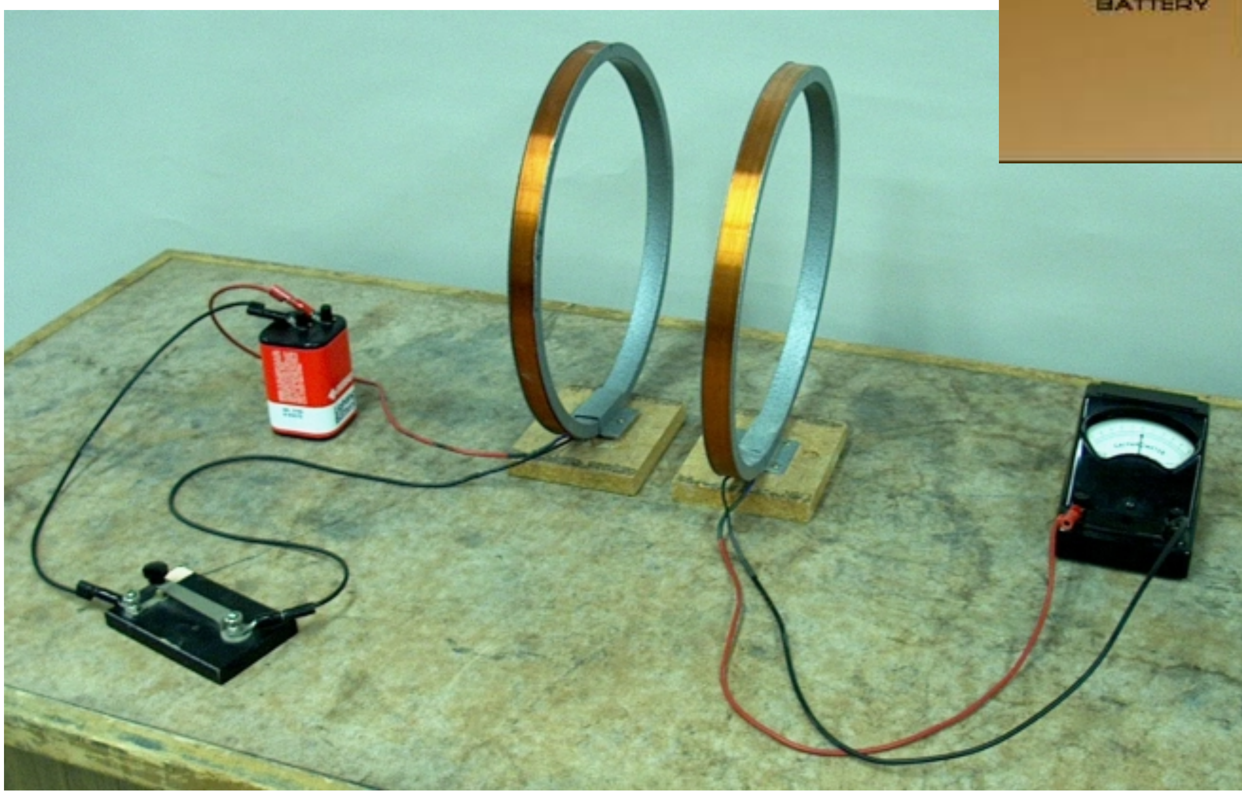
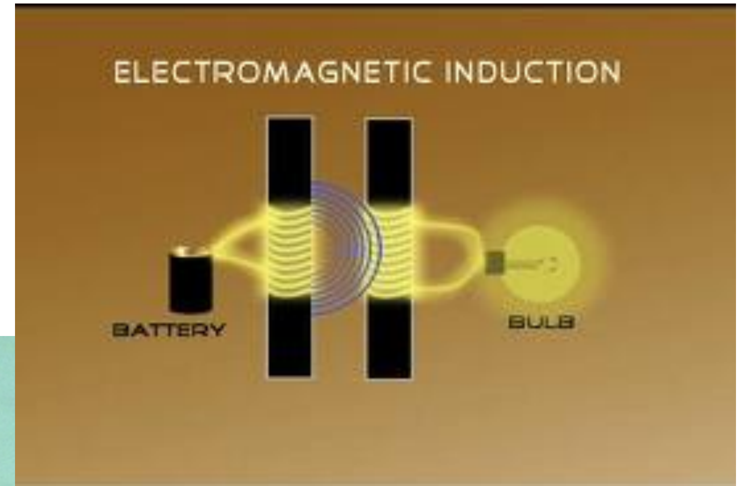
ME490B : Lecture 3

- Announcements
  - Meeting schedule for today
  - Beginning evaluations
  - Organizing anybody who has issues with their projects
- Case study – energy harvesting

ME490B Case study 4: Wireless Charging and Energy Harvesters

Fall 2014




ELECTROMAGNETIC INDUCTION
BATTERY
BULB

Wired Charger

- Conventional direct ohmic contact between power source and the car
- High Efficiency: only small ohmic loss

- Challenge: Charging time

  Attempted solution

  1. Capacitor Storage
  2. DC Fast Charging

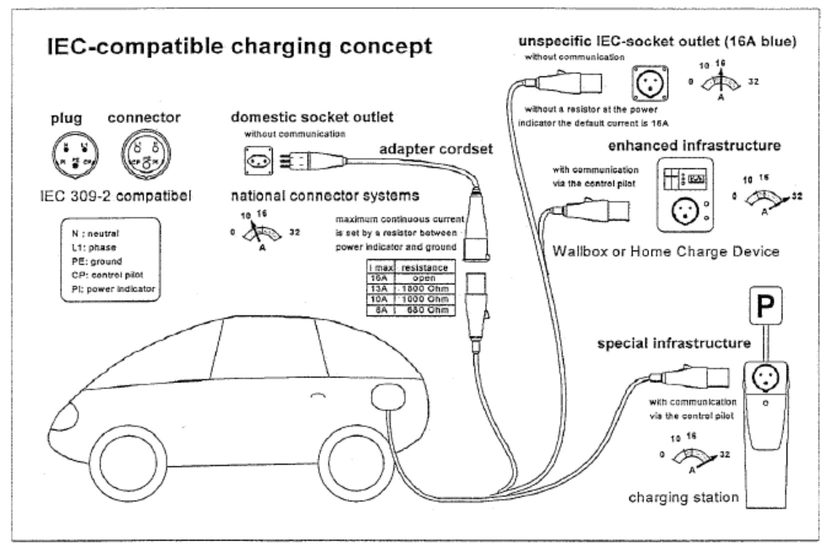


Fig. 2. Example of possible conductive charging infrastructure.

Capacitor Storage

- Advantage: Fast charge/discharge rate
- Ex. Shanghai Capacitor Bus

One charge
-Charging time 30-80 sec
-Running distance 3-6 kms
-Charging System DC 320-600V

Wireless Transmitting Method

- Microwave Transmission
- Magnetic Induction
- Magnetic Resonance Coupling
- Capacitive Coupling

Guided microwave power beam

- Advantage: transmission beam can be steered electrically with no moving parts
- Potentially transfer up to 400kW with distance 1km

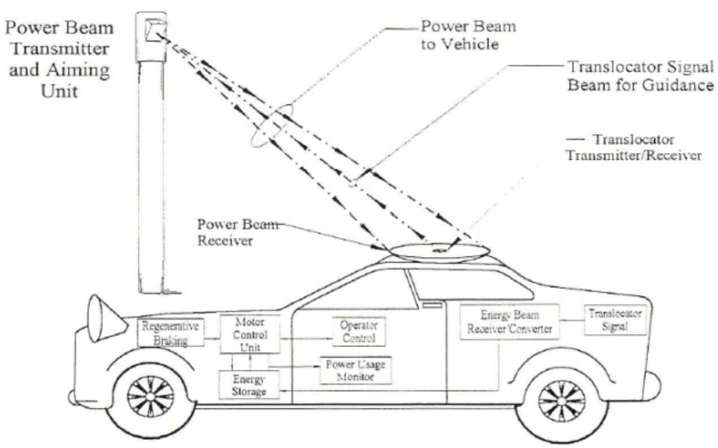


Figure 1: All-Electric Vehicle Components

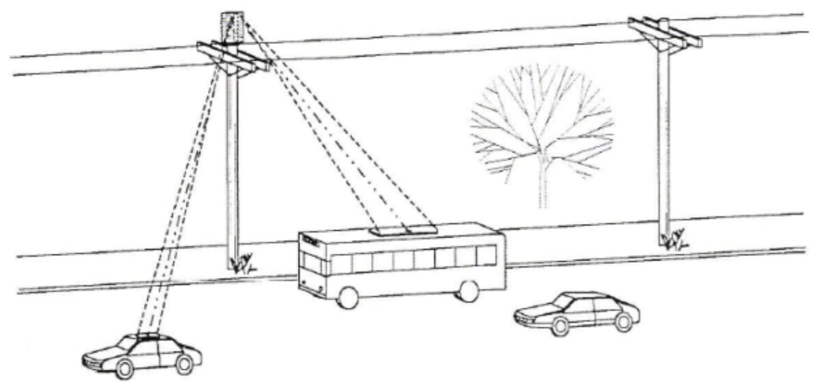


Figure 2: Wireless Power Beam Network

Magnetic Induction

- Transferring electrical power from the source to the load magnetically, inducing current/voltage in receiver coil

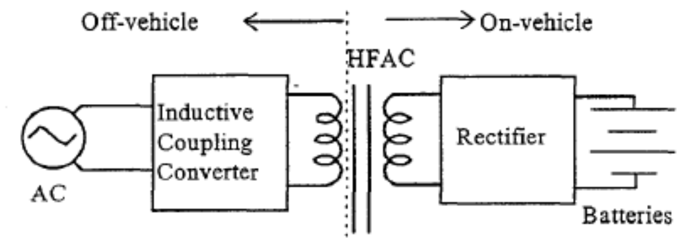
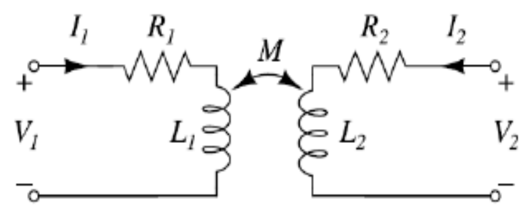


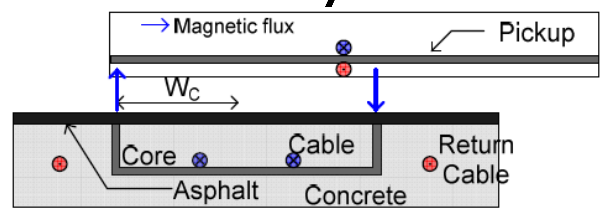
Fig. 4. Block diagram of power flow from the utility to the electric vehicle batteries.

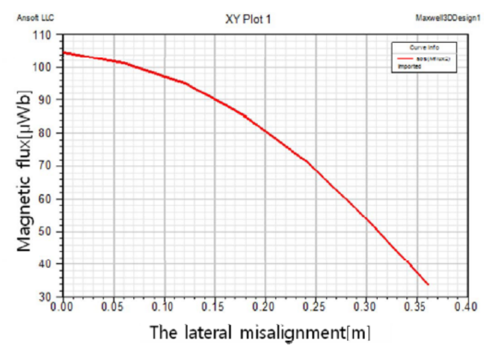


OLEV by KAIST

- On-Line Electric Vehicle since 2009
- Efficiency severely subject to misalignment,

  -> use position control module for accuracy within





Regarding Human Health

- Nagano Japan Radio 13.56MHz, 1kW
- Efficiency > 80% (for 10~30 cm gap)
- Aluminum plate to shield magnetic field

Fig.11 System Configulation of WPT for small EV

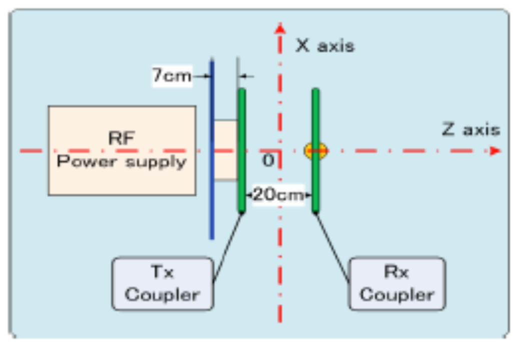


Fig.8 Aligment of Al plate for supression

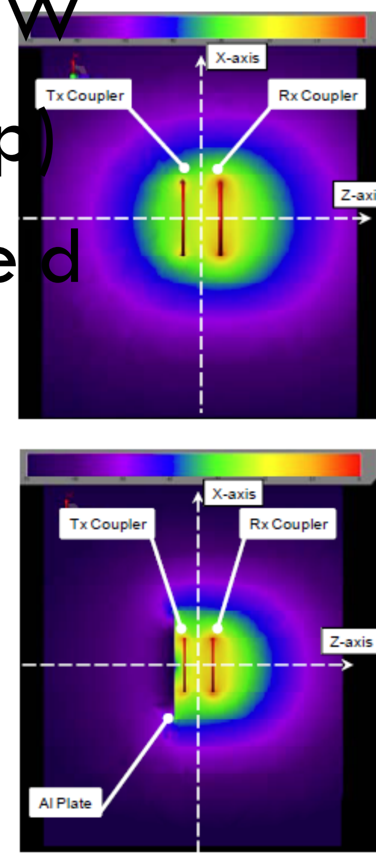
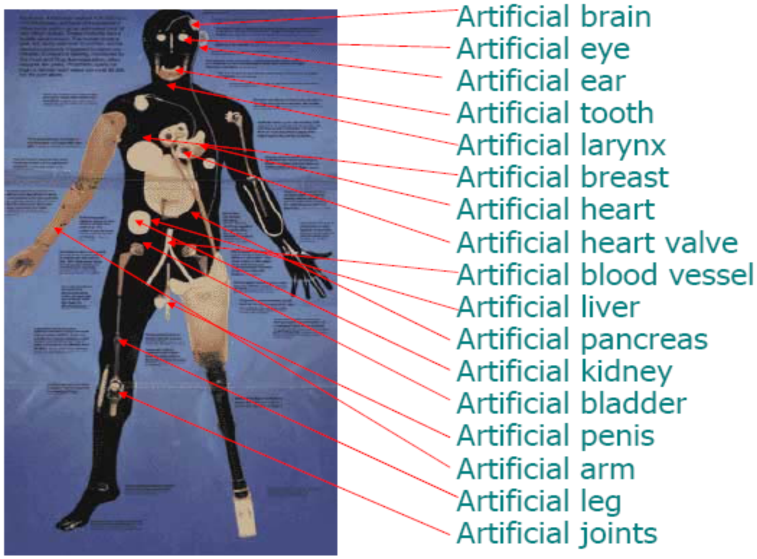
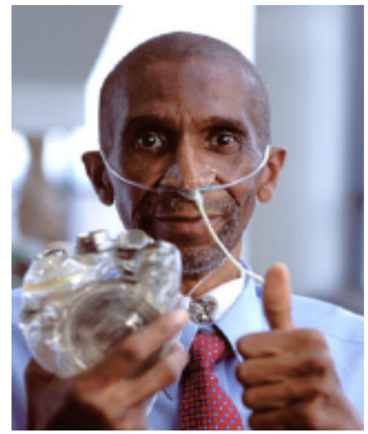
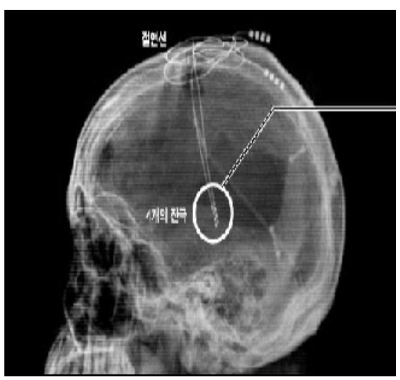
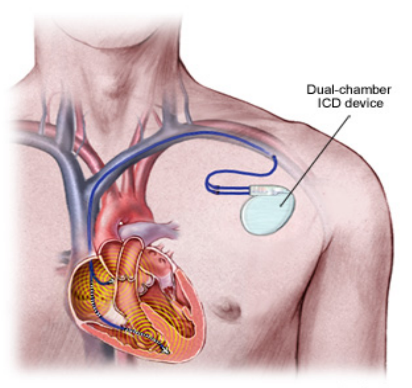


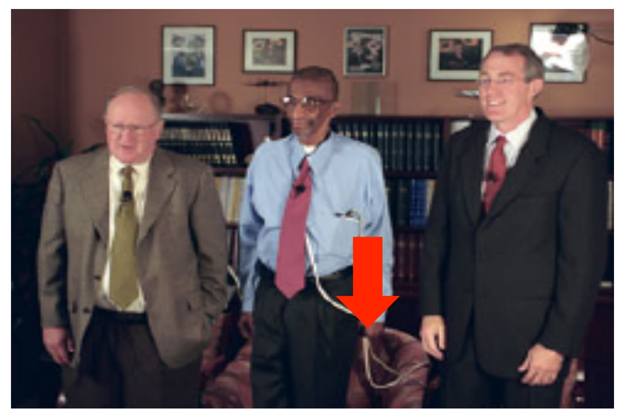
Fig.9 Simulated result (upper: no plate, lower: insert Al plate)


Artificial brain
Artificial eye
Artificial ear
Artificial tooth
Artificial larynx
Artificial breast
Artificial heart
Artificial heart valve
Artificial blood vessel
Artificial liver
Artificial pancreas
Artificial kidney
Artificial bladder
Artificial penis
Artificial arm
Artificial leg
Artificial joints



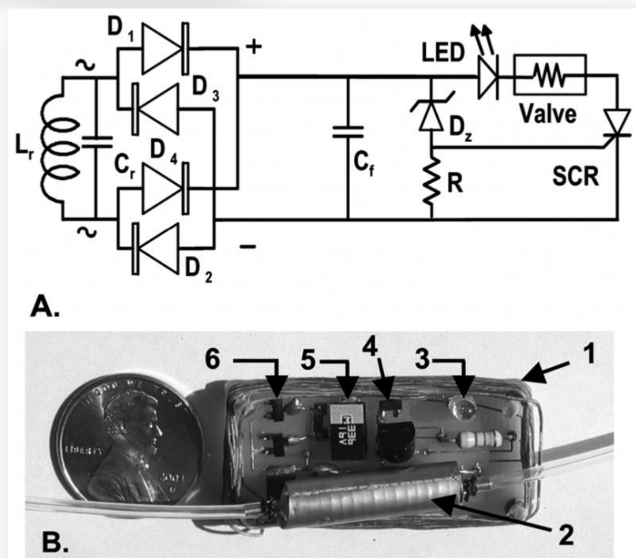


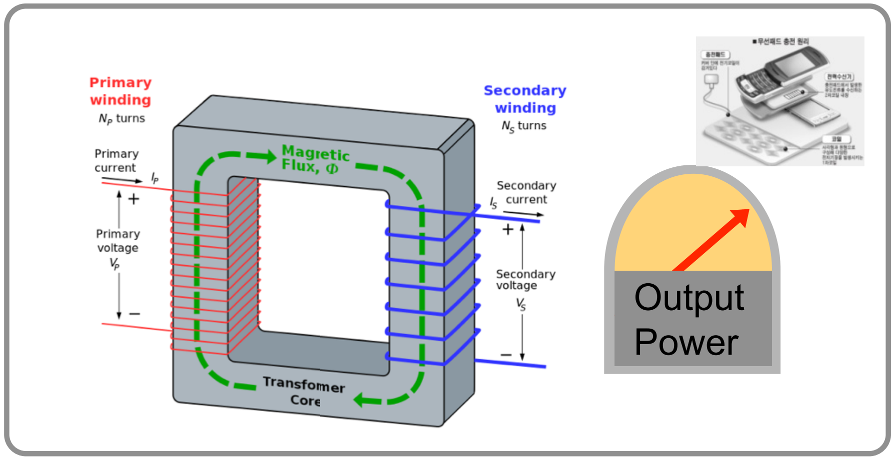

Dual-chamber
ICD device
© medmovie.com

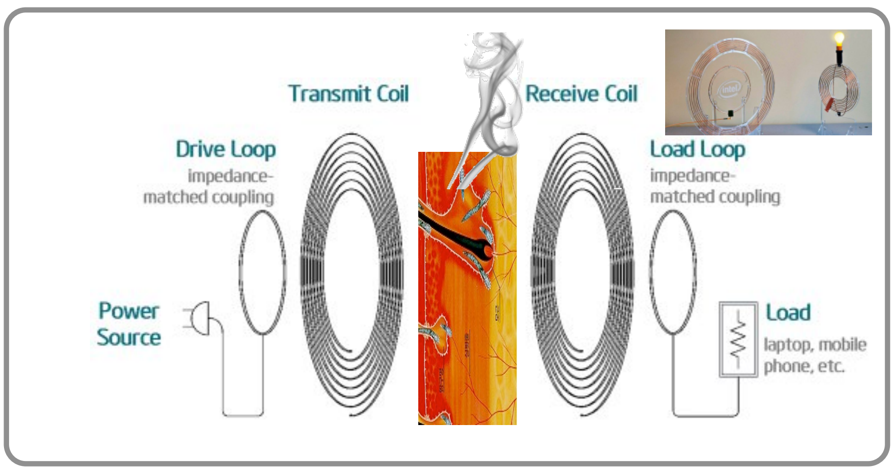


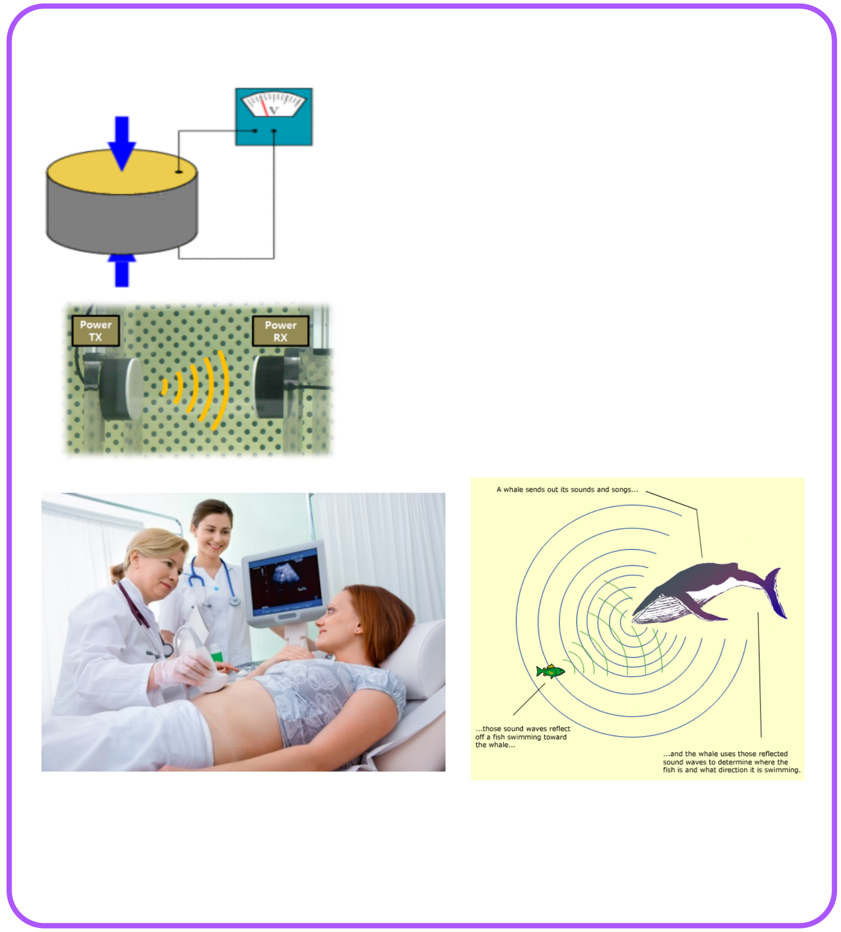
Total Implantable Multichannel Electronics" (TIME) spinal cord stimulator shown in this picture went into clinical trials around 1988

This device was one of the first to feature four stimulation channels, and was paired with Neuromed's tetrapolar stimulation lead described in US Patent Number 4,379,462



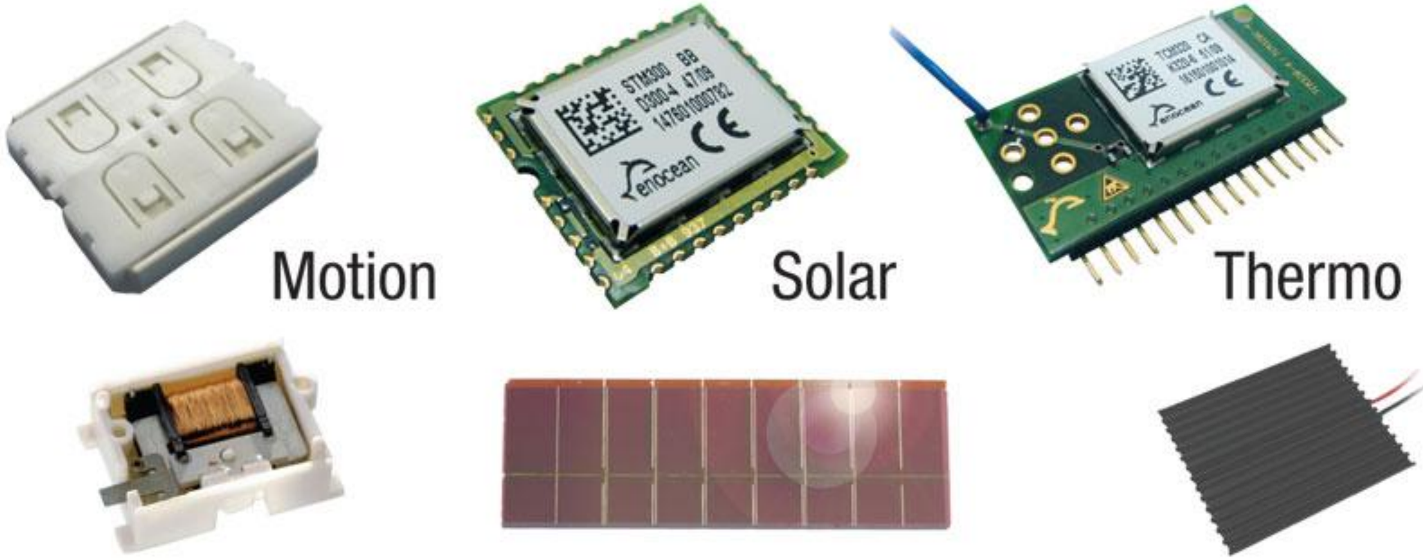

Primary winding
N_P turns
Primary current
I_P
Primary voltage
V_P
Magnetic Flux, Φ
Secondary winding
N_S turns
Secondary current
I_S
Secondary voltage
V_S
Transfomer Core
Output Power

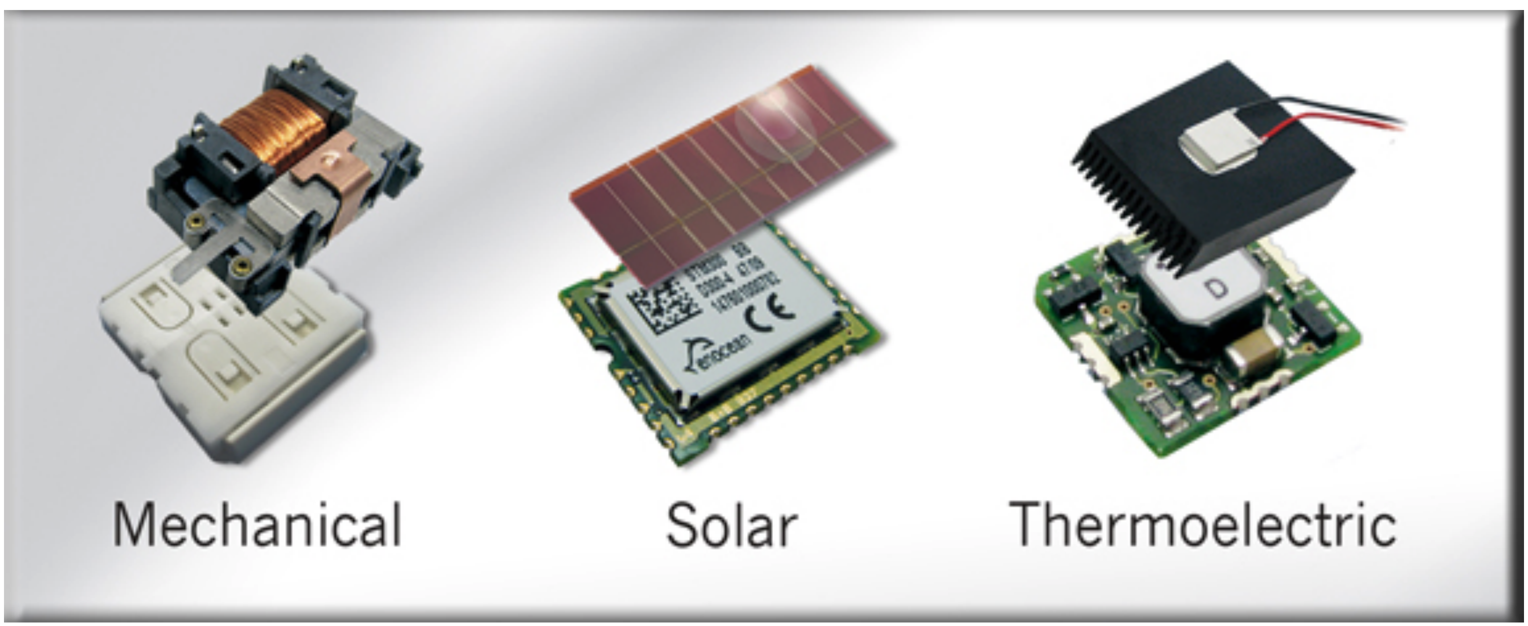

Transmit Coil
Receive Coil
Drive Loop
impedance-matched coupling
Load Loop
impedance-matched coupling
Power Source
Load
laptop, mobile phone, etc.


Power TX
Power RX
A whale sends out its sounds and songs...
...those sound waves reflect off a fish swimming toward the whale...
...and the whale uses those reflected sound waves to determine where the fish is and what direction it is swimming.

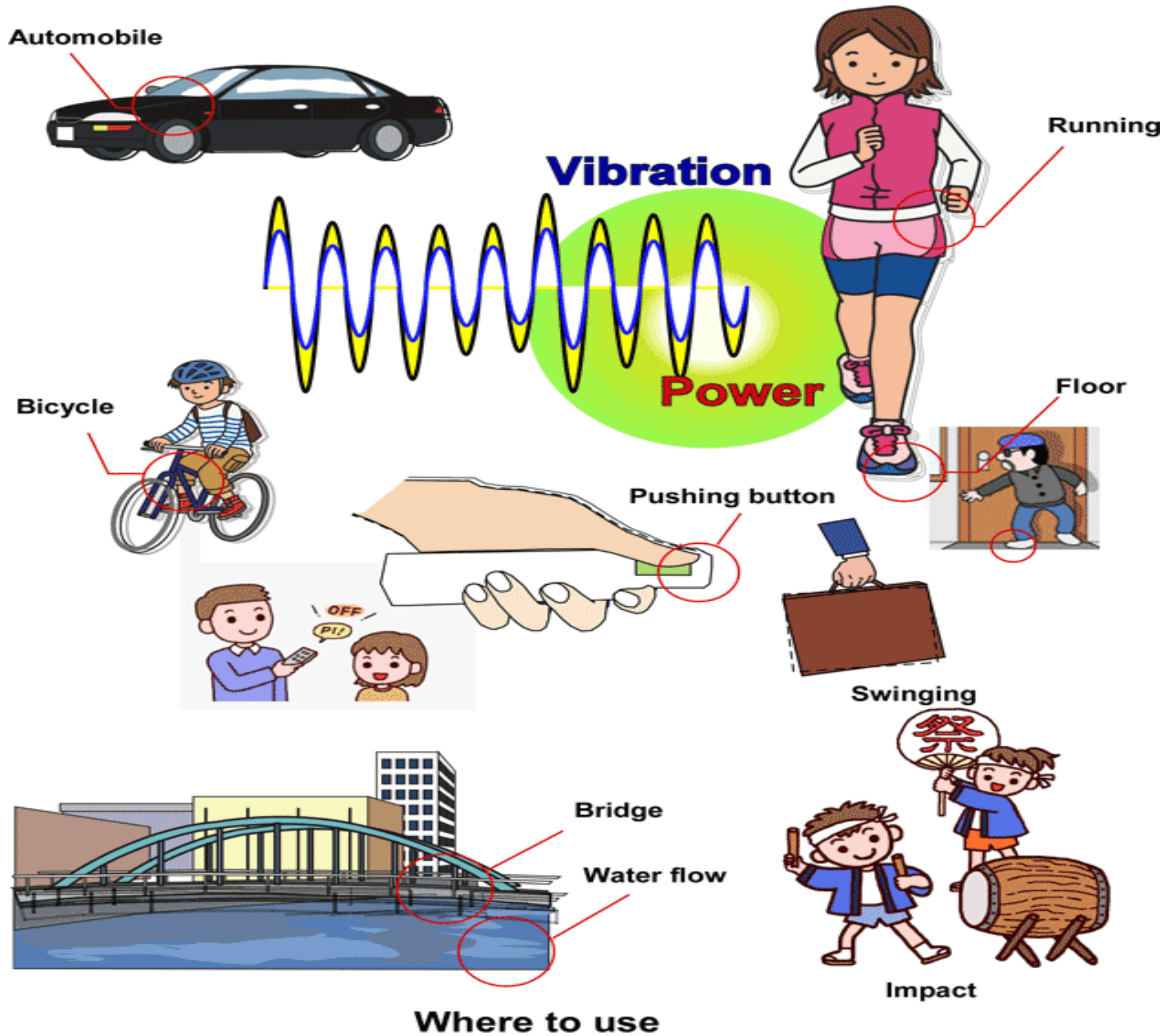
Energy-Harvesting System♪

- In today's high-tech world
  - microelectronic portable devices
  - impose increasingly severe power requirements
  - because of the volume constraints of portable
  - electronics, available, stored energy is limited
  - resulting in short operation life
- Self-renewable energy reservoir that can continually self-replenish energy consumed
  - finds a niche in a wide variety of portable applications.♪


Motion
Solar
Thermo


Mechanical
Solar
Thermoelectric

Motion and Vibration



Electromagnetic Energy Harvesting Methods♪

- No voltage source required
- Rectification and power conditioning
- Difficult integration of magnet
- Very low output voltage
- Moving parts♪

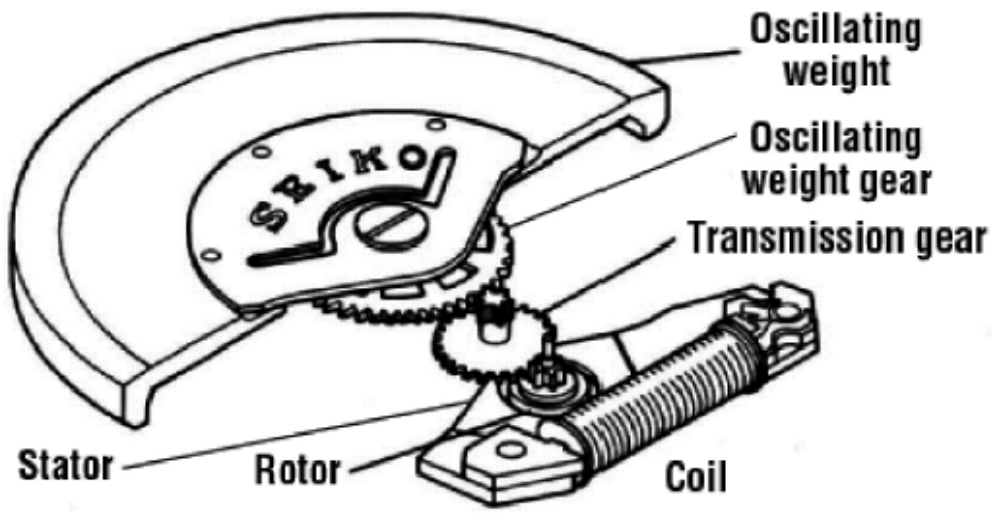
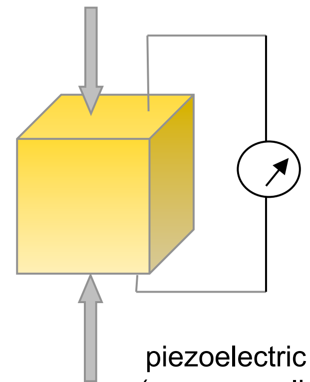


Figure 1. The Seiko Kinetic watch. (Courtesy Seiko Watch Corporation.)

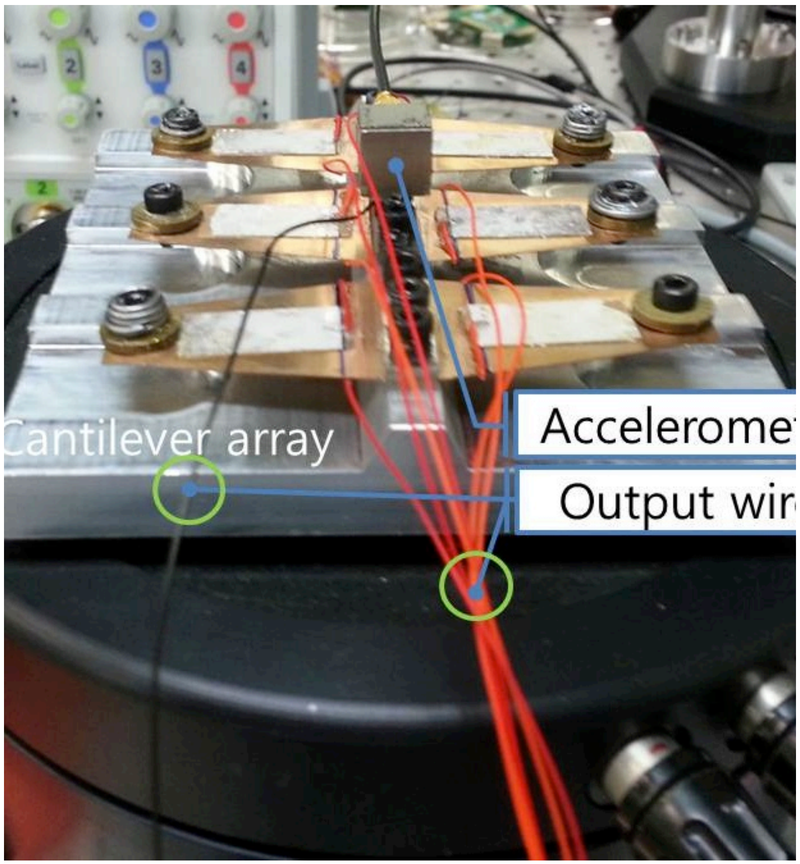
Piezoelectric Energy Harvesting Methods♪

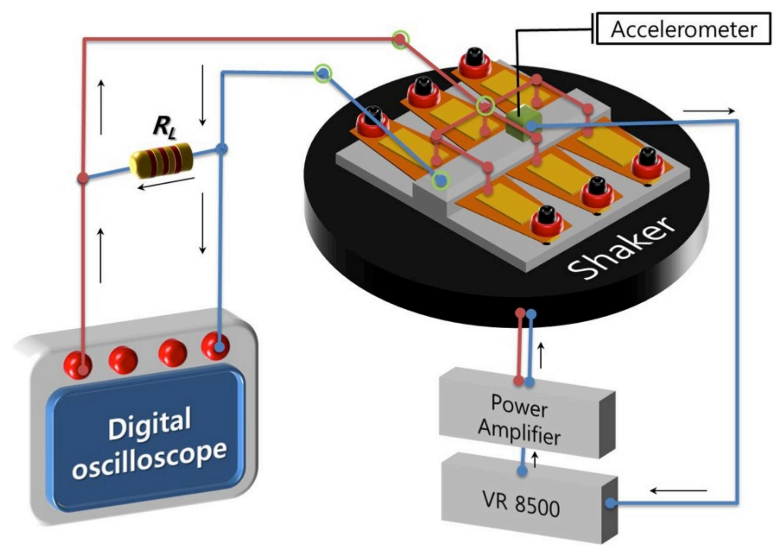
- No voltage source required
- Rectification and power conditioning
- Difficult integration of piezoelectric material
- Higher output power and voltage
- Moving parts
- Decreased coupling and brittleness of thin films♪



converse piezoelectric effect: Materials showing this phenomenon also conversely have a geometric strain proportional to an applied electric field.♪

measuring equipment used for the resonant frequency and output voltage of the cantilever array



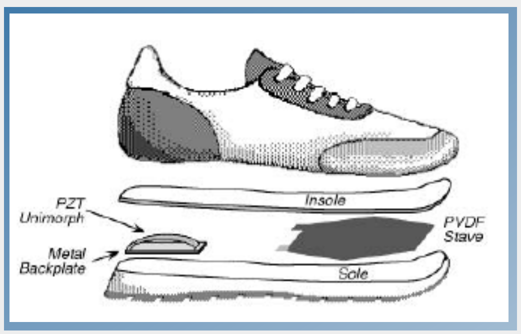


- Energy harvesting♪

Mechanical vibration → **Energy harvesting by Piezoelectric effect** / **Output processing** → Electrical energy →
- Power storage
- Wireless
- Remote sensing
- Personal mobile

- Examples of Energy harvesting using piezoelectric effect

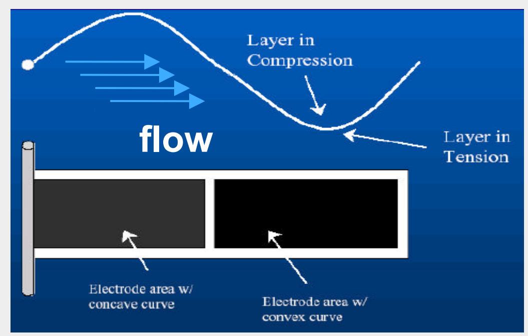
♪



MIT shoe

by Joe Paradiso at MIT media Lab,1998

1mW with $25cm^2$ piezoelectric element



Piezo el

by Robert Nowak (DARPA), Tom Curtin (ONR), 2000

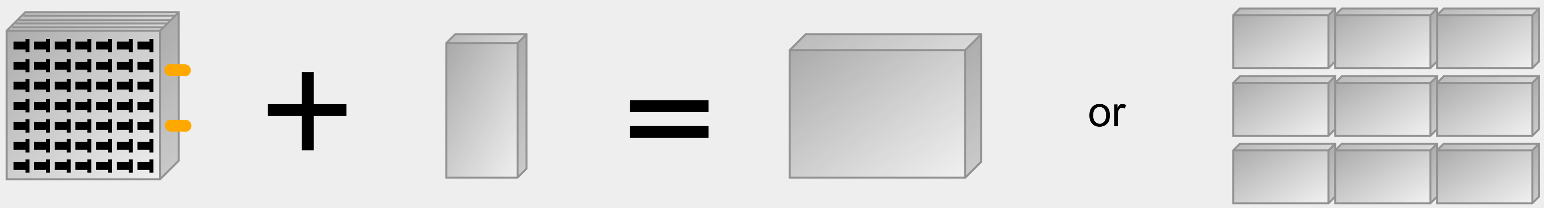
0.6 W at flow rate of 1m/s from a $60cm^2$ structure

MEMS Energy Harvester

- Modulized self-generating power source:

  Targeting dimension: 1 × 1 × 0.3 *cm3*
- Small functional unit –

  Implantable or disposable functional unit for remote sensing, tracking location, personal GPS and battery alternative for mobile devices



Stacked

piezo-elements

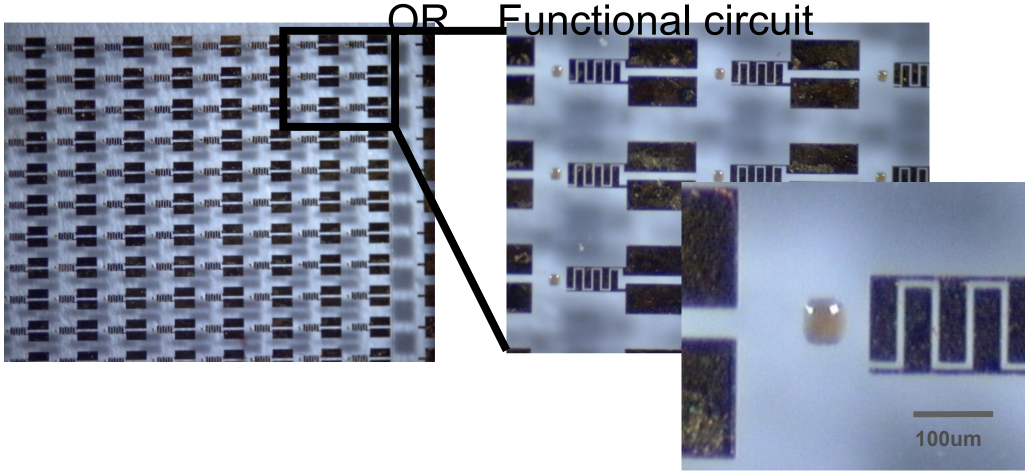
Signal conditioning block:

ratifying and storage

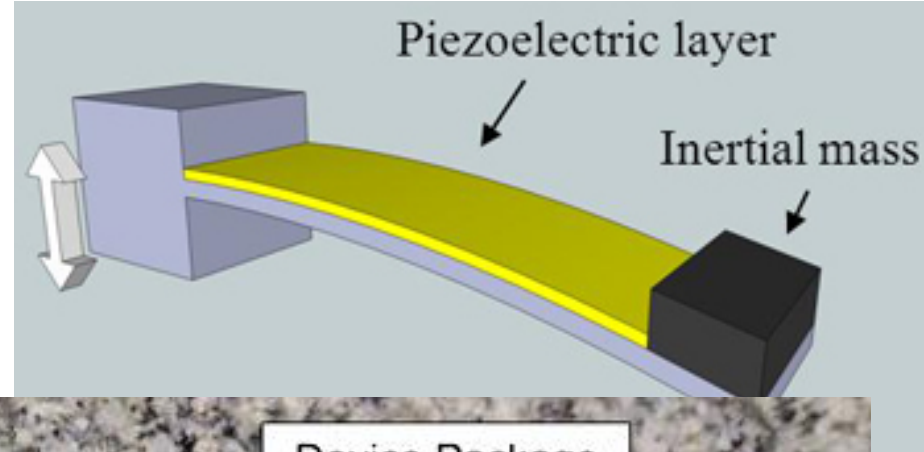
OR   Functional circuit

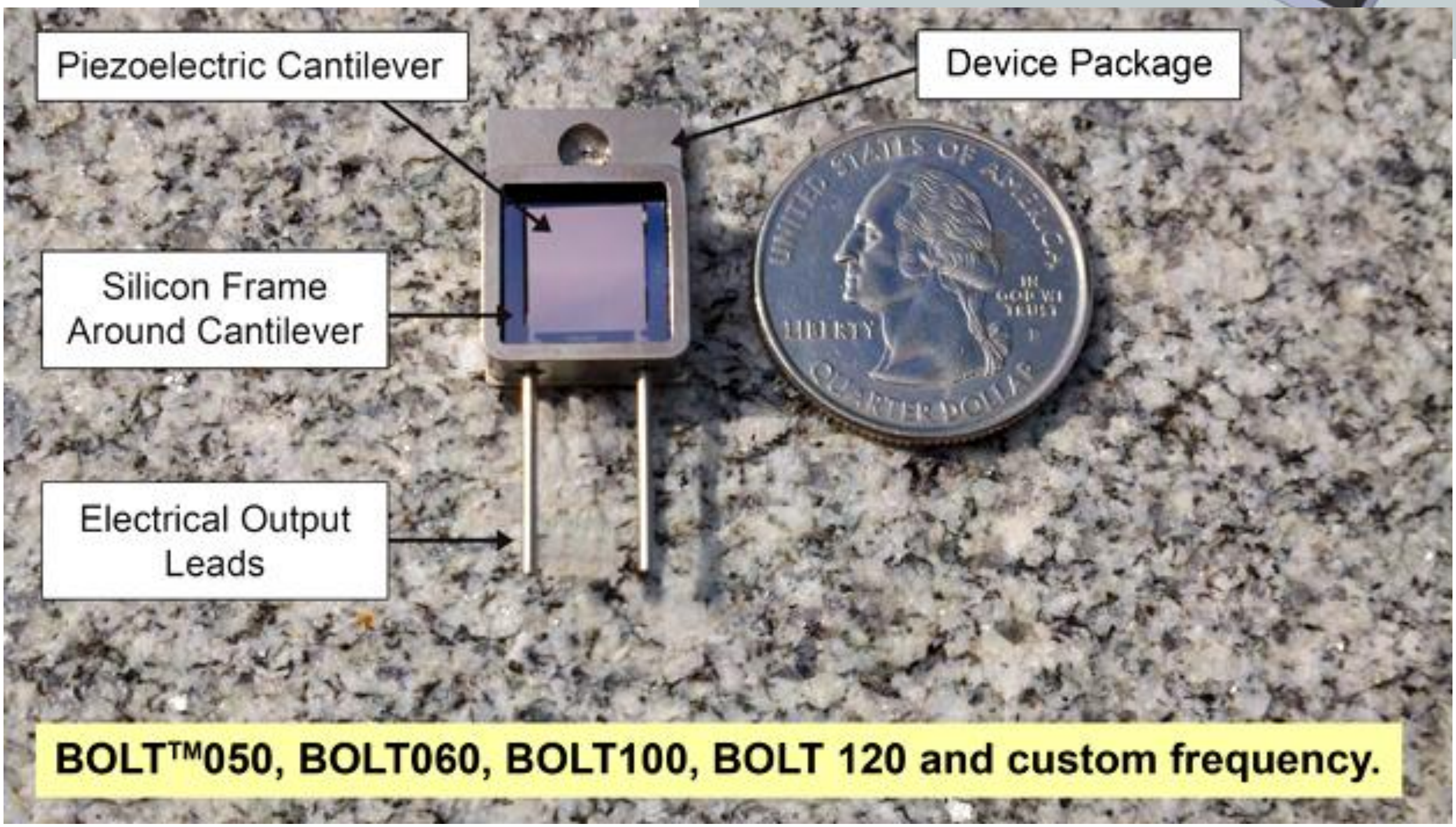
Self-power module

OR independent functional unit



- Micro cantilever array
- Adjustable frequency
- Efficient rectifying circuit


Piezoelectric layer
Inertial mass


Piezoelectric Cantilever
Device Package
Silicon Frame Around Cantilever
Electrical Output Leads
BOLT™050, BOLT060, BOLT100, BOLT 120 and custom frequency.

Thermoelectric Energy Harvesting Methods♪

- No moving parts, reliable
- Very low conversion efficiency
- Low temperature gradients
- Scalable
- Low output voltage
- Durable♪

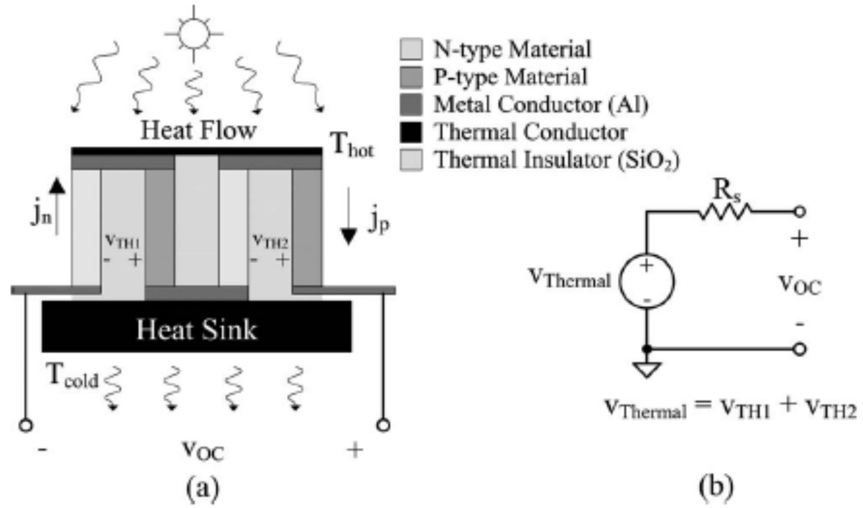
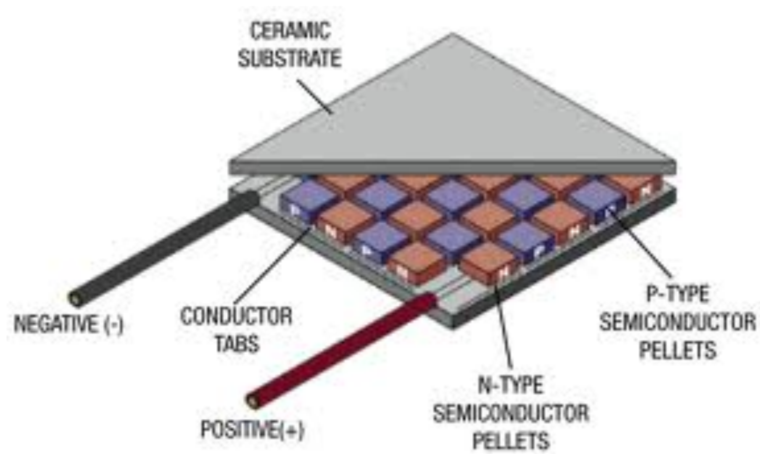
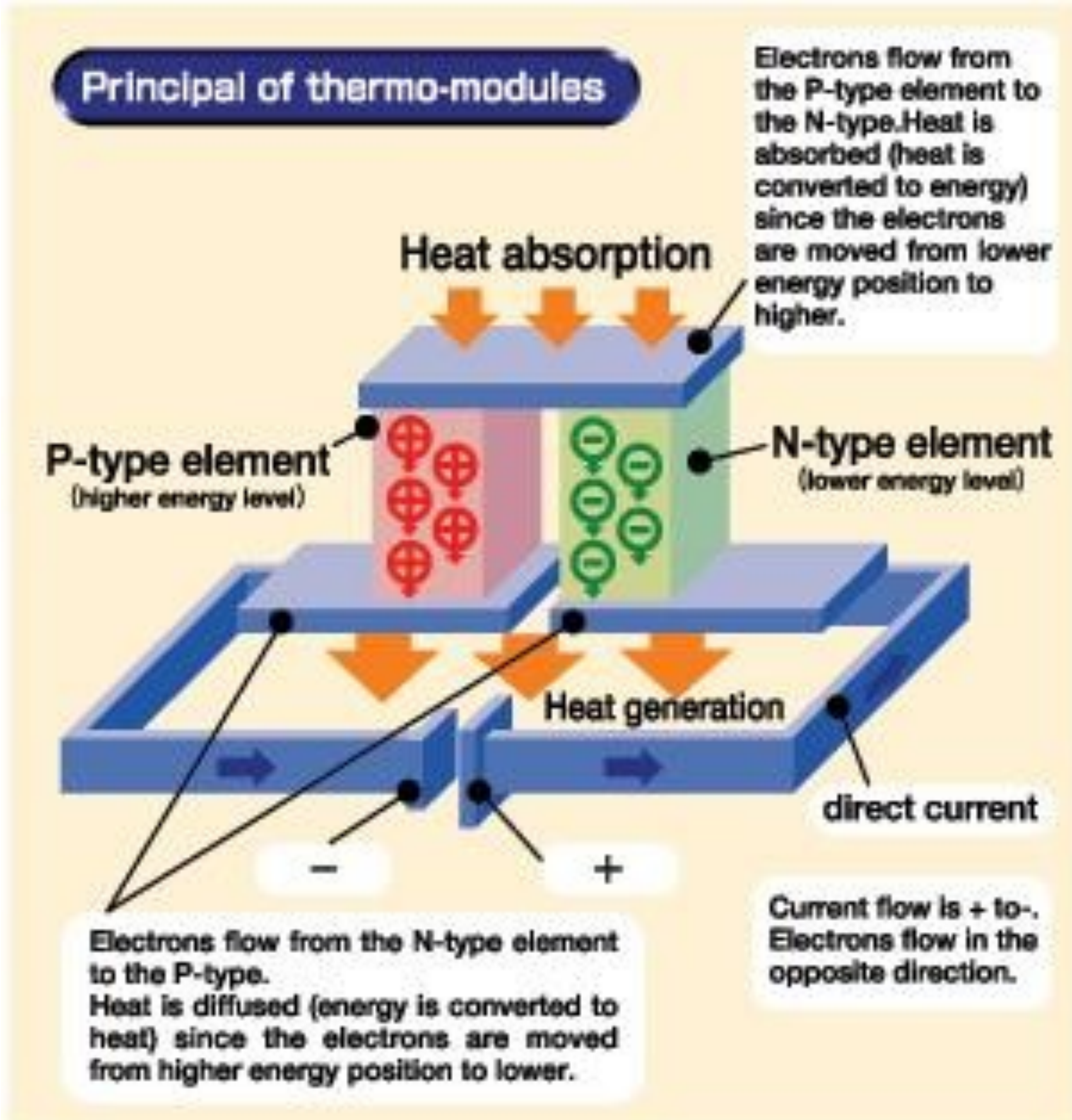
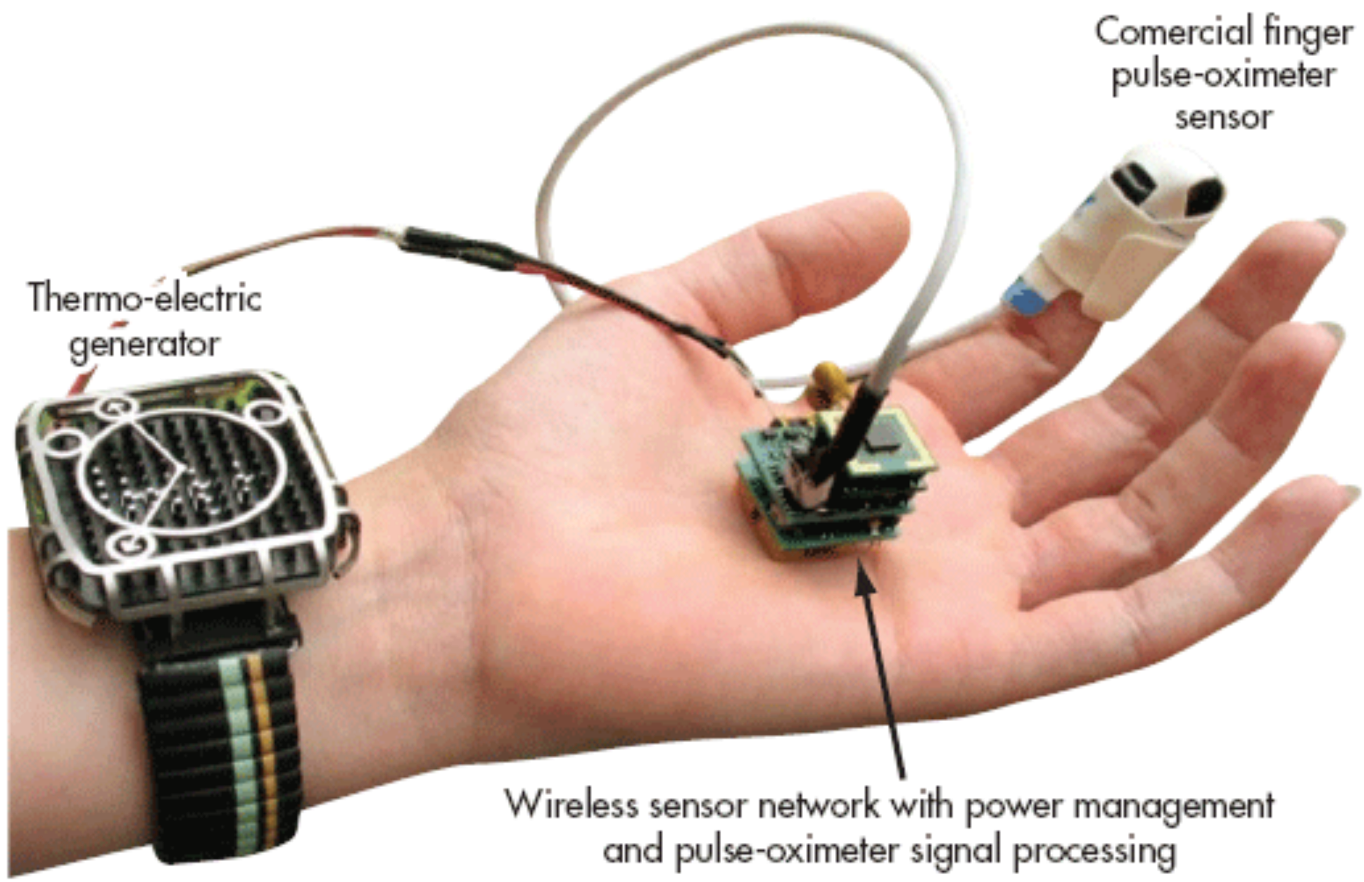


Fig. 2. (a) Thermoelectric energy converter composed of two series thermocouples; (b) its circuit model




Principal of thermo-modules
Electrons flow from the P-type element to the N-type.Heat is absorbed (heat is converted to energy) since the electrons are moved from lower energy position to higher.
Heat absorption
P-type element
(higher energy level)
N-type element
(lower energy level)
Heat generation
direct current
−
+
Electrons flow from the N-type element to the P-type.
Heat is diffused (energy is converted to heat) since the electrons are moved from higher energy position to lower.
Current flow is + to-.
Electrons flow in the opposite direction.


Comercial finger pulse-oximeter sensor
Thermo-electric generator
Wireless sensor network with power management and pulse-oximeter signal processing

Electrostatic (capacitive) Energy Harvesting Methods♪

- Scalable
- Energy investment requirement
- Mechanical stability
- Compatible with current technology
- Synchronization with vibrations
- Moving parts
- High voltages charge constrained♪

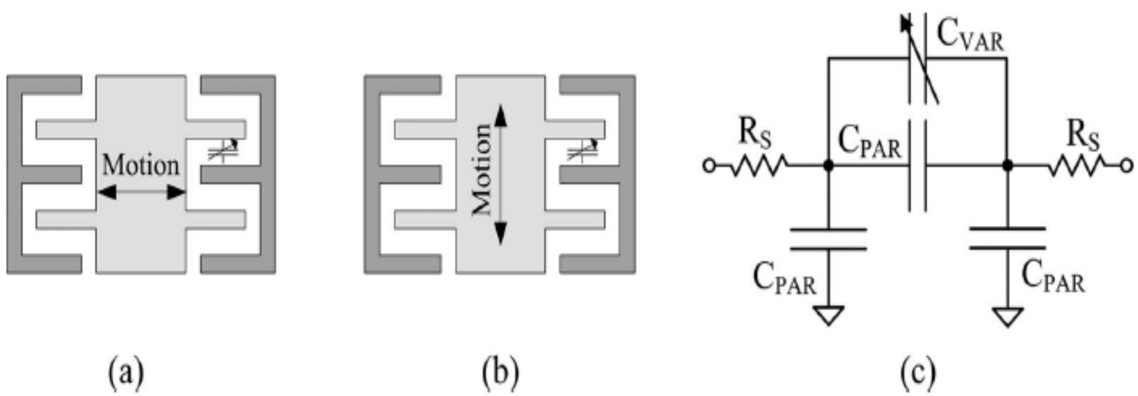


Fig. 7. (a) Changing overlap area; (b) gap distance in-plane variable capacitors; and (c) an energy harvesting circuit highlighting the model of the variable capacitor

Electrostatic (capacitive) Energy Harvesting Methods♪

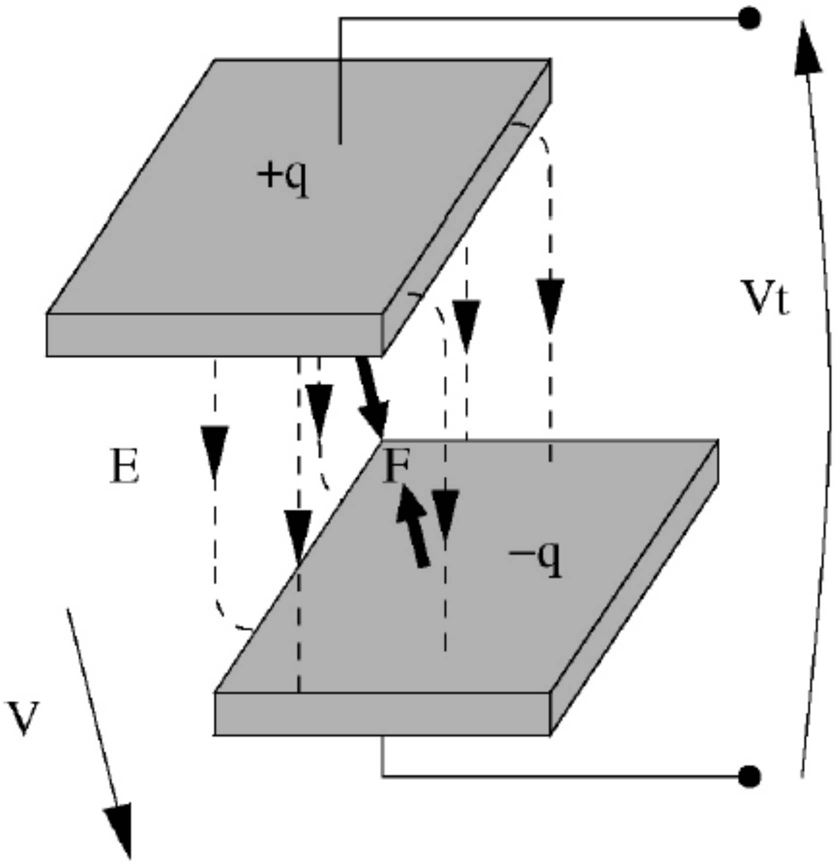


Figure 2. The electrostatic transducer, showing the charges on the electrodes $+q$ and $-q$, the electric field E, a constant voltage V and time varying voltage V_t.

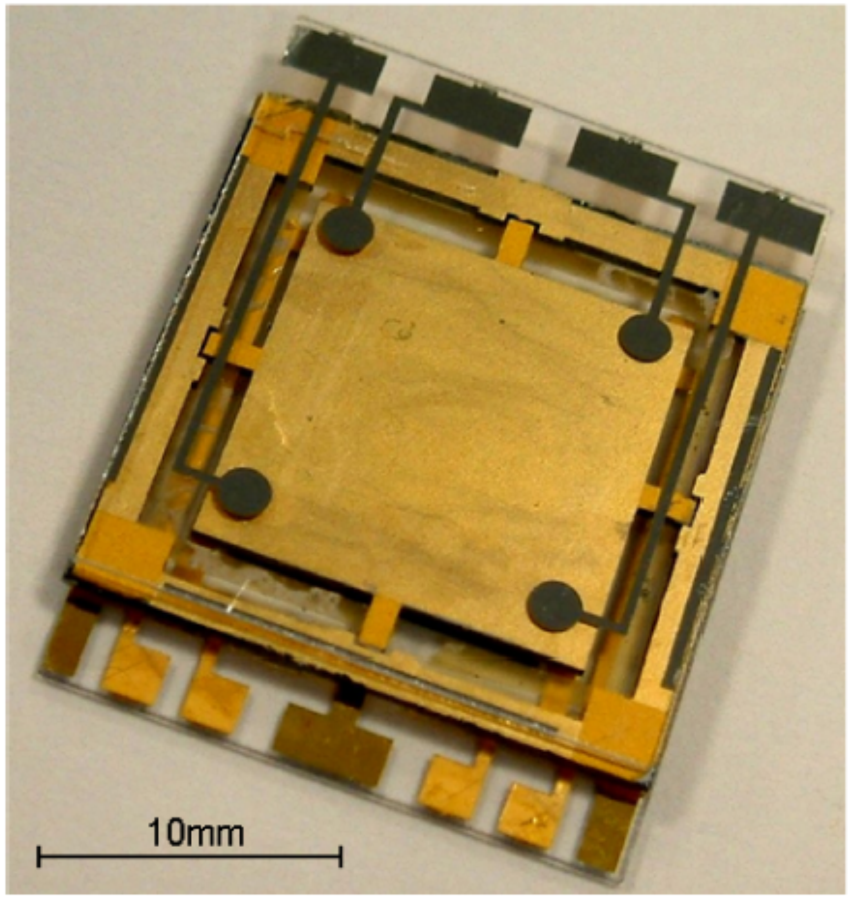


Figure 3. MEMS electrostatic energy harvester fabricated at Imperial College London.

THE HUMAN GENERATOR

How far would you be willing to go to get off the grid?

SOLAR-PANEL "UMBRELLA" (40 WATTS) The "Sun-brella," currently in beta, taps the sunlight it's keeping off you, via photovoltaic cells.

SUSPENDED-LOAD BACKPACK (15 WATTS) University of Pennsylvania biologist Lawrence Rome's "Lightning Pack" generates electricity from the up-and-down bounce of a 50-pound load while the user walks.

RESPIRATION MASK (0.4 WATT) Oxygen masks used by military aircraft pilots and astronauts could be adapted to capture breath pressure.

HAND-CRANK GENERATOR (10 WATTS) Spawn of an early human-powered electrical device—the hand-crank telephone—produces dependable DC electricity.

SPRING-LOADED GESTURE HARVESTER (1.5 WATTS) Could harness the arm gestures made once every two seconds throughout the day.

STATIONARY BICYCLE (75 WATTS) Cyclists spinning at the Green Microgym in Portland, Oregon, supply electricity to help run the place: Ceiling fans, LCD TVs and stereos are all people-powered.

NECK CUFF (0.1 WATT) A fair amount of heat comes off a body at rest. Full-body suits are impractical, but a neoprene neck cuff could skim a little off the top.

HEEL-STRIKE GENERATOR (2 WATTS) Inserts in the boot sole made of special polymers create an electrical charge when the material is stressed or stretched.

BIOMECHANICAL ENERGY HARVESTER (7 WATTS) This gadget, developed by kinesiologist Max Donelan, harnesses the power of the human gait by tapping the natural braking motion at the end of every stride.

GRAND TOTAL: 151 WATTS
That's enough energy to power:
75 BlackBerry phones, or
7 Nintendo Wiis, or
1 desktop computer or 32-inch HD TV