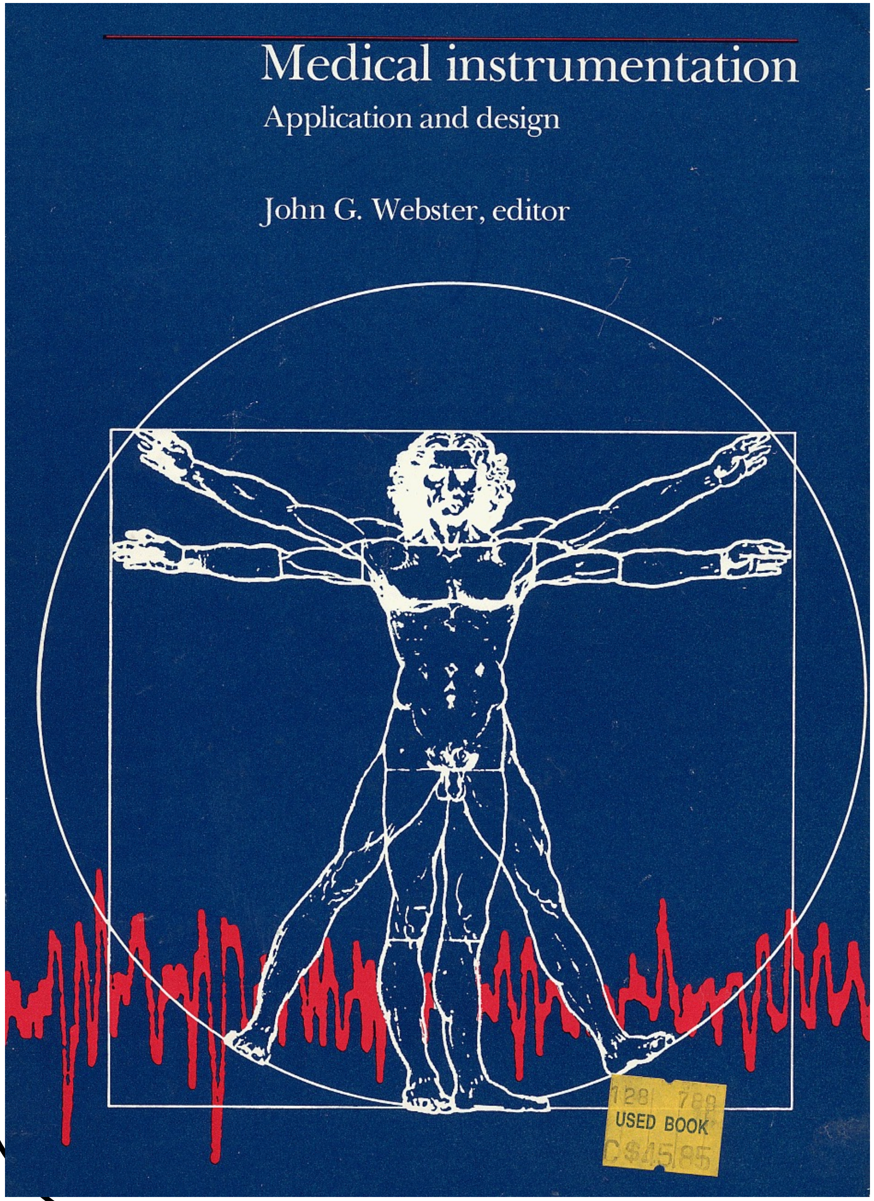
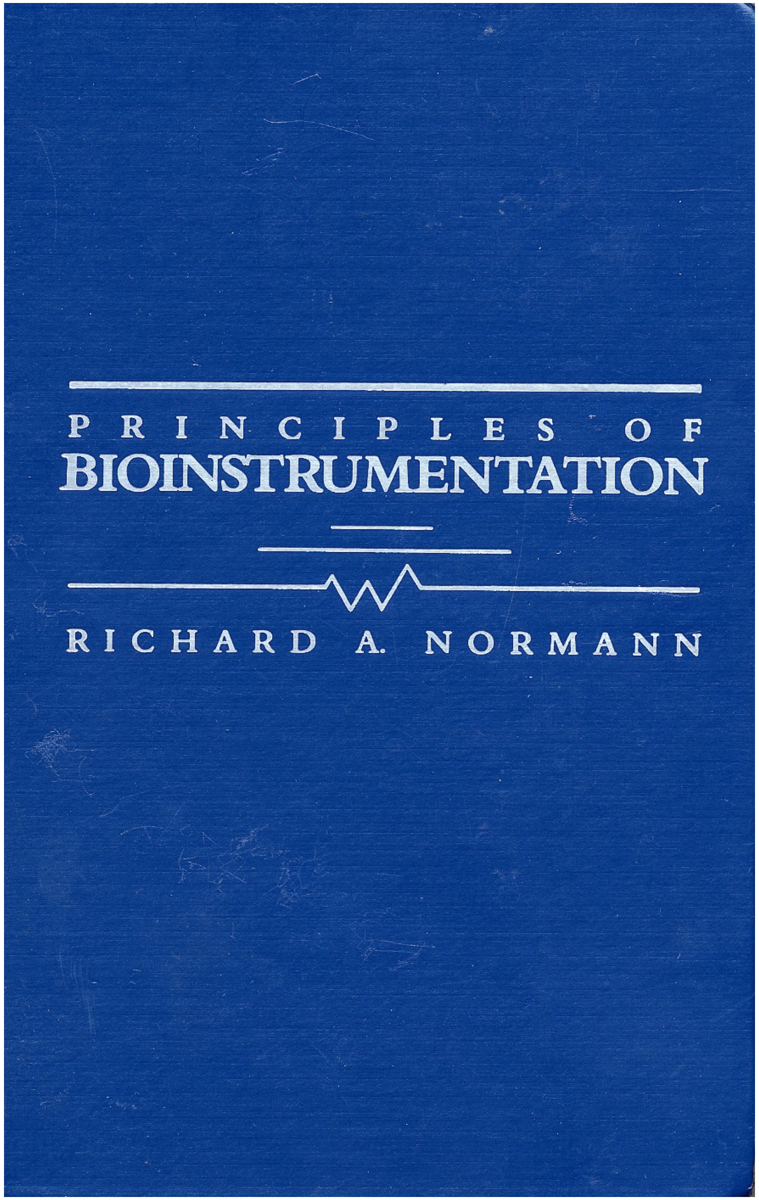
MAS836 – Sensor Technologies for Interactive Environments

Lecture 13 – Bioelectric Sensing and Misc.

Interesting Books





For current Research

IEEE EMBS (Transactions and Conference Proceedings)
http://www.embs.org/

BSN Conference
(Wearable and Implantable Body Sensor Networks)
http://ubimon.doc.ic.ac.uk/bsn/m621.html

BodyNets Conference
http://www.bodynets.org/

Biodevices
http://www.biodevices.biostec.org/

Bioelectric Interfaces

- EMG, EKG, EEG all just low-noise, low-frequency instrumentation amplifiers
  - Active EMG looks at external signal propagation through nerves
- GSR just measures current through skin resistance
- Electronics are fairly trivial; from first lectures
  - Art is in shielding, grounding, filtering (e.g., removing 60 Hz, etc.), electrode design and placement

Getting Signals off the skin

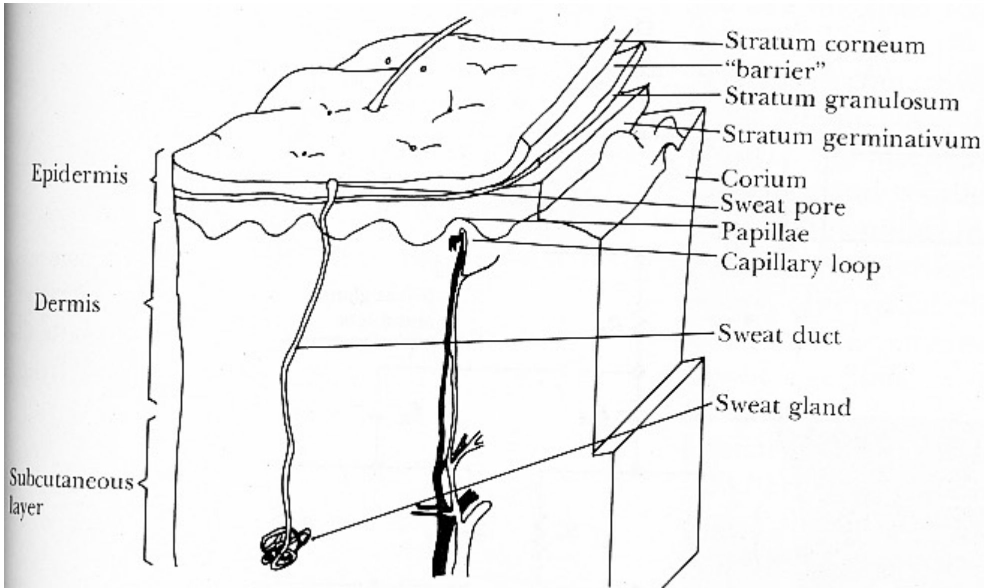


Figure 5.11 Magnified section of skin, showing the various layers. (Copyright © 1977 by The Institute of Electrical and Electronics Engineers. Reprinted, with permission, from *IEEE Trans. Biomed. Eng.*, March 1977, vol. BME-24, no. 2, pp. 134–139.)

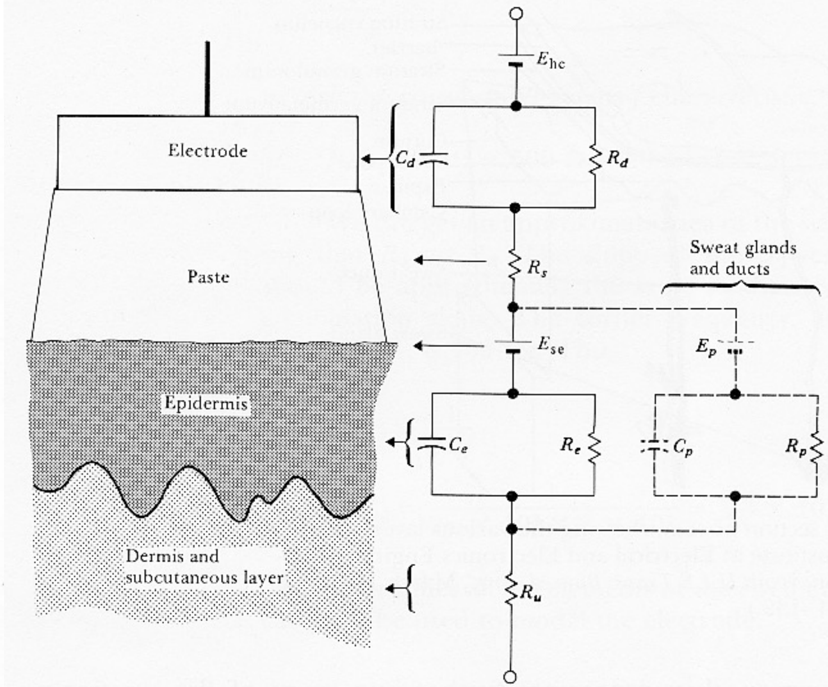


Figure 5.12 Body-surface electrode placed against skin, showing total electrical equivalent circuit obtained in this situation. Each circuit element on the right is at approximately the same level at which the physical process that it represents would be in the left-hand diagram.

- Complicated - insulating top layer, ionic current flow underneath

Bioelectric Electrodes

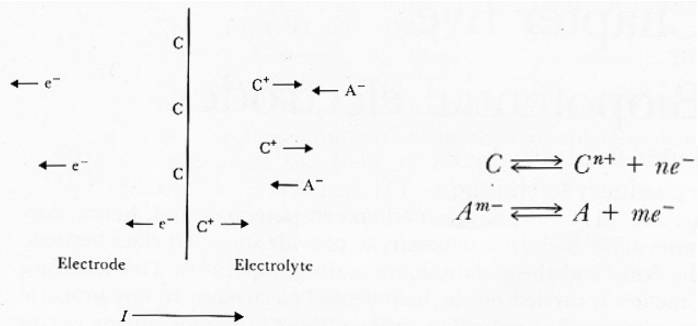


Figure 5.1 Electrode-electrolyte interface with current crossing it from left to right. The electrode consists of metallic atoms *C*. The electrolyte is an aqueous solution containing cations of the electrode metal C^+ and anions A^-.

Metal and reaction	Potential E^0, V
$Al \longrightarrow Al^{3+} + 3e^-$	−1.706
$Zn \longrightarrow Zn^{2+} + 2e^-$	−0.763
$Cr \longrightarrow Cr^{3+} + 3e^-$	−0.744
$Fe \longrightarrow Fe^{2+} + 2e^-$	−0.409
$Cd \longrightarrow Cd^{2+} + 2e^-$	−0.401
$Ni \longrightarrow Ni^{2+} + 2e^-$	−0.230
$Pb \longrightarrow Pb^{2+} + 2e^-$	−0.126
$H_2 \longrightarrow 2H^+ + 2e^-$	0.000 by definition
$Ag + Cl^- \longrightarrow AgCl + e^-$	+0.223
$2Hg + 2Cl^- \longrightarrow Hg_2Cl_2 + 2e^-$	+0.268
$Cu \longrightarrow Cu^{2+} + 2e^-$	+0.340
$Cu \longrightarrow Cu^+ + e^-$	+0.522
$Ag \longrightarrow Ag^+ + e^-$	+0.799
$Au \longrightarrow Au^{3+} + 3e^-$	+1.420
$Au \longrightarrow Au^+ + e^-$	+1.680

Table 5.1 Half-cell potentials for common electrode materials at 25°C. The metal undergoing the reaction shown has the sign and potential E^0 when referenced to the hydrogen electrode. Data from *Handbook of Chemistry and Physics*, 55th edition, CRC Press, Cleveland, Ohio, 1974–1975, with permission.

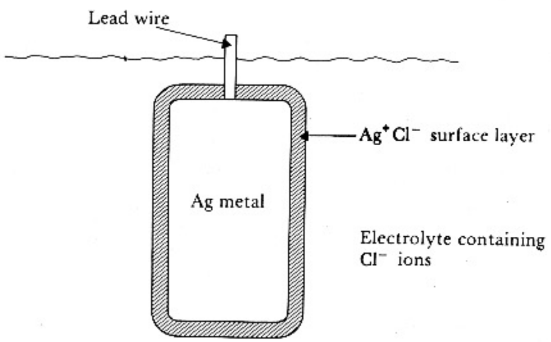


Figure 5.3 A silver–silver chloride electrode, shown in cross section.

Modern electrodes tend to be flexible

- Contact electrodes work by changing ionic current flow to current in a wire
  - Kind of like batteries
    - Oxidation/Reduction reactions

Nerve Excitations

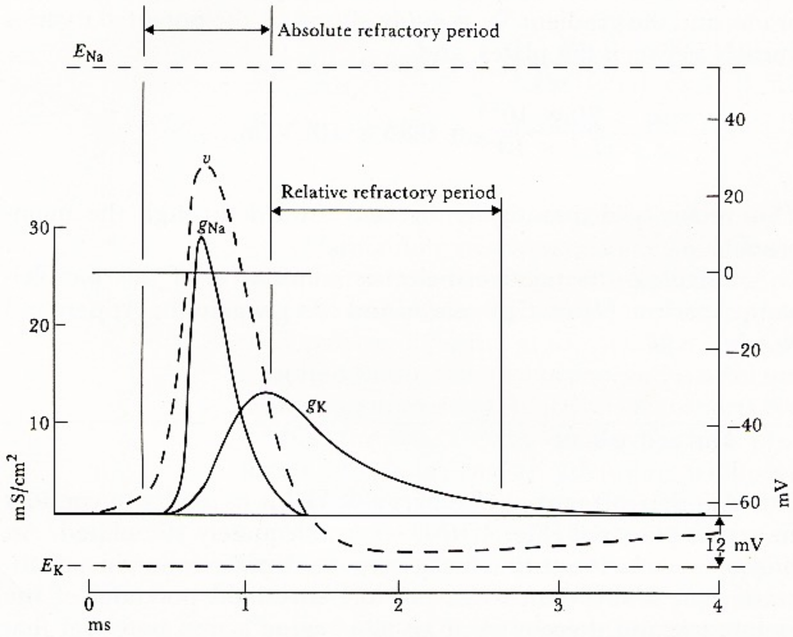


Figure 4.2 Theoretical action potential v and membrane ionic conductance changes for sodium (g_{Na}) and potassium (g_K) obtained by solving the differential equations developed by Hodgkin and Huxley for the giant axon of the squid at a bathing medium temperature of 18.5°C. E_{Na} and E_K are the Nernst equilibrium potentials for sodium and potassium across the membrane. Modified from A.L. Hodgkin and A.F. Huxley, "A Quantitative Description of Membrane Current and Its Application to Conduction and Excitation in Nerve," *J. Physiology* 1952, **117,** p. 530.

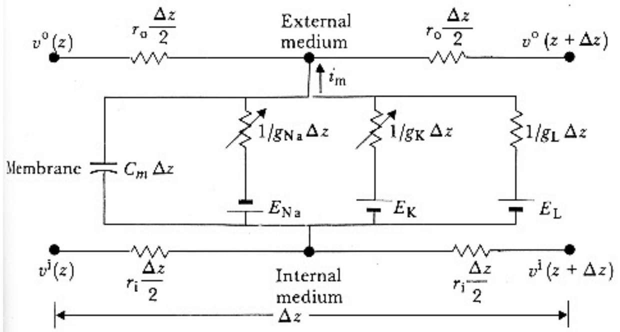


Figure 4.3 Diagram of network equivalent circuit of a small length (Δz) of nerve or muscle. The membrane proper is characterized by specific membrane capacitance C_m (μF/cm²) and specific membrane conductances g_{Na}, g_K, and g_{Cl} in mS/cm² (mmho/cm²). Here an average specific leakage conductance is included that corresponds to ionic current from sources other than Na^+ and K^+ (for example, Cl^-). This term is usually neglected. The cell cytoplasm is considered simply resistive, as is the external bathing medium; these media may thus be characterized by the resistance per unit length r_i and r_o (Ω/cm), respectively. Here i_m is the transmembrane current per unit length (A/cm) and v^i and v^o are the internal and external potentials v at point z, respectively. (Modified from A.L. Hodgkin and A.F. Huxley, "A Quantitative Description of Membrane Current and Its Application to Conduction and Excitation in Nerve," *Journal of Physiology*, 1952, **117,** p. 501.)

- Several ionic components to nerve signal propagation

Stimulated EMG

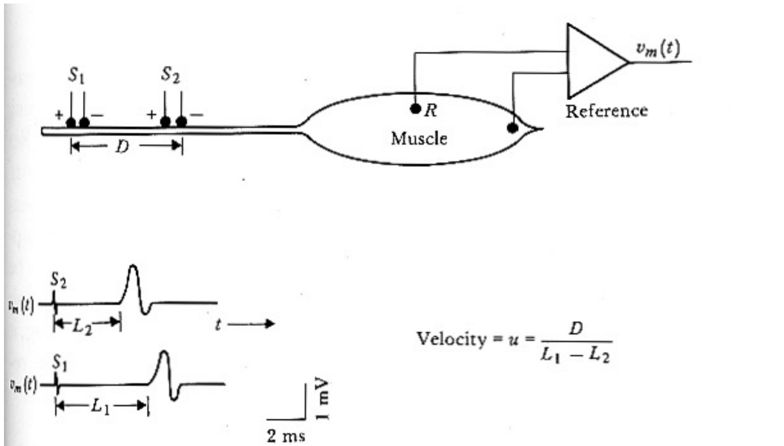


Figure 4.7 Measurement of neural conduction velocity via measurement of latency of evoked electrical response in muscle. Nerve stimulated at two different sites a known distance D apart.

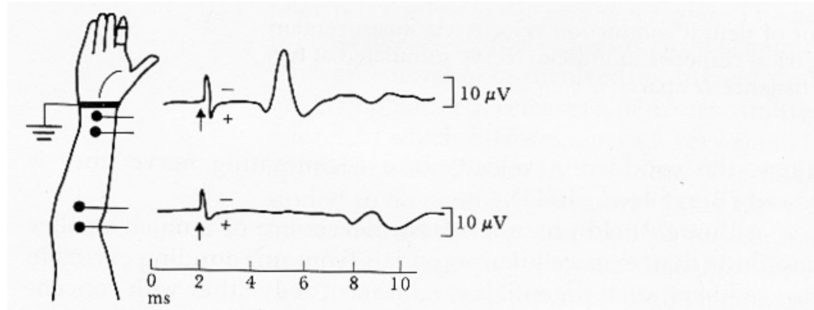


Figure 4.8 Sensory nerve action potentials evoked from median nerve of a healthy subject at elbow and wrist after stimulation of index finger with ring electrodes. Potential at the wrist is triphasic and of much larger magnitude than delayed potential recorded at the elbow. Considering the median nerve to be of the same size and shape at the elbow as at the wrist, we find that the difference in magnitude and waveshape of the potentials is due to the size of the volume conductor at each location and the radial distance of the measurement point from the neural source. (From J.A.R. Lenman and A.E. Ritchie, *Clinical Electromyography*, 2nd ed., Philadelphia: Lippincott, 1977; reproduced by permission of the authors.)

- Stimulated EMGs stimulate nerves and look at response.
- Passive EMGs listen for nerve firings
  - Active EMG electrodes have on-electrode amplification
- Skin-surface electrodes are commonly used
  - Clinical EMGs use thin wires (e.g., needles) that penetrate the skin and touch the nerve

The Eye Mouse

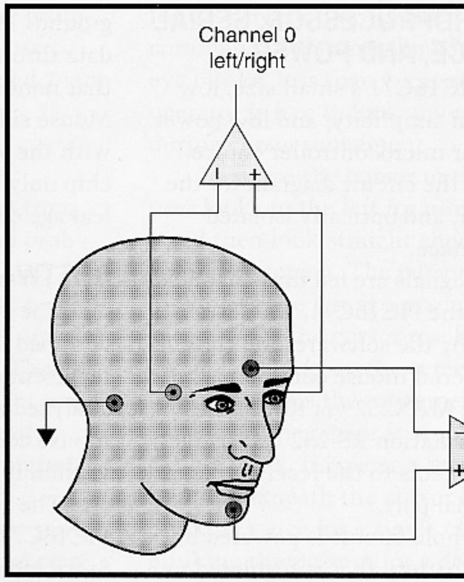


Figure 1—*The Eye Mouse amplifies voltages from eye movements using five surface electrodes and two differential amplifiers. The electrodes are strategically placed so that vertical and horizontal eye movements produce the largest voltages.*

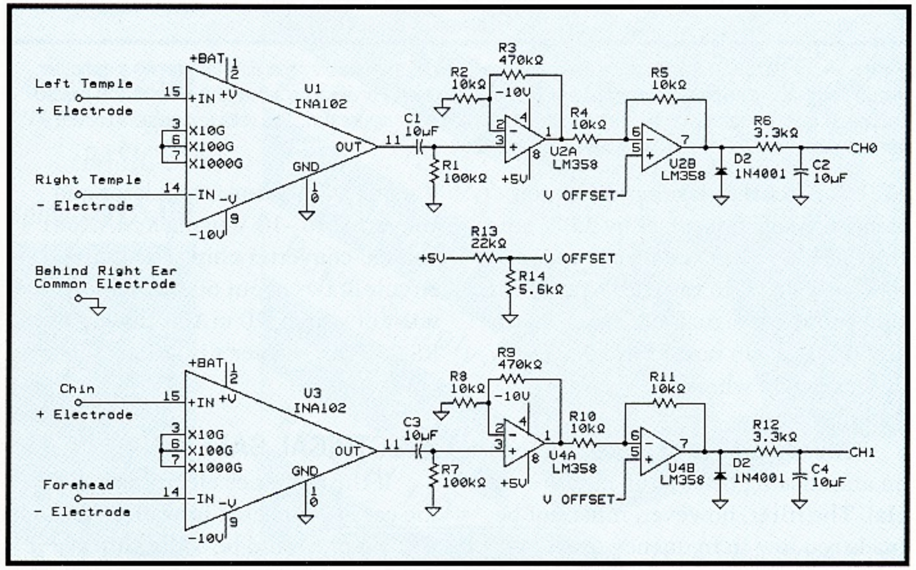


Figure 2—*The horizontal and vertical eye movements are amplified and filtered on separate channels before being read into the PIC16C71. The first stage of each channel is a differential amplifier with a gain of 100. Next, the DC and "electrode drift" component of each signal is removed before they are further amplified by 470. Finally, a 2.5-V offset is added to each signal before they are filtered to attenuate noise above 4.8 Hz.*

From Circuit Cellar, June 1995
Gregg Moris & Eric Wilson, p. 20

- EOG

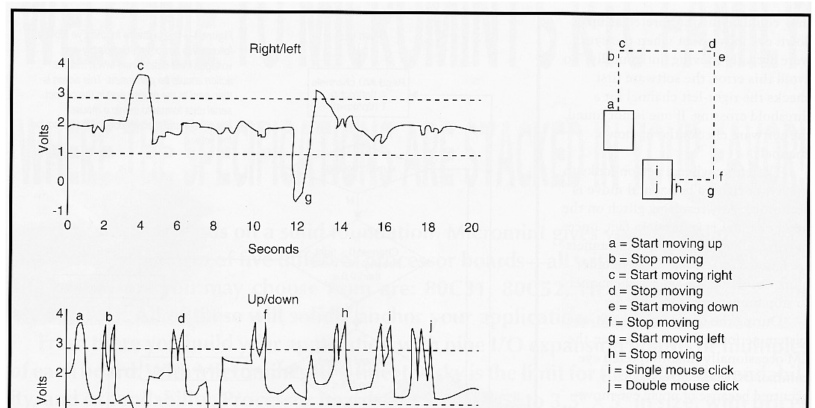
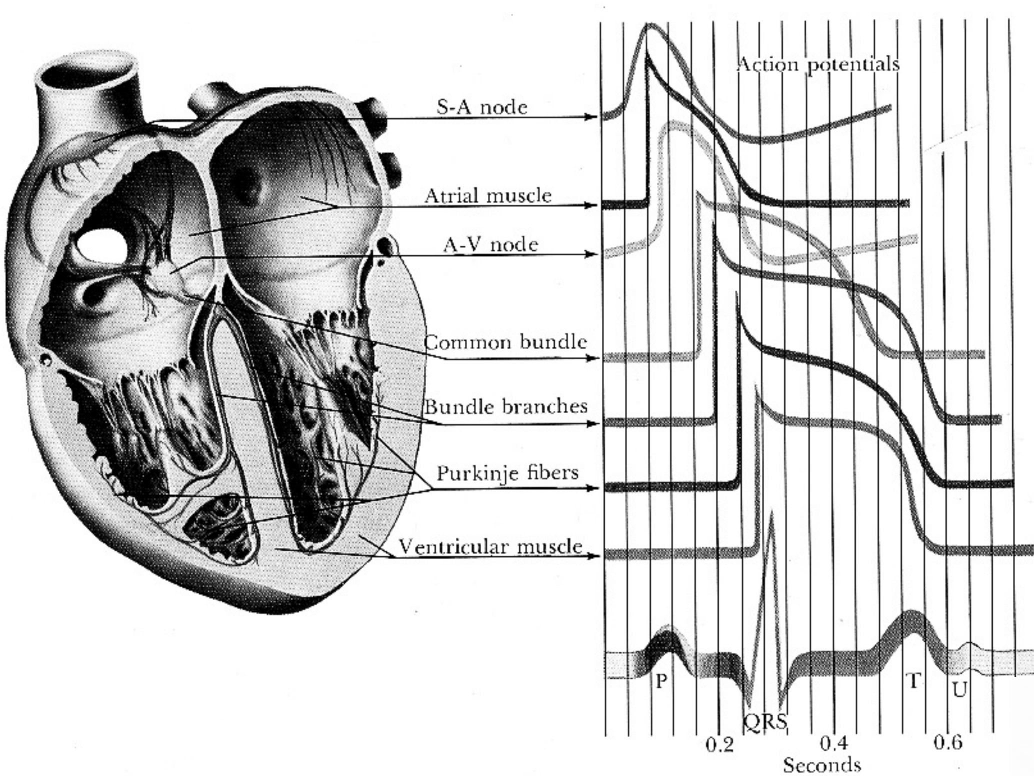


Figure 5—*Here are the resulting eye voltages when the eyes move in the following pattern: look up, blink twice, look right, blink twice, look down, blink twice, look left, blink twice, blink twice again, blink three times. This sequence moves the cursor up, stops it, moves right, stops it, moves down, stop it, moves left, stops it, and then performs a single and double mouse click.*

Heart Electropotentials & propagation



N8-65 Vol. 5/I — Heart Physiology of Conduction System II — Dr. Brian Hoffman

Figure 4.14 Representative electrical activity from various regions of the heart. Bottom trace is scalar ECG. (© Copyright 1969 CIBA Pharmaceutical Company, Division of CIBA-GEIGY Corp. Reproduced, with permission, from *The Ciba Collection of Medical Illustrations,* by Frank H. Netter, M.D. All rights reserved.)

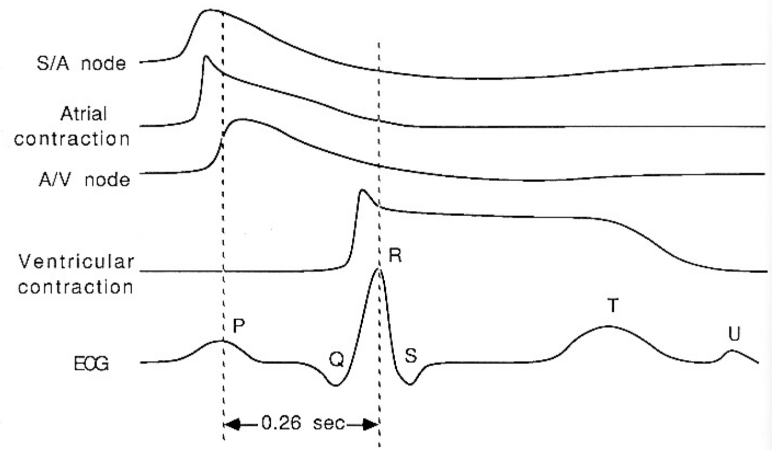


Figure 5.12 The components of the electrocardiogram.

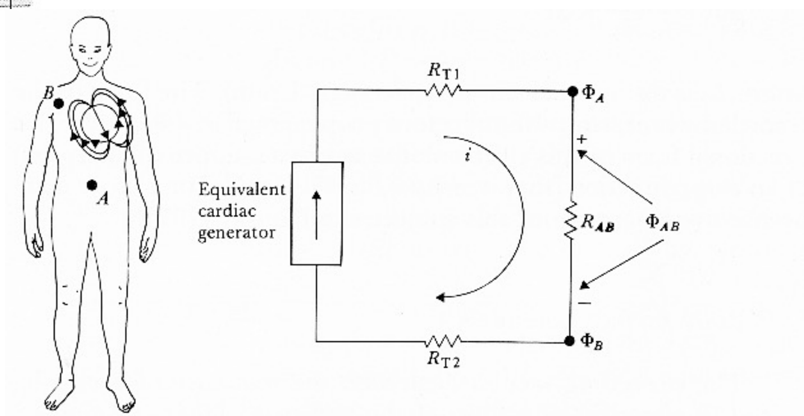


Figure 4.18 The electrocardiographic problem. Points A and B are arbitrary observation points on the torso, R_{AB} is the resistance between them, and R_{T1}, R_{T2} are lumped thoracic medium resistances. The bipolar ECG scalar lead voltage is $\Phi_A - \Phi_B$, where these voltages are both measured with respect to an indifferent reference potential.

- Many sources of heart signals - must propagate through the body to electrodes outside

EKG Electrode Placement

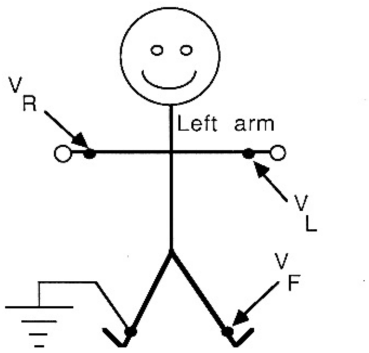


Figure 5.13 The location of electrodes used to measure standard limb leads.

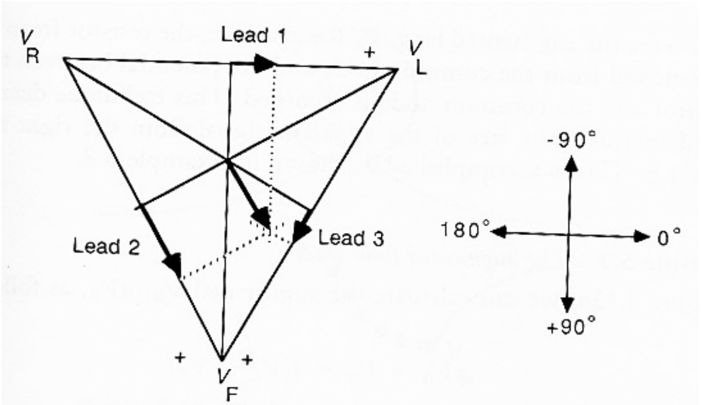


Figure 5.14 Einthoven's triangle and the cardiac vector.

Sum of all 3 signals is zero by Kirchoff's Law

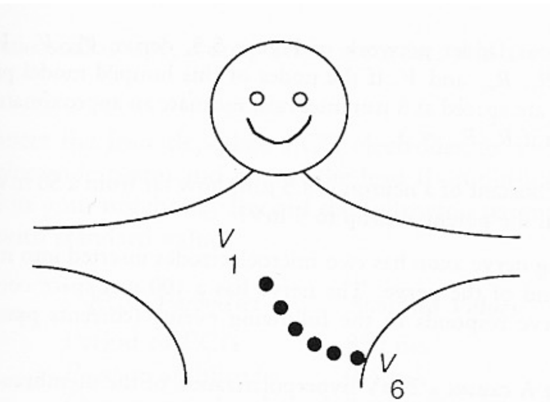
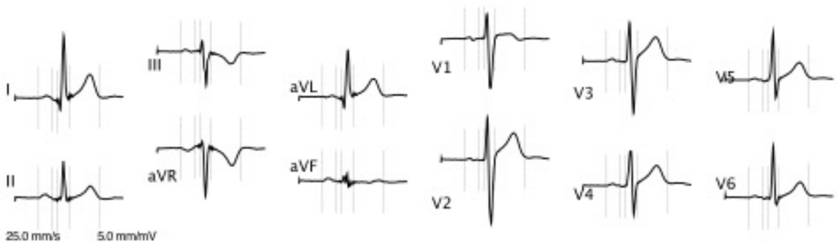


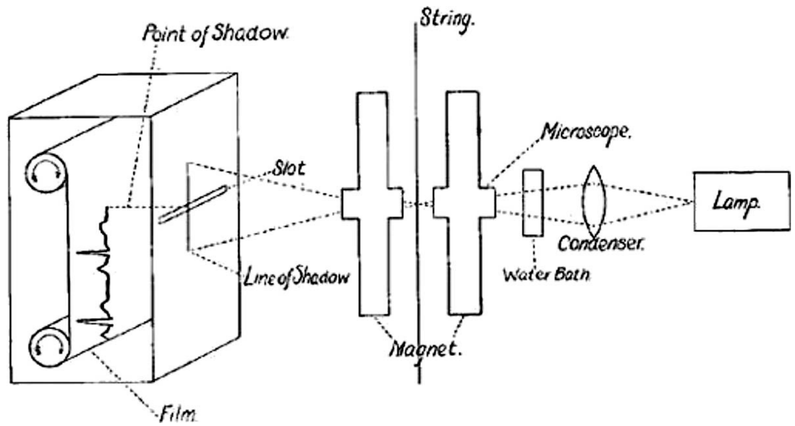
Figure 5.16 The unipolar electrode configuration.

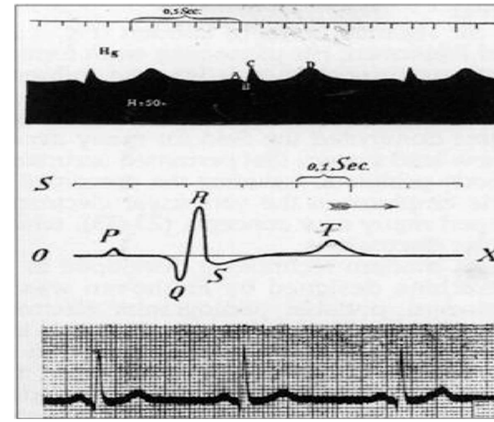


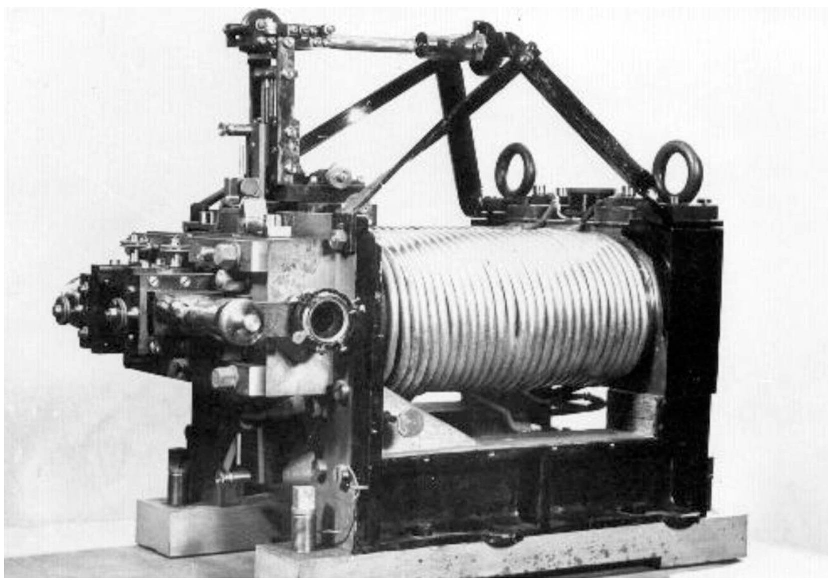
- Standard 3-lead EKG on limbs (top left)
- Advanced EKG layout for 3D reconstruction (bottom)
- Right Leg Driver (cuts common mode)

First Electrocardiogram - 1902

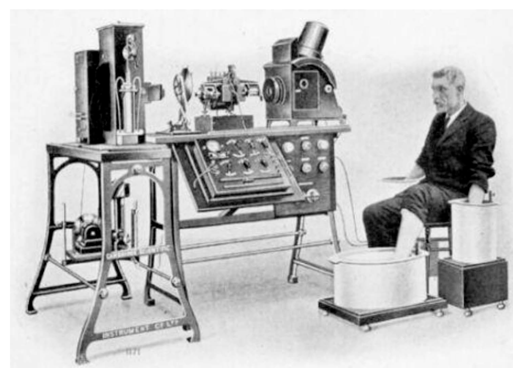
Dijk, J.   van Loon, B, “ The Electrocardiogram Centennial,” IEEE Proceedings, December 2006







String galvanometer - silver-coated string moves with current in magnetic field - shadow is imaged through slit onto moving film roll



Early ECG patients with salt-water electrodes

Willem Einthoven used the string gavanometer to make the first ECG in 1902 (also used to display coded radio messages in 1923). Awarded Nobel Prize for Medicine in 1924

The EEG

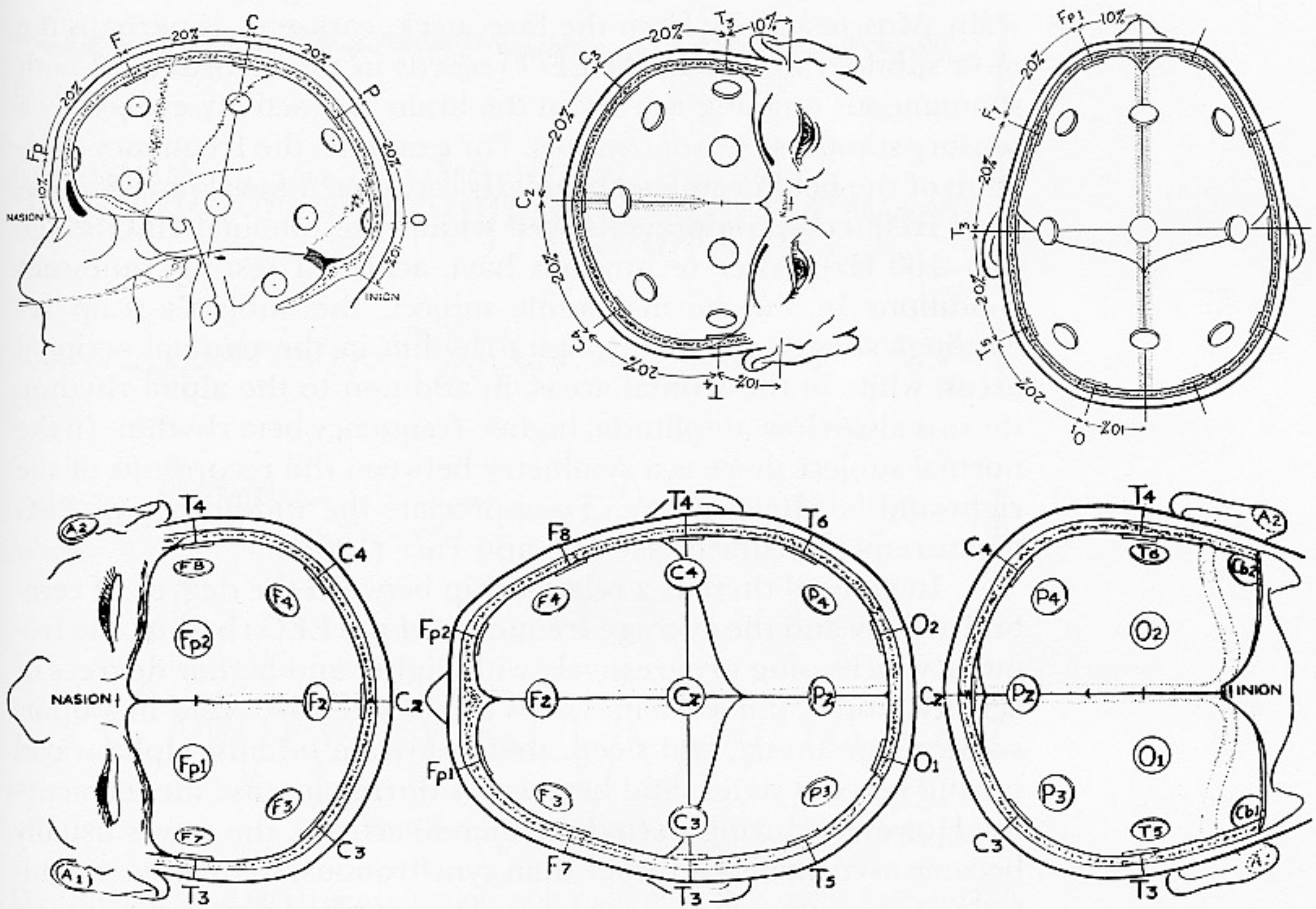
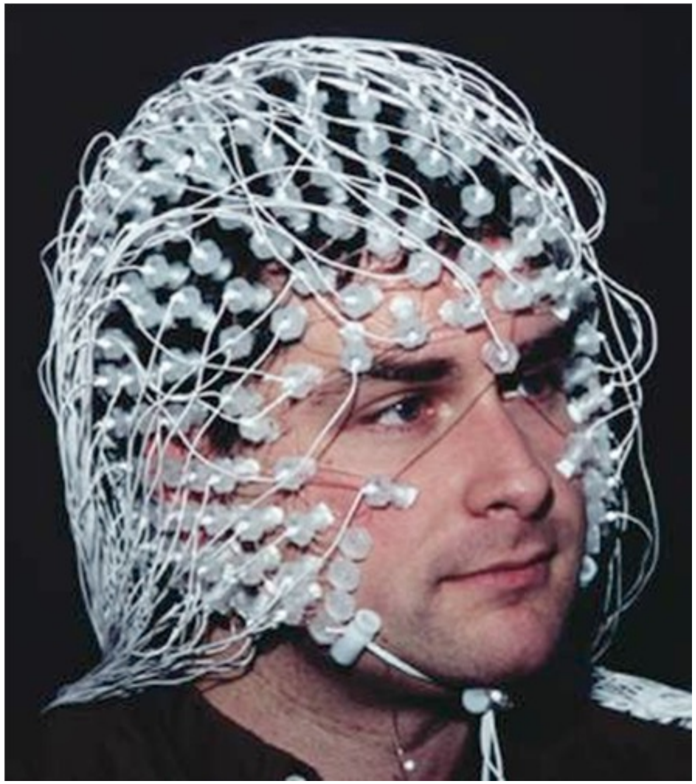


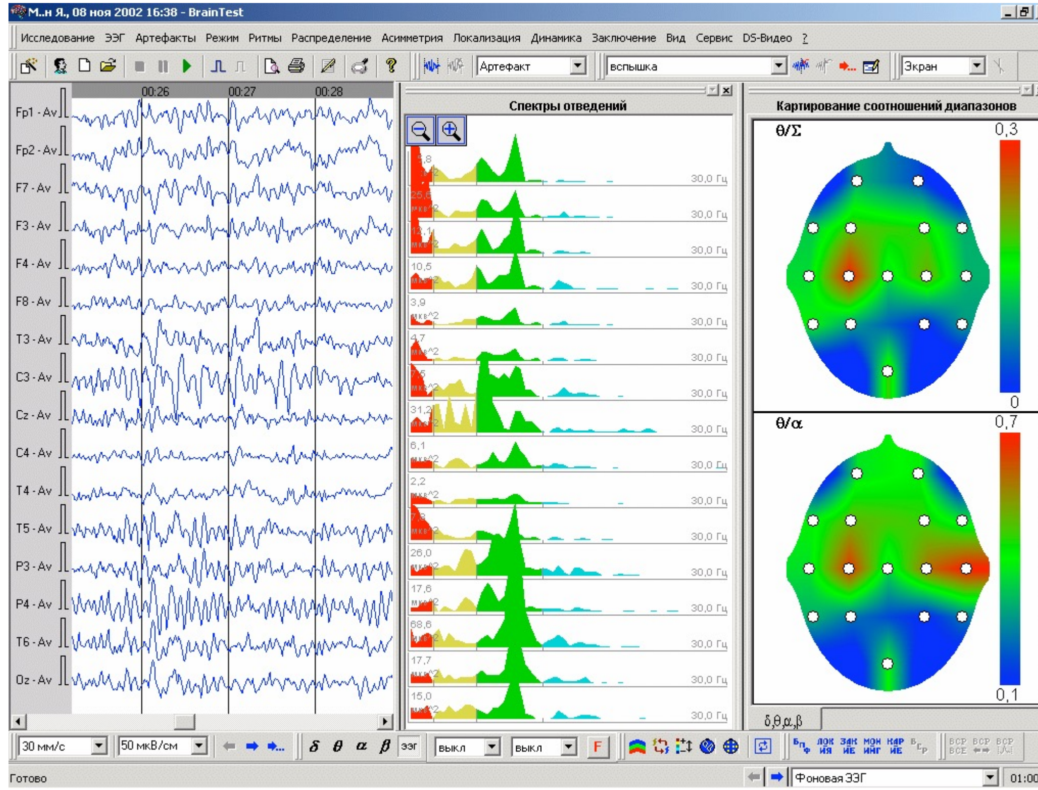
Figure 4.31 The 10-20 electrode system recommended by the International Federation of EEG Societies. (From H.H. Jasper, "The Ten-Twenty Electrode System of the International Federation in Electroencephalography and Clinical Neurophysiology," *EEG Journal*, 1958, **10** (Appendix), 371–375.)

http://openeeg.sourceforge.net/doc/

Big EEG arrays



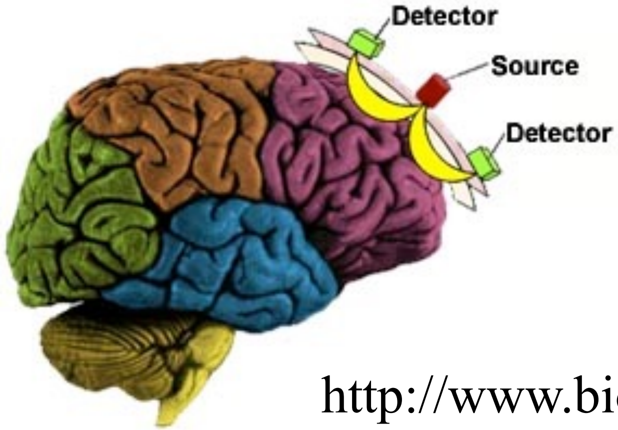
Mark Holmes Epilepsy Study



http://simetronsac.com/

- Can somewhat image signal sources
- Passive magnetic brain imaging also used

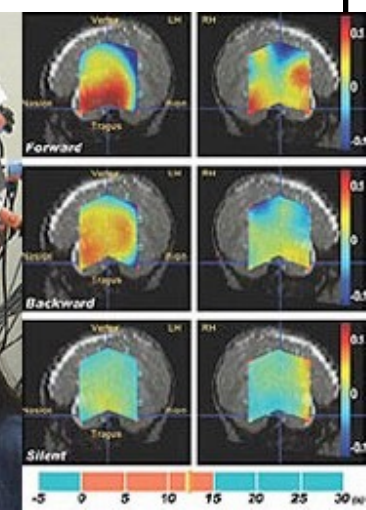
Near-IR Brain Imaging



http://www.biopac.com

NSF.gov

Pinktentacle.com



- Pulsed intense IR laser detected by APD
- Can see diffusively through the skull
- See's outer brain in adults (circa 1 cm)
  - Motor cortex, etc.
  - Sees deeper in infants
- Spatial resolution coarse, but fast.

Other Electropotential measurements

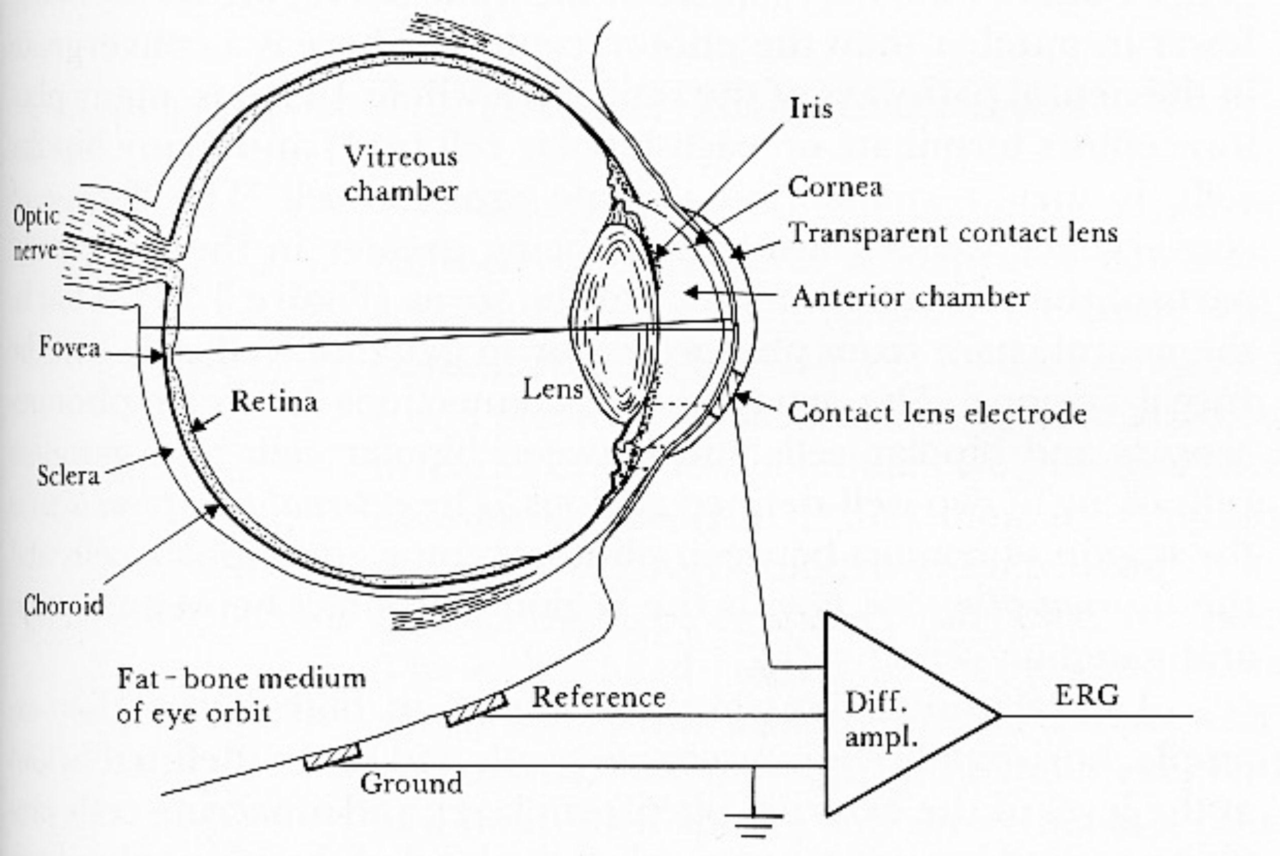


Figure 4.24 Transparent contact lens containing one electrode, shown on horizontal section of right eye. Reference electrode is placed on right temple.

ERG gives pulses in response to retinal activity (e.g., light flashes)

Simple 2-lead EKG Front-End

APPLICATION CIRCUITS

Medical ECG Applications

Figure 9 shows the INA321 configured to serve as a low-cost ECG amplifier, suitable for moderate accuracy heart-rate applications such as fitness equipment. The input signals are obtained from the left and right arms of the patient. The common-mode voltage is set by two 2MΩ resistors. This potential, through a buffer, provides an optional right leg drive. Filtering can be modified to suit application needs by changing the capacitor value of the output filter.

Low-Power, Single-Supply Data Acquisition Systems

Refer to Figure 5 to see the INA321 configured to drive an ADS7818. Functioning at frequencies of up to 500kHz, the INA321 is ideal for low-power data acquisition.

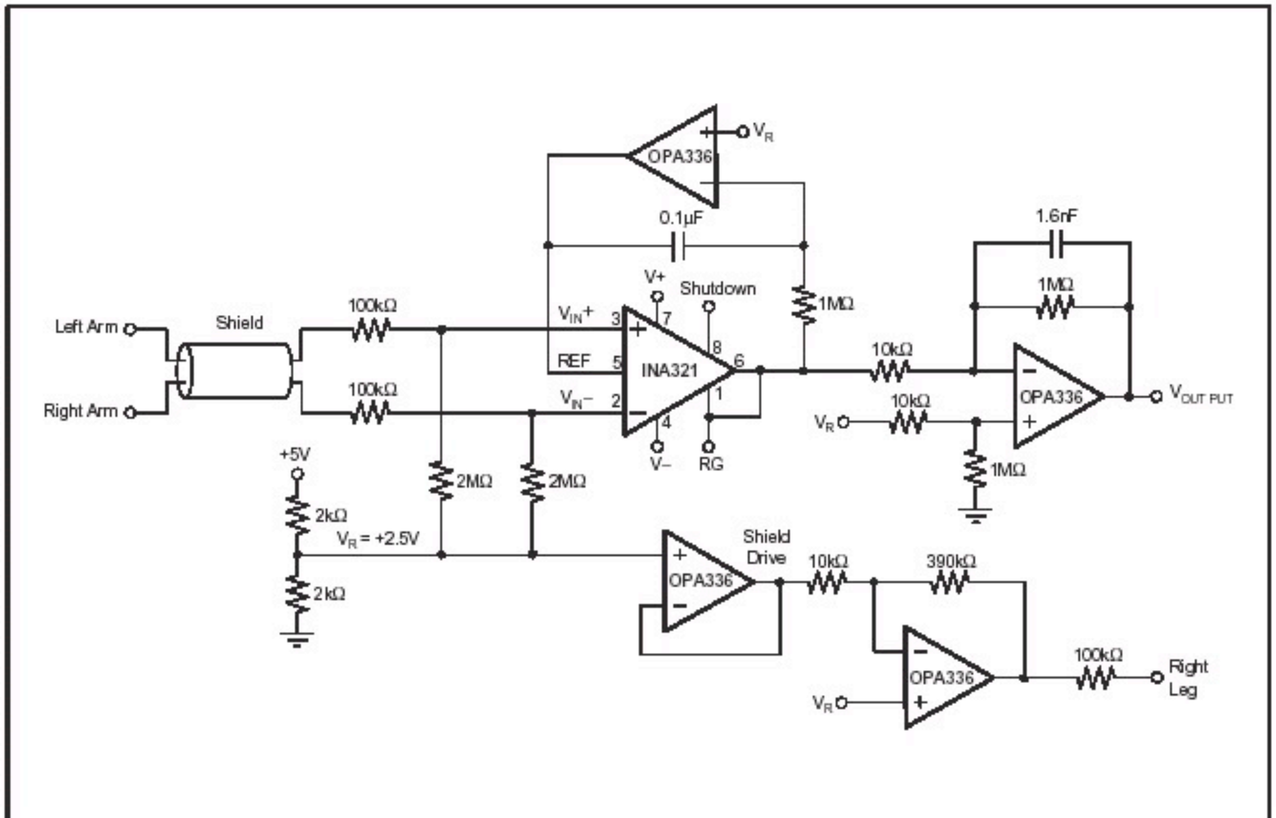
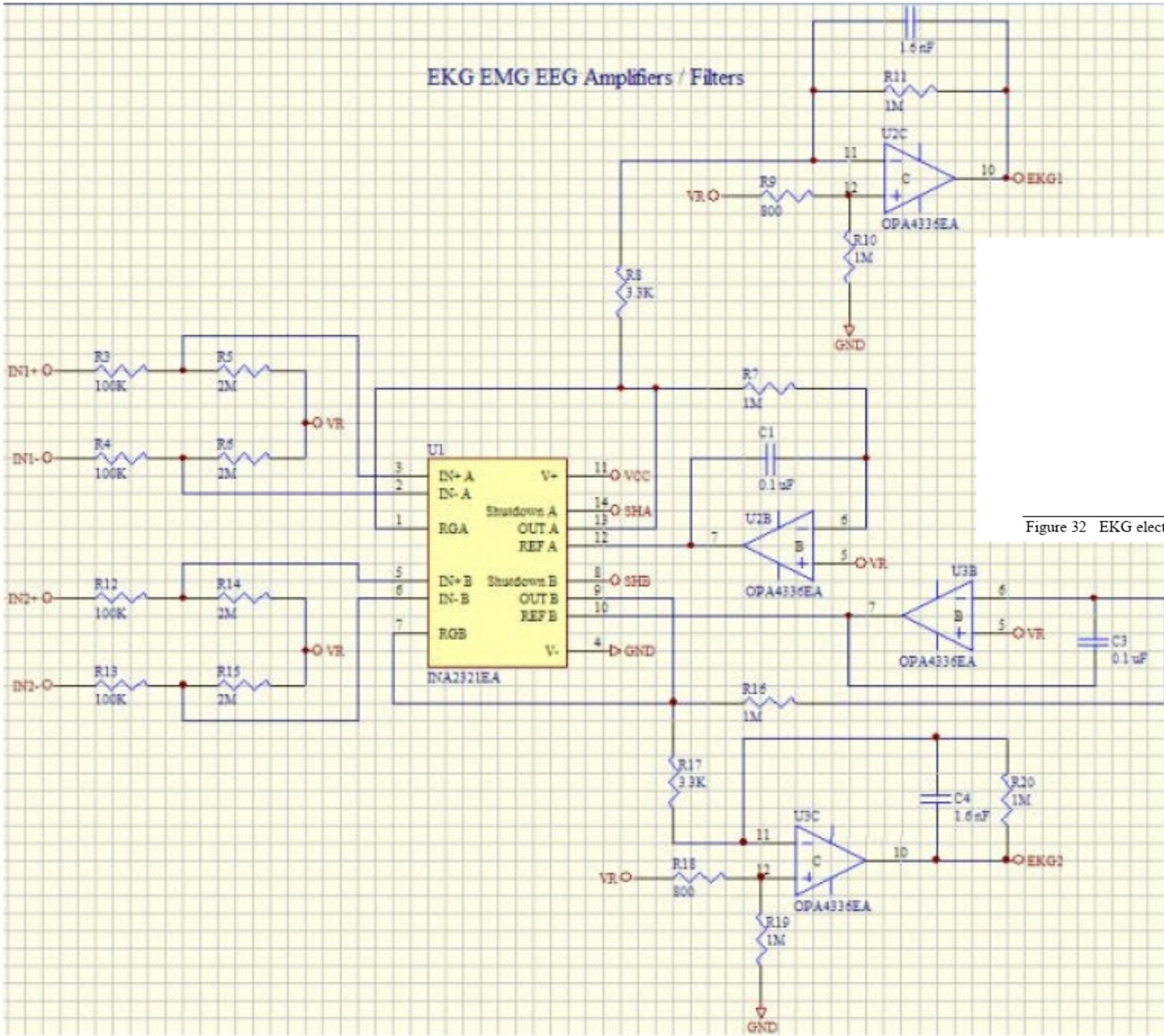


Figure 9. Simplified ECG Circuit for Medical Applications

Vadim Gerasamov's Bioelectric Front End



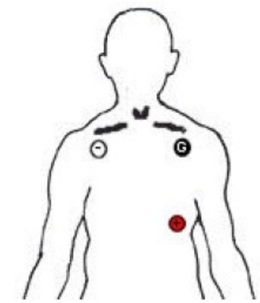


Figure 32 EKG electrode placement

Non-contact (displacement current) electrodes

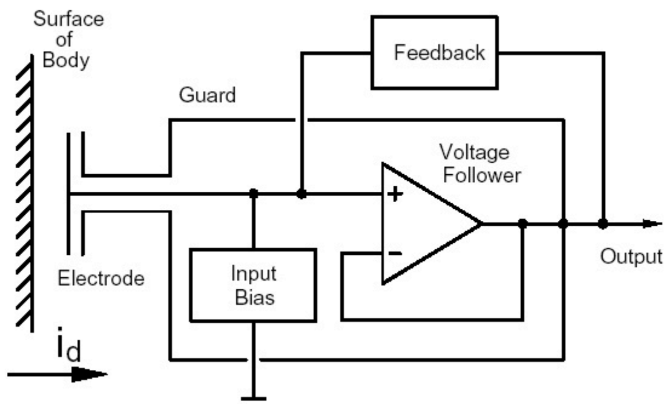
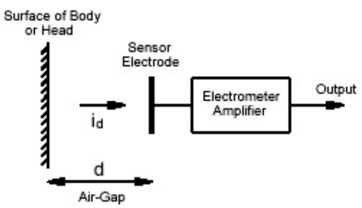
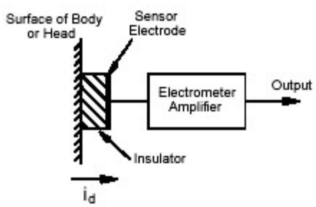


Figure 1. Block diagram of a typical electric potential sensor probe, showing the sensor electrode, and the electrometer amplifier (i_d is the displacement current).



Remote Mode



Contact Mode

(i_d = displacement current)

Link to Harland.pdf

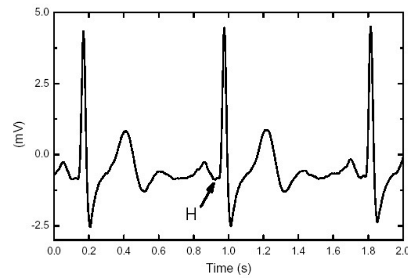


Figure 2. An example of the quality of ECG that can be acquired from the surface of the chest with a pair of displacement current sensors mounted in the V4-lead configuration. The feature 'H' corresponds in timing to the cardiac His bundle depolarization.

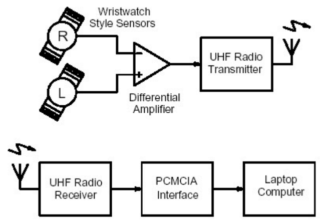
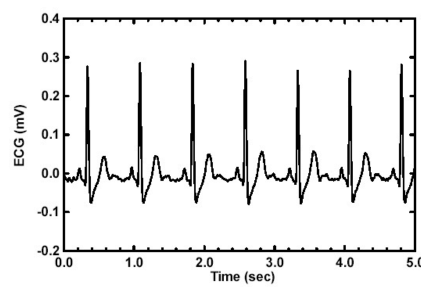


Figure 3. Schematic diagram of a differential pair of electric potential sensor probes mounted in wrist-watch format and configured as a wireless ambulatory ECG data collection system.



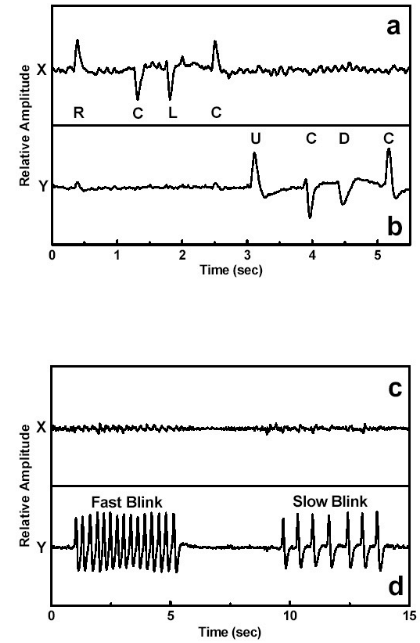


Figure 5. Examples of electro-oculograms (EOGs), showing the voltage deflections resulting from eye movements when using sensors located around the eyes. X and Y correspond to movements of the eyeballs in the left-right and up-down directions respectively. (a) The result of moving the eyeballs to view from centre to right (R), back to the centre (C), centre to left (L) and back to centre (C). (b) The result of moving the eyeballs to view from centre upwards (U), back to the centre (C), from centre downwards (D) and back to the centre (C). (c) and (d) show the X and Y voltage deflections resulting from fast and slow blinking of the eyelids.

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Centre for Physical Electronics and Quantum Technology
University of Sussex, Brighton, Sussex, BN1 9QT, U.K.

NEC Electro-Optic E-Field Pickups

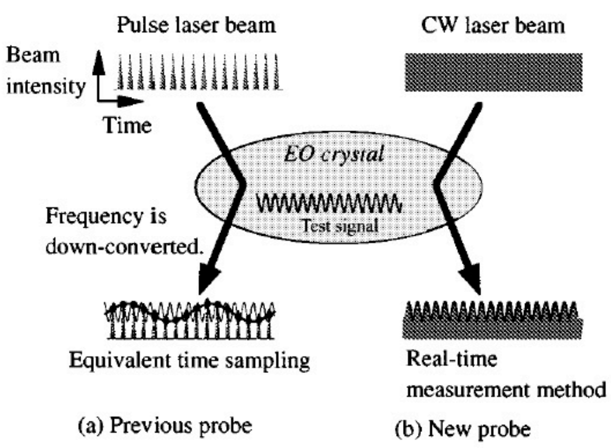


Fig. 2. Equivalent time sampling and real-time measurement method.

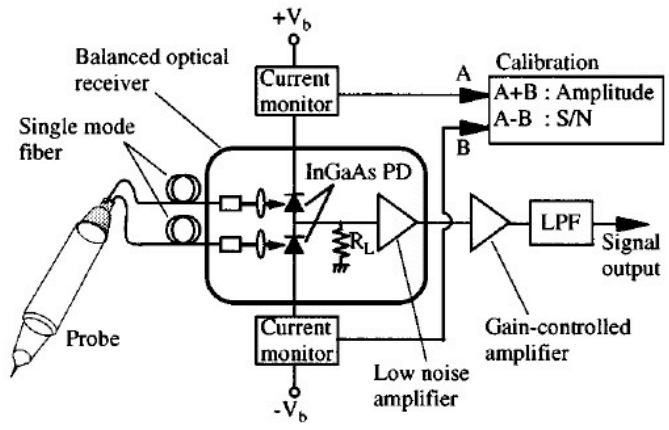


Fig. 4. Schematic diagram of probe system.

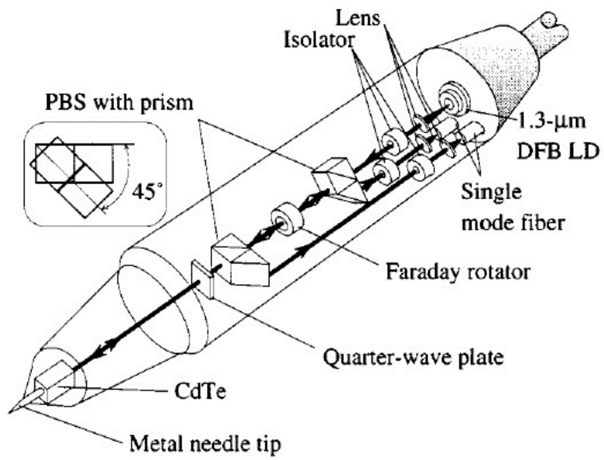


Fig. 3. Configuration of probe module.

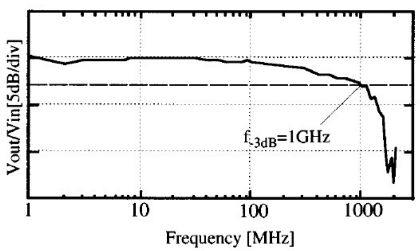


Fig. 6. Frequency characteristics of the EO handy probe.

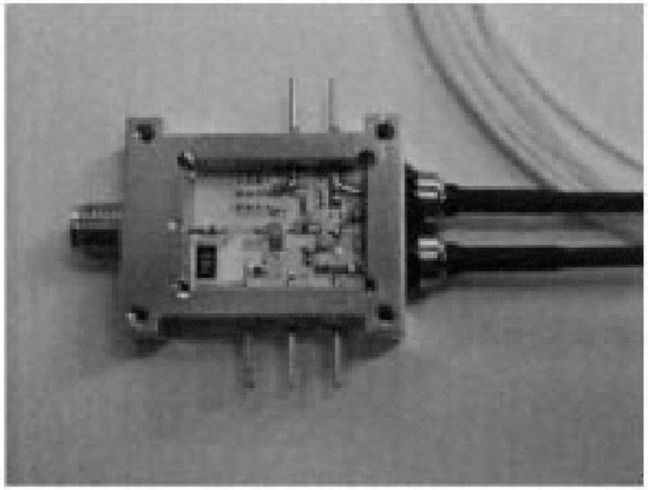


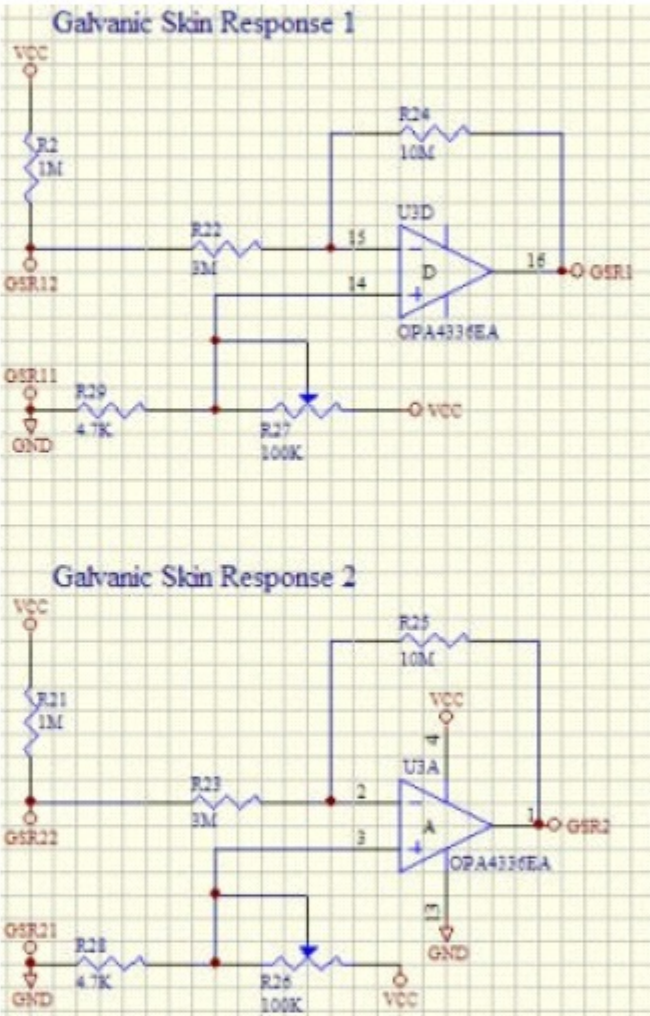
Fig. 5. Balanced optical receiver module.

A Real-Time Electro-Optic Handy Probe Using a Continuous-Wave Laser

Mitsuru Shinagawa, *Member, IEEE*, Tadao Nagatsuma, *Member, IEEE*, Kazuhide Ohno, and Yoshito Jin

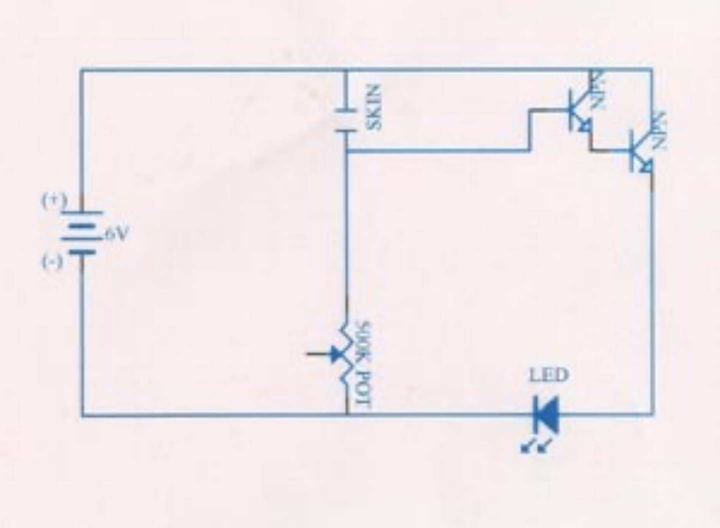
Video Link

GSR Probes



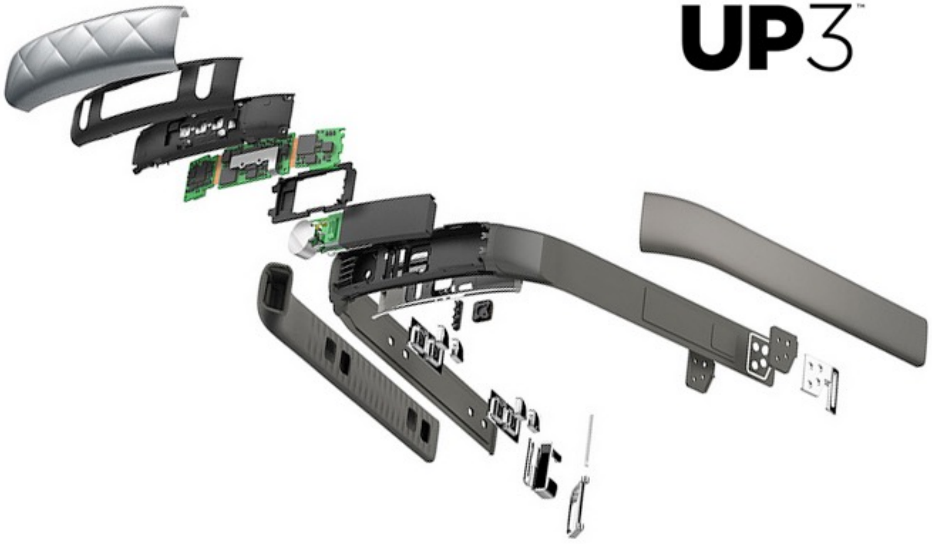
Vadim Gerasamov's GSR

The Galvactivator
Sheirer and Picard
1999



Electrode Placement Important!

Jawbone Bands with Bioimpedance



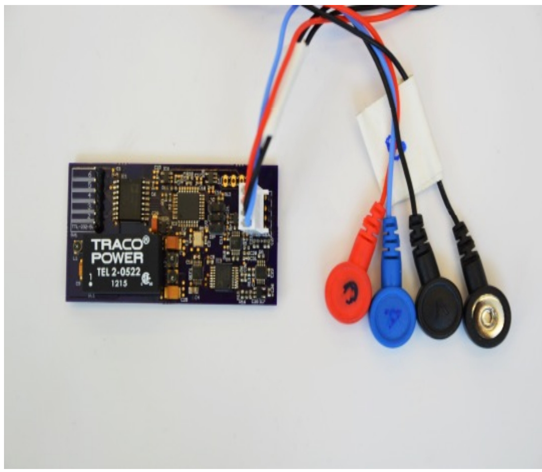
- Get heart rate & respiration from changes in bioimpedance at the wrist
- In the EMB literature for a decade or so.
- Resting only

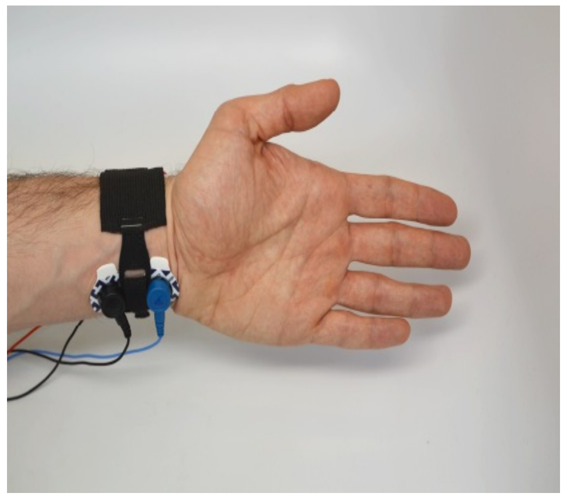
GSR at the wrist - Empatica

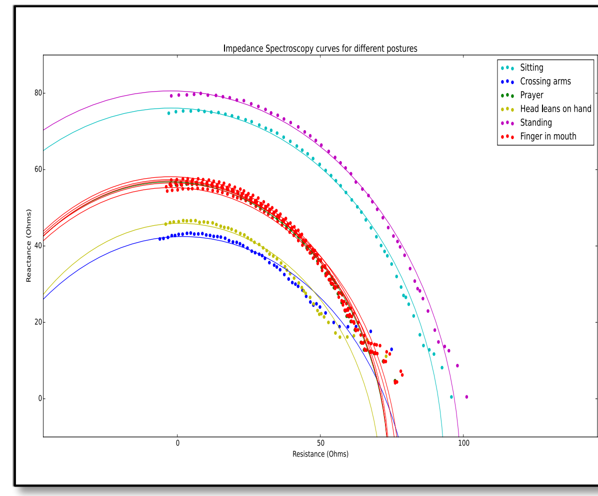
Thumbs Up

Wearable Sensing Device for Detecting Hand-to-Mouth Compulsi

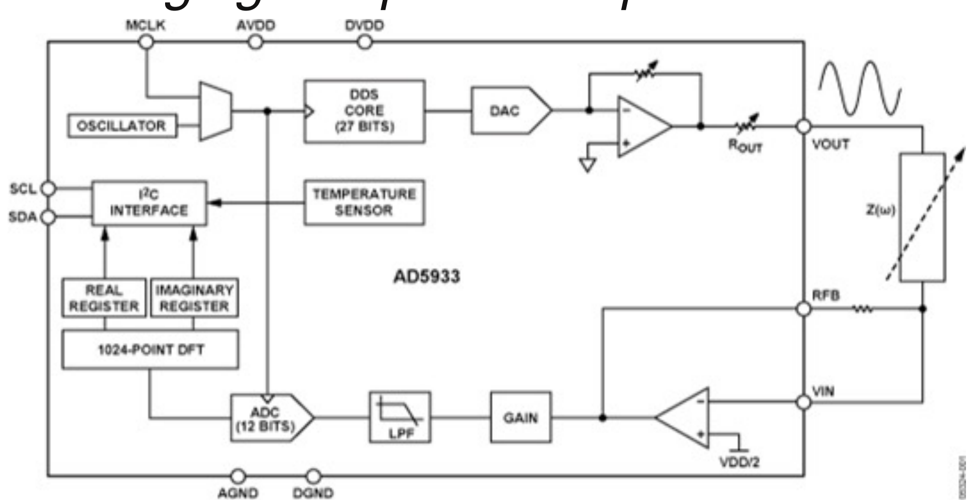
Habits







Wearable leveraging complex bioimpedance measurement & machine learning



Analog Devices AD5933

Asaf Azaria

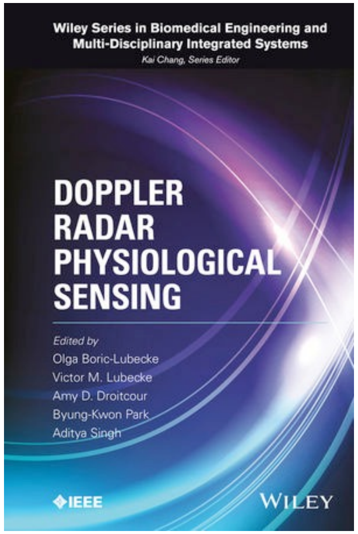
Doppler Radar Pulse measurement

Cell phones next to disabled survivors, etc.

Doppler radar (Greneker, 1997), - 'Radar Technology For Acquiring Biological Signals'

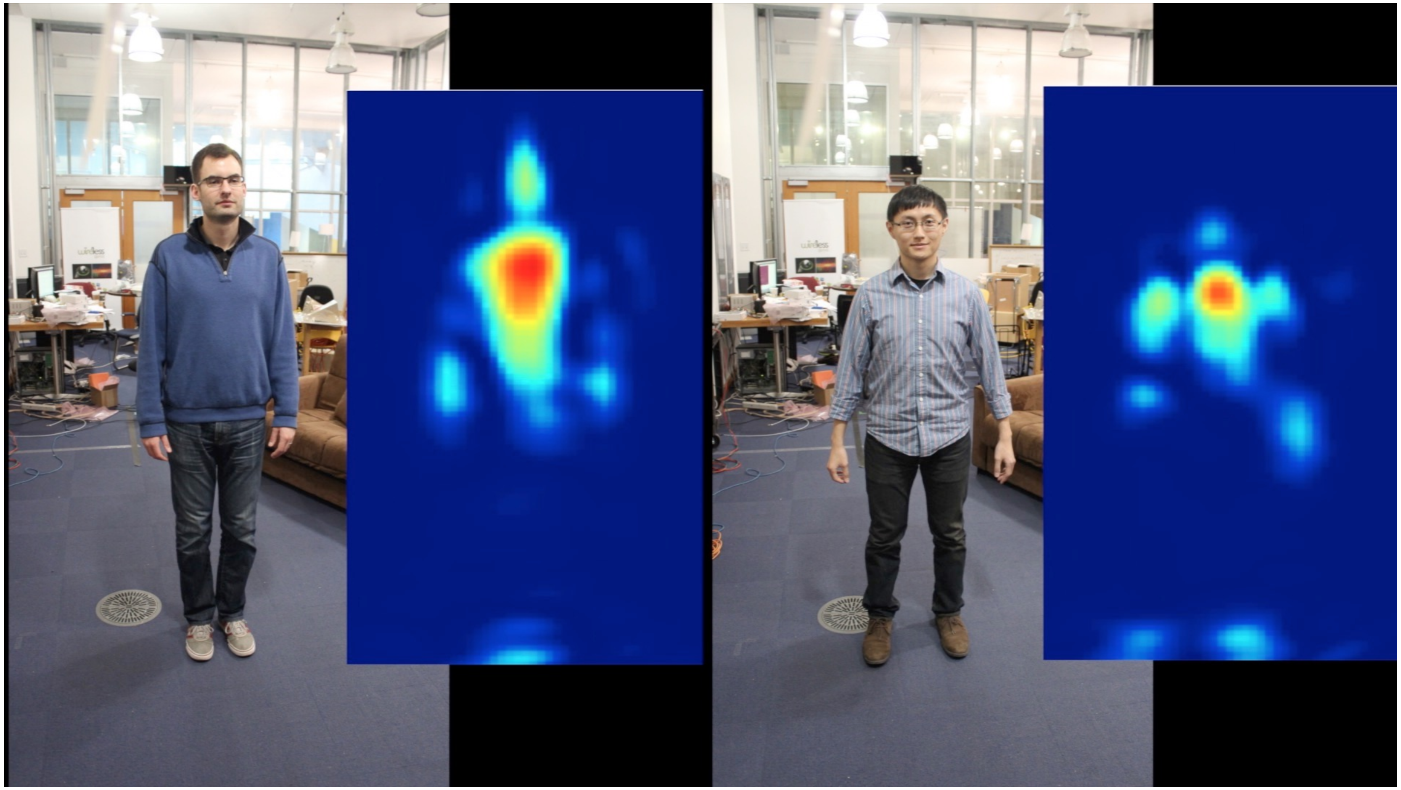
http://truth.charleshontsphd.com/JCAAWP/2006_No_2/2006_127-134.pdf

Olga Boric-Lubecke, Victor M. Lubecke, Amy D. Droitcour, Byung-Kwon Park, Aditya Singh, *Doppler Radar Physiological Sensing*, Wiley 2015



Dina Katabi and Fadel Adib

Project Emerald



http://people.csail.mit.edu/fadel/wivi/

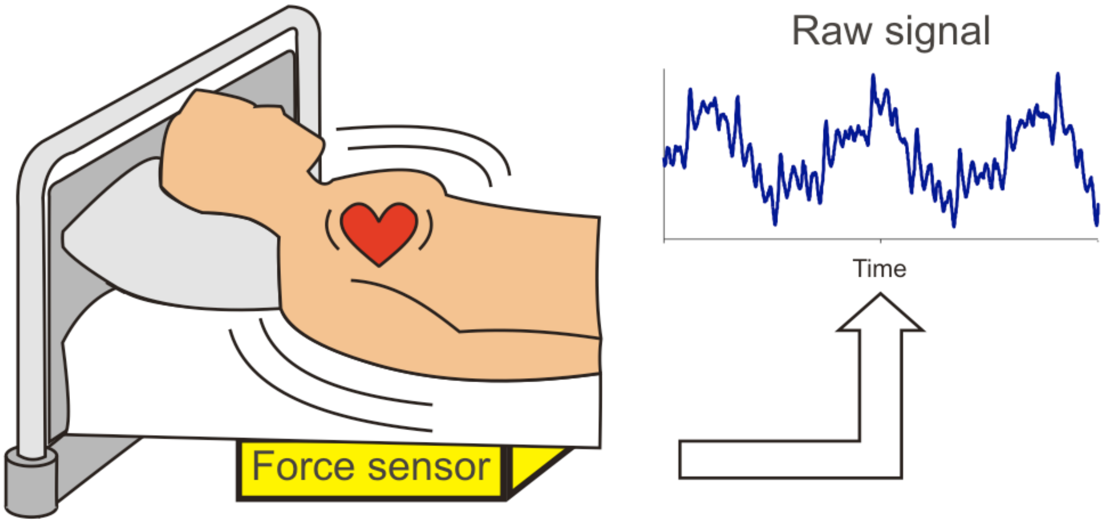
http://www.cbsnews.com/news/mit-researchers-invent-wireless-x-ray-vision-project-emerald/

Pulse and vital signs from CV Color

Ming-Zher Poh, Roz Picard et al – Magic Mirror

http://web.media.mit.edu/~zher/papers/Poh-etal-Siggraph.pdf

Ballistocardiography



http://www.medit.hia.rwth-aachen.de

Measure small body motions from periodic blood flow
Use accelerometers, piezo pickups, computer vision, …

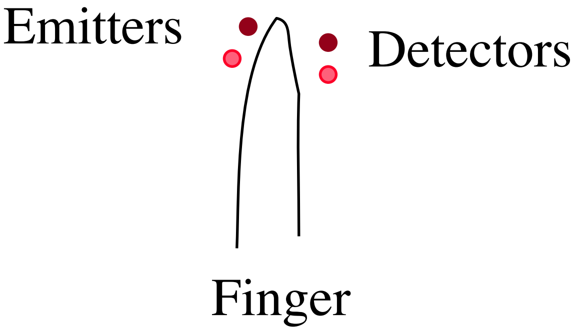
E.g., see: Pinheiro, Postolache, and Girão, 'Theory and Developments in an Unobtrusive Cardiovascular System Representation: Ballistocardiography', http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3111731/

Fredo Durand et al

'Detecting Pulse from Head Motions in Video',
Guha Balakrishnan, Fredo Durand, John Guttag
MIT CSAIL

http://people.csail.mit.edu/mrub/vidmag/

Pulse Oximeters (Photoplethysmography)



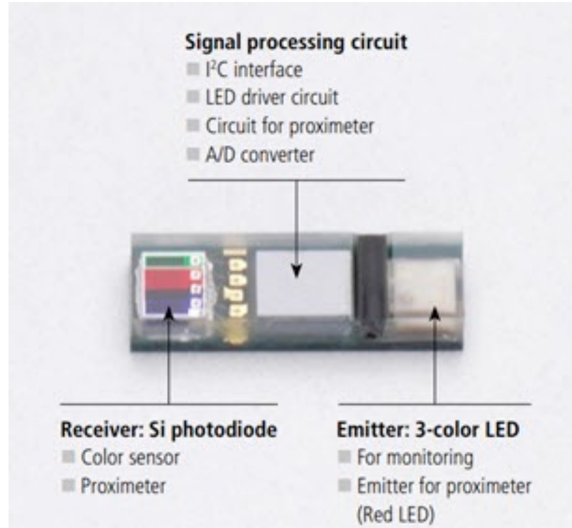
How does an oximeter work? A source of light originates from the probe at two wavelengths (650nm and 805nm). The light is partly absorbed by haemoglobin, by amounts which differ depending on whether it is saturated or desaturated with oxygen. By calculating the absorption at the two wavelengths the processor can compute the proportion of haemoglobin which is oxygenated. The oximeter is dependant on a pulsatile flow and produces a graph of the quality of flow. Where flow is sluggish (eg hypovolaemia or vasoconstriction) the pulse oximeter may be unable to function. The computer within the oximeter is capable of distinguishing pulsatile flow from other more static signals (such as tissue or venous signals) to display only the arterial flow

Heart Rate at the Wrist

- The best ones RF communicate with a chest strap – otherwise, they look at differential potential across fingers.
- Some have looked at optical measurements from the strap, but tend to be sensitive to motion

Optical Heart Rate at the Wrist

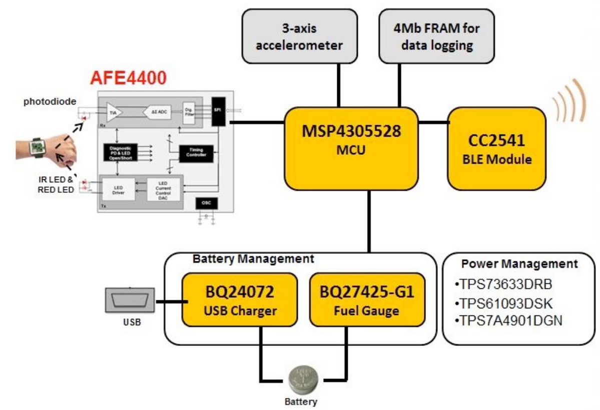
The Basis Watch



Hamamatsu

Maxim

Optical Wrist Based HRM



TI

See: http://www.mdtmag.com/article/2014/09/designing-heart-rate-monitor-wearable-devices

Earring Sensors

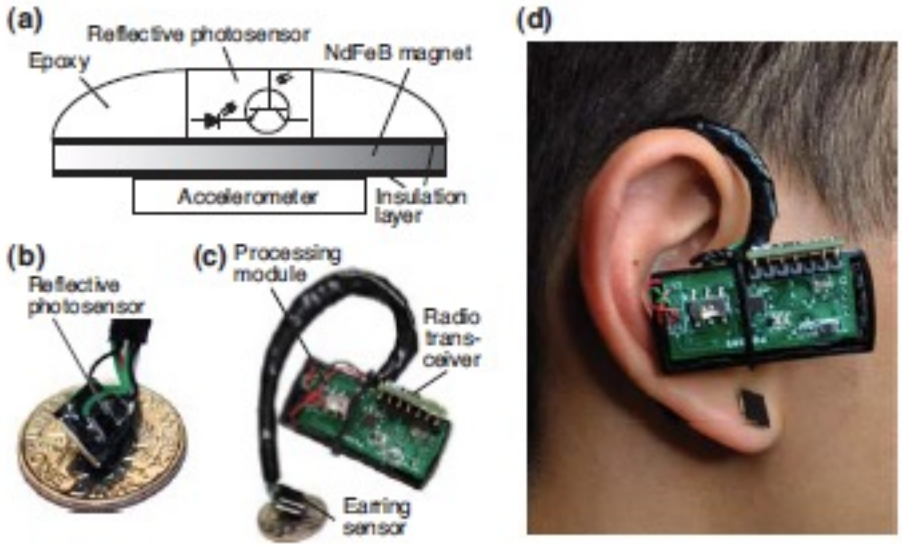


Fig. 1. Overview of the wearable system. (a) Schematic of the earring sensor. (b) Prototype of earring sensor showing an embedded reflective photosensor. An accelerometer (not visible) is embedded on the opposite side. (c) Packaging of the magnetic earring sensor and the wireless earpiece containing a processing module and radio transceiver. (d) Appearance of device when worn by user.

Motion Tolerant Magnetic Earring Sensor and Wireless Earpiece for Wearable Photoplethysmography

Ming-Zher Poh, *Student Member, IEEE*, Nicholas C. Swenson, and Rosalind W. Picard, *Fellow, I*

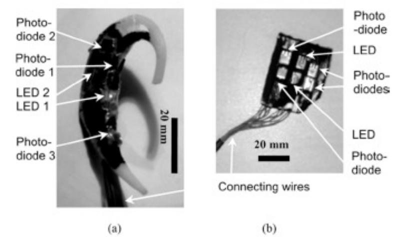


Fig. 1. Hardware setup showing the LED and photodiode components were encapsulated into (a) an e-AR sensor and (b) a patch, forming the reflectance based earpiece PPG and patch PPG sensors. Optical shunt was avoided by a recessed design and careful component layout. For the e-AR sensor, the photodiodes 1 (BPW34FS), 2 (BPW34FS) and 3 (BPW34) formed the reception channels 1, 2, and 3, correspondently, with identical active areas. When worn, the e-AR sensor has two perpendicular optical sensing planes, one being parallel to the temporal scalp (reception channel 2), another being vertical to the temporal scalp (reception channels 1 and 3).

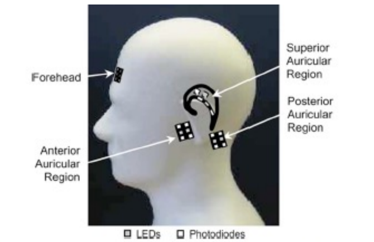


Fig. 2. Different locations of the PPG sensor(s). For ambient light shielding, an opaque medium was used to cover the earpiece sensor/the auricular region. All locations were indicated with sensors here, but for every experiment, there was only one sensor to be worn.

Lei, Lo, and Yang, "Multichannel reflective PPG earpiece sensor with passive motion cancellation" IEEE EMBS 2007

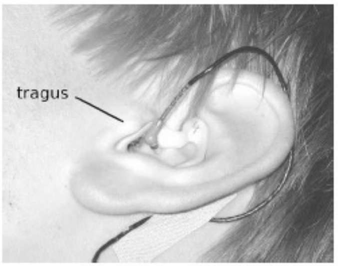


Fig. 1. Microoptic reflective sensor *in situ*. The tragus is a thick layer of

IEEE TRANSACTIONS ON INFORMATION TECHNOLOGY IN BIOMEDICINE, VOL. 13, NO. 6, NOVEMBER 2009

In-Ear Vital Signs Monitoring Using a Novel Microoptic Reflective Sensor

Stefan Vogel, Markus Hülsbusch, Thomas Hennig, Vladimir Blazek, and Steffen Leonhardt, *Senior Member, IEEE*

Cuffless Blood Pressure

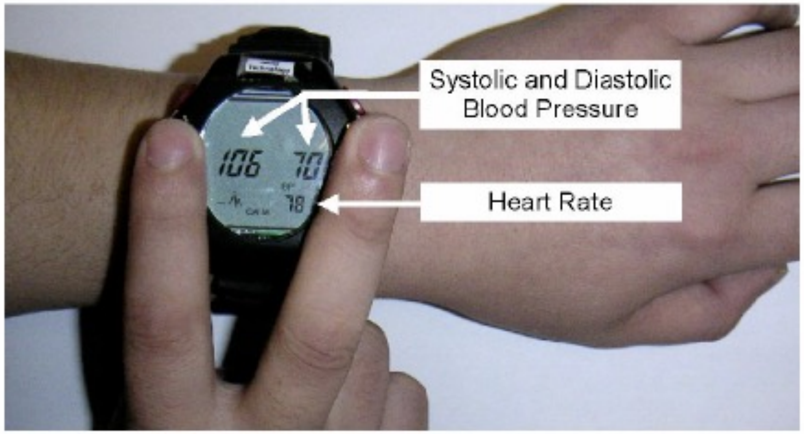


Fig.1. A prototype of the cuff-less BP watch produced by Jetfly Technology Ltd. using the PTT-based technology developed at JCBME.

M-Health: The Development of Cuff-less and Wearable Blood Pressure Meters for Use in Body Sensor Networks

Carmen C.Y. Poon, Yee Man Wong and Yuan-Ting Zhang*
Joint Research Centre for Biomedical Engineering, Department of Electronic Engineering, The Chinese University of Hong Kong, Shatin, Hong Kong
ytzhang@ee.cuhk.edu.hk

Pulse Transit Time

A hydrostatic pressure approach to cuffless blood pressure monitoring

P. Shaltis[1], A. Reisner[2], H. Asada[1]
[1]Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA
[2]Massachusetts General Hospital, Boston, MA, USA

Ring finger noninflatable cuff, plus estimation of arm height to get pressure measurements at different heights, from which BP can be derived.

Novel Design for a Wearable, Rapidly Deployable, Wireless Noninvasive Triage Sensor

Phillip Shaltis*, Levi Wood, Andrew Reisner, and Harry Asada

Fig. 1. CAD image of clip-type triage sensor unit

Fig. 2. Finger clip sensor being inserted onto the finger base.

Fig. 3a. PPG LED array

Fig. 3b. PPG PD array

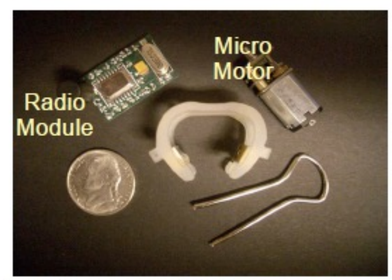


Fig. 8. Major components used in the new finger clip triage sensor.

Blood Pressure from change in PPG with applied pressure on finger

Fabric Sensors for Health Monitoring

KNITTED BIOCLOTHES FOR CARDIOPULMONARY MONITORING

R. Paradiso[1], A Gemignani[2], E, P. Scilingo[3] and D. De Rossi[3]
[1]MILIOR SpA and SMARTEX s.r.l., Prato, Italy
[2]Dipartimento di Fisiologia e Biochimica, Faculty of Medicine - Univ. of Pisa, Italy
[3]Centro "E. Piaggio", Faculty of Engineering - Univ. of Pisa, Italy

II.WEALTHY SYSTEM

Strain fabric sensors based on piezoresistive yarns, and fabric electrodes realized with metal based yarns, enable the realization of wearable and wireless instrumented garments capable of recording physiological signals and to be used by the patient during the everyday activity. Breathing pattern, electrocardiogram, activity sensors, temperature, can be listed as physiological variables to be monitored through the proposed system.

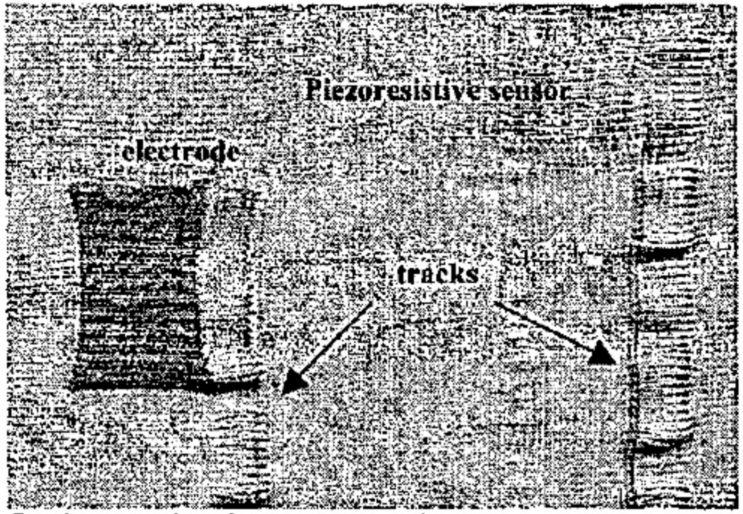


Fig. 2: Particular of WEALTHY interface

Many players in this area now
(e.g., Smart Fabrics conferences)

Reliably sensing in fabric can be difficult
- Material problems (hysteresis, resolution)
- Humidity/sweat problems

But lots of work here using new materials and coatings

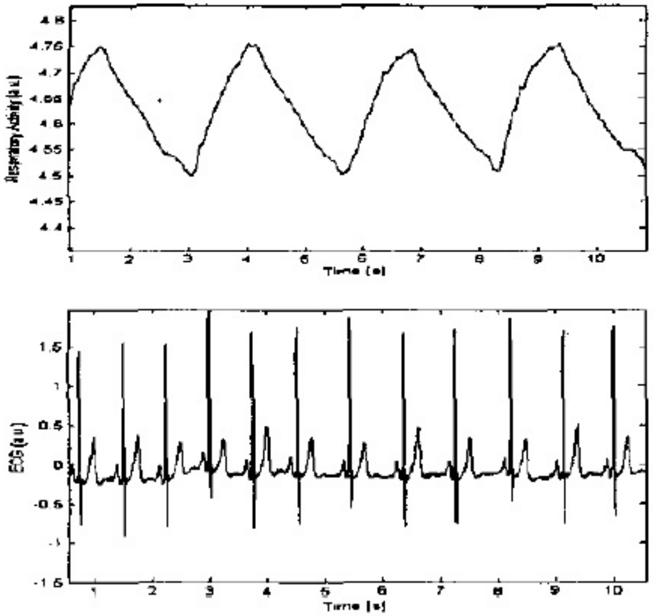


Fig. 4 Respiration activity and ECG trace

More on WEALTHY

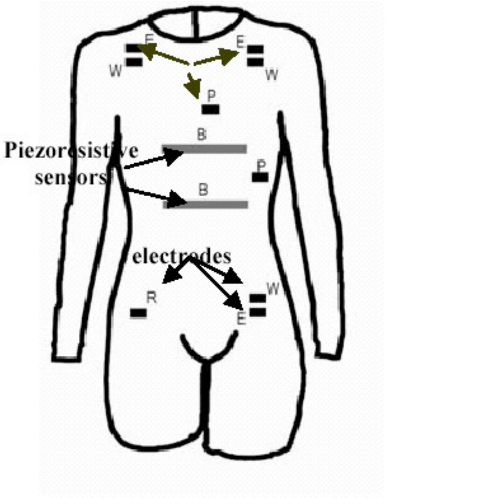


Fig.1: Prototype model, E Einthoven, W Wilson, R Referee, P Precordial leads, B Breathing sensors.

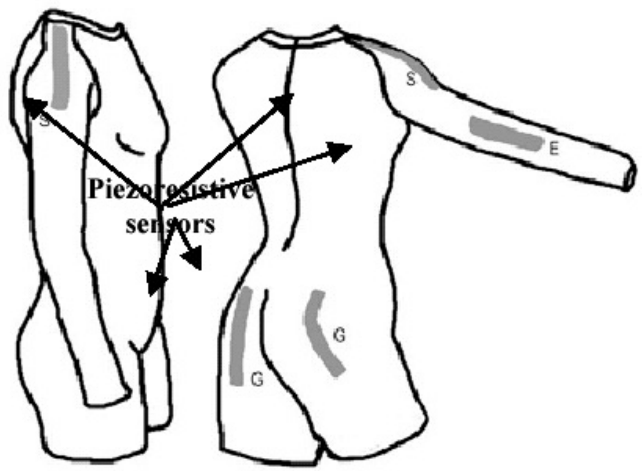


Fig. 2: Movement sensors.

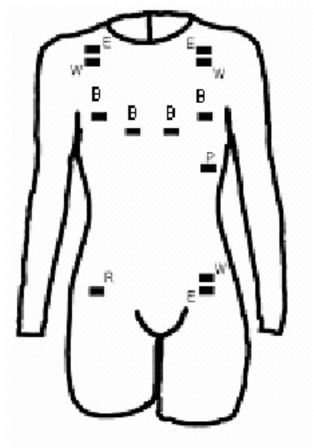


Fig.4: Electrodes position for impedance pneumography

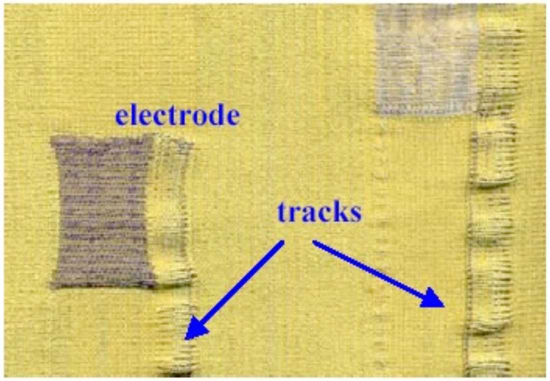


Fig.3: Particular of WEALTHY interface

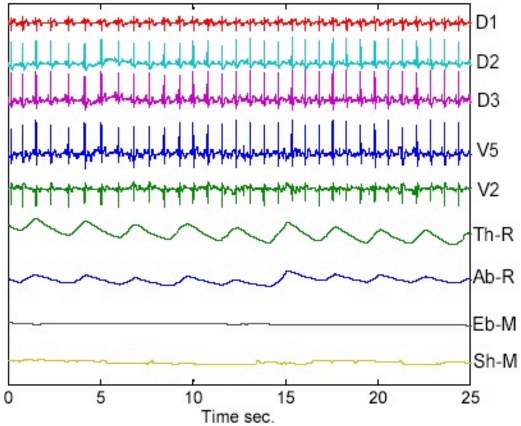


Fig.5: Signals in basal condition, D1, D2, D3 Einthoven leads I, II, III. V2, V5: Standard precordial leads V2 and V5. Th-R, Ab-R: Respiration sensors on thoracic and abdominal position respectively. Sh-M, Eb-M: Movement sensors on the left shoulder and elbow, respectively.

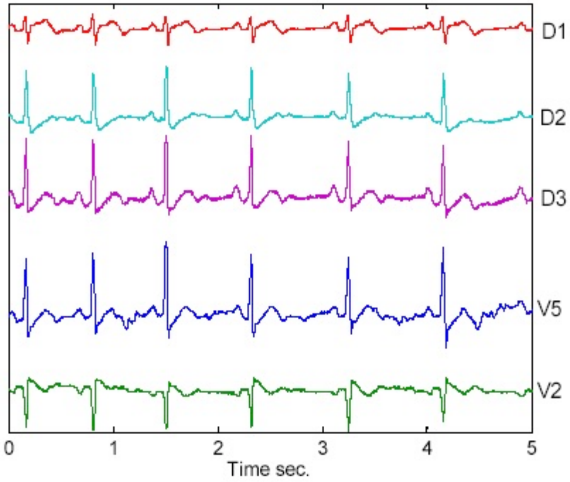


Figure 6: Enlargement of ECG signals in basal condition

More WEALTHY Data

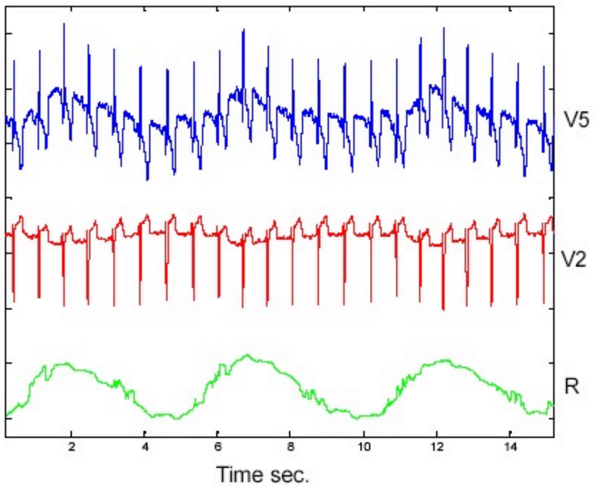


Figure 9: Standard precordial leads V5, V2 and respiratory activity (impedance pneumography)

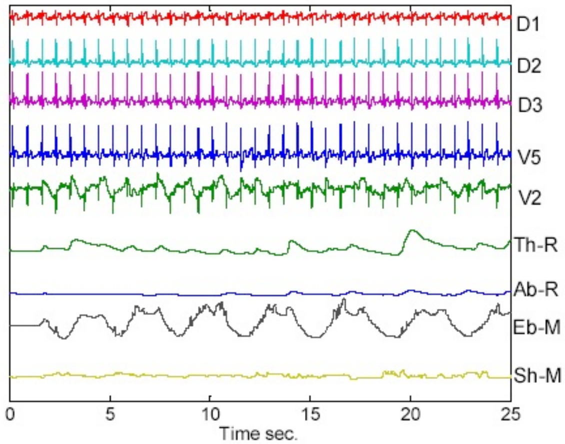


Figure 7 Signals obtained during flex-extension of the left elbow

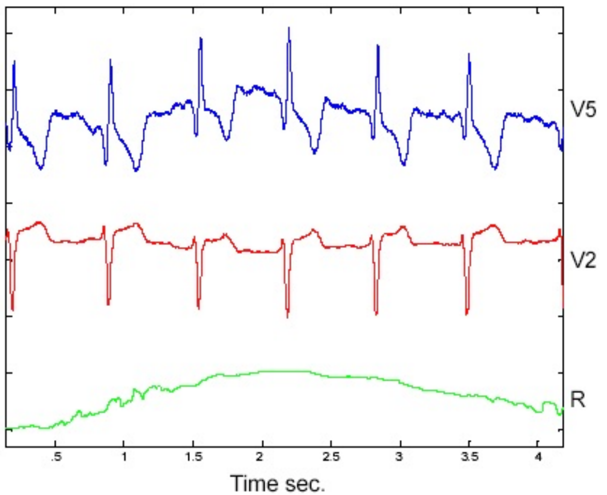


Figure 10: Enlargement of signals shown in Figure 9.

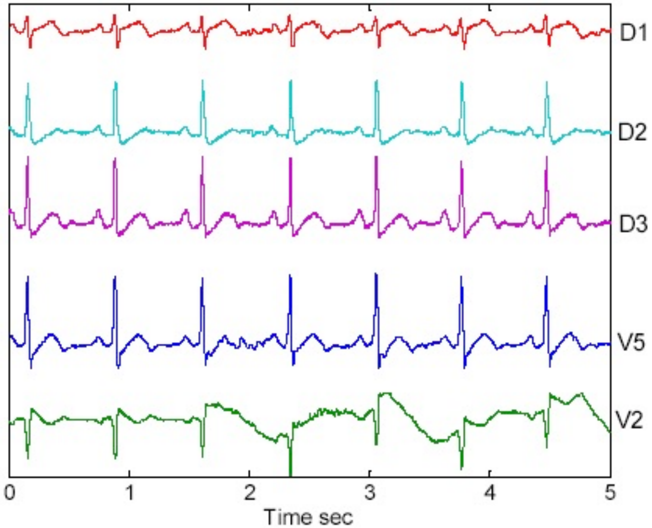


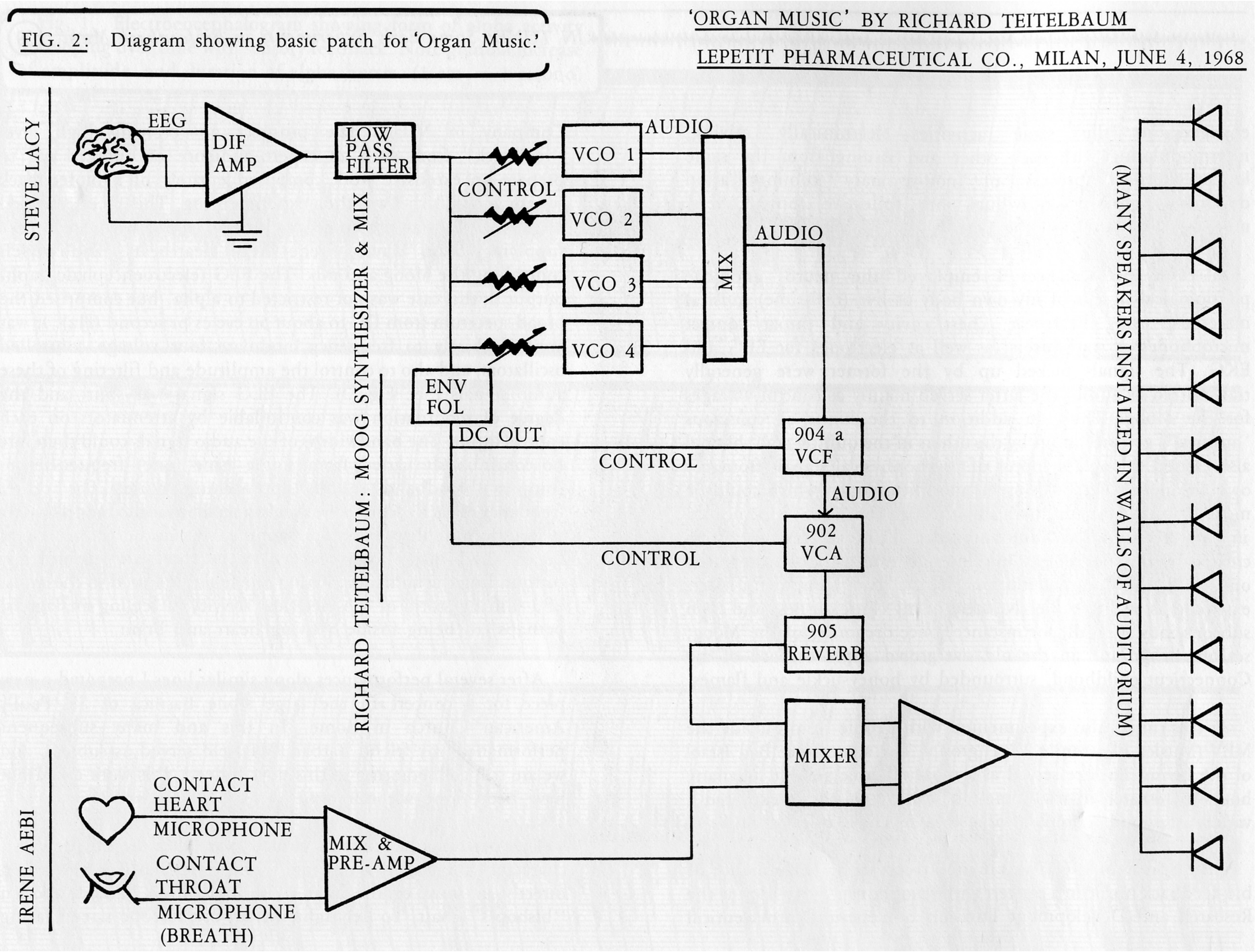
Figure 8 Enlargement of ECG signals during flex-extension of the left elbow

The Body Electric

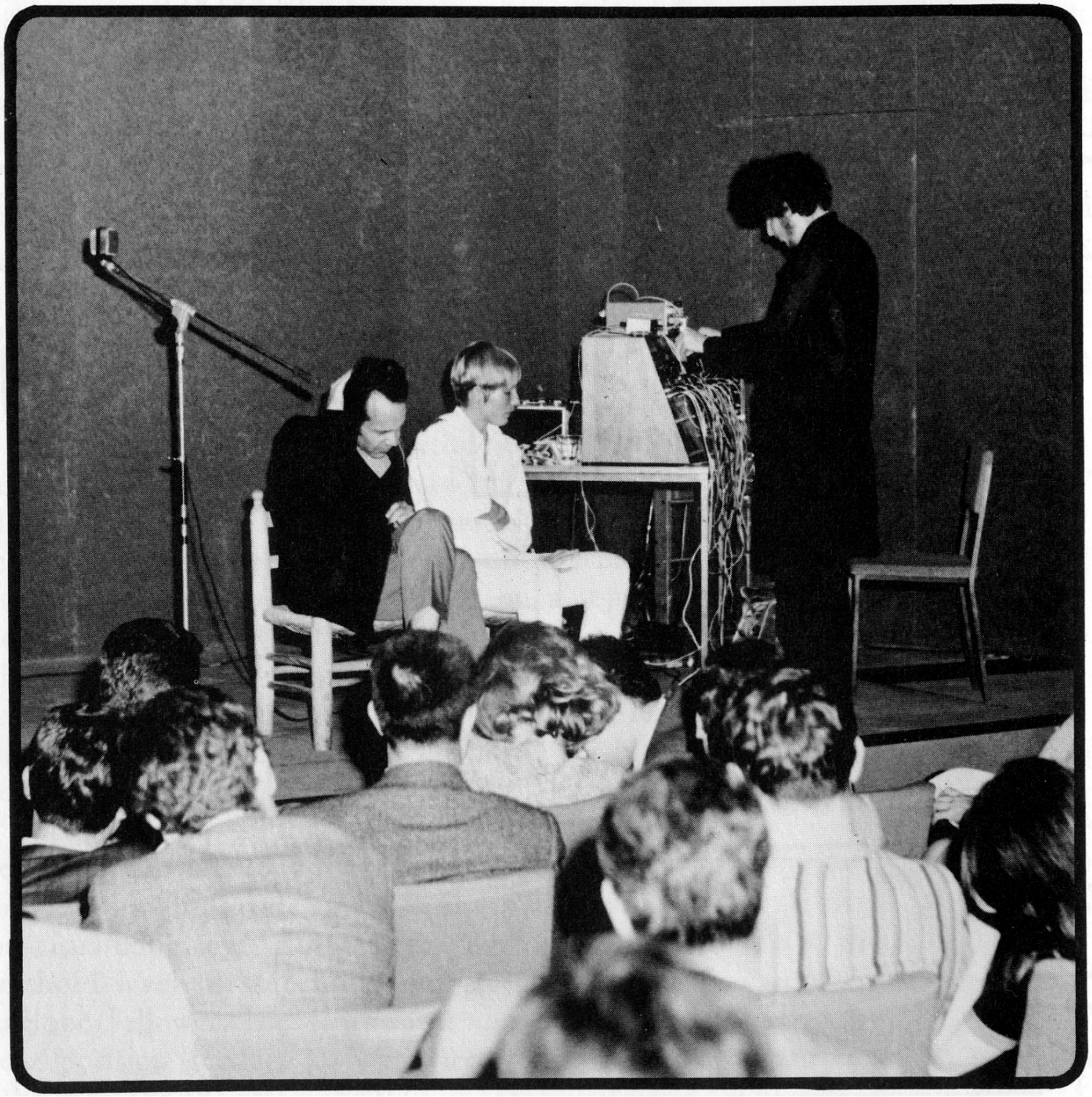
Bioelectric Interfaces for Electronic Music

- Wiring the body….
  - Controlling music with bioelectric signals
    - EMG, ECG, EEG, GSR, breath rate…
    - Sympathetic vs. Direct control (or lack thereof)
    - What does a performance offer?
    - Biofeedback applications dominate…

Richard Teitelbaum, 1968



Organ Music in performance



Milan, 1968

David Rosenboom, Ecology of the skin, 1970

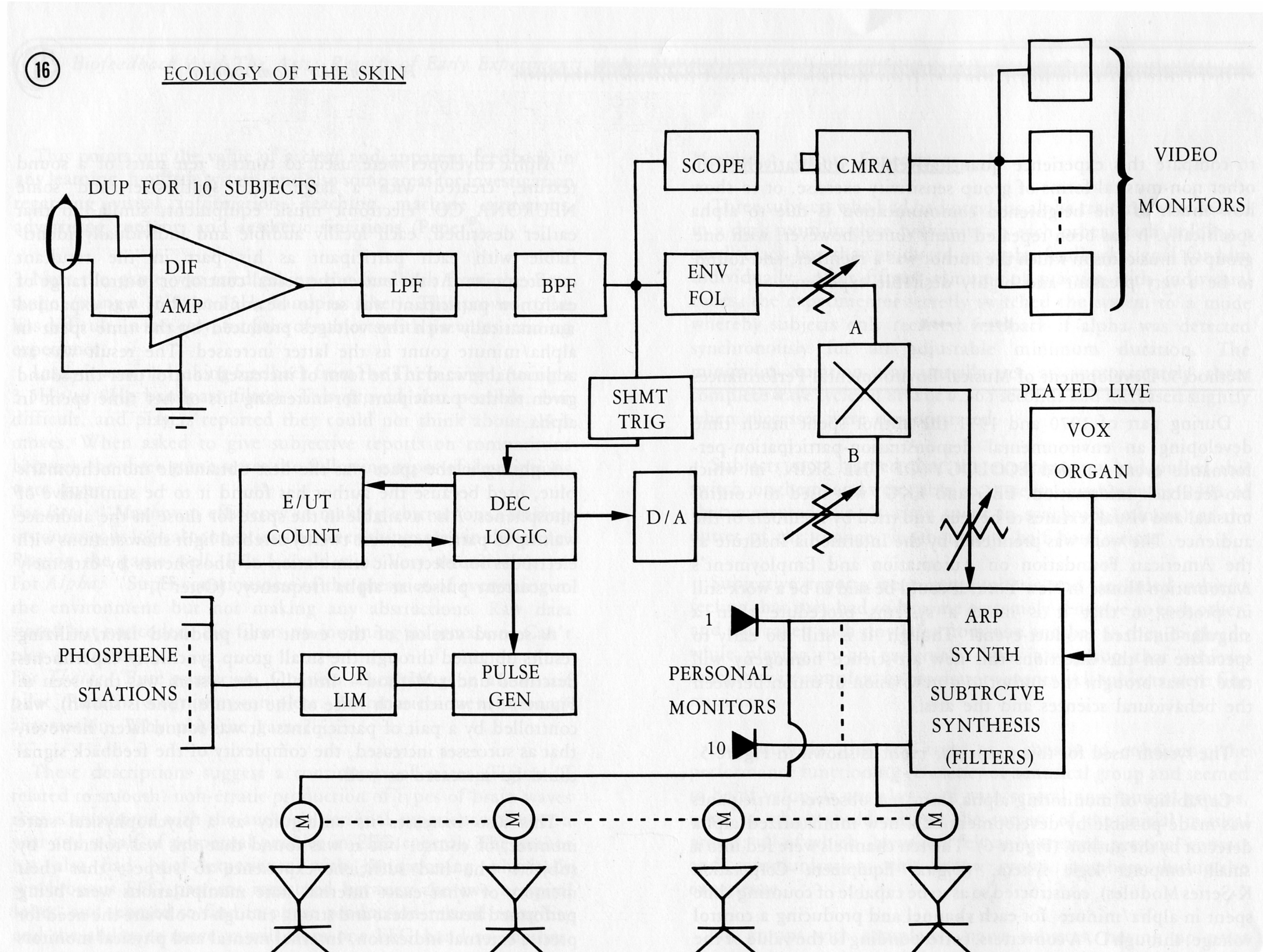


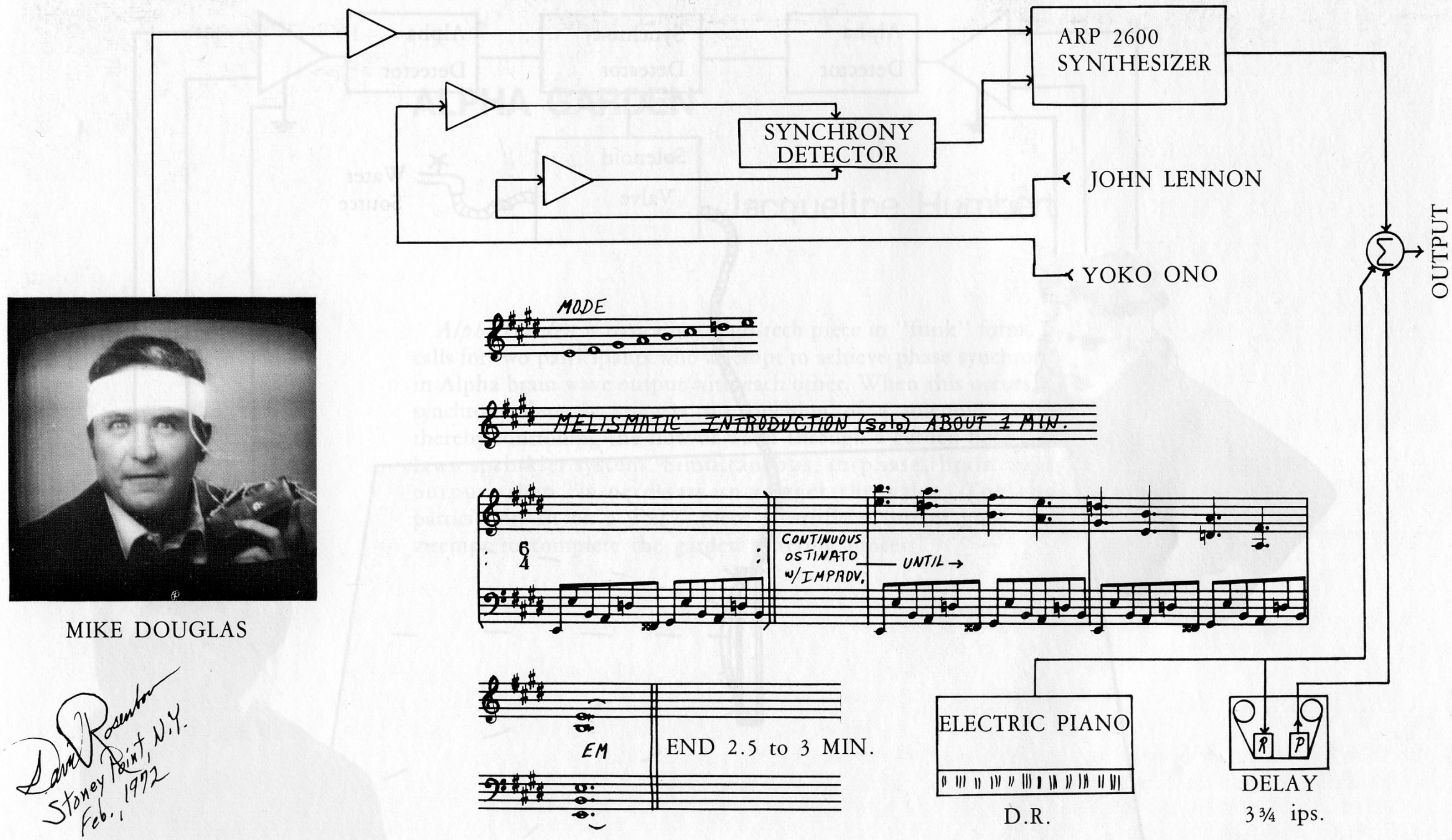
FIGURE 5

Ecology of the Skin

Left: Participant in ECOLOGY OF THE SKIN, with electrodes attached, holding a miniaturized brain wave detector and interface with electronic music system. Right: Composer, David Behrman, at a ''cerebral light show'' station receiving electronic stimulation of phosphenes.

Brain Music for John & Yoko, 1972

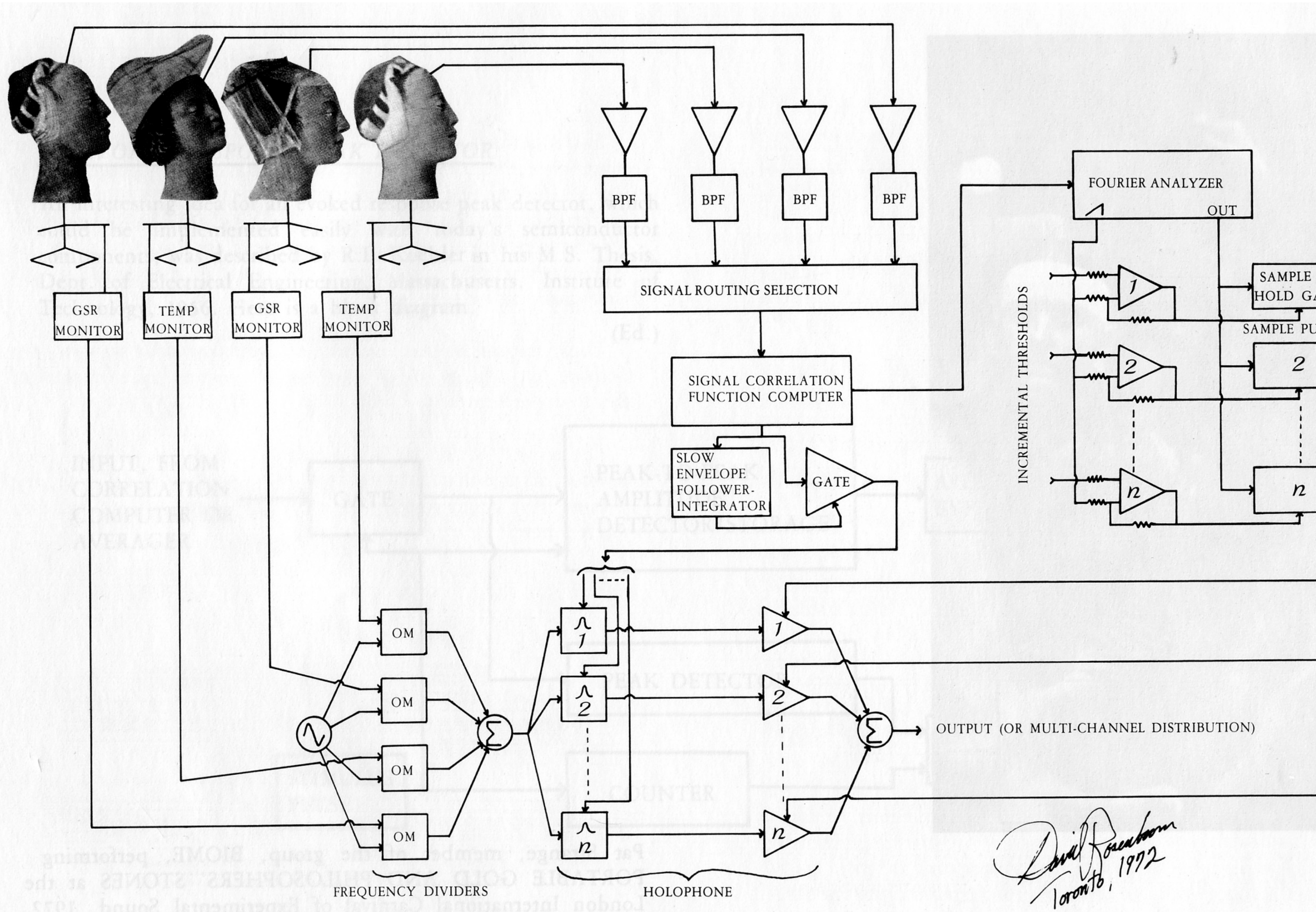
BRAIN MUSIC FOR JOHN AND YOKO† David Rosenboom



Photos on page right are views from the Mike Douglas Show, 1972, with John Lennon, top left and, Mike Douglas, bottom left, wired to perform BRAIN MUSIC FOR JOHN AND YOKO by David Rosenboom, top right.

†(FOR PERFORMANCE ON THE MIKE DOUGLAS SHOW)

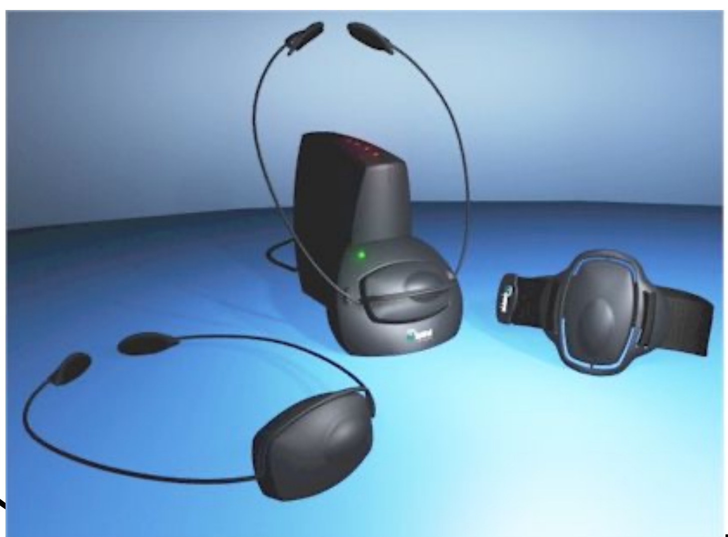
Philosopher's Gold, 1972



Chris Janney's HeartBeat, 1983

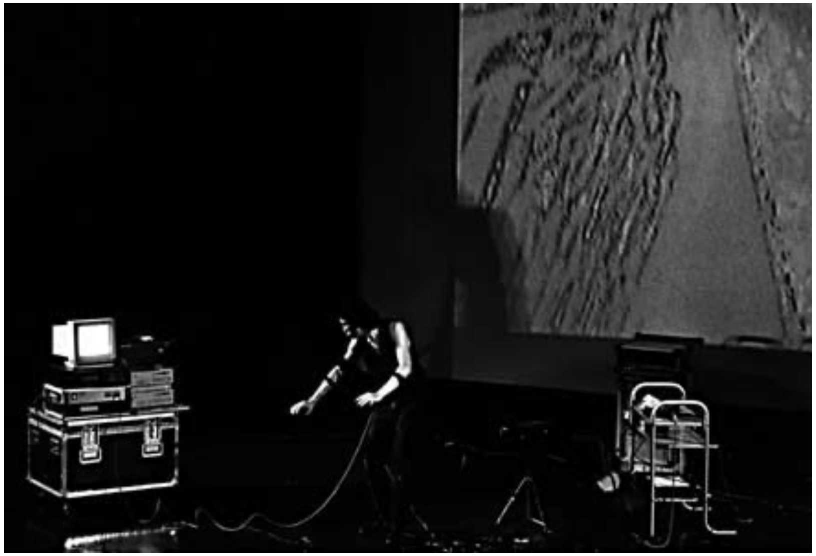
In 1981, at MIT, Janney began researching heartbeat monitor systems. He talked extensively with David Pettijohn, then a Research Fellow in MIT's Psychology Department studying the brain behavior of rats as they ran through mazes. Working with Pettijohn, Janney modified Pettijohn's wireless telemetry system. By building a custom audio filter, Janney was able to find and isolate what he felt was an interesting sound of the electrical impulses coming from the brain to the heart and its surrounding muscles. In 1982, Janney was introduced to choreographer/dancer Sara Rudner, who's fluid polyrhythmic form he was familiar with from Twyla Tharp Dance. Together, they developed the first performance, exploring the heart as both a machine for pumping blood and the "seat of the soul." The piece was first performed in 1983 at The Institute of Contemporary Art in Boston and was chosen as the "Best in Boston" in dance for that year. Since that time, Janney has experimented with the machine on: poets, saxophone players including Stan Strickland, and singers. Since then, it has been performed in numerous Janney concerts from California's Mohave Desert to New York's Lincoln Center. "HeartBeat" uses a bio-engineering device developed by Transkinetics, Inc. which monitors the electrical impulses to a patient's heart and surrounding muscles via wireless telemetry.Placed on a performer's chest and amplified through filters and a sound system designed by Janney, this machine provides an unusual percussion track. Layered over this sound is live vocal music based on jazz scat and Indian tabla rhythms.

The Biomuse



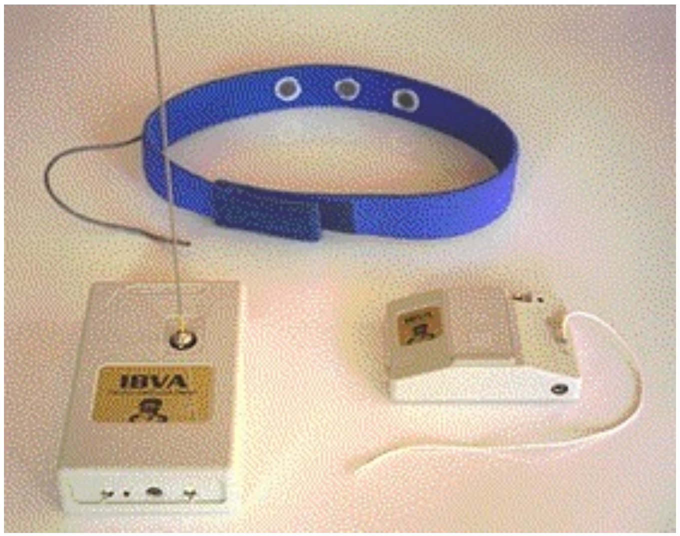
- Acquires signals from muscles (EMG signals), eye movements (EOG signals), the heart (EKG signals), and brain waves (EEG signals).
  - These signals are acquired using standard non-invasive transdermal electrodes.
- Has MIDI output and mapping functions
- Developed by Ben Knapp (Stanford/CCRMA) and Hugh Lusted, 1989 (BioControl).
- Other products for HCI?

Atau Tanaka and the Biomuse

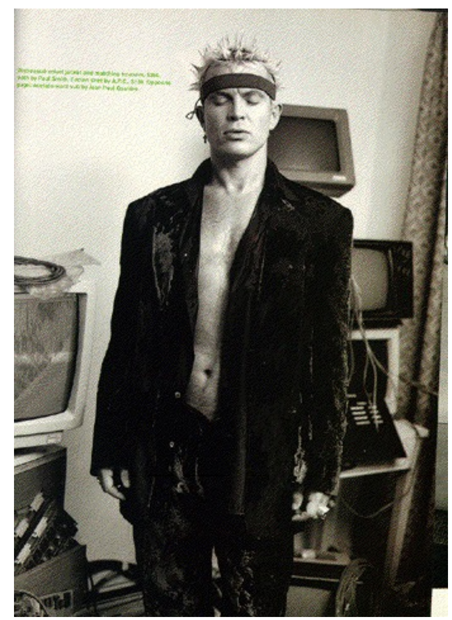


- Colleague of Knapp at Stanford
- Uses Biomuse often in performance

IVBA (Interactive Brainwave Visual Analyzer



- In Norwalk, CT.
- Music is one of the markets?



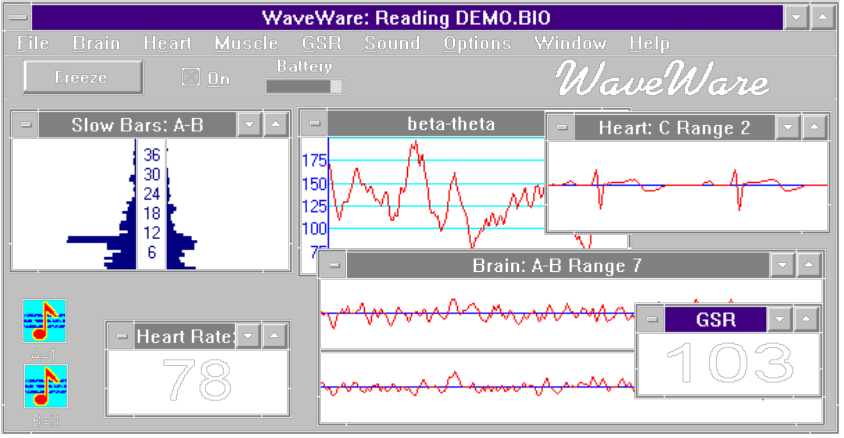
Billy Idol w. IBVA

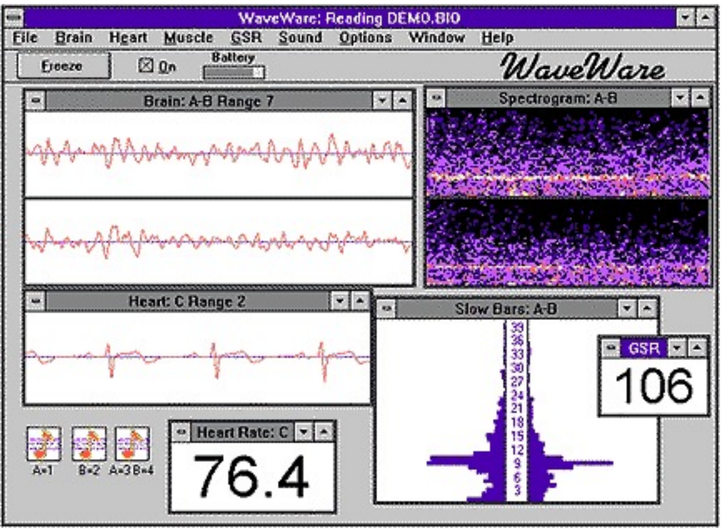
The BodySynth

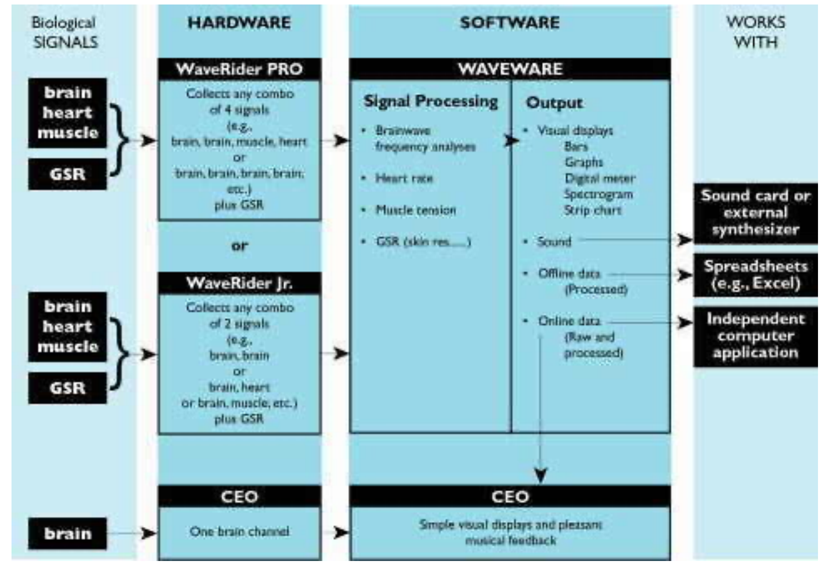
Pamela Z, Laurie Anderson, etc.

- The BodySynth™, created by Chris Van Raalte and Ed Severinghaus (Copyright 1994), is MIDI controller that transforms movement, gestures, and other muscle efforts into sounds. The *BodySynth* is a wearable, wireless muscle-activated MIDI controller that is used to generate music and lighting effects in time to a dancer's movements. The basic system consists of four muscle tension (electromyogram, or EMG) sensors, a small body unit (1"x2.5"x4") for signal amplification and conditioning, a wireless transmission system, and a processor unit. The processor unit runs several real-time filters on an internal DSP processor, including metronomic functions, tempo adjustment (between 50-300 beats per minute), peak detectors, and impulse averagers. It can process up to eight channels at 40-80Hz sampling rate with twenty parameters per channel.

The Waverider

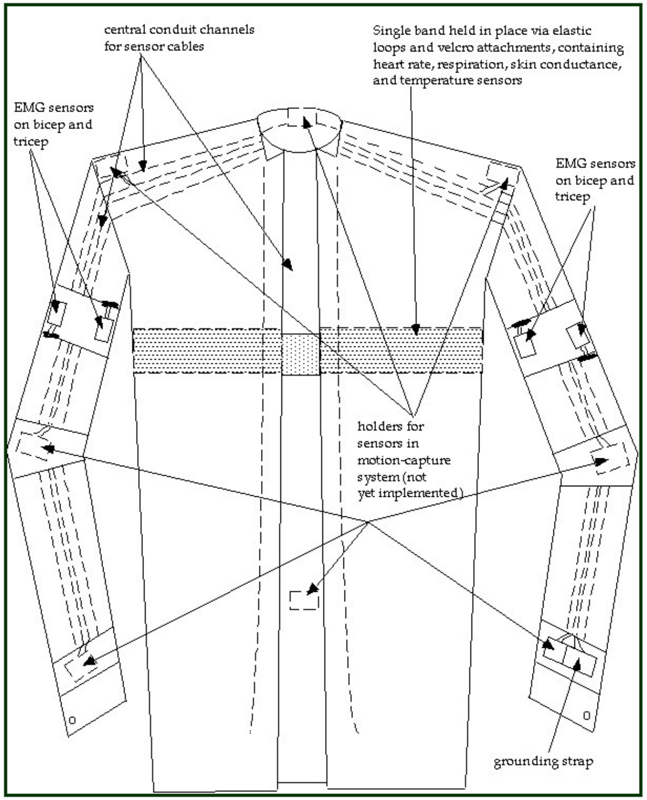


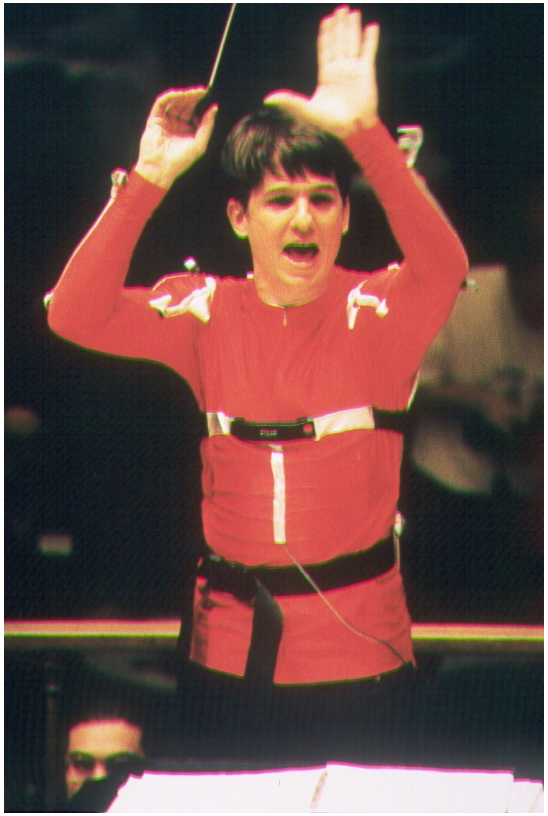




- Multiple capture device for biofeedback & Music
  - EEG, EMG, GSR, HR
- http://www.mindpeak.com/waverider.htm
- http://www.futurehealth.org/waveride.htm
- http://www.wnyc.org/studio360/archive.html

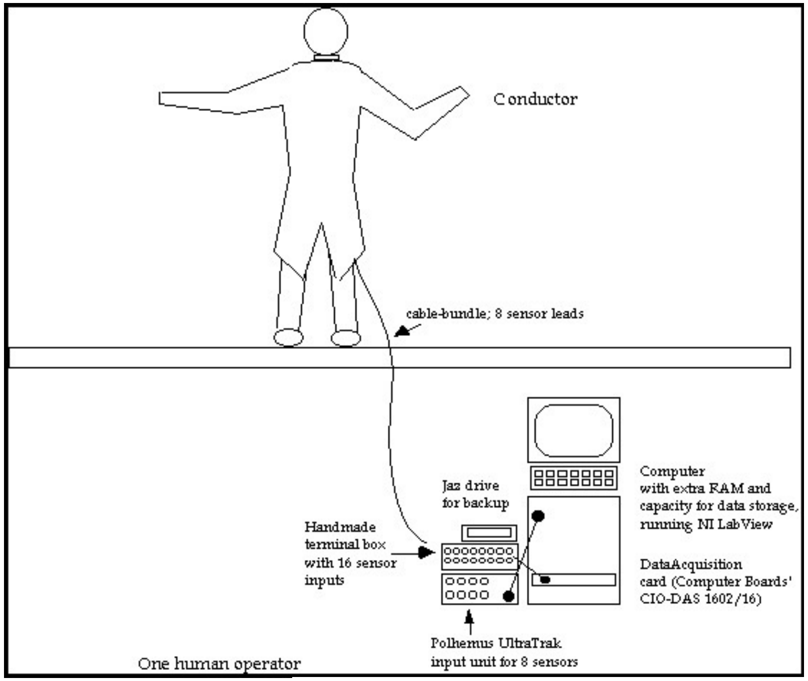
The Conductor's Jacket, 1999

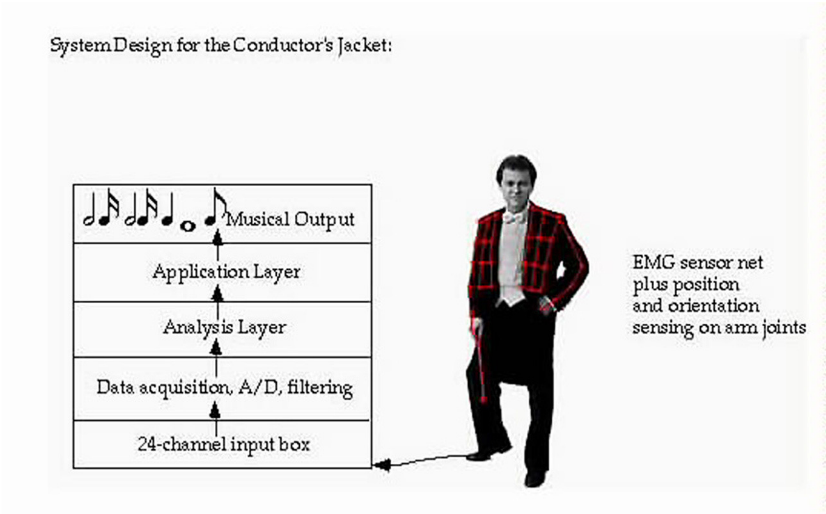


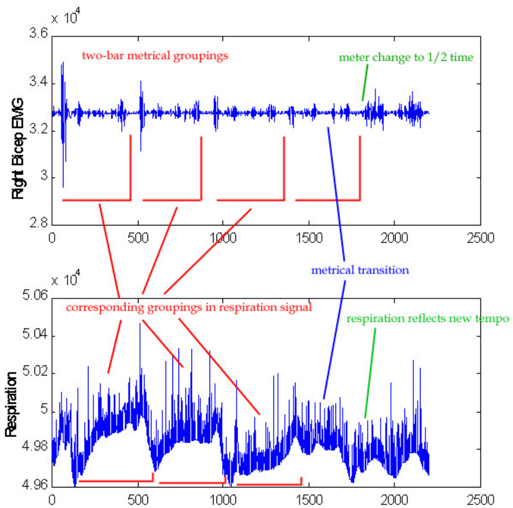


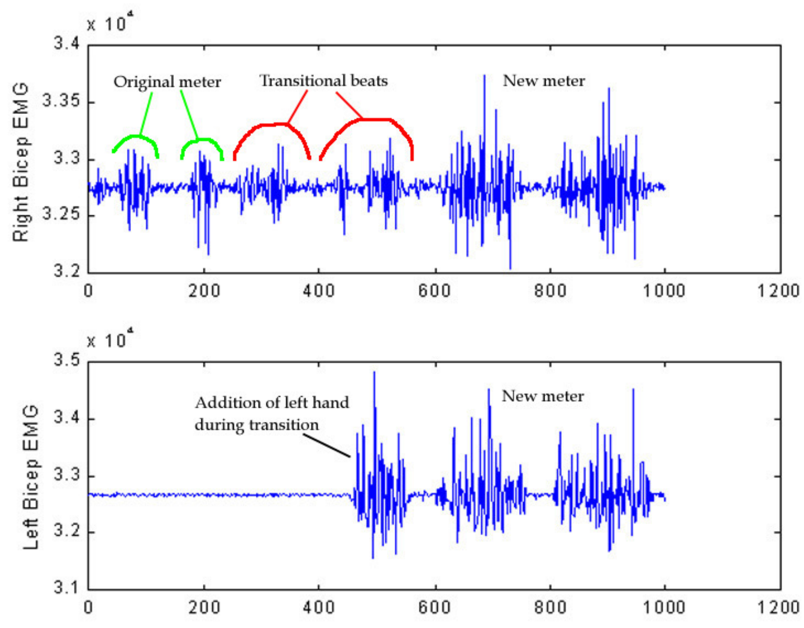
- Teresa Marin's PhD project in the Affective Computing Group
- Wired EMG, GSR, heart rate sensors into a conductor's vest
- Analyzed features vs. portion of performance
  - Inferred Conductor's state
- Then used it as a controller to conduct

Conductor's Jacket

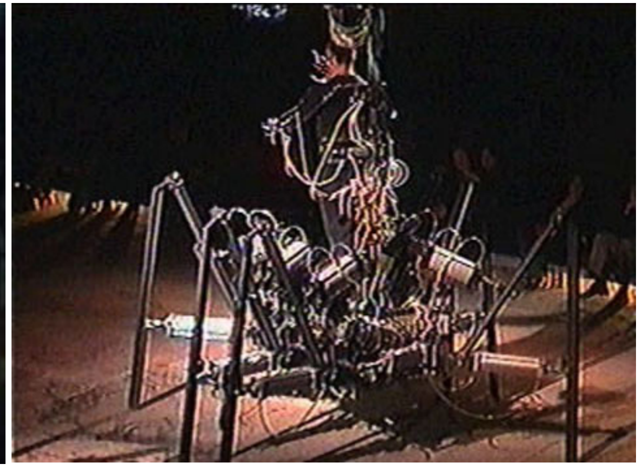


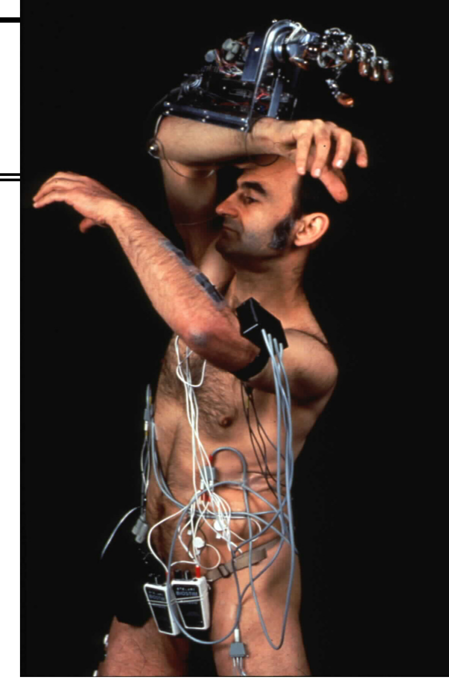






Stelarc…





- Exoskeletons driven by EMG's, etc.

To Be Added...

Smoke Detectors, Radiation Detectors, Noses, etc.