Piezofilm Amplifier

This simple circuit was created for TENSS 2018. It is a little amplifier circuit for piezo vibration sensors. It is low-cost means to detect rodent whisking events in freely moving animals.

Design

The circuit is a charge amplifier followed by a second order low-pass filter. Therefore, the output is a bandpass filtered measurement of the charge accumulation on the sensor due to motion. The only special thing about it is that the feedback capacitance is kept small (10 pF) in order to increase the charge amplifier's sensitivity to tiny motions in the sensor. The parallel feedback resistance is very large to prevent the small capacitance from resulting in a high frequency cutoff that is too large for detecting whisker induced defections. The J-FET amplifier's has very high input impedance and low input bias current. These properties allow it to work with these extreme values without (1) loading the sensor itself and (2) leading to saturation in the output due to bias currents charging the capacitor at a rate that exceeds compensation through the feedback resistor, respectively.

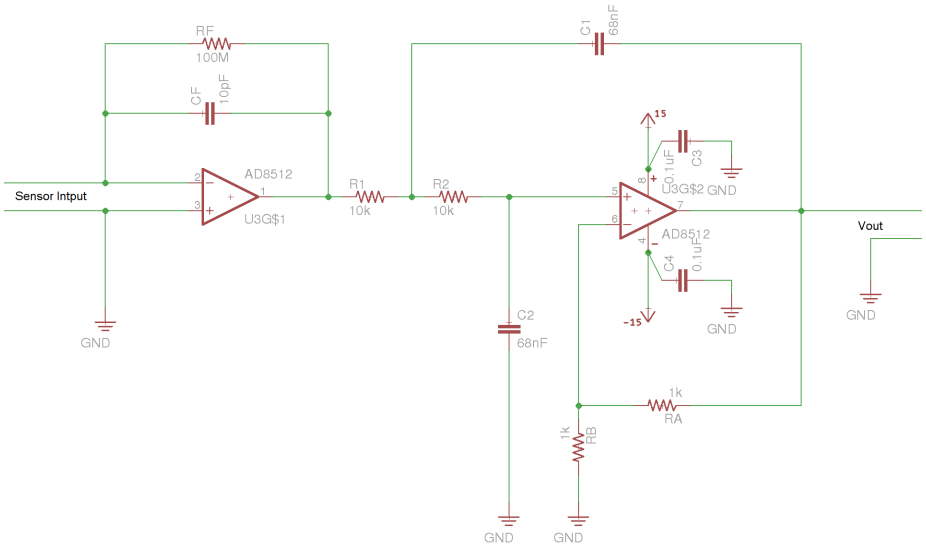

Figure 1: Amplifier circuit

The charge-to-voltage conversion gain of the first stage is given by:

$$K_1 = 1/C_f$$

where C_f is the feedback capacitance. The high-pass cutoff of the charge amplifier is given by

$$f_{high} = 1/(2\pi R_f C_f)$$

where R_f is the feedback resistance. With the values in this circuit, this works out to 159Hz (TODO: This is too high, raise C_f and increase second stage gain). The passband gain of the low-pass filter that follows the charge amplifier is given by

$$K_2 = 1 + R_A/R_B$$

where $R_{A,B}$ are the values of resistors in the voltage dividers forming the feedback network for the op-amp. This works out to 2 in the current circuit. The low-pass cutoff is given by

$$f_{low} = 1/(2\pi\sqrt{R_1 R_2 C_1 C_2}$$

This works out to 234 Hz in the current circuit. This is just above the upper end of the 180 Hz resonant frequency response for the LDT0-028K piezofilm sensor.

Bill of Materials

The BOM is available on this google doc.

Usage

- 9V batteries can be connected to the bottom or power can be provided through the middle screw terminal. Use something in the range of +/- 18V.
- The switch turns the amplifier on.
- The output comes from the right most screw terminal.
- Input can be provided through either the screw terminal (Input B) or 0.1" pitch socket (Input A). These are connected internally, so only use one.
- To use it with freely moving animals, the PCB must not be rigidly attached to the behavior arena – it will readily pick up vibrations due to the animal running around. Instead, it must be mechanically decoupled from the environment. A good solution is to mount the PCB on a heavy object (e.g. a steel plate), and then place that assembly on a cushion made of twist ballons. The piezofilm sensor can then extend through the elevated floor of an arena via a hole.