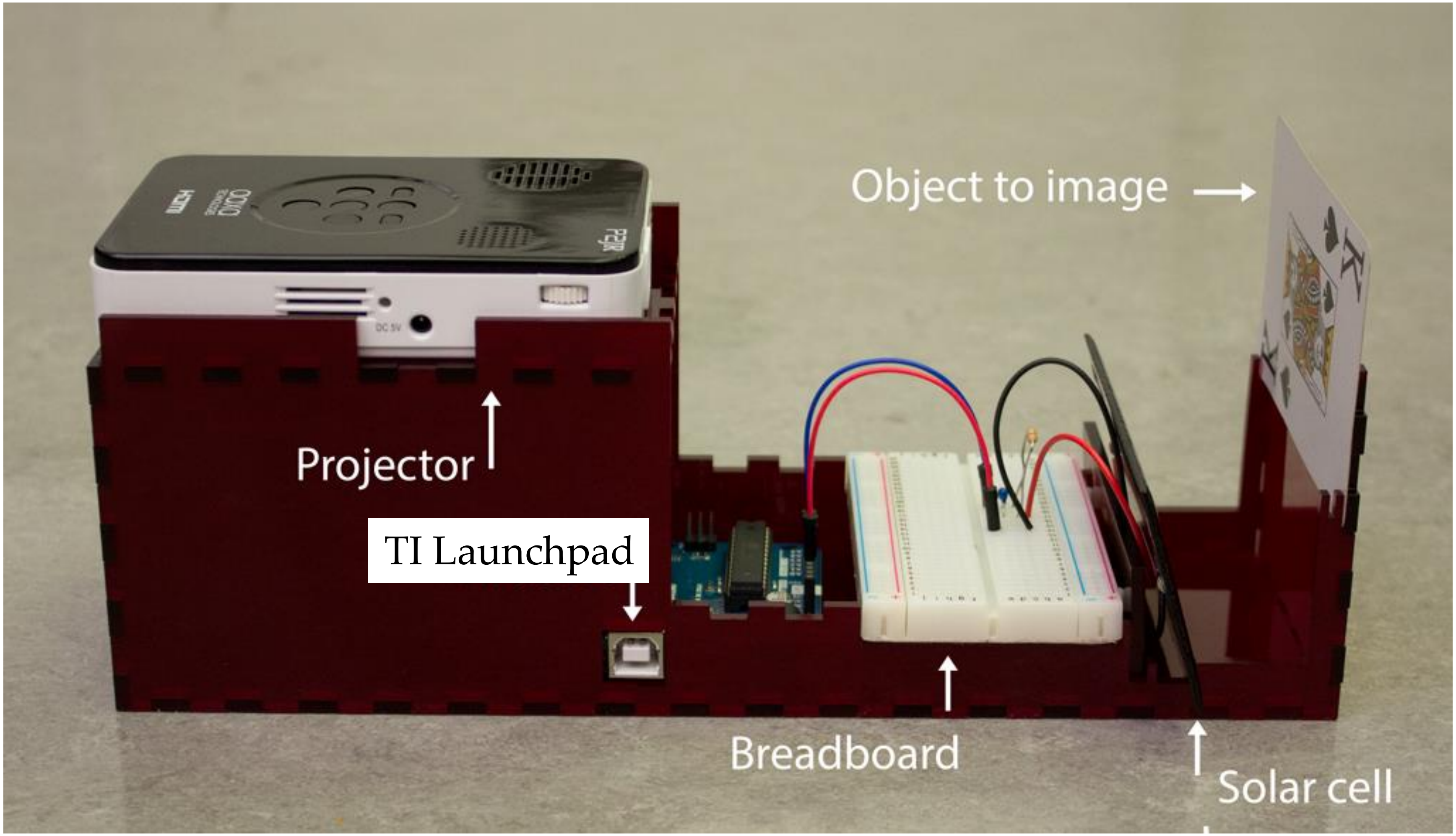
- **The depth dimension is recovered by keeping track of how long it took the echo to come back**

- **The x-y dimensions are recovered by electronically focusing and steering the sound waves**
  - That is, no moving parts needed (except for the transducer itself)

Imaging Lab #1



Your Setup


Object to image
Projector
TI Launchpad
Breadboard
Solar cell

An Imager with Just One Sensor?

- **After all, today's cameras have millions of pixels…**

- **Great teaching vehicle: you can actually get a lot out of surprisingly simple designs**
  - Once you know the right techniques!

- **In some systems the sources and/or detectors might actually be expensive**
  - Take this opportunity to learn a little more about how detectors usually work
  - And how we get them to "talk" to our electronic systems

Photodetector Basics

- **Let's focus on light as our example source**
  - Same basic principles apply to many other detectors
- **Turns out that light comes in discrete packets called photons**
  - The brighter a source of light is
  - The more photons it is emitting over a given period of time
- **An electronic photodetector captures these photons and converts them to electrons**
  - Electrons are the basic unit of **electrical charge (Q)**

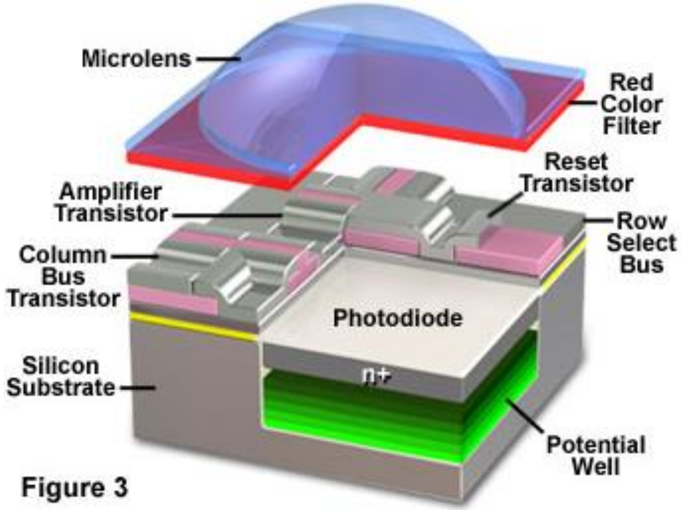


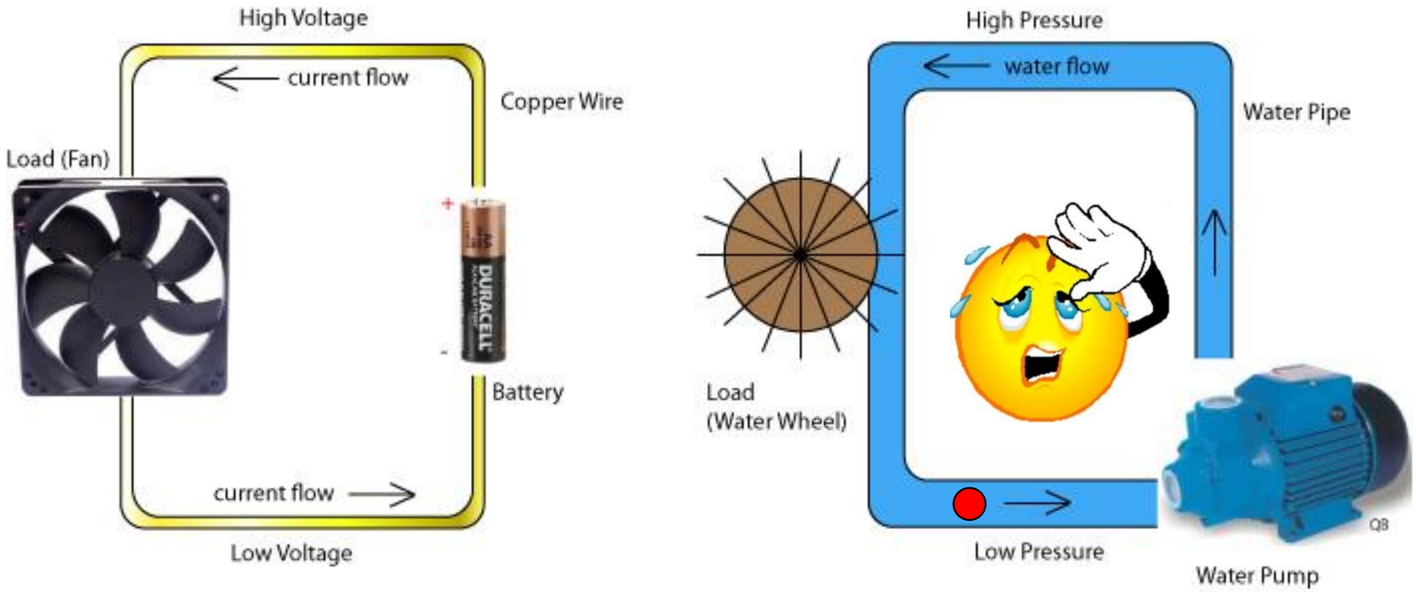
Figure 3

So What Do We Do With Those Electrons?

- **Simplest option might be to let those electrons build up somewhere over a period of time**
  - And then count how many we accumulated

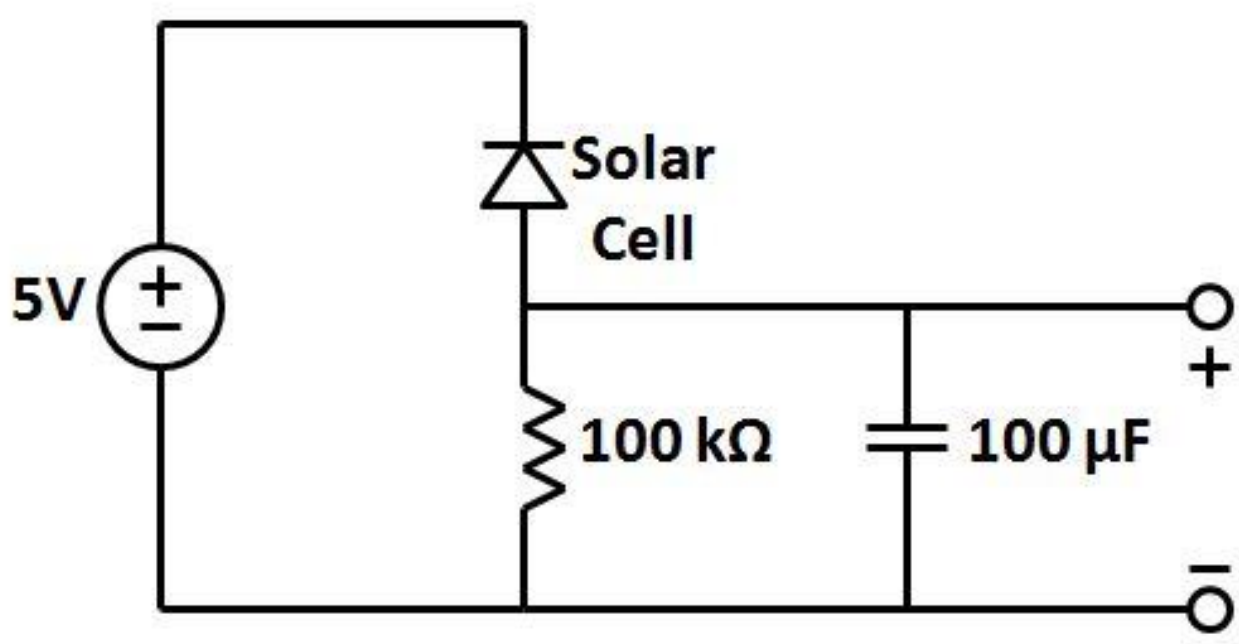
- **All electrical elements (including the photodetectors themselves) can actually build up charge (electrons)**
  - The more charge they store, the higher the **voltage (V)** across them
  - The relationship between the amount of charge and the voltage is known as **capacitance (C)**
    - Defined by **$Q = C*V$**
  - The number of electrons flowing through the device per unit time is defined as the **current (I)**

An Analogy (More Later)



- **Key points for now:**
  - **Current flows from high to low voltage (high pressure to low pressure)**
  - **These are called "circuits" for a reason – the loop has to be closed**

Photodetector:
The Actual Circuit You'll Use



More Complex Imaging Scenario

- What if we can't shine light (i.e., focus energy) either uniformly on all spots or in just one spot?

- The signal we receive on our detector will be a **linear combination** of several features of the image from different points.

- Can we recover the original image?
  – In many cases, yes!
  – Will start to see how next…