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DT0061
Design tip

Electromyogram application based on X-NUCLEO-IKA01A1 expansion board

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Main components	
TSZ124	Very high accuracy (5 µV) zero drift micropower 5 V operational amplifiers

Purpose and benefits

The X-NUCLEO-IKA01A1 boards embeds several configurations based on operational amplifiers. This design tip will show you how to configure it in order to develop an electromyogram (EMG) application.

Actually, based on this tip, you will be able to trigger an action thanks to your muscles using the TSZ124 operational amplifier. This application can be used for fitness, healthcare, remote control, video games for an improved game experience and for others activities.

Description

Introduction

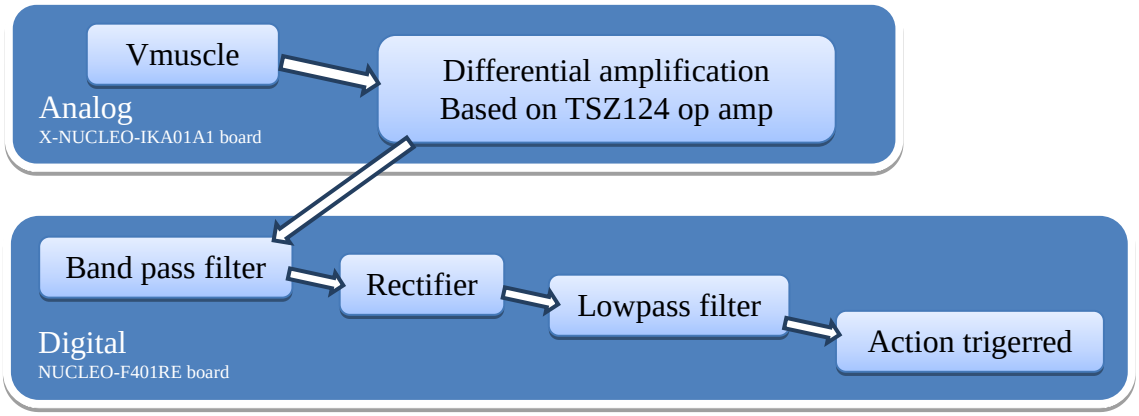
Signal generated by muscles are very small. In order to properly record it, three skin electrodes are need. One electrode connected to one side of a muscle, another one on the other side of the muscle, around 2cm far away the first electrode. The last electrode will be used as reference. Thanks to these skin electrodes, the electrical potential generated by the muscles between the two electrodes can be conducted to the demo board. This signal is in the range of 50uV to few mV.

Amplification of electrical muscle activity

In order to be able to analyze the muscle signal, it has to be conditioned. In this section, we will see how we can achieve it thanks to a NUCLEO-F401RE board and the operational amplifier expansion board X-NUCLEO-IKA01A1.

Here is a block diagram of the signal conditioning chain:

Figure 1. EMG signal conditioning block diagram



1. Differential measurement explanation

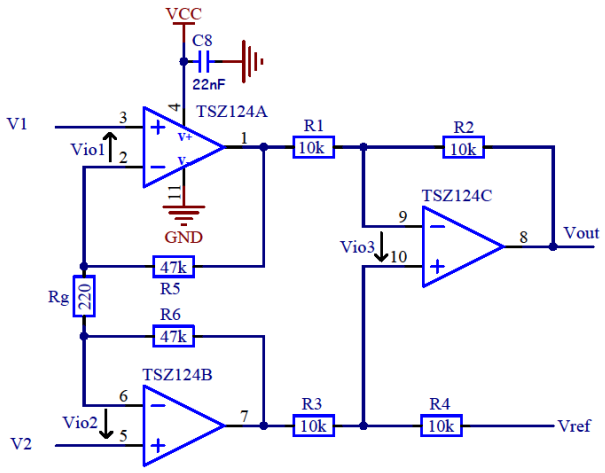
What is important for the measurements is the voltage difference between each side of the muscle. That's why we have to amplify the electrical difference between the two electrodes.

In order to achieve it correctly, we have to take care of the main constraints which are the input impedance and the accuracy of the input stage. Since the body is not low impedance, the first amplifying stage has to have a high impedance. In addition to this feature, the first stage needs to be very accurate because the signal is very small and thus a big amplification is required. By amplifying the signal, we will also amplify the offset due to the amplifier, thus this input voltage offset (Vio) must be as low as possible.

For these reasons, the selected structure for this stage is the instrumentation amplifier structure based on three op-amps.

The figure 2 shows the schematics of this first amplifying stage.

Figure 2. First amplifying stage based on instrumentation amplifier structure.



With R1=R2=R3=R4=R and with R5=R6

We obtain the following output voltage formula:

$$Vout = (V2 - V1)\left(1 + 2\frac{R5}{Rg}\right) + Vref - (Vio2 - Vio1)\left(1 + 2\frac{R5}{Rg}\right) - 2 * Vio3$$

The maximum frequency that is generated by the muscle is 500Hz. Thus, in addition to a high accuracy op-amp, we also need an op-amp with a sufficient GBP.

Considering R5=R6=47kΩ and Rg=220Ohm, the gain of the first op-amp stage is 216, thus the minimum required GBP without any margin is 160kHz (213*500Hz ≈ 110kHz).

Taking into account these two main constraints, the best op-amp would be the TSZ124 which has the following features:

- Very high accuracy and stability:
  - Input offset voltage : **5 µV max** at 25°C
  - 8 µV over full temperature range (-40°C to 125°C)
- Rail-to-rail input and output
- Low supply voltage: 1.8 - 5.5 V
- Low power consumption: 40 µA max at 5 V
- Gain bandwidth product: **400 kHz**
- Tiny-package: QFN16 3x3 or TSSOP14

Note that on X-NUCLEO-IKA01A1 board, the voltage reference is performed thanks to the TSU104 operational amplifier, but of course, the fourth op-amp of the TSZ124 can be used in order to set Vref to half Vcc.

2. Hardware considerations

For EMG application, it is important to note that we are dealing with an AC signal that is generated by our muscle. Thus in addition to the standard instrumentation amplifier structure seen above, we need to add coupling capacitor on both inputs. This schematic can be performed thanks to minor changes on X-NUCLEO-IKA01A1 board. Actually, we only need to change the value of two capacitors and one resistor.

Requirements:

- NUCLEO-F401RE
- X-NUCLEO-IKA01A1
- 22nF capacitors (x2)
- 220Ohm resistor (x1)
- Three skin electrodes (x3)
- Wires (x3) to connect the electrodes between body and X-NUCLEO board

3. X-NUCLEO-IKA01A1 modifications

Few steps have to be performed in order to configure the board for EMG application.

- Disconnect : jumpers JP4 and JP5
- Connect : jumpers JP6 and JP7
- Solder the 220Ohm resistor between Rgain_a and Rgain_b nodes.
- Replace C3 and C4 with the 22nF capacitors. It is also possible solder these 22nF capacitors in parallel of C3 and C4 by using connections of JP4 and JP5.
- Solder the wires:
    - One wire connected to Inst_n (the other side of this wire will be connected to an electrode)
    - One wire connected to Inst_p (the other side of this wire will be connected to an electrode)
    - One wire connected to R4 (in order to connect your body the referenced voltage).
- Stick the skin electrodes on your arm for example:
    - The first one on your arm muscle
    - The second close to the first one around 2 cm far away.
    - The last one is the reference, it can be stuck close to the elbow

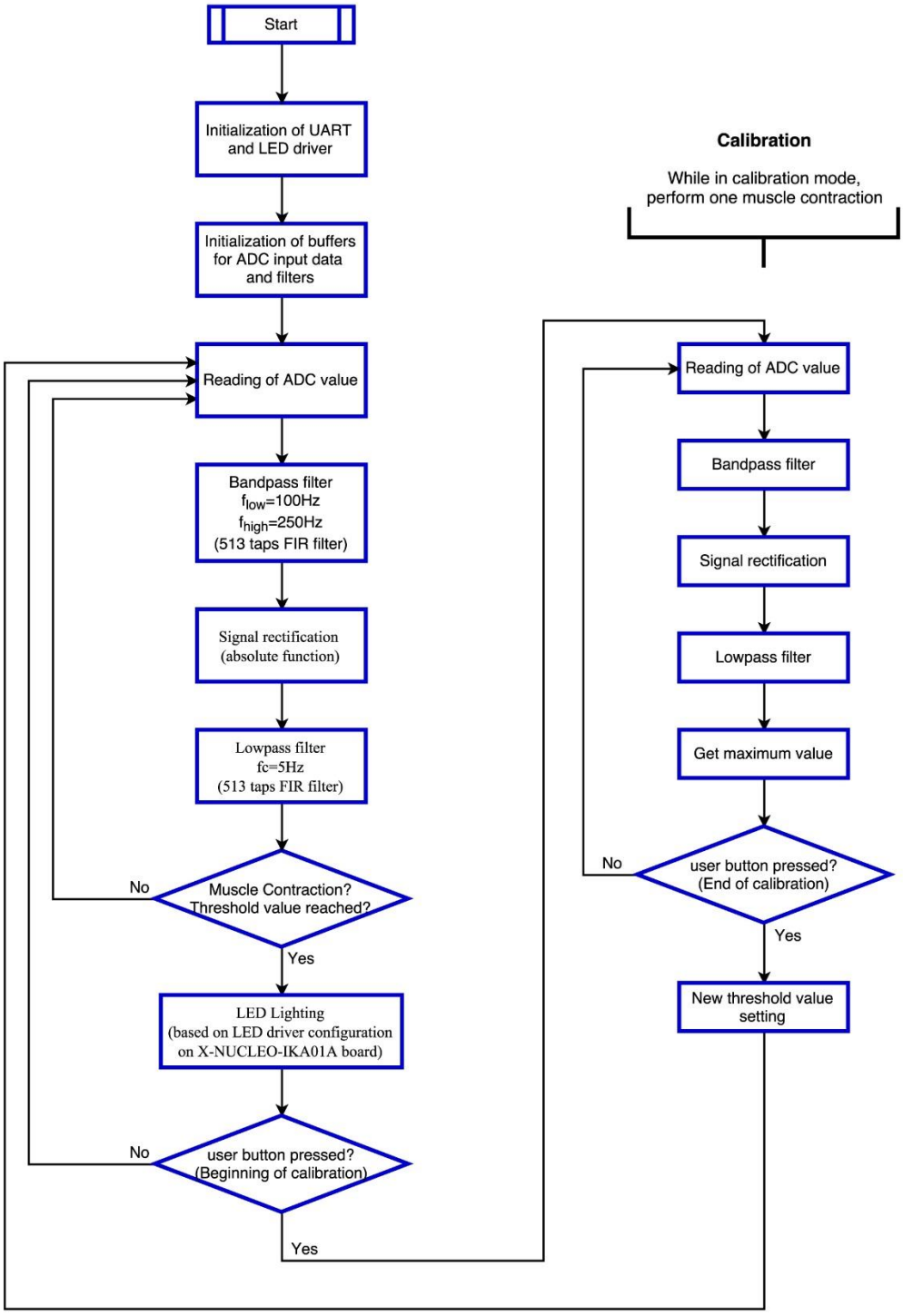
Figure 3. Electrodes connection to X-NUCLEO-IKA01A1 board

Once these steps performed, your X-NUCLEO-IKA01A1 is ready to use. We need to insert the appropriate firmware in the NUCLEO board. You can download it on ST website in “Related Tools and Software” section of X-NUCLEO-IKA01A1 web page.

4. Firmware explanation

Thanks to the TSZ124 operational amplifier, we are able to enough condition the signal so that the STM32 is able to compute it. Actually, the STM32 will allow us to easily perform the different functions. The flowchart in figure 4 show this.

Figure 4. Firmware flow chart



For this demonstration, when a muscle contraction is detected, a LED lights. Of course, we can think to more advanced actions, such as increase a song volume, change TV channel or other action for games for example.

Note: The firmware described here is contained in STSW-OPAMP002 package available on www.st.com

5. Calibration

Depending on your body characteristics, the differential of potential monitored can vary. Thus, we need to perform a calibration in order to properly detect the contractions.

That's why we need to perform a calibration. That's why a calibration possibility has been implemented. In order to enter in the calibration mode, follow these three steps:

- Press the STM32 Nucleo user button (Blue button) while your muscle is relaxed.
- Then contract one time your arm muscle.
- Finally press again on the User button.
- Calibration is done.

Conclusion

Electromyogram application is well known in the medical business field, but it is more and more common in the daily life. With this application note, you will be able to monitor your muscle activity in order to trigger an action. It can be used for fitness, healthcare, video games for an improved game experience and for others activities.

The analog signal conditioning chain uses a TSZ124, a micropower and accurate quad op amp in order to have a portable application.

For other op amp or comparator performances such as a higher bandwidth or higher power supply voltage, you can have a look to ST catalog. Moreover, you may also benefit of a wide portfolio of analog switches, voltage references, temperature, pressure sensors or microcontroller to develop your application, making STMicroelectronics your one stop shop.

Figure 5. X-NUCLEO-IKA01A1 schematics 1/2

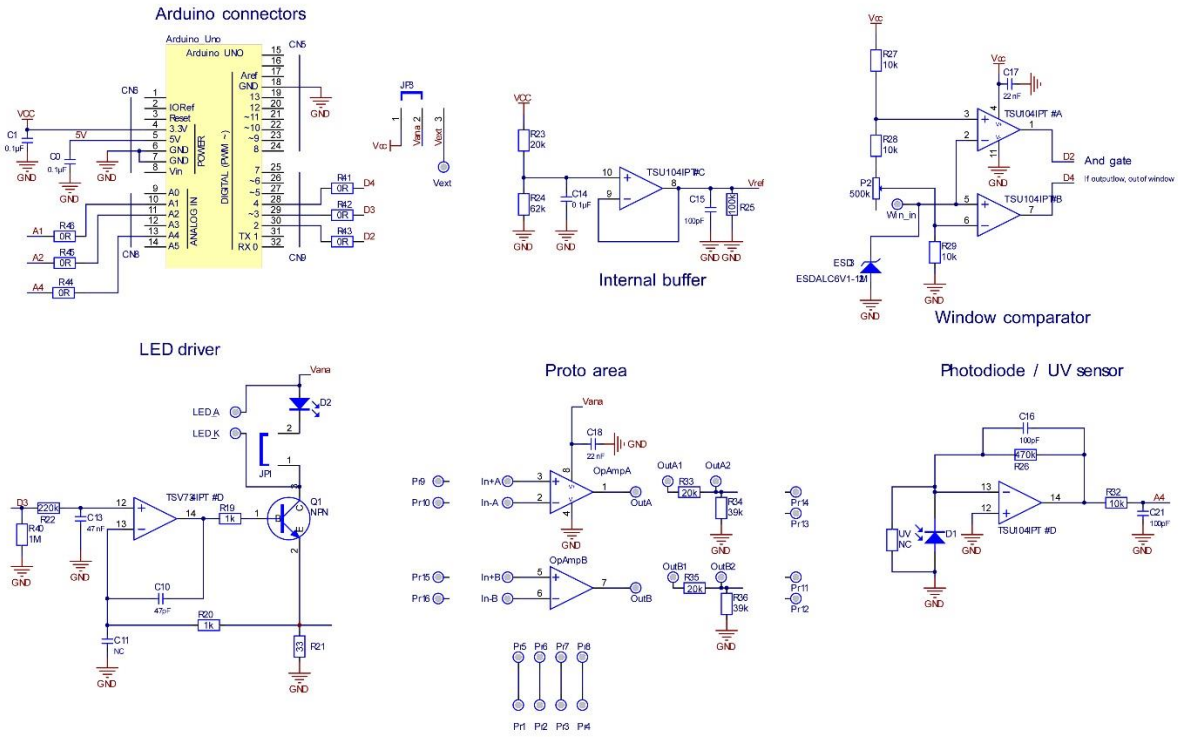
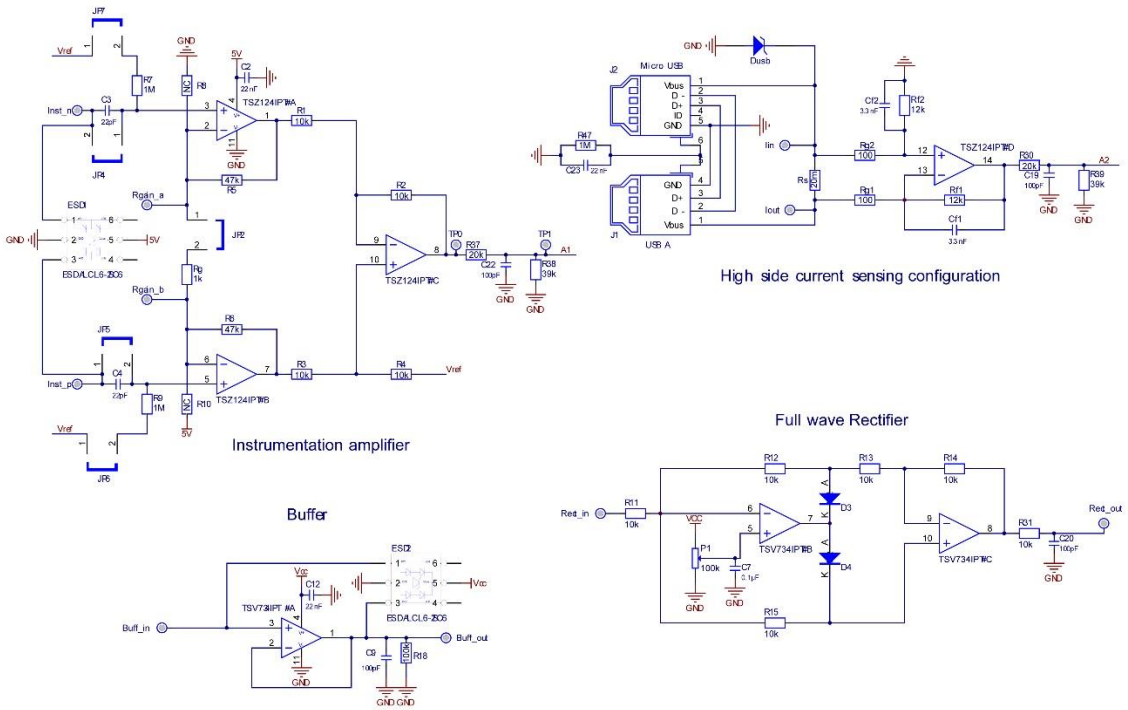


Figure 6. X-NUCLEO-IKA01A1 schematics 2/2



Support material

List of related support material and documents which are in link with this design tip.

Related design support material
Product/ system Evaluation board – X-NUCLEO-IKA01A1
Gerber files – X-NUCLEO-IKA01A1 gerber files
Bill of materials - X-NUCLEO-IKA01A1 BOM
Schematic - X-NUCLEO-IKA01A1 schematic
Documentation
Datasheet, TSZ124 : Very high accuracy (5 µV) zero drift micropower 5 V operational amplifiers
User manual, **UM1955**, Getting started with the multifunctional expansion board based on operational amplifiers for STM32 Nucleo

Revision history

Date	Version	Changes
04-May-2016	1	Initial release
28-June-2016	2	Improved quality of Figure 4, 5 and 6.

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