CHARACTERIZATION AND DESIGN OF ORGANIC FIELD-EFFECT TRANSISTOR CIRCUITS FOR SENSING BIOELECTROMAGNETISM

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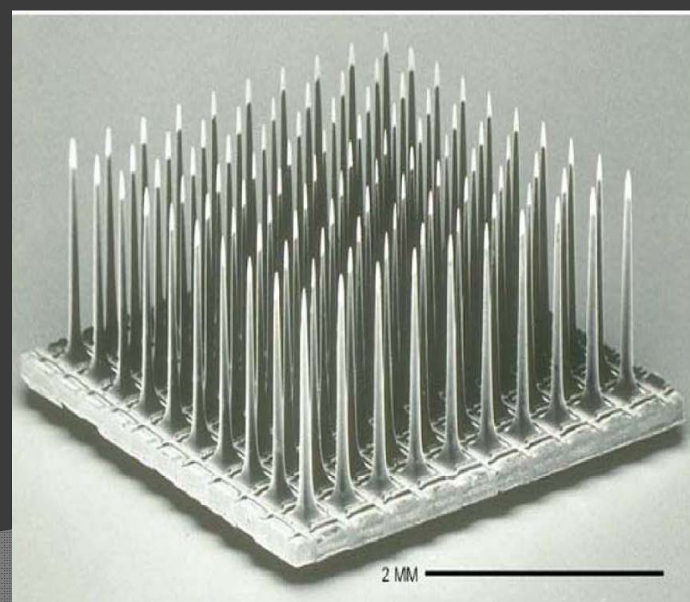
Bioelectromagnetism

- Refers to electric, magnetic, and electromagnetic fields originating in living tissue
- Examples include:
  - Brainwaves
  - Heart contractions

Neurological Signals

- Local Field Potential (LFP) frequency range 1 – 100 Hz
- Signal amplitude 30 µV – 2 mV
- Currently measured with ECoG through Utah Electrode Array

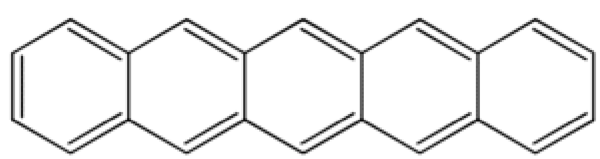


Purpose

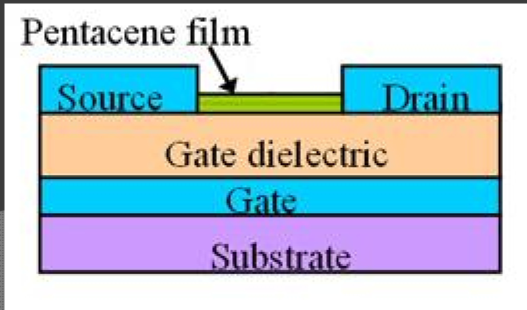
- Create a circuit that can:
  - Conform to the brain
  - Cover a large area of the brain
  - Express a high density output signal
  - Output an amplified low noise signal up to 100 Hz

Transistors

- Field-Effect Transistor
  - Constructed from semi-conductor materials
  - Has drain, gate, and source terminals
- Organic Field-Effect Transistor (OFET)
  - Pentacene used as organic semiconductor
  - Fabricated on Kapton substrate
  - Bottom-gate structure

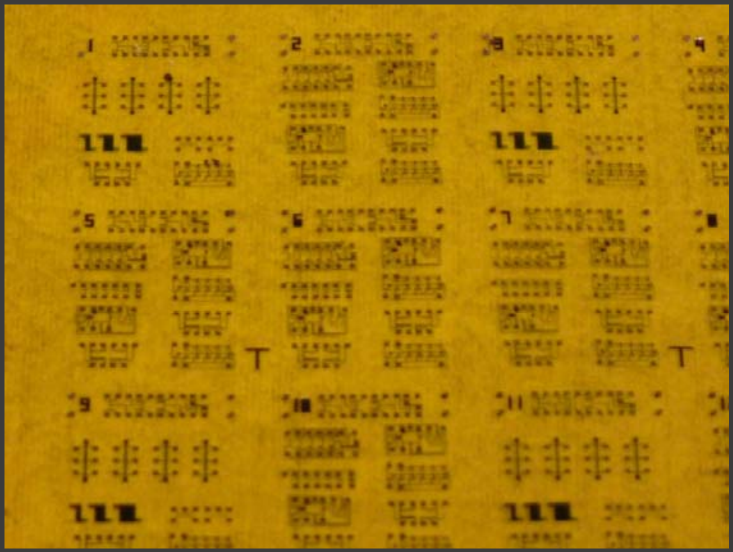


Pentacene

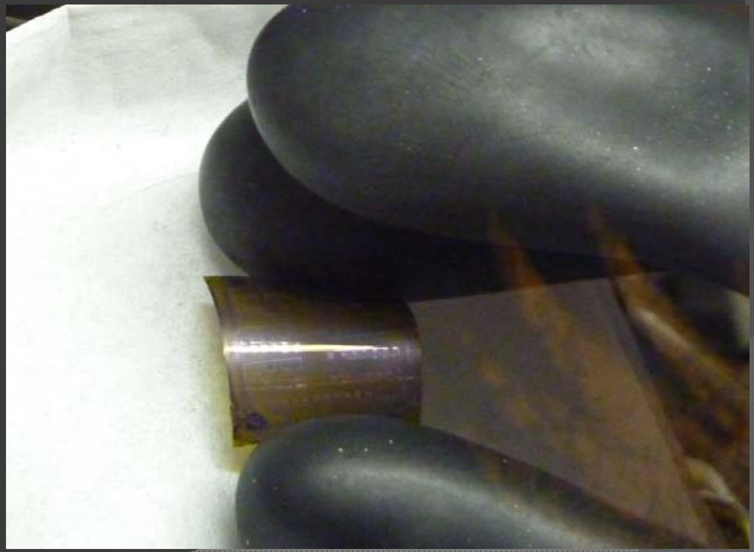


OFET Characteristics

- Potential to become low-cost and mass produced
- Able to bend and conform to a structure



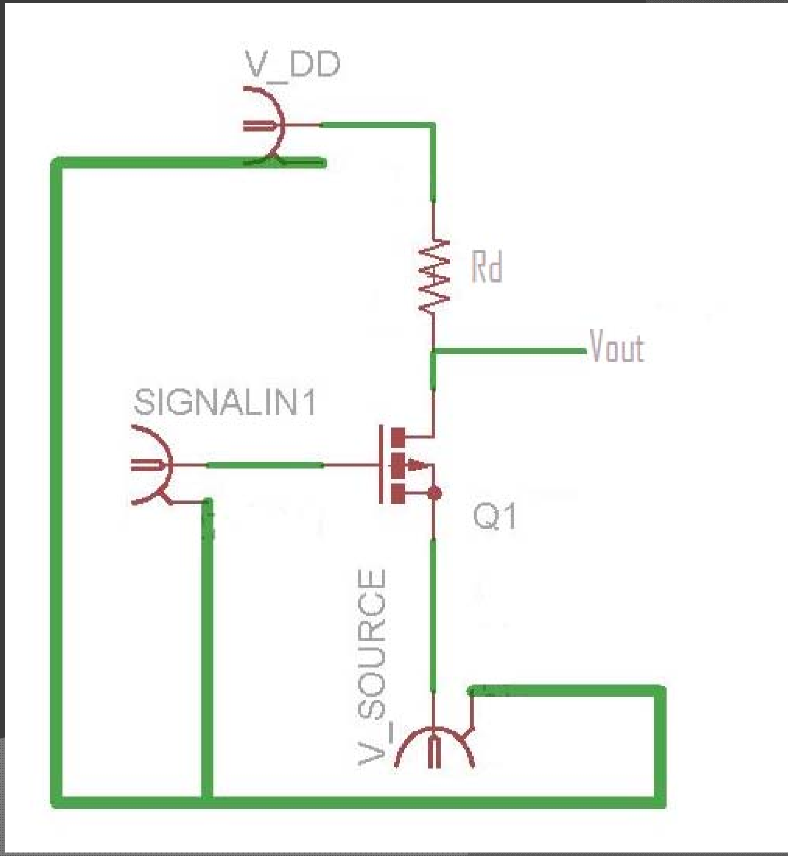
Devices on plastic



Plastic being bent

Common Source

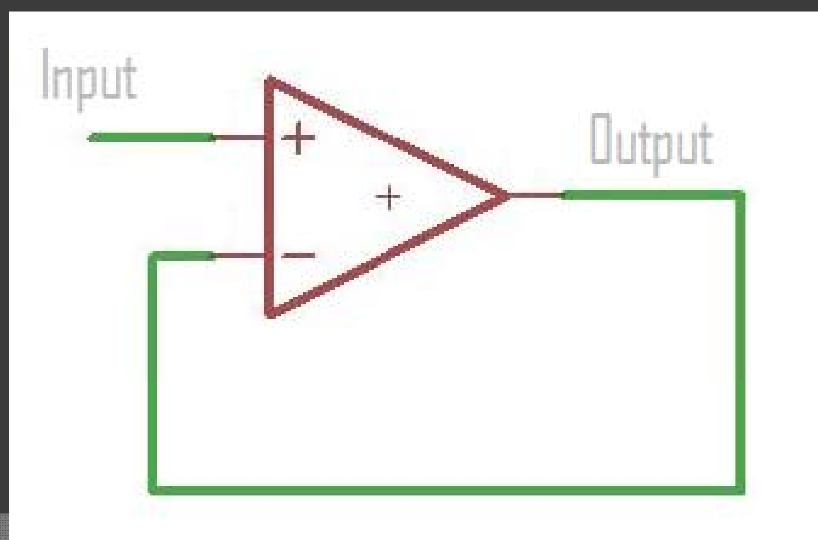
- Input stage
  - Q1 OFET Stage
  - Used as a voltage amplifier
  - Gain ∝ Rd
  - Cutoff Frequency ∝ 1/Rd



Unity Gain Buffer

- Converts high output impedance to low impedance

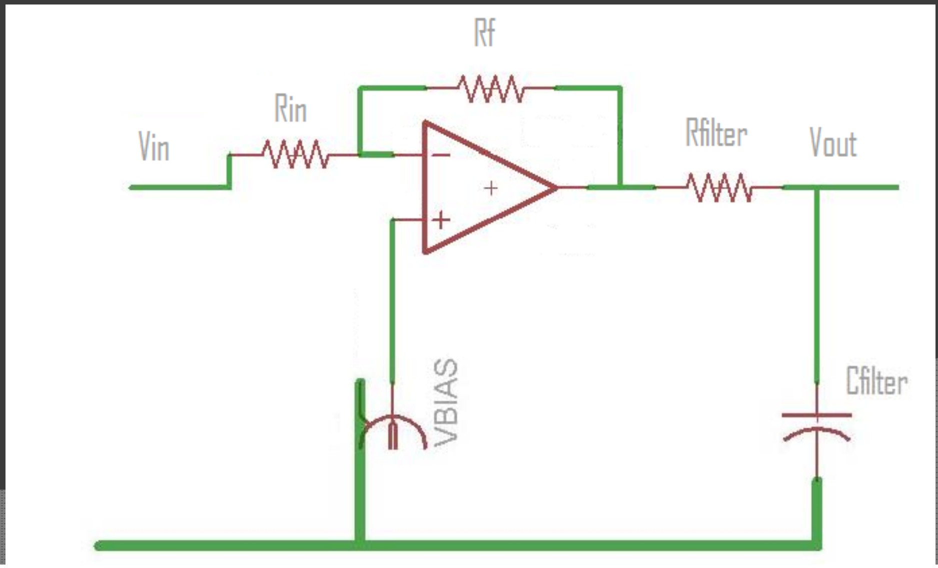
- Gain of 1V/V



Amplifier

- Inverting Amplifier
  - Amplifies input voltage
    - Causes a 180º phase shift
    - Amplifies signal according to equation

$$V_{Out} = -\frac{R_f}{R_{in}} * V_{In}$$

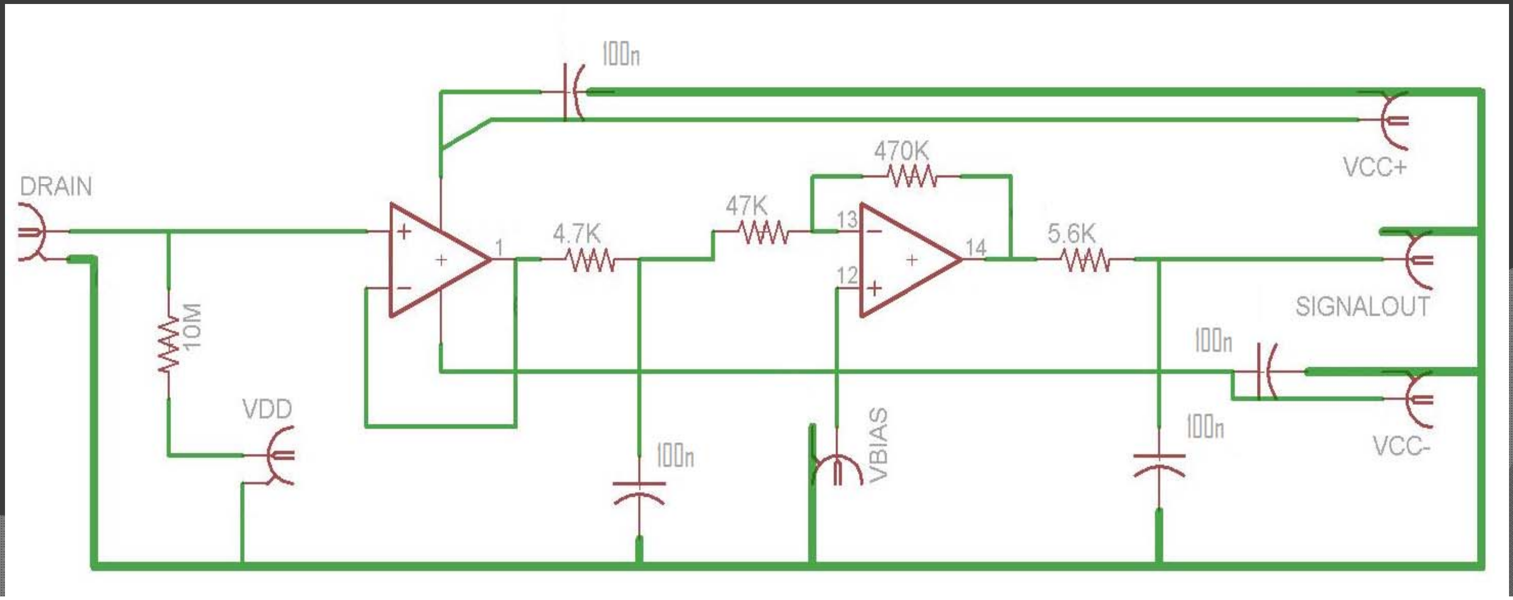


Noise

- Interference caused by surrounding electronics or components
- Can become dominant presence when a small input is used
- Can be filtered out of signal
  - Low-Pass Filter – Allows low frequency signals to pass but cuts off higher frequencies

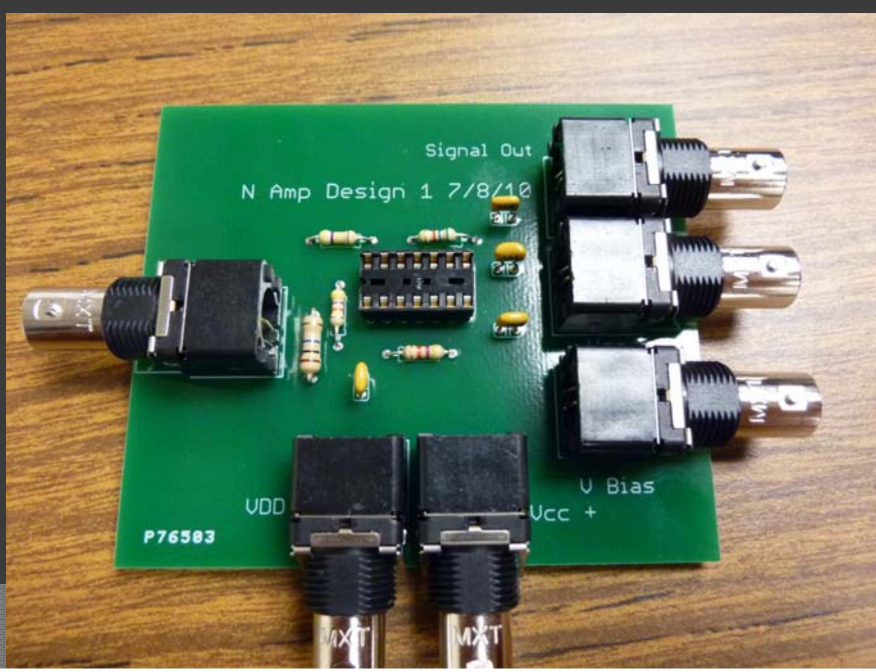
Complete Neurological Circuit

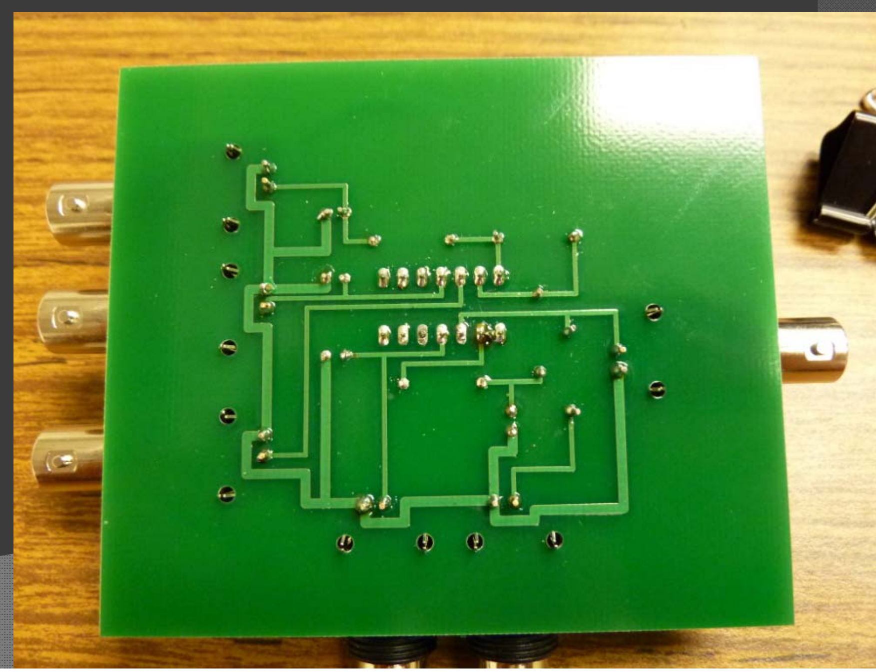
- Combines
  - Common Source
  - Unity Gain Buffer
  - Two Low-pass Filters
  - Inverting amplifier



Printed Circuit Board

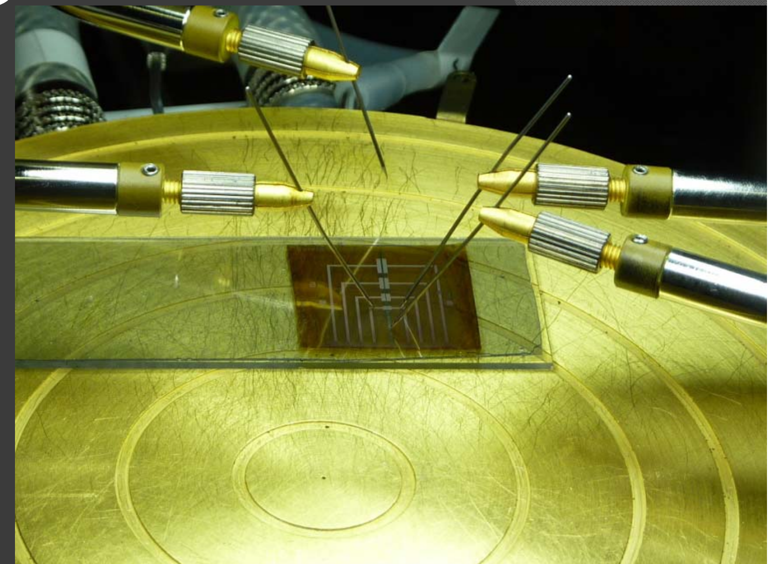
- Circuit fabricated on a Printed Circuit Board (PCB)
- Connections made through BNC cables
- Components soldered onto PCB

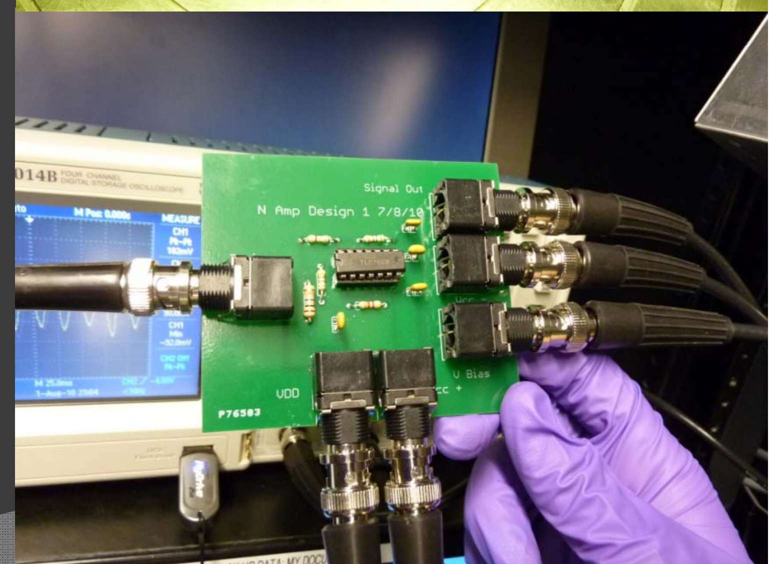




Experimental Setup

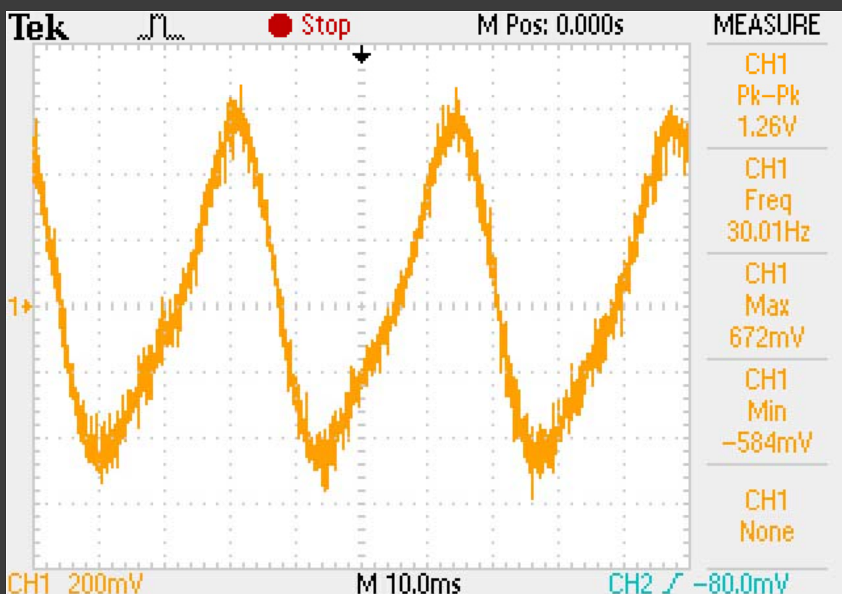
- OFET kept in GloveBox
- Drain connected to
  2nd stage and 10MΩ resistor
- Gate connected to input
- Source connected to voltage source
- Op amp connected to voltage source
- Amplifier set to bias value
- Output read from Oscilloscope



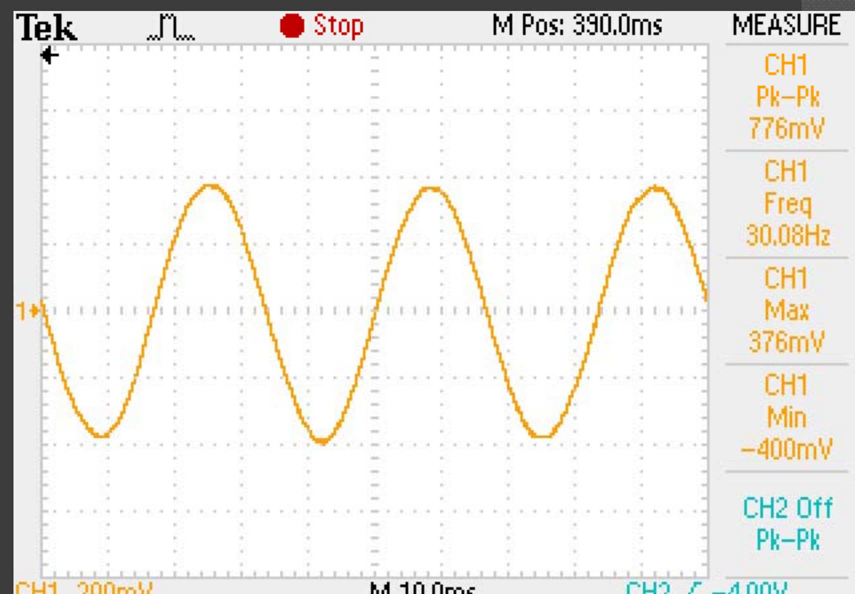


Signal Response

- Response for 100 mV input at 30 Hz
  - PCB shows
    - Low noise
    - Gain of 7.76 V/V



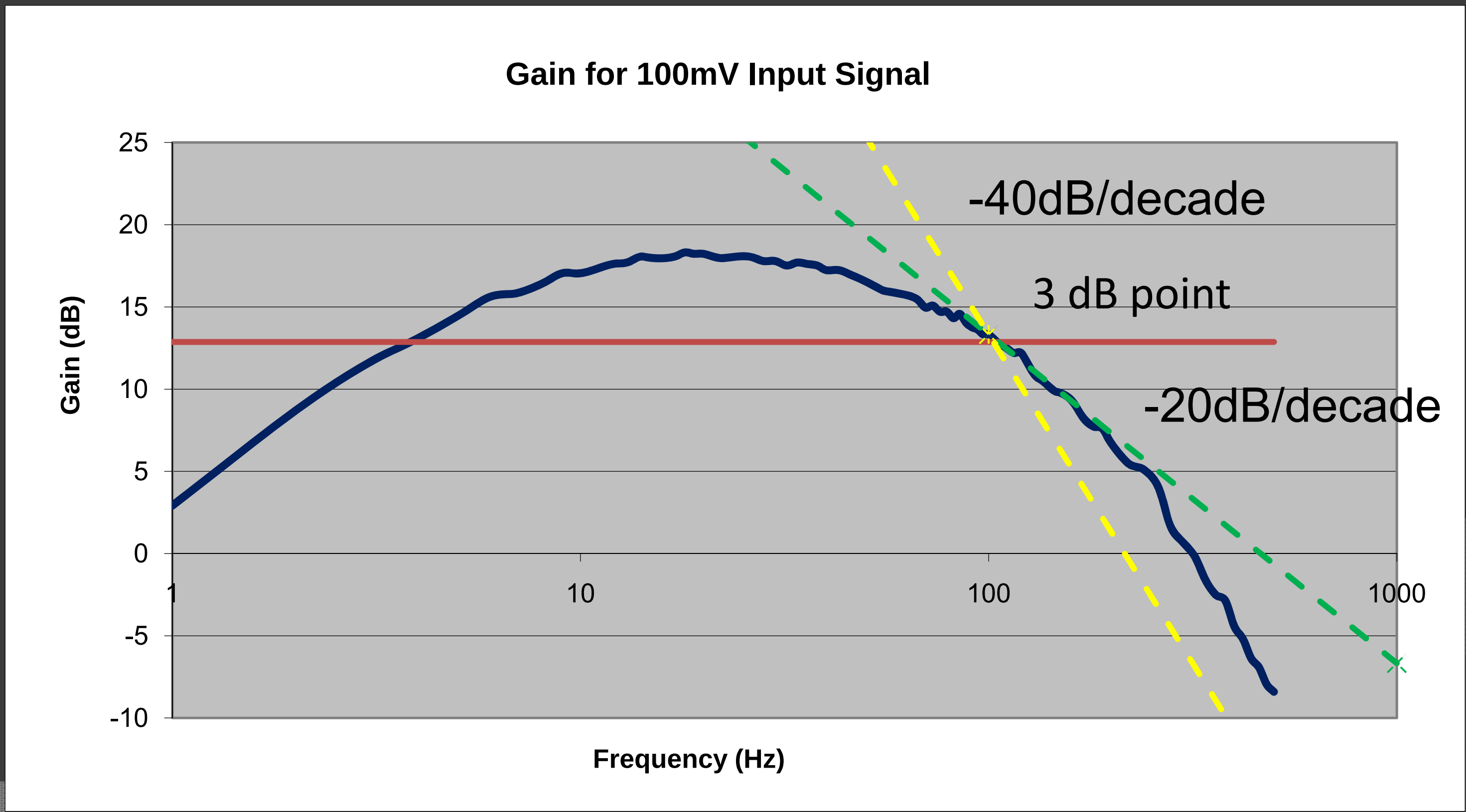
Circuit on Breadboard



Circuit on PCB

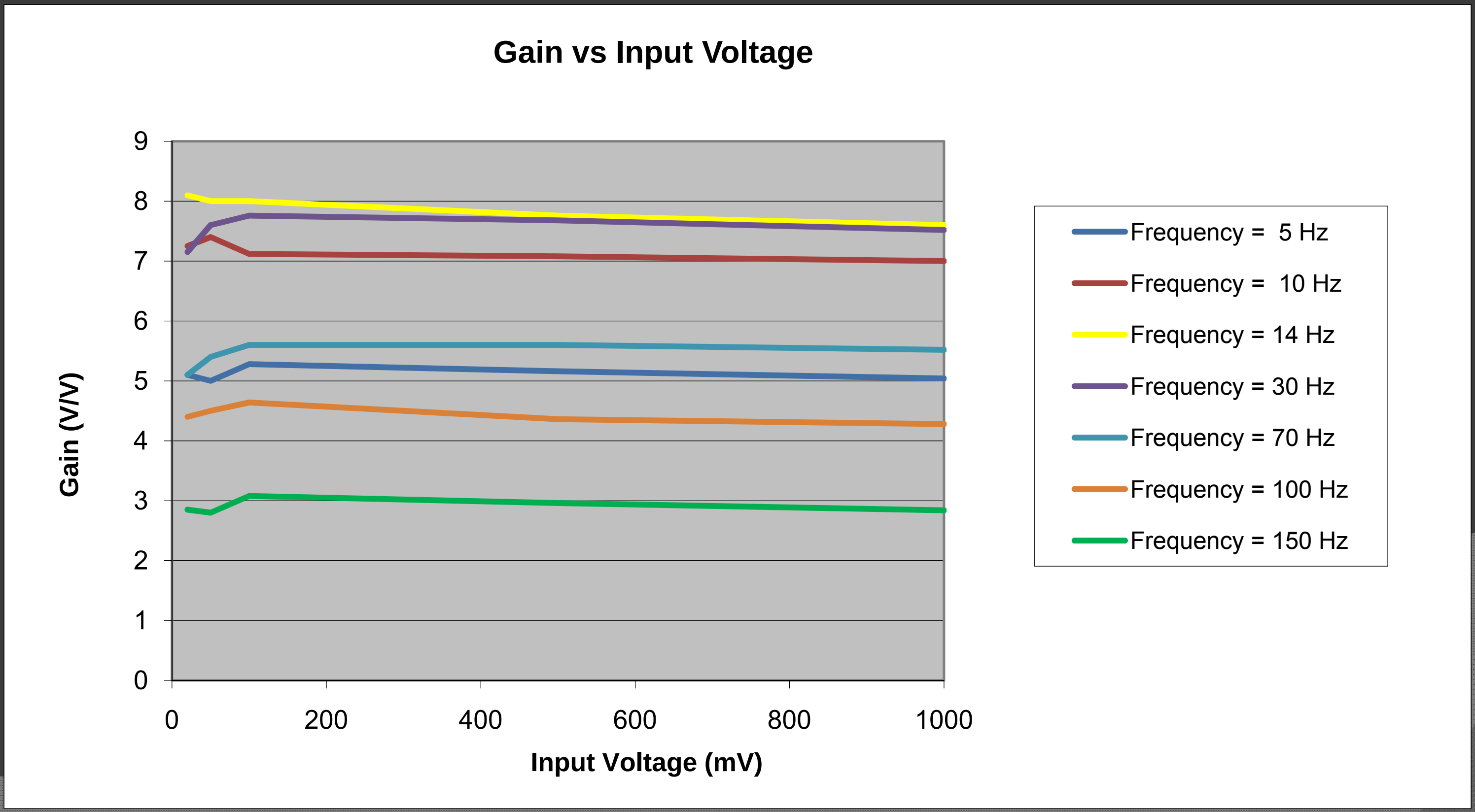
Frequency Response

- Graphical Analysis of 100 mV input
  - Bandwidth at ~100 Hz



Gain vs Input Voltage

- Gain shows negligible variation with voltage



Further Investigation

- Scale thickness of dielectric to operate at lower voltages
- Use of other amplifiers
- Use for other measurements
- Organic transistor to provide stimulation to an area
  - Use as a pacemaker for the heart

Acknowledgements

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