# Changes to the AD8232 module

Although the **AD8232** is versatile, its standard configuration on commercial modules (the cheap ones you find for Arduino) is optimized for the **ECG**, which has a much narrower bandwidth (typically **0.5 Hz - 40 Hz**) compared to the **EMG** (**20 Hz - 500 Hz**).

To get a clean EMG signal, you will need to change the values of some passive components (resistors and capacitors) directly on the module.

## Recommended Values - Table (EMG vs ECG)

If you decide to desolder and replace the SMD components on the module, here are the approximate reference values:

| Parameter | ECG Value (Standard) | EMG Value (Recommended) |
|---|---|---|
| **Bandwidth** | 0.5 Hz - 40 Hz | 10 Hz - 500 Hz |
| **High-Pass Filter** | 10 uF / 10 MOhm | 0.1 uF / 10 MOhm |
| **Low-Pass Filter** | 10 nF / 1 MOhm | 1 nF / 1 MOhm |

*(In the diagram above, identify the HP and LP blocks to locate the capacitors to replace on your specific module.)*

## Can I do everything via software without desoldering?

**Not exactly.** If the chip's analog low-pass filter cuts off at 40 Hz (as in the standard module), the EMG frequencies (which reach 400 Hz) will be physically attenuated by the hardware before they even reach your Arduino pin.

- **The result:** You will see a very "soft" and slow signal, losing all the rapid details of the muscle contraction.
- **Advise:** If you don't want to solder, look for an AD8232 module that explicitly states a wider bandwidth, or accept a lower resolution by focusing only on the "ground" of the signal at low frequencies.

# Modifications to the AD8232 module

## 1. High-Pass Filter

In the AD8232 schematic, this filter is managed by the pins HPSENSE and HPDRIVE. It is currently set to cut very low frequencies (physiological ECG).

- **Components to modify: C4** and **C6**.
- **Current value:** 0.33 uF.
- **New recommended value: 0.1 uF** (or 100 nF).
- **Effect:** Raises the lower cutoff frequency to 10-20Hz, eliminating gross artifacts from cable and skin movement.

## 2. Low-Pass Filter

This is the critical point. The AD8232 schematic uses the internal op-amp as a two-pole Sallen-Key filter. Current components cut off sharply above 40 Hz, "eating" the entire EMG signal.

- **Components to modify: C3** and **C1**.
- **Current value:**C3 = 10 nF, C1 = 1.5 nF.
- **New recommended value:**
  - **C3: 1 nF** (to move the cutoff above 400 Hz).
  - **C1: 220 pF** (to maintain filter stability).
- **Effect:** Allows the fast frequencies of the muscle fibers to reach the output SIGNAL_OUT.

## 3. Gain

The EMG has a greater amplitude than the ECG.

The gain of the final stage (Instr. Amp + OpAmp) is given by: Gain = 100 * (1 + R9 / R8 )

With R9 = 1 MOhm and R8 = 100 kOhm, the total gain is about 1100.

If the signal is too distorted and "bumps" into 3.3V and 0V, reduce R9

- **Components to modify: R9** ( linked to OPAMP- )
- **Current value:** 1 MOhm
- **Edit:** Reduce to **470 kOhm** or even less

# Recalculating the cutoff frequency control

To calculate the cutoff frequencies (f_c), we will use the formulas of the active filters implemented in the AD8232 based on the values we chose to fit it to the EMG.

## 1. High-Pass Filter (Low Cut)

The AD8232 uses a two-pole high-pass filter. The cutoff frequency is determined by the components on the pins. HPSDRV and HPSEL. With the new values:

- **Resistors R11, R12, R13:** 10 MOhm and 1.4 MOhm (standard on the module).
- **Capacitors C4, C6:** 0.1 uF (new proposed value).

The approximate formula for the two-pole filter is:

**$$f_{c-high} = \frac{1}{2\pi \sqrt{R_{12}C_4R_{13}C_6}}$$**
**Replacing the values ($1.4\text{ M}\Omega$ and $10\text{ M}\Omega$ with $0.1\mu\text{F}$):**
**$$f_{c-high} \approx \mathbf{13.3\text{ Hz}}$$**

The 13 Hz result is perfect for EMG because it eliminates hand shake and lead movements (usually < 10 Hz) without affecting the muscle signal.

## 2. Low-Pass Filter (Upper Cut)

The low-pass filter is a two-pole Sallen-Key made with the internal op-amp.

- **Resistors R7, R8, R9:** 1 MOhm and 100 kOhm (standard on the module).
- **Capacitors C3, C1:** 1 nF and 220 pF (new proposed values).

The formula for the cutoff frequency is:

**$$f_{c-low} = \frac{1}{2\pi \sqrt{R_7 R_8 C_3 C_1}}$$**
**Replacing the values ($1\text{ M}\Omega$ and $100\text{ k}\Omega$ with $1\text{ nF}$ and $220\text{ pF}$):**
**$$f_{c-low} \approx \mathbf{340\text{ Hz}}$$**

Compared to the original 40 Hz of the ECG module, we now have 340 Hz which is a wide enough bandwidth to capture most of the EMG signal energy, which decays rapidly after 400-500 Hz.

## Bandwidth Summary

ECG (Original): from 0.5 Hz to 40 Hz

EMG (Modified): 40 Hz to 340 Hz

# Replacement Summary (SMD on Module)

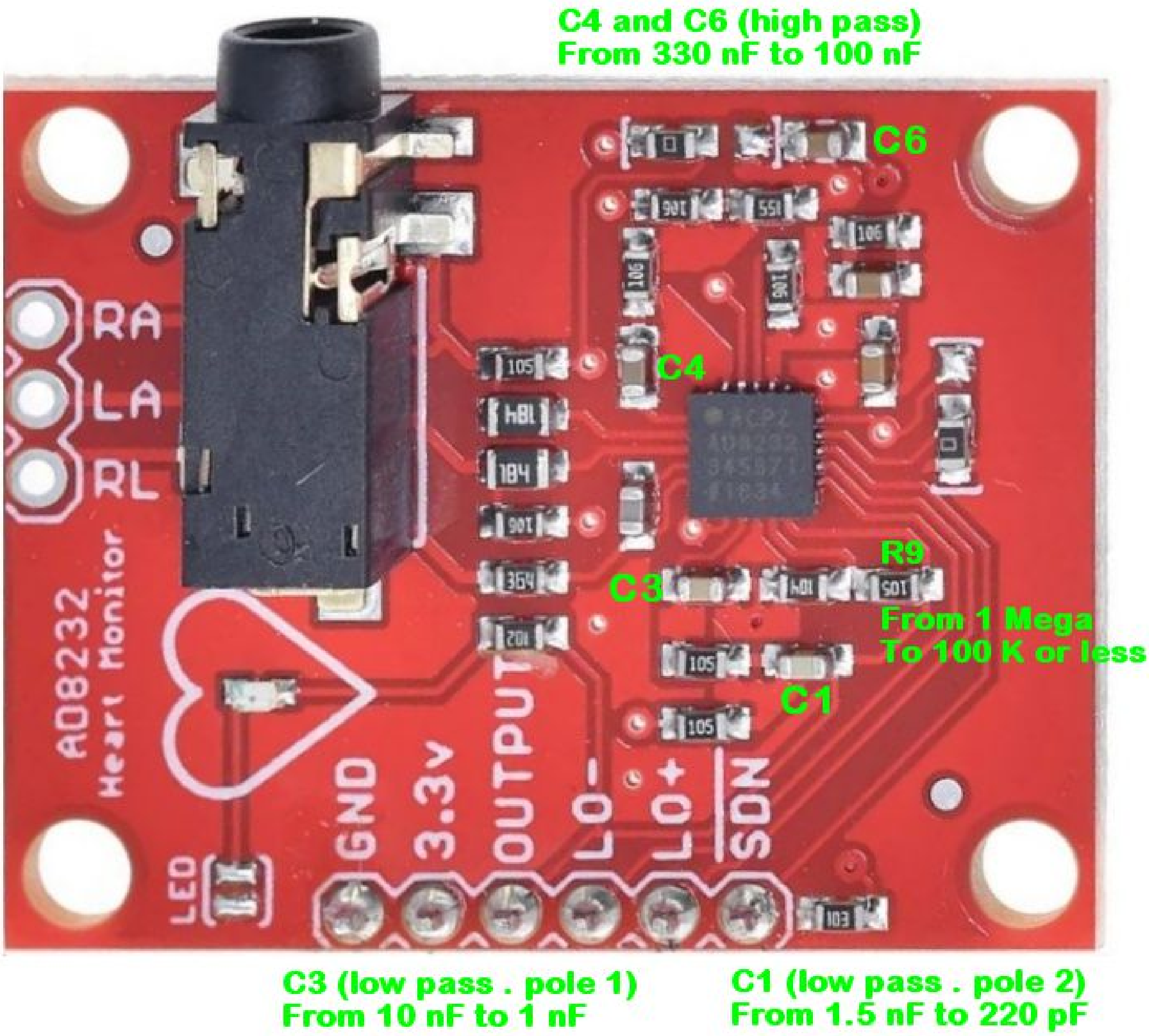
| Label | Function | Original Value | New Value (EMG) |
|---|---|---|---|
| **C4** | High-pass (Pole 1) | 0.33 uF | **100 nF** |
| **C6** | High-pass (Pole 2) | 0.33 uF | **100 nF** |
| **C3** | Low-pass (Pole 1) | 10 nF | **1 nF** |
| **C1** | Low-pass (Pole 2) | 1.5 nF | **220 pF** |

### Notes for the realization

1. **Welding:** The components on the form are usually in the form **0603** so you will need a fine-tipped soldering iron or a hot air station.
2. **Electrode C:** As you can see in the Myoware schematic, the reference electrode (C) is essential. On the AD8232 module, connect it to pin **RL** (Right Leg).
3. **Software:** Once these hardware changes are made, the pin SIGNAL_OUT will give you the **EMG RAW** (the one that in the Myoware scheme comes out of the first block). At that point you can apply the rectification (abs) and the integrator (moving average) via software as explained in the second PDF.

# PCB modifications

Replace C1, C3, C4, C6 and R9 as shown in the following image.



# AD8232 Schematics

This is the schematic of the AD8232 with the ECG components (before the EMG modifications).