Hi Pavani and Sai, Please see the following blurb regarding the work we are going to do on a multiplexed EMG amplifier. Also please take a look at the attached paper for a similar application. A critical need in several areas of human functional rehabilitation is to develop better non-invasive technologies that can quantify neurophysiological change over time. This project will develop the first stick-to-skin multichannel electromyography (EMG) amplifier and matrix EMG electrode for use in muscle performance quantification. Multichannel amplifiers are often cumbersome systems that inhibit mobile use application, such as those required in human movement. By engineering a novel hardware architecture using amplifier multiplexing, we aim to miniaturize EMG amplifiers such that they can be embedded onto small flexible circuit boards that can be attached to the human body. This new amplifier design can potentially revolutionize the usability of EMG systems for monitoring and assessing neuromuscular functionality, including post-stroke therapeutics, assessment of astronaut task-readiness following gravitational transition, or in athletic performance quantification. From a technical perspective, the major technical deliverable for this project is the development of the first skin-stick multichannel biopotential amplifier. Most commercial multichannel EMG amplifiers are too large for wearable applications, and only recently has miniaturization of these amplifiers been possible. For this particular application, we focus on next-generation electromyography which consists of densely packed electrodes in a small surface area. The technical complexity is defined by the number of EMG electrodes – in our case 32 electrodes – which all require amplification. Standard amplifiers would necessitate parallel circuitry for each sensor (i.e., 32 sensors, 32 amplifiers). Here, we propose a novel multiplexed amplifier that enables simultaneous amplification of multiple channels which minimizes the hardware requirements for these high-density sensors. The system is designed by using a 32-channel multiplexer, such as the ADG732, which routes 32 channels of EMG data through a high-frequency switch, a bioinstrumentation amplifier (gain typically > 2000), filters (typical bandpass between 0.5 to 500 Hz), and a precision rectifier. The processed data are transmitted from the skin-stick device to a host computer using an on-board microcontroller (MCU) and WIFI. The signal is then de-multiplexed (DMUX) and used for muscle performance classification, etc. Figure 1. Skin-stick Hardware System. The multiplexer (MUX) routes 32 channels of EMG data through a single bioinstrumentation amplifier, filters, and rectifier circuit. Data are sent to a small MCU with WIFI data transmission to a host. The multiplexed high-density EMG enables numerous channels of high quality biopotential data to be stacked, while minimizing electrical signal and throughput cross-talk, while minimizing the footprint of the electronic systems needed to process the significant amounts of input data. This reduces the number of electronic components needed to build the amplifier system, and allows for a single layer of integrated circuits (IC) to be adhered to skin-stick materials. An amplifier such as this has thus far not been developed for wearable applications, which we believe will revolutionize non-invasive devices for human performance applications.

**ChatGPT said:**

ChatGPT

The blurb you've provided describes an innovative project focused on developing a multiplexed EMG amplifier for wearable applications. This technology aims to improve the usability of EMG systems in various fields, including rehabilitation, astronautics, and athletic performance by creating a miniaturized, flexible, and non-invasive device. The technical challenges revolve around efficiently amplifying signals from multiple electrodes using a novel multiplexing approach, which reduces the hardware footprint and enhances the portability of the system.

Would you like any revisions or further clarification on the content? Also, do you need help summarizing the attached paper or any specific details from it?

4o

**You said:**

biocas\_mux\_v2019-08-30d\_submitted.pdf

PDF

ChatGPT

The paper you've attached provides a detailed overview of a multiplexed EMG recording system designed to enable the in vivo selection of optimal electrode configurations. Here’s a summary:

**Overview:**

The study describes the development and characterization of an implantable EMG amplifier with a novel multiplexed frontend. The system is designed using commercially available components and allows for the selection of the best electrode configurations after implantation. This approach addresses the challenge that optimal configurations are often unknown before the implantation process.

**Key Components:**

* **Multiplexers (MUX):** Three 8x8 multiplexer arrays (ADG2188) are used, allowing flexibility in electrode configuration.
* **Amplification and Recording:** The system uses a 6-channel ADC (ADS1298) biopotential amplifier with a 2 kHz sampling frequency and 16-bit resolution. The design includes a bandpass filter and a precision rectifier to process the EMG signals.
* **Signal Transmission:** Processed data are transmitted via Bluetooth to a laptop for further analysis.

**Characterization and Results:**

* **Input Impedance:** The input impedance was measured to be 5.8 MΩ, suitable for EMG recording applications.
* **Frequency Response and SNR:** The system showed a common mode rejection ratio (CMRR) of 49.0 dB and an SNR of 51.4 dB, though in vivo EMG recordings yielded a lower SNR (13.5 dB) compared to a commercial system (19.5 dB).
* **In Vivo Testing:** EMG recordings from implanted electrodes showed that while the signal quality was lower than that of commercial systems, it was still sufficient for applications like myoelectric control of prostheses.

**Conclusion:**

The paper concludes that the system, although currently less effective than commercial systems in some metrics, represents a significant advancement in the field of implantable EMG devices due to its flexibility and potential for further miniaturization and improvement.

This system shares similarities with the work you're planning on the multiplexed EMG amplifier, particularly in its focus on miniaturization and flexibility in electrode configurations. If you need a more detailed breakdown or further comparisons, feel free to ask!

4o

**You said:**

What is the concept of multipler used for and how to design a multiplxer amplifier

**ChatGPT said:**

ChatGPT

**Concept of a Multiplexer in EMG Systems**

A **multiplexer (MUX)** is an electronic component that selects one of many input signals and forwards the chosen input into a single line. In the context of EMG (electromyography) systems, where multiple electrodes are used to record electrical activity from muscles, a multiplexer allows these multiple signals to be routed through fewer channels of amplification and data processing.

**Why Use a Multiplexer?**

1. **Signal Routing:** EMG systems often use many electrodes to capture detailed muscle activity. Without a multiplexer, each electrode would require its own dedicated amplifier and data processing channel, leading to bulky and complex hardware.
2. **Miniaturization:** By multiplexing, you can significantly reduce the number of required amplifiers, filters, and other electronic components. This reduction enables the creation of smaller, more portable, and wearable EMG devices.
3. **Cost and Power Efficiency:** Fewer components mean lower production costs and power consumption, which are critical for wearable and implantable devices.

**Designing a Multiplexer Amplifier**

**1. Understanding the Requirements:**

* **Number of Channels:** Determine the number of electrodes that need to be monitored simultaneously. For example, a 32-channel EMG system would require a multiplexer that can handle inputs from all these electrodes.
* **Signal Integrity:** Ensure that the multiplexer does not degrade the quality of the signal. This includes maintaining a high signal-to-noise ratio (SNR) and ensuring minimal crosstalk between channels.
* **Speed:** The multiplexer must switch between channels rapidly enough to provide real-time data processing without missing any critical muscle activity signals.

**2. Choosing the Right Multiplexer:**

* **Type of MUX:** Select a multiplexer IC (Integrated Circuit) that fits your channel needs, such as the ADG732 (32-channel multiplexer) or ADG2188 (8x8 matrix switch).
* **Bandwidth:** Ensure the multiplexer has sufficient bandwidth to handle the frequency range of EMG signals, typically between 0.5 Hz and 500 Hz.
* **Switching Speed:** The MUX should switch fast enough to sample each channel in quick succession, ensuring no loss of data during transitions.

**3. Designing the Amplification Circuit:**

* **Amplifier Selection:** Choose a low-noise bioinstrumentation amplifier with high gain (typically >2000) to amplify the small EMG signals.
* **Multiplexing Integration:** The MUX routes the selected input to this amplifier. The amplified signal is then filtered to remove unwanted frequencies (e.g., a bandpass filter between 0.5 Hz and 500 Hz).
* **Precision Rectification:** After amplification and filtering, a precision rectifier can be used to convert the AC signal to a DC signal, which is easier to analyze and process.
* **Microcontroller Interface:** The processed signal can then be sent to a microcontroller (MCU) that handles data transmission, such as via WiFi or Bluetooth, to a host computer.

**4. Circuit Layout:**

* **Compact PCB Design:** Place the multiplexer and amplifier circuits on a compact PCB (Printed Circuit Board). Ensure the layout minimizes noise and crosstalk by carefully routing signals and providing adequate grounding.
* **Power Management:** Design the power supply to meet the needs of the multiplexed system, ensuring stable operation without introducing noise into the EMG signals.

**Example of a Multiplexer Amplifier Design**

In the document you uploaded, the authors used a 32-channel multiplexer (ADG732) to route 32 EMG signals through a single bioinstrumentation amplifier. The processed signal was then sent through filters and a rectifier before being transmitted to a host computer via WiFi. The key points in their design included minimizing the footprint of the hardware, ensuring high signal integrity, and maintaining low power consumption.

**Summary**

Multiplexers in EMG systems allow for efficient signal routing from multiple electrodes, reducing the hardware complexity and enabling the design of smaller, more portable devices. Designing a multiplexer amplifier involves selecting appropriate components, ensuring signal integrity, and integrating the MUX with amplification and signal processing circuits. The goal is to achieve a system that can reliably capture and process multiple EMG signals in a compact, power-efficient form.

4o

**You said:**

Give me a design for 32 channel multiplexer ADG732 with clear documentation

2/2

**ChatGPT said:**

ChatGPT

Designing a 32-channel multiplexer system using the ADG732 involves integrating it with an appropriate amplification and filtering circuit, as well as a microcontroller for data handling. Below is a step-by-step guide, including clear documentation for each part of the design.

**1. Overview of the Design**

The design will consist of:

* **ADG732 32-Channel Multiplexer**
* **Bioinstrumentation Amplifier**
* **Bandpass Filter**
* **Microcontroller (MCU)**
* **Power Supply and Decoupling**

**2. Component Selection**

* **Multiplexer**: ADG732 (32:1 multiplexer)
* **Amplifier**: AD620 (low-noise, high-gain instrumentation amplifier)
* **Filter**: Active bandpass filter with an operational amplifier (e.g., TL074)
* **MCU**: STM32F103 (for data processing and transmission)
* **Power Supply**: 3.3V/5V regulated power supply

**3. Circuit Design**

**3.1. Multiplexer (ADG732)**

* **Input Channels**: The ADG732 has 32 input channels, labeled S1 to S32.
* **Control Lines**: The multiplexer is controlled using 5 digital lines (A0, A1, A2, A3, A4) to select one of the 32 input channels.
* **Output**: The selected input is routed to a single output D.
* **Enable Pin (EN)**: This pin is active low; grounding it enables the multiplexer.

**Schematic:**

* **Inputs (S1 to S32)**: Connect the EMG electrode outputs to these pins.
* **Output (D)**: Connect this to the input of the bioinstrumentation amplifier.
* **Control Pins (A0 to A4)**: These will be connected to the MCU to select the active channel.
* **Power Supply**: Connect VDD to 3.3V or 5V and VSS to GND. Decouple with a 0.1µF capacitor close to the IC.

**3.2. Bioinstrumentation Amplifier (AD620)**

* **Input**: Connect the output D of the ADG732 to the non-inverting input of the AD620.
* **Gain Setting**: Set the gain using an external resistor (RG). For EMG signals, a gain of 2000 might be appropriate. This can be set using the formula:

G=1+49.4kΩRGG = 1 + \frac{49.4k\Omega}{R\_G}G=1+RG​49.4kΩ​

For example, a resistor of 24.7Ω gives approximately a gain of 2000.

* **Output**: This will go to the bandpass filter.

**Schematic:**

* **Input (+IN)**: Connect D from the multiplexer.
* **Reference (REF)**: Connect to GND.
* **Gain Resistor (RG)**: Set gain using a resistor as mentioned.
* **Power Supply**: Connect to 5V and GND. Decouple with 0.1µF capacitors close to the IC.

**3.3. Bandpass Filter**

* **Design**: Use a second-order active bandpass filter with a passband of 20Hz to 500Hz.
* **Component Selection**: Use a TL074 operational amplifier for the filter design. The filter can be designed using standard Sallen-Key topology.

**Schematic:**

* **Input**: Connect the output of the AD620.
* **Output**: Connect to the ADC input of the microcontroller.
* **Power Supply**: Connect the op-amp to 5V and GND. Decouple with 0.1µF capacitors close to the IC.

**3.4. Microcontroller (STM32F103)**

* **Control**: Use GPIO pins to control the ADG732’s address lines (A0 to A4) to select the input channel.
* **ADC**: Connect the output of the bandpass filter to the ADC pin of the MCU.
* **Data Transmission**: Use UART, SPI, or I2C for communication, or connect a WiFi module (e.g., ESP8266) for wireless data transmission.

**Schematic:**

* **GPIO Pins**: Connect to A0 to A4 on the ADG732.
* **ADC Input**: Connect to the output of the bandpass filter.
* **Communication Pins**: Connect UART or SPI for data transmission.
* **Power Supply**: Provide 3.3V to the MCU, with appropriate decoupling capacitors.

**4. Power Supply**

* **Design**: Use a 5V linear regulator (e.g., 7805) if a higher voltage source is available. For the 3.3V rail, use an LDO regulator (e.g., LD1117-3.3V).
* **Decoupling**: Place 0.1µF capacitors close to the power pins of each IC to reduce noise.

**Schematic:**

* **Input**: Provide a 7-12V input to the 7805.
* **Output**: 5V output from 7805 and 3.3V from the LD1117.

**5. PCB Layout Considerations**

* **Signal Integrity**: Keep analog signal paths short and separate from digital control lines to reduce noise and crosstalk.
* **Ground Plane**: Use a solid ground plane under the analog section of the circuit to provide a low impedance return path.
* **Decoupling**: Place decoupling capacitors as close as possible to the power pins of all ICs.

**6. Testing and Debugging**

* **Initial Testing**: Power up the circuit and verify power levels and correct operation of the multiplexer selection.
* **Signal Chain Verification**: Test the output of the multiplexer and amplifier stages using an oscilloscope to ensure proper signal amplification.
* **System Test**: Integrate the MCU and check for correct channel selection, ADC readings, and data transmission.

**7. Documentation and Notes**

* **Control Logic**: Document the control logic used for channel selection in the MCU firmware.
* **Component Values**: List all resistor and capacitor values used in the gain and filter circuits.
* **Firmware**: Provide a basic code example for the MCU to control the multiplexer and read data from the ADC.

**Example Block Diagram**

plaintext

Copy code

EMG Electrodes -> ADG732 -> AD620 -> Bandpass Filter -> MCU (STM32) -> Data Transmission (WiFi/UART)

This design gives you a compact, flexible 32-channel EMG amplifier using the ADG732 multiplexer, which can be tailored further to specific needs or constraints in your project.