Interface between life and physical sciences

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The CURIE project team
Semiconductor revolution

1946
Eniac

1948
First transistor

1946 2011
Genome revolution
Energy revolution?

Non-Renewable Energy

Renewable Energy

- Biomass
- Solar
- Geothermal
- Water
- Wind
Breakthrough is at the interface

ECE

Life

Energy
Projects for CURIE 2011

• Infrared pulse meter (biomedical)
• Sleep apnea feedback device (biomedical)
• Microvascular on chip (biomedical)
• Protein localization in mammalian cell (bio)
• Electronic cricket (bio-inspired design)
• Electrical vs. genetic oscillators (systems & synthetic biology)
• Sun tracker (energy)
• Wireless combination lock (electronics)
Project 1: Infrared Pulse Meter

- Idea: Use noninvasive infrared light to probe blood pressure and pulse rate in a finger tip.
- Uses: A variant of this device is used routinely in hospitals and is called a pulse-oximeter.
- Components:
  - Comparator
  - Amplifiers and filters
  - Light emitting diodes and photosensors
The clear device to the left is an infrared emitting LED.
- amount of light $\rightarrow$ amount of current $L = k*I$
- Wavelength (color) sets voltage. For IR, $V$ is around 1.2 volts
- Only works one direction
- Use your cell phone camera to see if it operates.

The black device to the right is an IR sensor (phototransistor)
Current flows when light is absorbed:
$I = k*L$

Your finger absorbs more IR if there is more blood. Each heart beat sends more blood into your finger and changes the IR absorption, but the change is small.
Project 2: Sleep Apnea Feedback Device

- The most common treatment is an assisted breathing device called a continuous positive airway pressure (CPAP) mask, designed to keep the upper airway open during sleep.
Project 2: Sleep Apnea Feedback Device

• Idea:
  • Create auditory and visual feedback systems to relate the amount of force back to the person exerting the force

• Potential uses:
  • Biomedical training device
  • Superior to existing treatment?

• Components:
  • Microcontroller
  • Resistor
  • Light emitting diodes (LEDs)
  • Transistor
  • Peizo Buzzer
  • Analog-to-digital converter (ADC)
  • Digital potentiometer
  • Force sensor (load cell)
Project 3: Microvascular on Chip

- LSI
- Body on chip
- Concentration gradient

- Sperm sorter for IVF
- Traction force microscopy
- Portable medical diagnostics
Project 3: Microvascular on Chip

• Idea: To characterize a simple model of the microvascular system using a microfluidic device

• Potential Uses:
  – Simulate clot, stroke, plaque buildup in arteries
  – Discern effect of vessel blockage or occlusion on blood pressure

• Components:
  – PDMS microdevice
  – Tubing
  – Syringe pump
  – Silicone sealant
  – Beads for visualization
  – Microscope
  – Image capture software
  – Image analysis software
Project 4: Protein Localization in Mammalian Cells

- Cystic fibrosis (CF)
- Familial hypercholesterolaemia (FH)
- Congenital sucrase-isomaltase deficiency (CSID)
Project 4: Protein Localization in Mammalian Cells

• Idea: Compare localization of proteins (ZFP568 & GALT) in two types of mammalian cells

• Significance: Protein location is essential for proper function, mislocalization is associated with disease

• Biological Techniques:
  – DNA extraction & purification
  – Transfection of DNA into HEK293T (human embryonic kidney) & NIH3T3 (mouse embryonic fibroblast) cells
  – Cell staining & fluorescence microscopy to visualize protein location with GFP
Project 4: Protein Localization in Mammalian Cells

Miniprep to extract DNA from bacteria (Tues)

Stain & look at our cells to see where the protein is (Thurs/Fri)

Transfect to put our DNA in mammalian cells (Wed)
Project 5: Electronic Cricket

• Idea:
  – Use photoresistor to detect light, only chirp when dark
  – Create sort-of-realistic cricket noise using several oscillators
  – Match to real cricket calls: google “cricket chirping”

• Potential uses: annoy people; investigate cricket social interactions (see Genetic Control of Acoustic Behavior in Crickets – Ron Hoy)

• Components:
  – Photoresistor
  – Oscillators
  – Speaker
Project 5: Electronic Cricket

- Field cricket:
- Syll. frequency 4-5 kHz.
- Syll. Repeat 35 mSec
- Duty Cycle ~50%
- Chirp repeat rate ~2-4/sec

From http://www.uni-graz.at/~hartbaue/introduction.html
Project 6: Electrical vs. Genetic Oscillators

- Oscillator is ubiquitous in electrical systems
  - cell phone, computer, TV, PDAs, satellite ...
- Clock in living organisms
  - circadian rhythm
  - synthetic genetic clock

http://www.youtube.com/watch?v=pnjdAr4EjI0
Project 6: Electrical vs. Genetic Oscillator

• Idea:
  – Use electronic circuits to understand the operation of a genetic oscillator.
  – Genetic oscillators must be involved in circadian rhythms and other periodic protein expression.
  – Similar math can be used to understand both electronics and gene circuits.

• Potential uses: Help with understanding feedback effects in biology.

• Components:
  – Timing circuits
  – Amplifiers
  – Light emitting diodes
Project 7: Sun Tracker

• Challenges for Harvesting solar energy
  – Efficiency
  – Cost
    • Manufacturing
    • Maintainence
Project 7: Sun Tracker

• Idea:
  – Use two photodiodes to detect where the sun is
  – Control a motor to turn toward the sun
  – When sun is “half-way” between PD, stop.

• Potential uses: solar cell tracking

• Components:
  – Stepper motor
  – Shift register
  – Photodiodes
  – Comparators

• Optional: build clock circuit and power with batteries to take outside
Project 8: Remote Sensing Security

- Cyber security - Privacy is under attack:
  - Personal information
  - Banking
  - Network loophole
  - Medical records
    - Your DNA sequence?
Project 8: Remote Sensing Security lock

• Idea:
  – Create a 4bit password using switches
  – Send data serially (one bit at a time) using an LED
  – Receive the code serially and convert data into a 4 bit number
  – Compare the received data with original code
  – Unlock the key if it matches!

• Potential uses: TV/ DVD/Car unlock … remote control

• Components:
  – Timer
  – Shift Register
  – Amplifier
  – Switch
  – Comparators

• Optional: extending the system into 8-bit
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