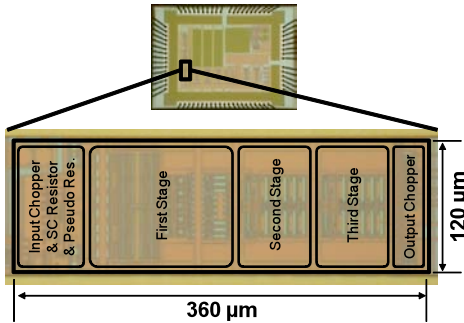


# A $1\mu\text{W}$ $85\text{nV}/\sqrt{\text{Hz}}$ Pseudo Open-Loop Preamplifier With Programmable Band-Pass Filter for Neural Interface System

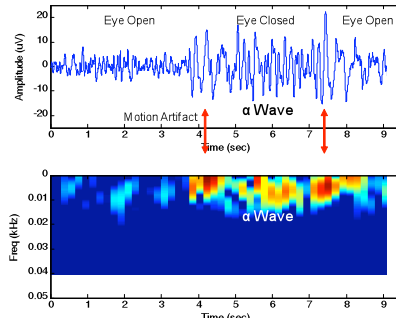
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With advances in CMOS technology, significant progress has been realized in implementing multichannel, implantable neural systems that will potentially enable us to diagnose disease and establish a direct interface between the brain and external electronic devices. However, chronic monitoring of brain activities, such as neural spikes, EEG, ECoG, etc., is still a challenge, especially in wireless ambulatory systems, due to stringent constraints in power, noise, and area. To overcome these obstacles, we have designed an energy-efficient, pseudo open-loop amplifier with embedded programmable band-pass filters for neural interface systems. The implemented amplifier consumes  $400\text{nA}$  at  $2.5\text{V}$ . The measured thermal noise level is  $85\text{nV}/\sqrt{\text{Hz}}$ , while the input-referred noise is  $1.69\mu\text{V}_{\text{rms}}$  from  $0.3\text{Hz}$  to  $1\text{kHz}$ . The amplifier has a noise efficiency factor of 2.43, the lowest for all differential topologies reported to date. By programming the switched-capacitor frequency and bias current, we can control the bandwidth of the preamplifier from  $138\text{mHz}$  to  $2.2\text{kHz}$  to meet various application

requirements. The entire preamplifier including band-pass filters has been realized in a small area of  $0.043\text{mm}^2$  using  $0.25\mu\text{m}$  CMOS technology. We have successfully recorded and distinguished waveforms from an EEG electrode monitoring eye activity. ■



Microphotograph of the fabricated preamplifier.



In-vivo EEG measurement: waveform and its spectrogram.