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EMB

Tainan Chapter

SOME RECENT DEVELOPMENTS IN THE DESIGN OF BIOPOTENTIAL AMPLIFIERS FOR ENG RECORDING SYSTEMS

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ACKNOWLEDGEMENTS

Professor N Donaldson,	*Department of Medical Physics & Bioengineering University College, London, UK*
Dr P Langlois,	*Department of Electronic and Electrical Engineering, University College, London, UK*
Dr J Robbins,	*Department of Pharmacology, King’ College, London, UK*
Dr A Sapelkin,	*Department of Physics, Queen Mary University, London, UK*
Dr R Rieger,	*Department of Electrical Engineering, National Sun Yat-sen University, Taiwan*
Dr D Pal,	*Department of Electronics & Communication Engineering, B.I.T. Mesra, India*
Dr M Schuettler,	*Department of Microsystems Engineering, University of Freiburg, Germany*
Dr N Rijkoff	*Centre for Sensory Motor Interaction (SMI), University of Aalborg, Denmark*

Engineering and Physical Sciences Research Council (UK) (EPSRC)

SUMMARY

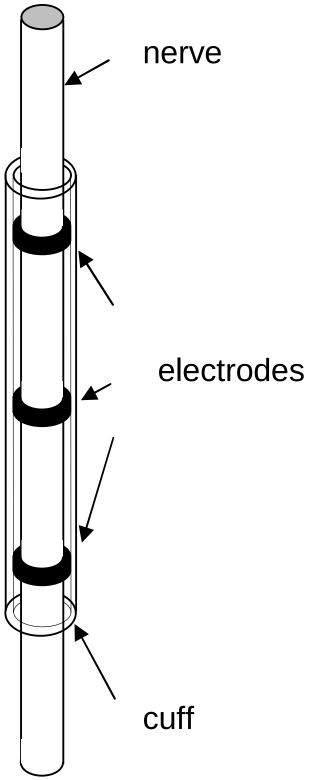
- The importance of real-time recording of *electroneurogram* (ENG) signals
- The difficulties of achieving a stable interface between tissue and electronic devices
- Illustrations of current problems being studied at Bath University
  1 *Velocity selective recording* (VSR) of ENG signals
  2 *In vitro* recording of ENG from cloned neurons
- Some possible future directions

THE IMPORTANCE OF ENG RECORDING

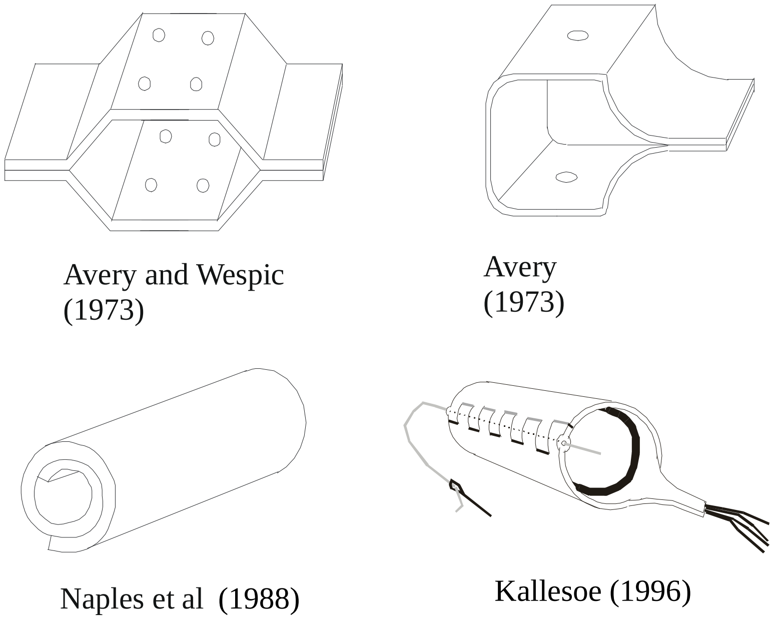
Although this area has been researched for some time, there is still much demand for improved systems for real-time ENG recording. Interest comes from eg:

- *Neuroscientists* requiring experimental data in fields such as neurophysiology and neuropharmacology
- *Engineers* requiring inputs for systems to control *Functional Electrical Stimulation* (FES) systems for a variety of rehabilitation applications such as neurogenic urinary incontinence by stimulation of the sacral roots
- There is a demand for recording methods with improved functionality, eg. Velocity/diameter selective recording (VSR)

NERVE CUFFS FOR ENG RECORDING



Nerve cuff with tripolar electrode assembly


Avery and Wespic (1973)

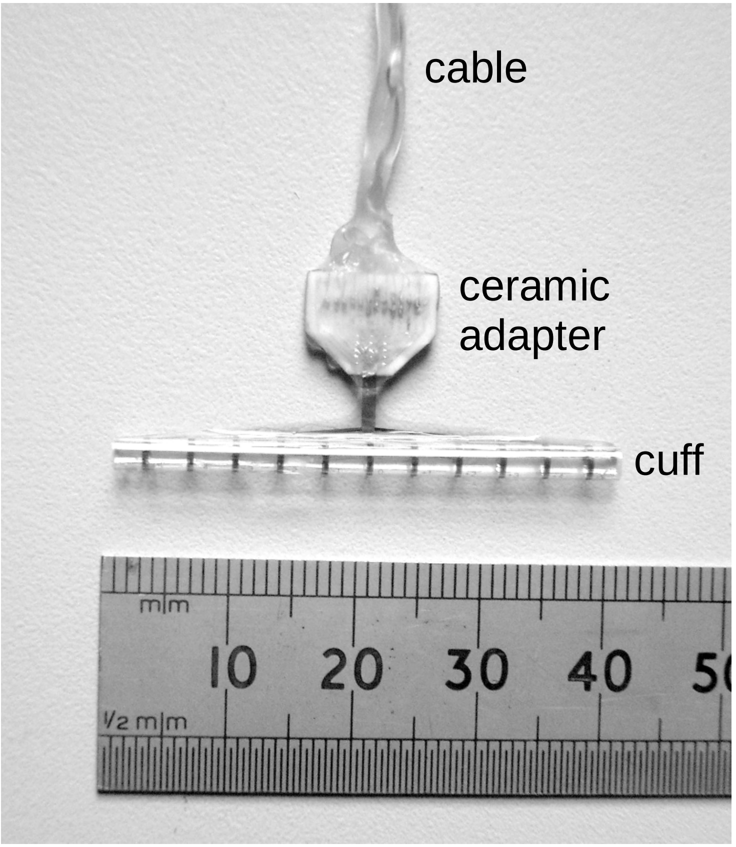
Avery (1973)

Naples et al (1988)

Kallesoe (1996)

Various types of cuff design

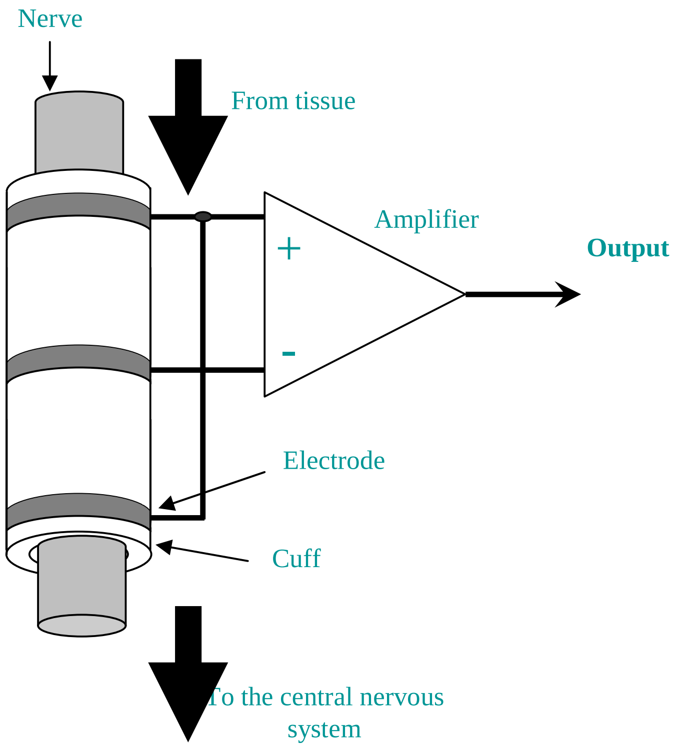
MULTIELECTRODE CUFF (MEC)



- Polyimide thin-film technology
- Sputtered platinum electrodes
- Etched using oxygen plasma.
- The final MEC was 1.5 mm in diameter, 40 mm long and carried eleven 0.5 mm wide, ring-shaped platinum electrodes

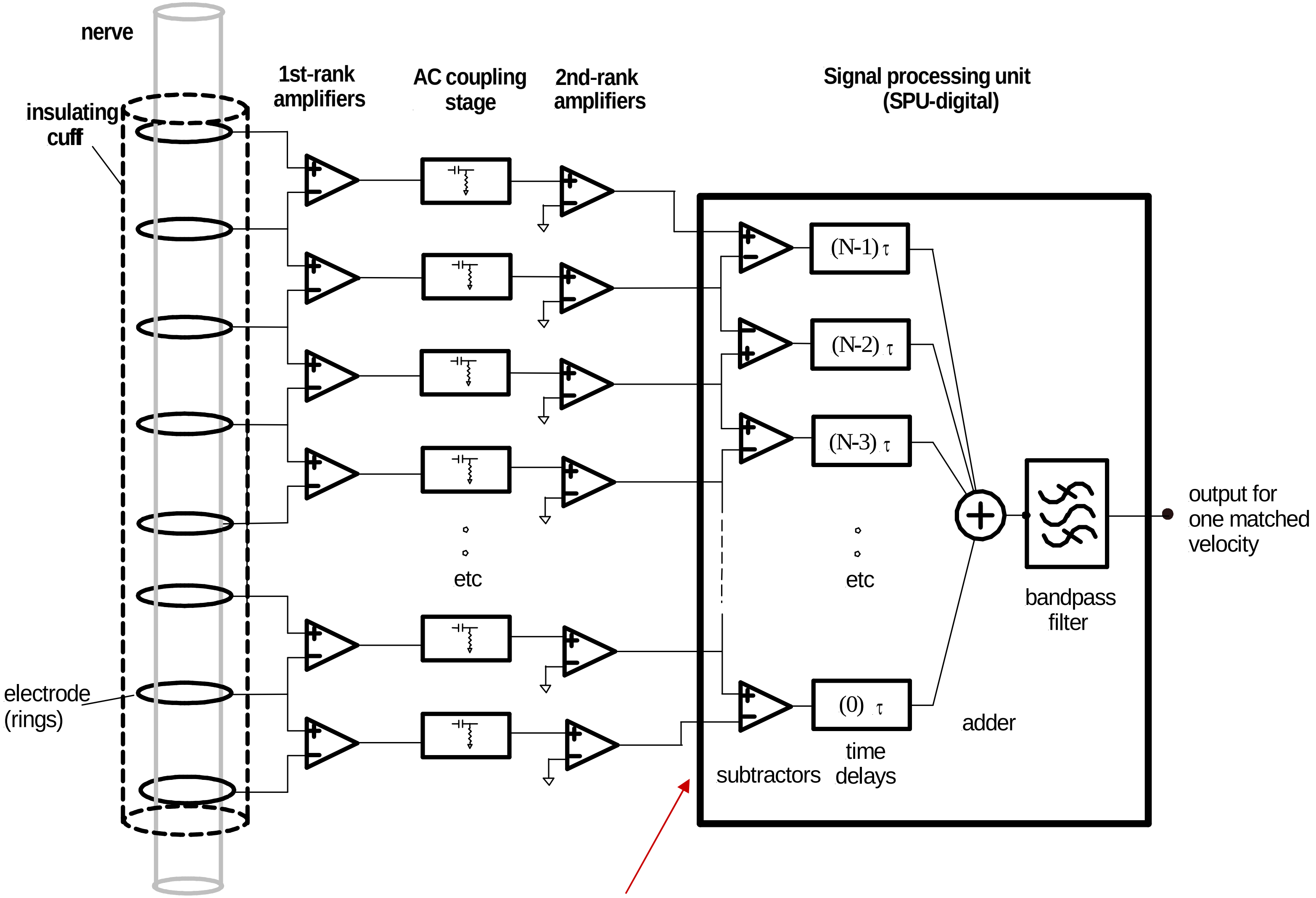
M Schuettler, 2006

RECORDING ENG USING NERVE CUFFS



This type of cuff/amplifier connection is called a *Quasi Tripole* (QT). It provides good suppression of EMG and other artifacts. It only requires one amplifier and is relatively simple to implement. It has been much used in practical ENG recording systems.

10 CHANNEL ENG RECORDING SYSTEM



nerve

insulating cuff

1st-rank amplifiers

AC coupling stage

2nd-rank amplifiers

Signal processing unit (SPU-digital)

(N-1) τ

(N-2) τ

(N-3) τ

etc

etc

(0) τ

subtractors

time delays

adder

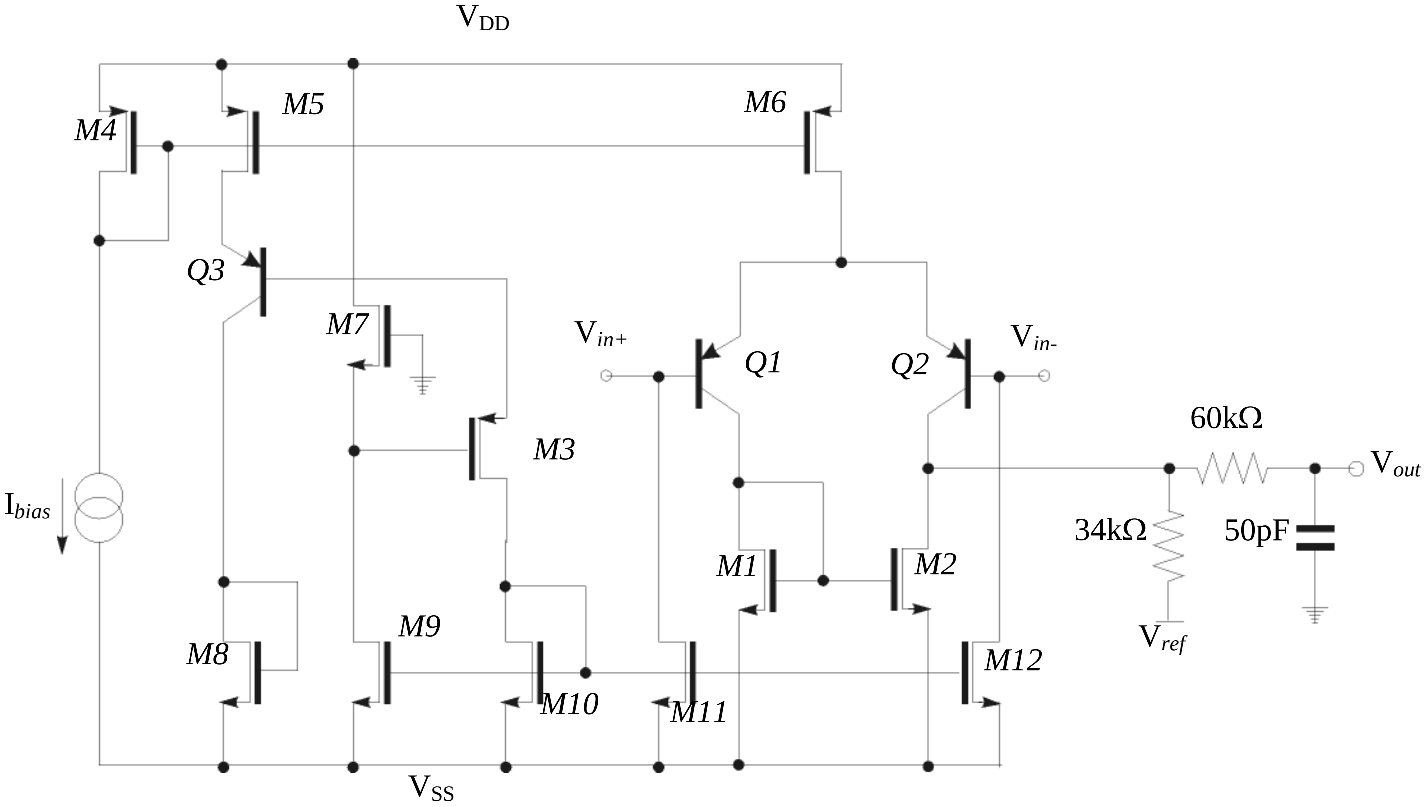
bandpass filter

output for one matched velocity

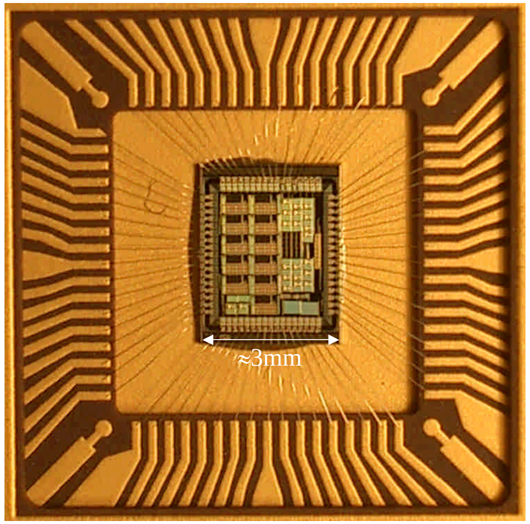
electrode (rings)

digitisation

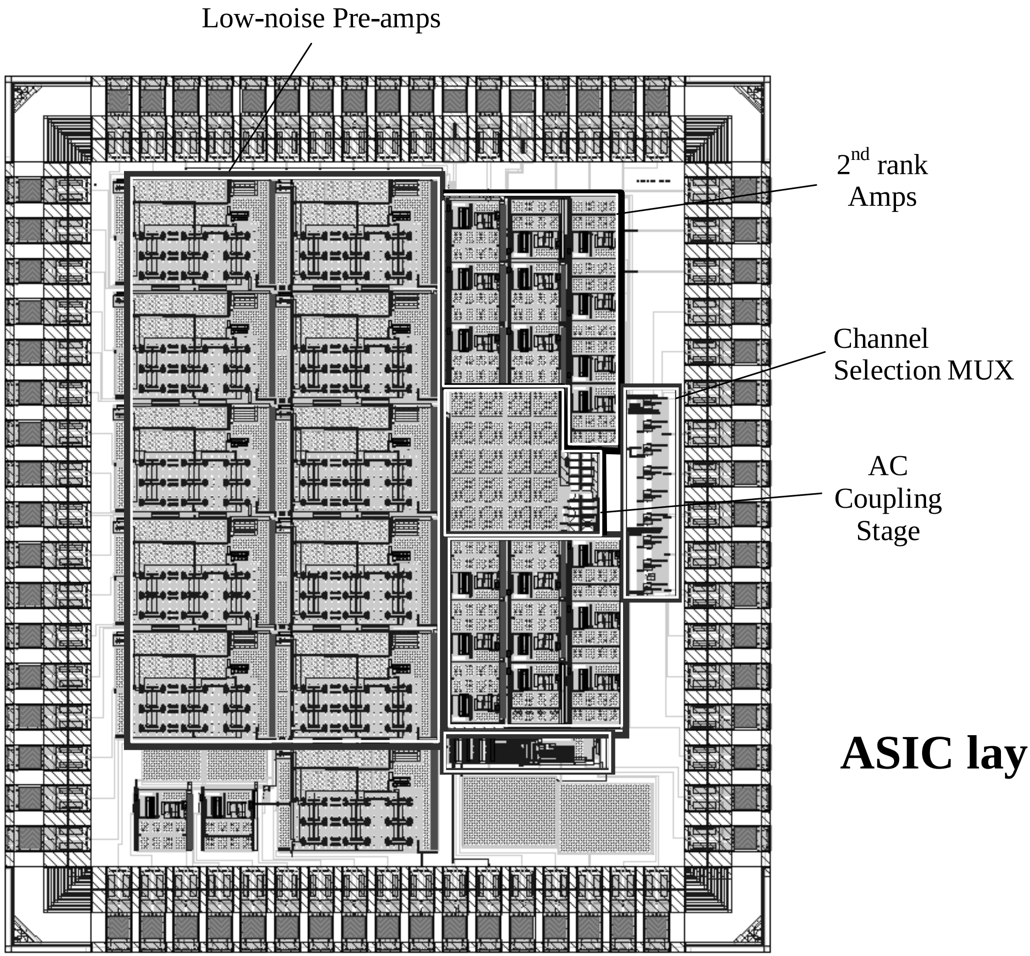
PREAMPLIFIER SCHEMATIC



10 CHANNEL ENG RECORDING SYSTEM

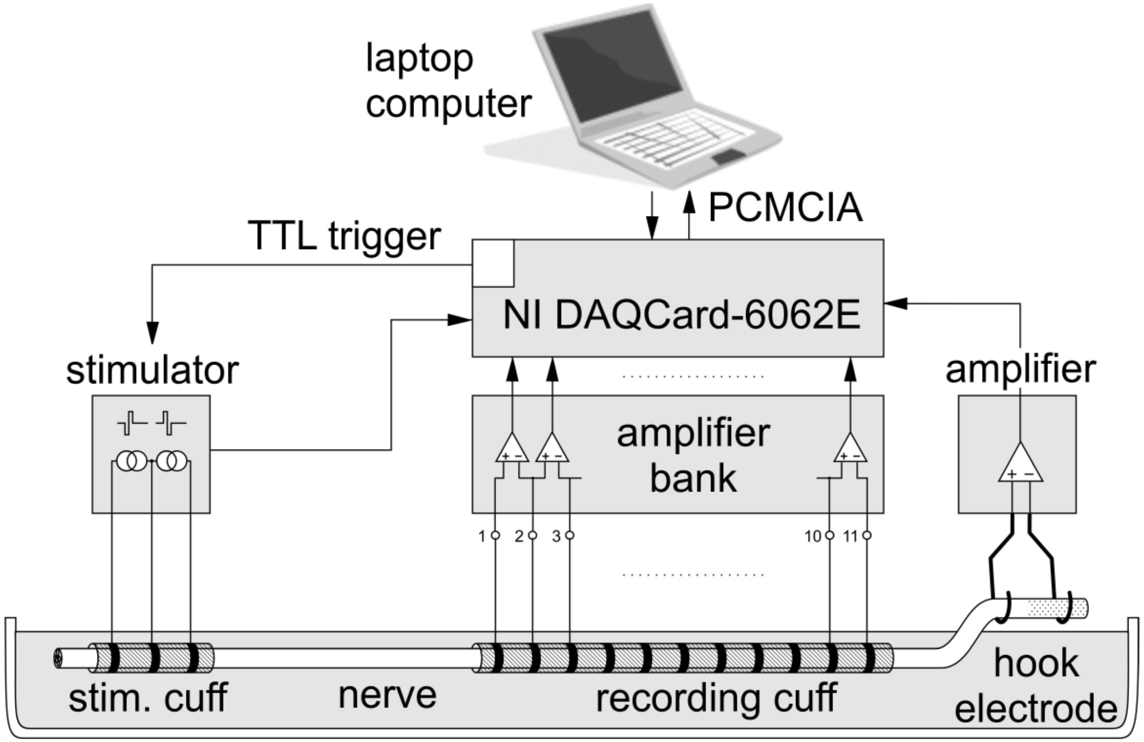


Die mounted in PGA package



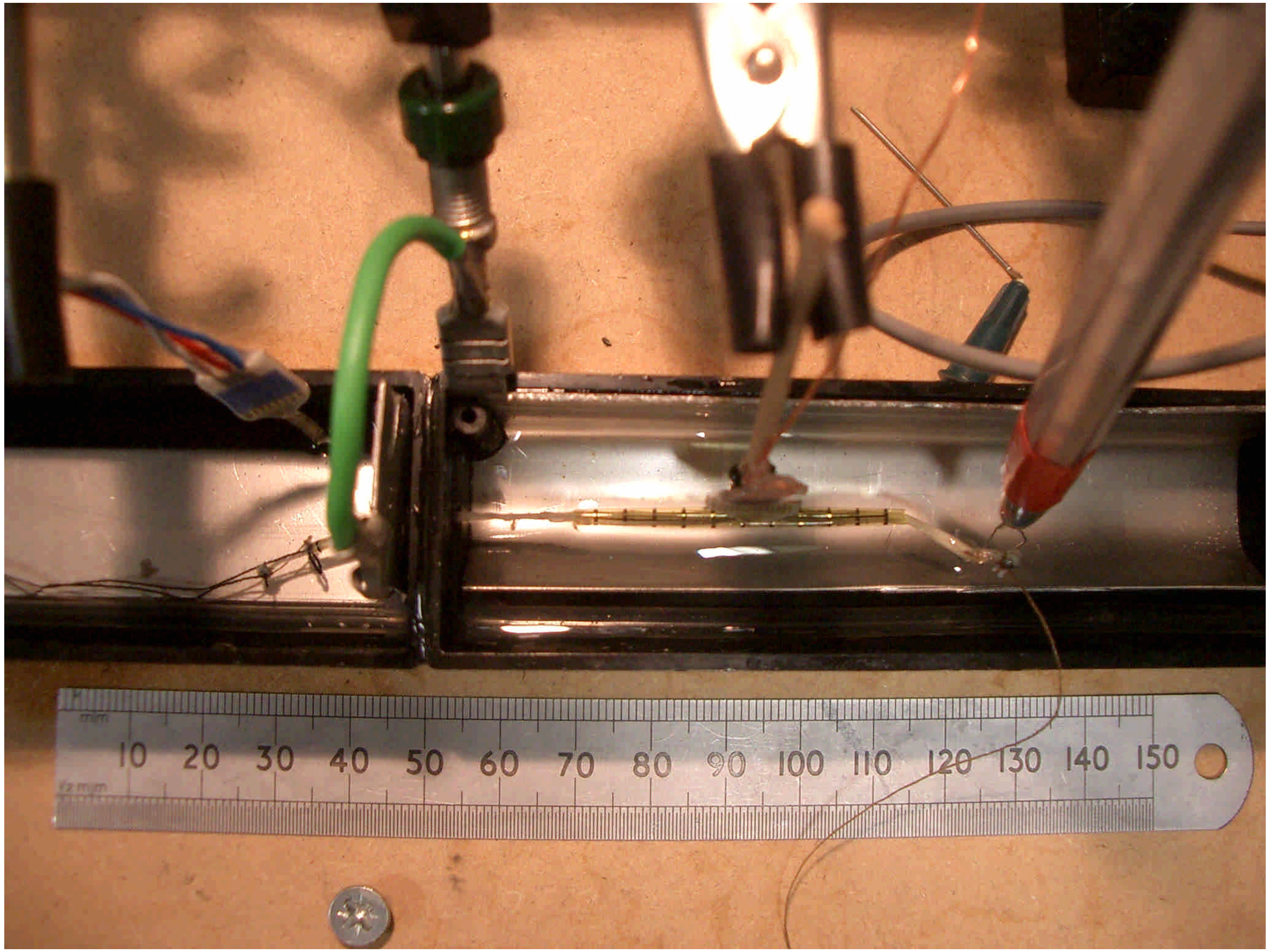
ASIC layout

EXPERIMENTAL SETUP FOR MEC RECORDINGS

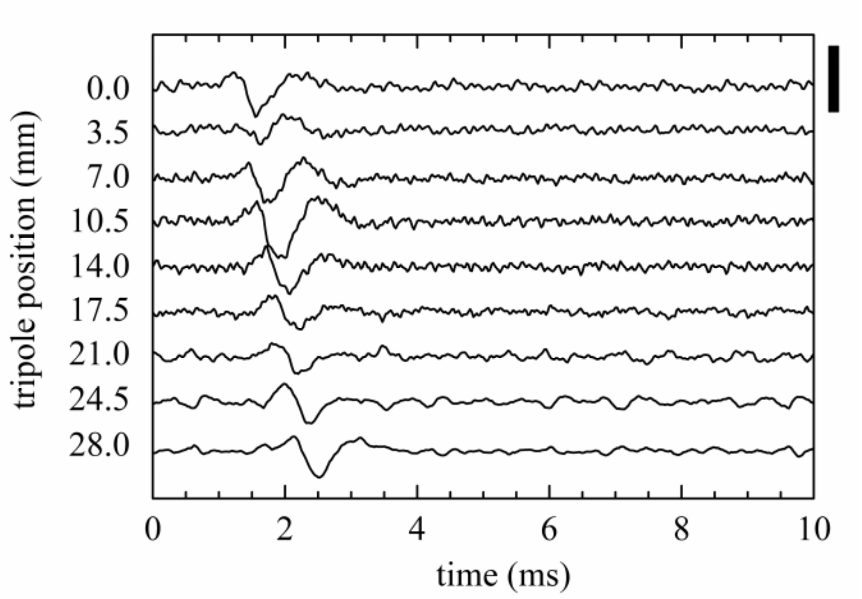


XENOPUS FROG PREPARED FOR REMOVAL OF *SCIATIC* NERVE

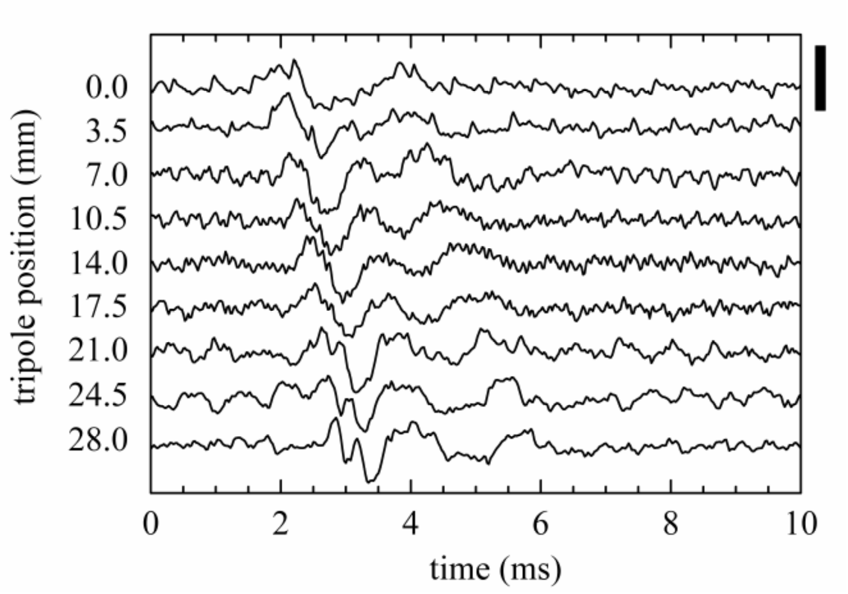
NERVE FITTED WITH MULTIELECTRODE CUFF *IN VITRO*



MEASURED RESULTS IN FROG

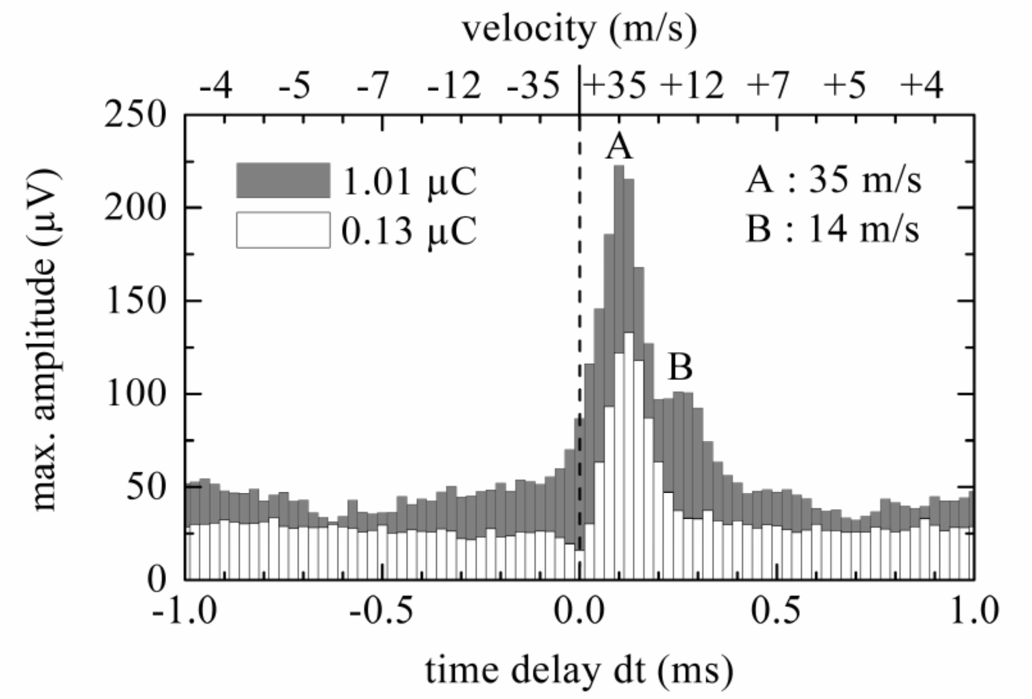


Stimulation intensity 0.13 µC



Stimulation intensity 1.01 µC

MEASURED VSR DATA IN FROG



Delay profiles corresponding to two different stimulation intensities:

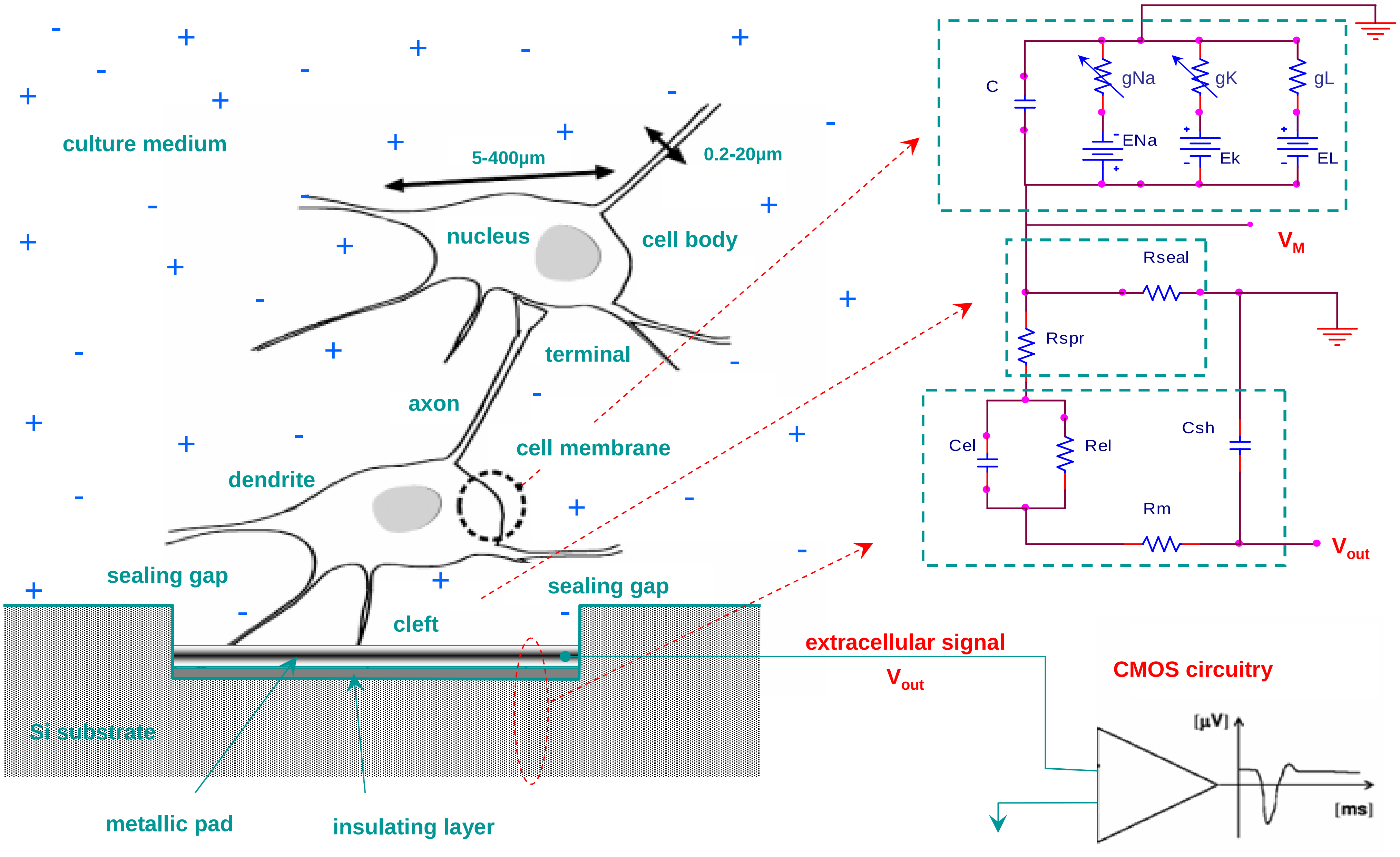
grey: 1.01 µC, *white:* 0.13 µC.

The bars have a width of 25 µs (reciprocal value of the sampling frequency)

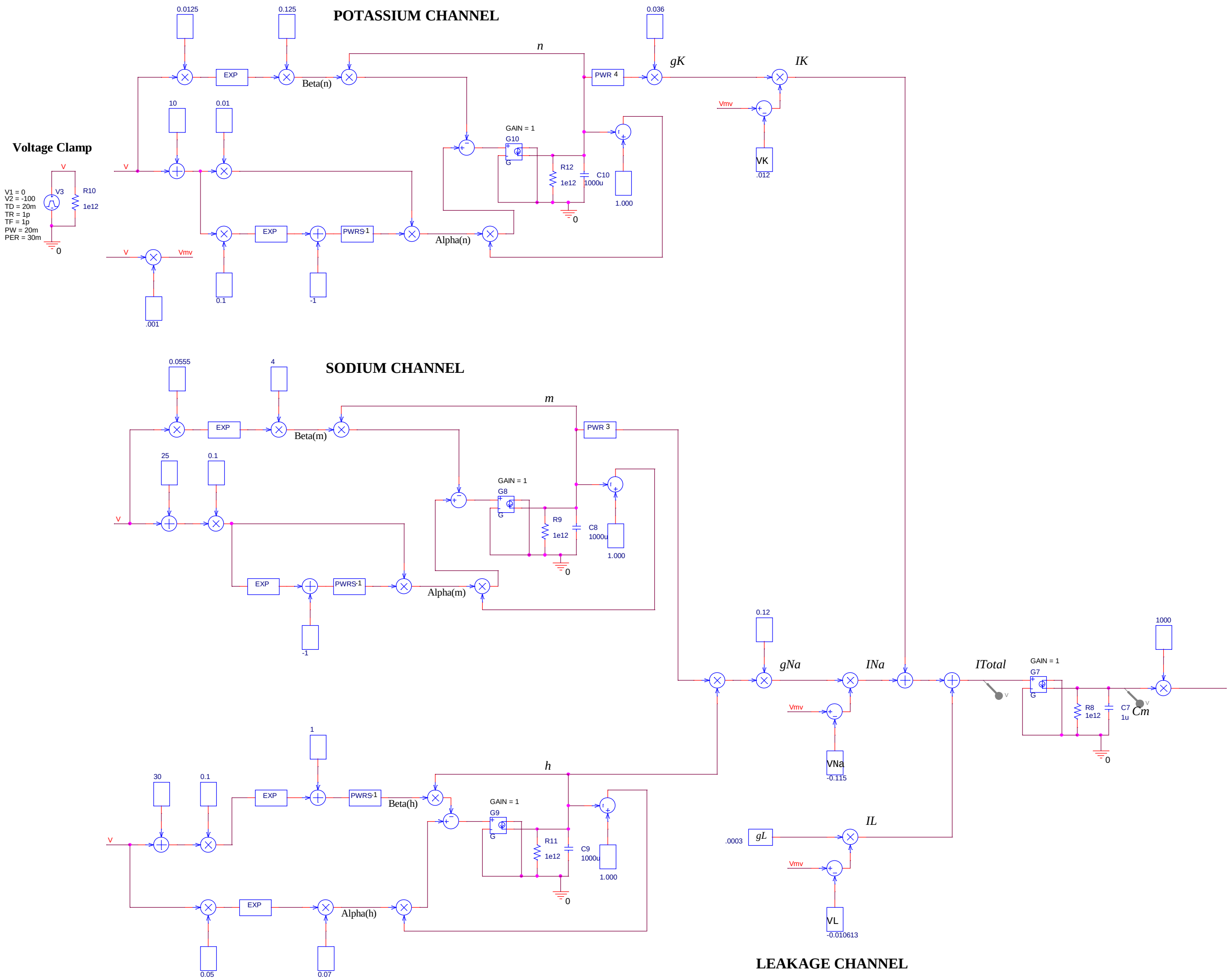
BI-DIRECTIONAL INTERFACING OF ELECTRONICS AND CULTURED NEURONS

- This is a collaborative programme involving E&EE at Bath, KCL/Guy’s Hospital (London), Dept of EE at University College (London) and the Department of Physics at Queen Mary University (London)
- The overall aim is to enhance our understanding of how mammalian nerve cells can be connected optimally to integrated electronic circuitry for neurobiological research and medical applications
- We intend to find an alternative method to traditional *patch clamping* which is non-intrusive, less labour intensive in use and is based on a simple, cheap, reproducible CMOS integrated circuit without any need for elaborate post-processing

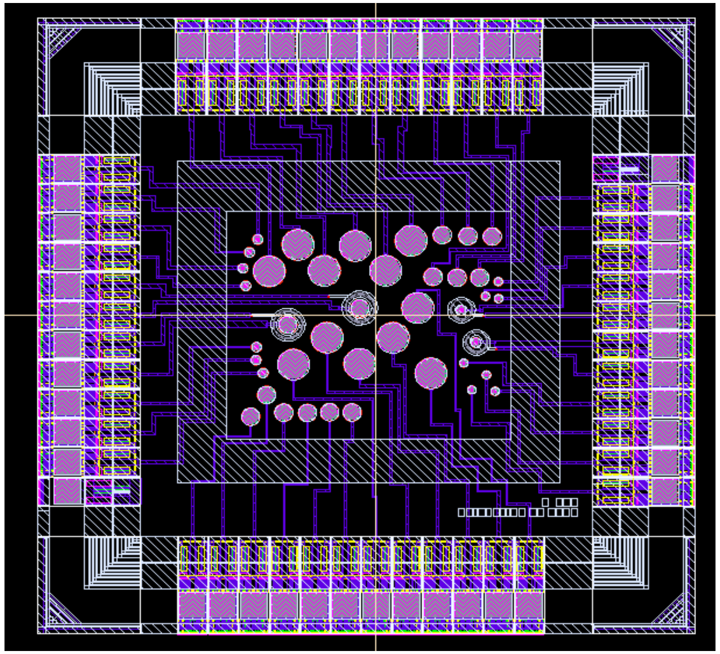
NEURON-ELECTRODE INTERFACE: EQUIVALENT CIRCUIT



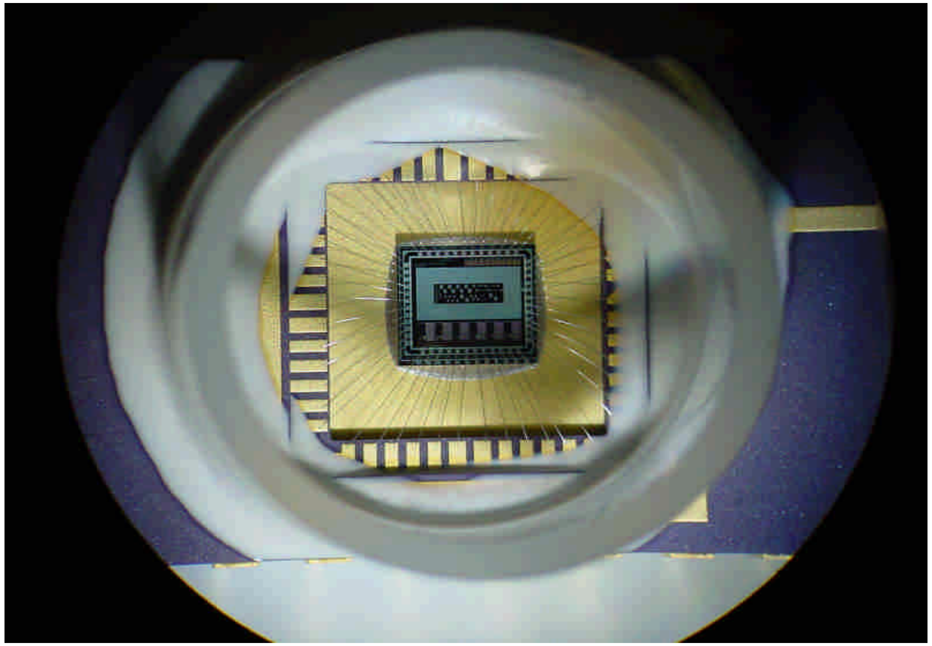
PSPICE REALISATION OF THE HODGKIN-HUXLEY MODEL OF A NEURON (1952)



PAD-ONLY CHIP LAYOUT

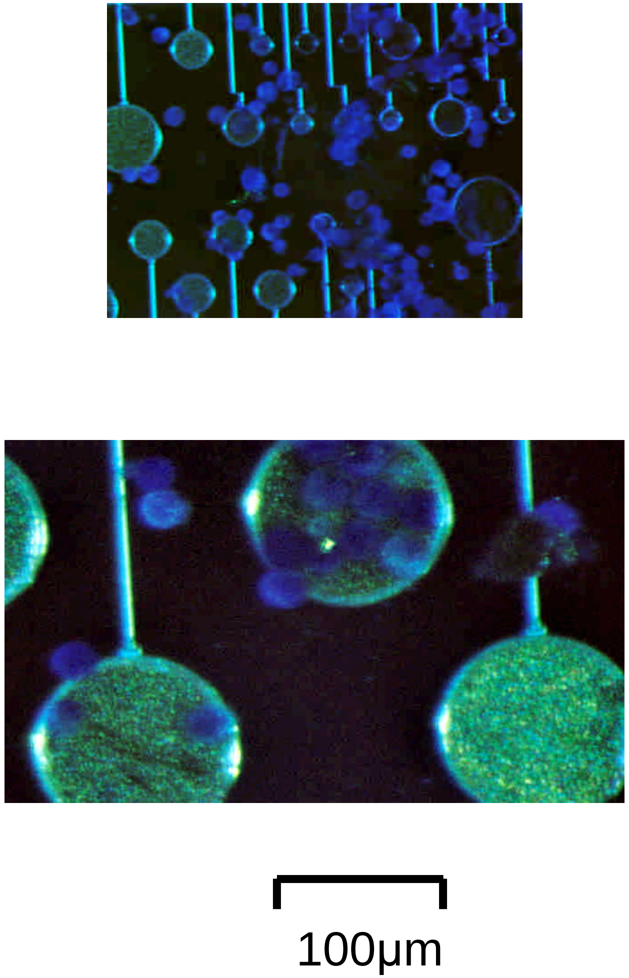


Chip layout



Packaged Die

GROWING NEURONAL CELLS ON CMOS

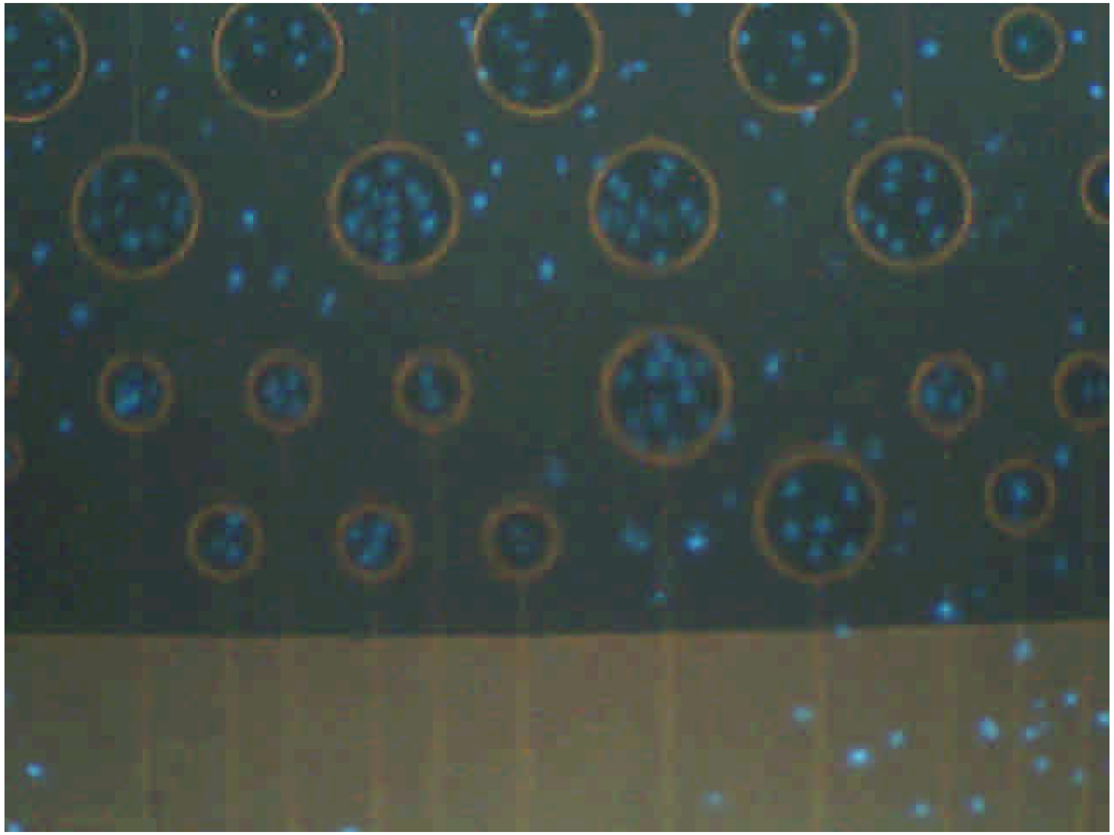


NG108-15 (neuroblastoma x glioma hybrid) cells, stained with methyl blue

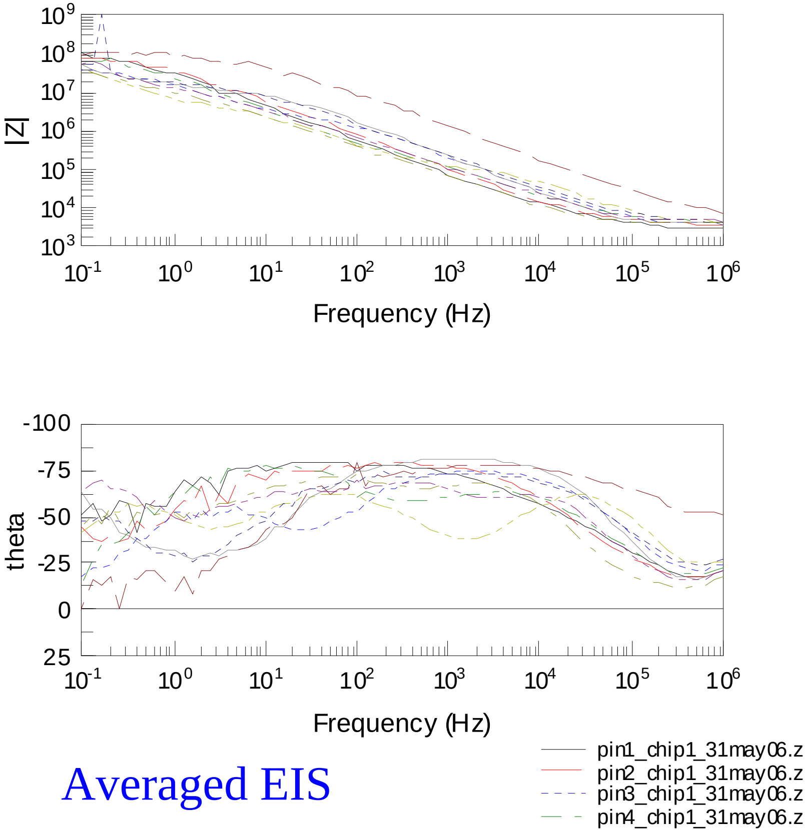
Grown on CMOS microchips pre-coated with a cationic polymer, (PE1), for 5 days

NEURONAL GROWTH ON POROUS SILICON

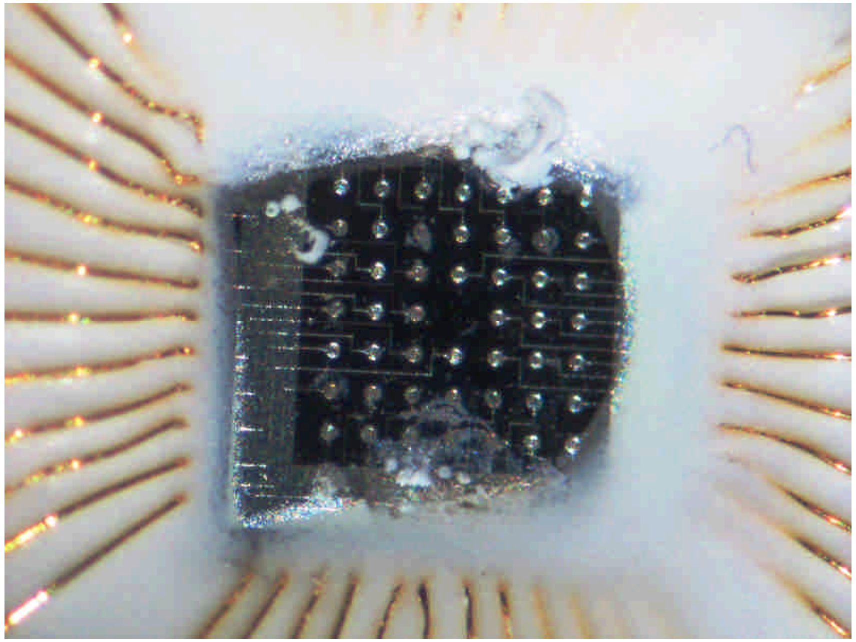
Etched from polysilicon on a CMOS chip



ELECTRICAL IMPEDANCE SPECTROSCOPY (EIS) MEASUREMENTS ON PACKAGED CMOS CHIPS



Averaged EIS measurements



Packaged die with insulated bond wires

FUTURE WORK

- *Neural Prostheses:* (i) complete the demonstration of velocity selectivity (start January 2007) (ii) consider new methods of neural recording, e.g. using optoelectronics
- *Electro-neural Interfacing:* (i) Demonstrate capture of ENG from single excited neurons; design on-chip signal processing for optimum SNR. (ii) Complete modelling work
- *SMART Orthopaedic Sensors:* (i) Develop an optimal implanted sensor for hip micromotion detection and verify with *in-vitro* experiments. (ii) Develop other possible applications for the use of SMART sensors and actuators in modern orthopaedic applications

SYSTEM SPECIFICATION

Parameter	Specification	Measured
Number of channels	10	
Power supply	±2.5 V	±2.5 V
Power consumption	< 50 mW	24 mW
Circuit area		12 mm^2
Midband gain	10,000	10,100
Bandwidth	300 Hz, 3.5 kHz	310 Hz, 3.3 kHz
CMRR @ 1kHz	100 dB	82 dB
Input-referred voltage noise density 1 Hz, 1 kHz	20 nV/√Hz, 4 nV/√Hz	11.5 nV/√Hz, 3.8 nV/√Hz
Input-referred current noise density 1 Hz, 1 kHz	20 pA/√Hz, 2 pA/√Hz	17 nV/√Hz, 1.5 nV/√Hz
Input-referred rms voltage noise 1 Hz -5 kHz	< 300 nV	291 nV
Residual DC input current	< 100 nA	15 nA, 20 nA, +,- inputs