

# P08050 Testing Strategy Document

## IFCN standards<sup>1</sup> for digital recording of clinical EEG Verification<sup>2 3</sup>

### Square-Wave Calibration Test

Summary: Square-wave signals must be recorded at the beginning, using a series of 100  $\mu\text{V}$  square waves of each recording, each 1–2 s long.

1. Set up function generator to output a square wave with a  $1\text{mV}_{\text{p-p}}$  amplitude and a frequency of 1 Hz. A voltage divider circuit must be used to step down the voltage to  $100\ \mu\text{V}$ . The schematic is shown below.

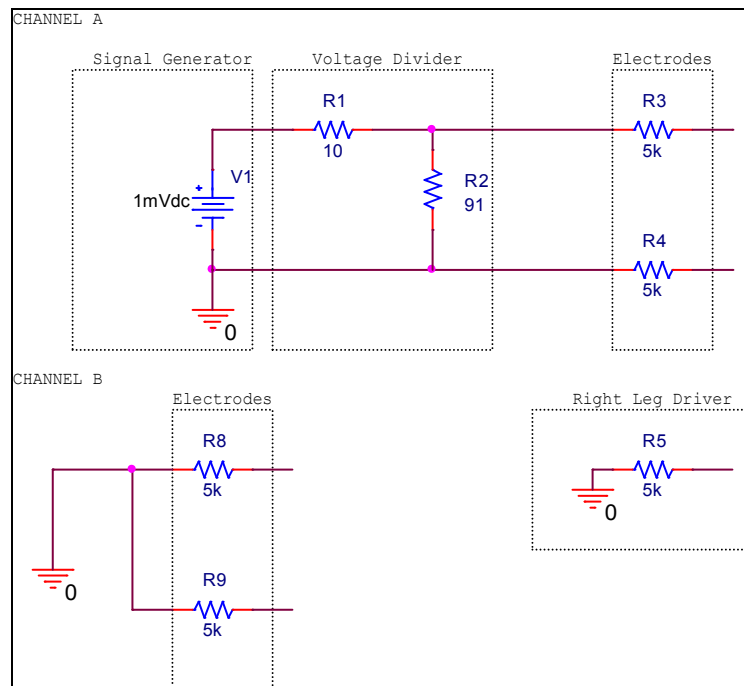


Figure 1 - Square Wave Calibration Test Setup

2. Apply the square wave signal to the electrodes of one channel. Ensure that the right leg driver is connected to ground and the unused channel inputs are also grounded.

<sup>1</sup> Standards Document: [https://edge.rit.edu/content/P08050/public/References/IFCN\\_Standards\\_106\\_259.pdf](https://edge.rit.edu/content/P08050/public/References/IFCN_Standards_106_259.pdf)

<sup>2</sup> Omitting noise tests because low noise components have been chosen.

<sup>3</sup> Omitting 60 Hz notch filter test as it will be implemented in software.

- Use an oscilloscope to ensure that the square wave is obtained at the output of the analog board with the required gain of  $4500V/V \pm 400V/V$ .

## Anti-Aliasing High-Filter Test

Summary: Prior to sampling at 256 samples/second, an anti-aliasing high filter at 70 Hz must be used, with a roll-off of at least 12 dB/octave.

- Set up function generator to output sine wave with a  $1mV_{p-p}$  amplitude and a frequency of 1.0 kHz.
- Apply the sine wave signal to the electrodes of one channel. Ensure that the right leg driver is connected to ground and the unused channel inputs are also grounded.
- Using an oscilloscope verify that the gain is approximately 0dB as measured at the output. See figure below for expected frequency response of amplifier.

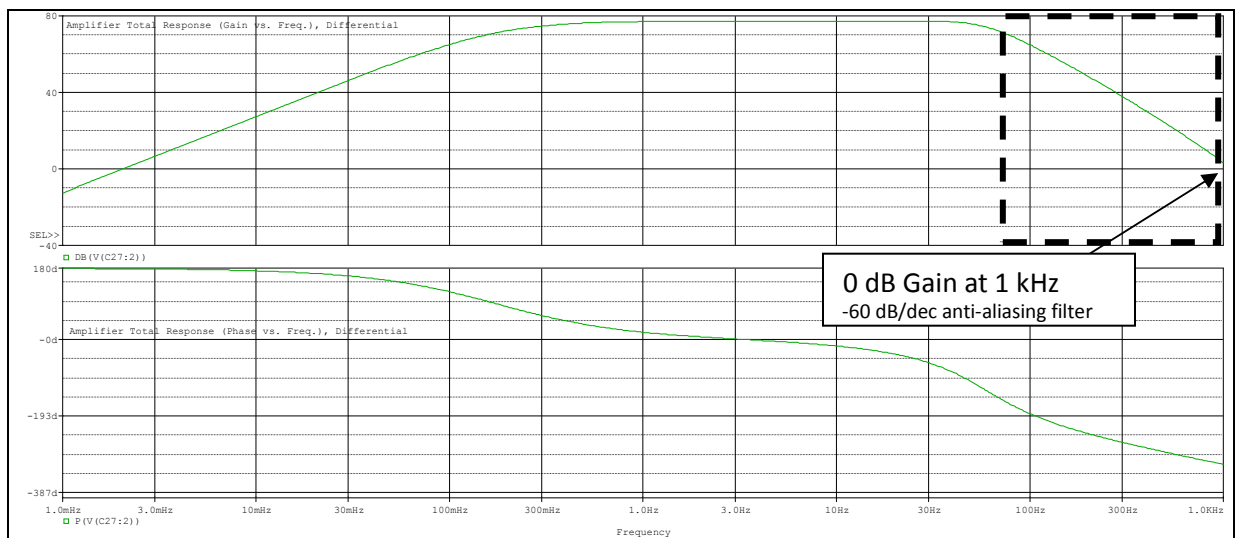


Figure 2 – Gain (TOP) and Phase (BOTTOM) vs. Frequency of Amplifier

## Low-Filter Test

Summary: Whenever possible the low filter should be set to 0.16 Hz or less for recording.

- Set up function generator to output sine wave with a  $1mV_{p-p}$  amplitude and a frequency of 2.0 mHz.
- Apply the sine wave signal to the electrodes of one channel. Ensure that the right leg driver is connected to ground and the unused channel inputs are also grounded.
- Using an oscilloscope verify that the gain is approximately 0dB as measured at the output. See figure below for expected frequency response of amplifier.

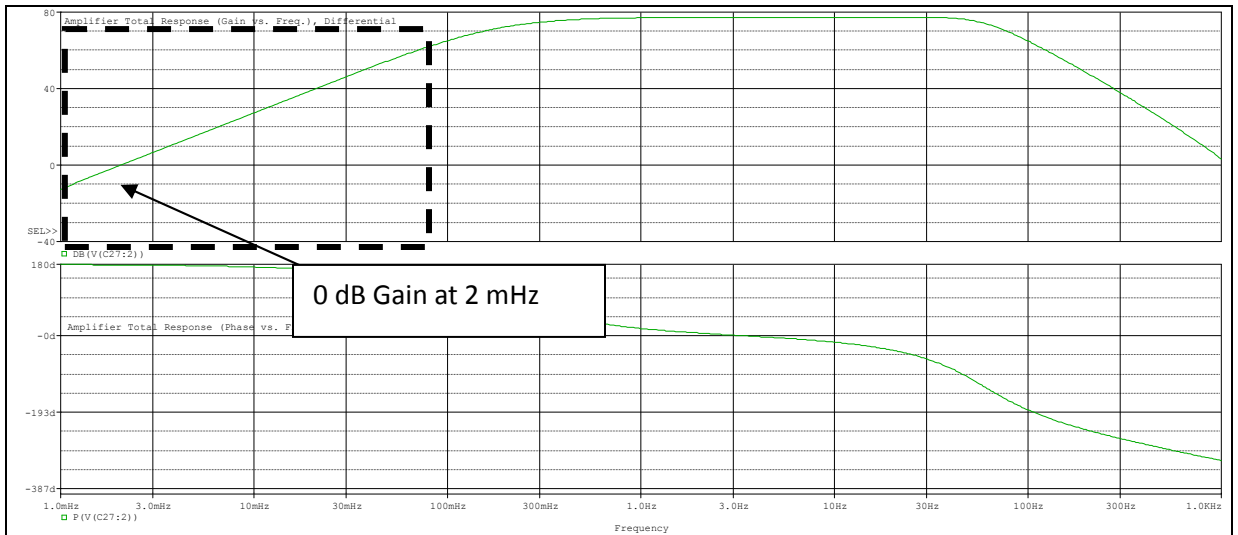


Figure 3 - Gain (TOP) and Phase (BOTTOM) vs. Frequency of Amplifier

## Electrode Impedances Test

Summary: Electrode impedances should be less than 5 k  $\Omega$ .

1. Set up a DC Power Supply to output 1 V<sub>DC,p-p</sub>.
2. Ground both the inputs to the electrode buffer amp of channel A as shown in figure below.
3. Ground right leg driver input and inputs of channel B as shown.
4. Connect 5 k $\Omega$ . resistor in series with output of DC power supply as shown, (Note the output impedance of DC power supply).
5. Measure voltage across the electrode as shown.
6. The electrode impedance is calculated as follows:

$$R_{electrode} = \frac{(R_{source} + 5k\Omega)}{1 - V_{electrode}} \cdot (V_{electrode})$$

Equation 1 - Calculation of Electrode Impedance

7. Ensure that the electrode impedance is less than 5 k  $\Omega$ ...

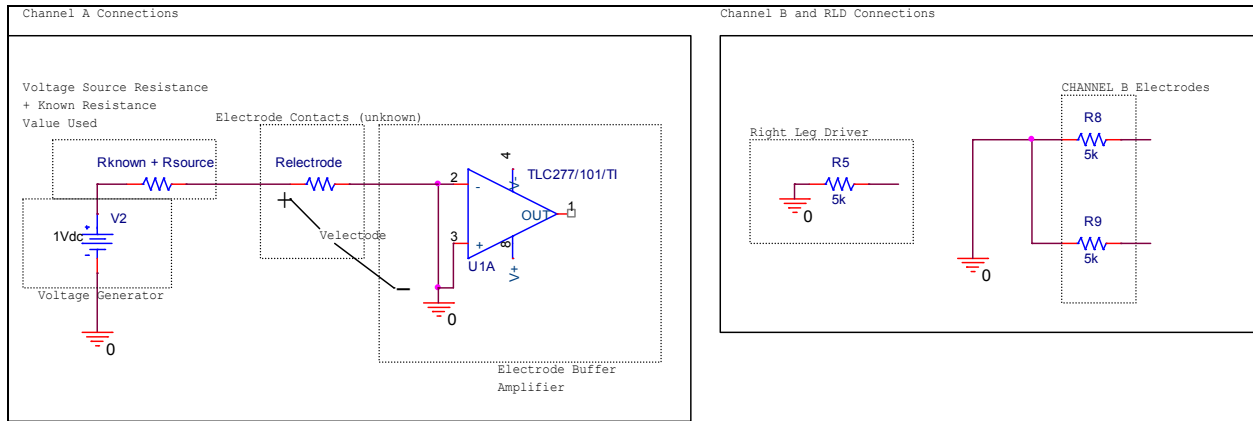


Figure 4 - Test Setup to Measure Electrode Impedance

## Preamplifier Input Impedances

Summary: Preamplifier input impedances must be more than 100 M $\Omega$ .

[TLC277: 10,000,000 M  \$\Omega\$  .](#)

[INA114: 100,000 M  \$\Omega\$  .](#)

## Common Mode Rejection Ratio (CMRR) Test\*

Summary: The common mode rejection ratio must be at least 110 dB for each channel measured at amplifier input.

1. Apply a 0.1mV differential signal to one channel of the amplifier.
2. Ground the inputs of the other channel and the right leg driver.
3. Measure the differential voltage gain of the amplifier after stage 1 using an oscilloscope.
4. Apply a 0.1mV common signal to one channel of the amplifier.
5. Measure the common mode voltage gain of amplifier after stage 1 using an oscilloscope.
6. The CMRR is calculated as:

$$CMRR = 20 \cdot \log\left(\frac{DifferentialGain}{CommonModeGain}\right)$$

Equation 2 - CMRR Calculation

7. Ensure that the CMRR is at least 110 dB.
8. Repeat steps 1-7 for the second channel of the amplifier board.

\*The CMRR for the INA114 is typically 106 dB at a gain of 10.

\*The CMRR for the TLC277 is typically 84 dB.

# Additional Amplifier Verification Tests

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## Analog Board Gain / Redundancy Test

Summary: The analog board gain must be 4500V/V ( $\pm 400\text{V/V}$ ). Two analog boards will be made with identical components and verified to operate similarly.

1. Apply an identical 0.1mV differential signal to channel 1 of both the amplifier boards.
2. For both the analog boards, ground the inputs of the other channel and the right leg driver.
3. Measure the differential voltage gain of both amplifiers using an oscilloscope.
4. Ensure the gain value is 4500V/V ( $\pm 400\text{V/V}$ ).

## Power Consumption

Summary: The power consumption of the system must be 150mW +/- 10mW for the analog portion, and 69mW +/- 5mW for the digital board.

1. Use a DC Power Supply to power the system by setting the DC output of the supply to 6V for the analog board, and 3V for the digital board. Do not turn on the output of the power supply yet.
2. Connect a 100 $\Omega$  resistor in series with the positive output of the power supply as shown in the figure below for each board.
3. Turn the DC power supply on.
4. Using a Digital Multimeter (DMM) measure the voltage across the 100 $\Omega$  resistor ( $R_1$ ).
5. The current drawn by each board can be calculated as:

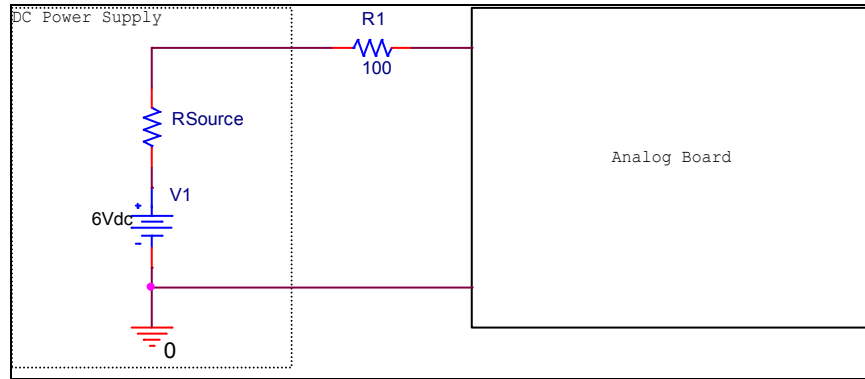
$$I_{R1} = \frac{V_{R1}}{R_1}$$

**Equation 3 -Current drawn by the analog board circuit**

6. The total power drawn from the power supply for each can then be calculated as:

$$P = I_{R1} \times V_{DC\ Power\ Supply}$$

7. The total power drawn from the power supply should be less than 150mW  $\pm$  10mW for the analog portion, and 69mW +/- 5mW for the digital portion.



**Figure 5 - Setup to test the power consumption specification of the analog board**

## Analog Board Battery Lifetime Test

Summary: The analog board must be able to operate continuously for a time of at least 24 hours. A brand new set of 4 AA batteries will be used to power the circuit.

1. Setup a switch in series with the circuit as shown in the Figure below.
2. Apply a 0.1mV differential signal to one channel of the amplifier.
3. Ground the inputs of the other channel and the right leg driver.
4. Close the switch to turn the analog board on. Start a timer.
5. Ensure that the analog board is functional as expected by checking the gain at the output.
6. Return after a period of 24 hours and check to see if the analog board is still properly functional.

## Operating Voltage / Battery Voltage

Summary: The circuit must operate on four AA alkaline batteries for a total battery voltage of 5.6V $\pm$ 0.4V.

1. Use a Digital Multimeter (DMM) to measure the total voltage across the 4 AA batteries.
2. Ensure that the battery voltage is 5.6V  $\pm$  0.4V.

## Simulated EEG Waveform Test

Summary: Using a simulated EEG waveform we will input it to the amplifier and make sure the amplifier is functioning properly.

1. Program a function generator to output a programmed EEG signal. This is done by using MATLAB to send the EEG waveform as a data file to the function generator.
2. Apply the output of the function generator as a differential input to one channel of the analog board.
3. Ground the inputs of the other channel and the right leg driver.
4. Observe the output signal from the analog board.
5. Ensure the appropriate gain and filtering is applied

# Signal Sampling

## Amplitude & Frequency Verification

- 1) Set waveform generator to output signal with  $1 V_{pp}$  amplitude and frequency of 20 Hz. Adjust DC offset such that the signal minimum is 0.5 V. Feed into analog board.
- 2) Feed output of analog board into ADC0 of digital board.
- 3) Acquire digital samples of signal using software
- 4) Plot samples in MATLAB and verify amplitude
- 5) Plot FFT of samples in MATLAB and verify frequency

# Software

## Software Functionality Test

- 1) Check connectivity by searching for a minimum of three motes in immediate surroundings
- 2) Check command receipt by verifying toggled LED on each mote
- 3) Check data packet receipt by observing incoming data stream

# Networking

## Multihop Verification

- 1) Establish connection to mote using software and begin sampling
- 2) Determine maximum distance from device to base station by observing cessation of packet transmission
- 3) Add intermediary device and verify re-established connectivity
- 4) Remove intermediary device and observe cessation of packet transmission

## Scalability Test

- 1) Establish connection to at least three motes using software and begin sampling from all of them
- 2) Perform all previous tests with three motes operating simultaneously

## Wireless Transmission Reliability

- 1) Obtain packet number for each received packet in the wireless network
- 2) Observe continuity between each packet and note skipped or repeated packets
- 3) Calculate the number of total errors including badly ordered, skipped, and repeated packets
- 4) Calculate the percentage of total errors from a sample size of 1000 packets