PSAPP-EmStat Pico module for Bio-FET application

Use the EmStat Pico potentiostat module with Field-Effect transistor-based biosensors

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1.1 Introduction

Field-effect transistor-based biosensors have drawn attentions due to its potential for small-scale, low cost, high-throughput and sensitive devices. Applications based on Bio-FET include, but not limited to, ion sensing, detection of DNA hybridization and protein binding. This document will illustrate how does EmStat Pico work for with Bio-FET application under several conditions. This does not, however, apply to the EmStat Pico dev board or other end user products made by PalmSens.

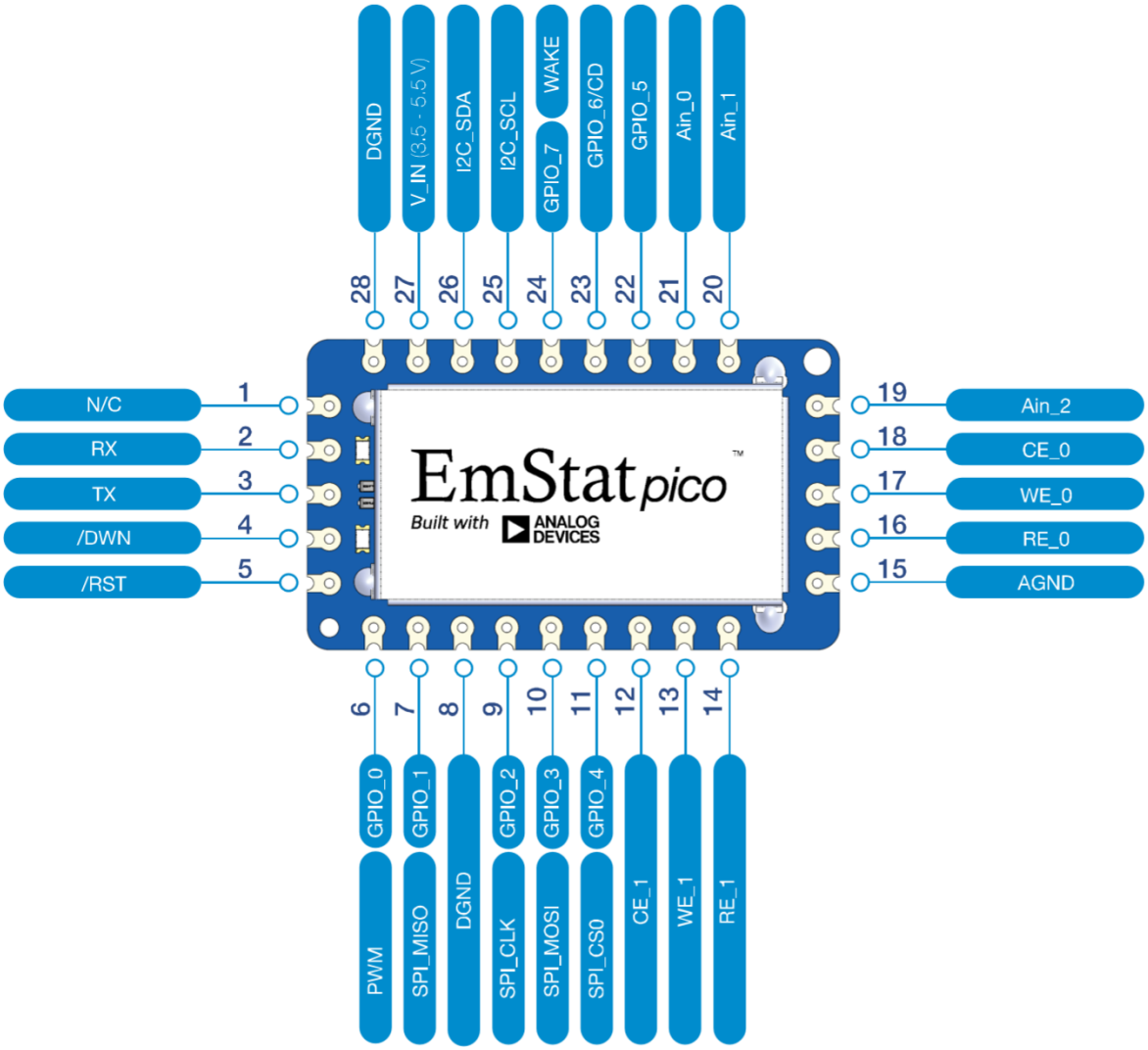

Figure 1: EmStat Pico pinout

2 Work with Bio-FET as a non-linear device

This part is for applications that measure current. Taking advantage of the FET as non-linear device, such as in subthreshold region, significant amount of current change can be measured upon binding/presence of the Bio-target.

2.1 Hardware connections for single/duo channels

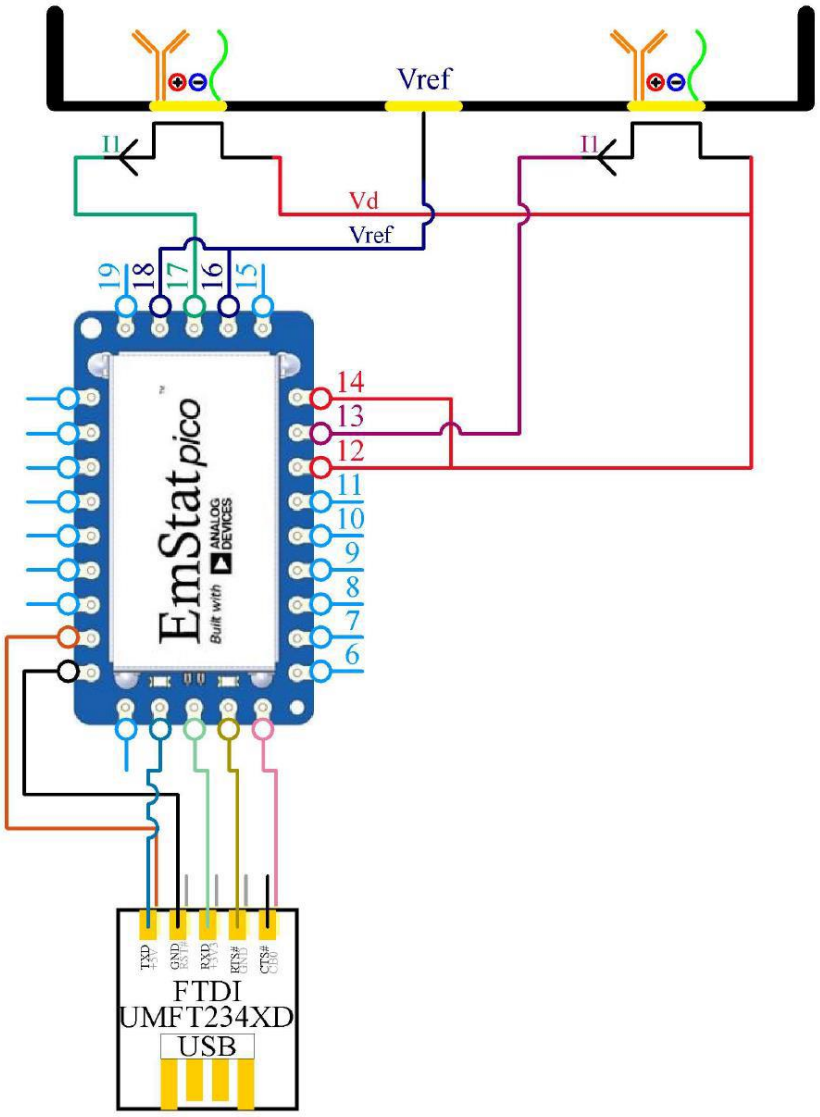

Figure 2: EmStat Pico for Bio-FET in non-linear mode

Pico has intrinsic Bi-Pot feature that allows to measure two current channels at once. This is suitable for control experiment or differential type. By shorting the RE&CE, it provides voltage output which can be used to drive the reference potential in the electrolyte of the Bio-FET. Additionally, the second voltage output channel can adjust drain-source voltage across the Bio-FET and keeps transistor to operate in the desirable region. Users can communicate with the EmStat Pico through FTDI UNFT234XD chip from their PC.

2.2 Hardware connections for multi-channels (32/16 channels)

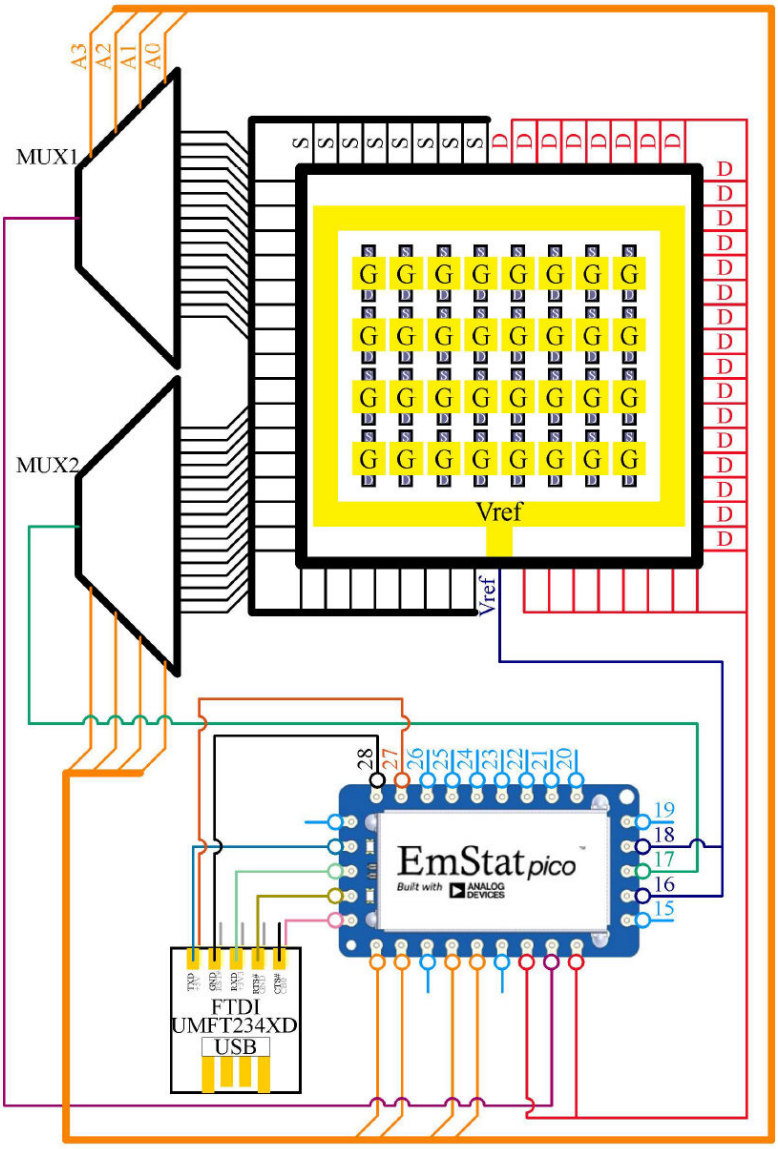

Figure 3: EmStat Pico for Bio-FET in non-linear mode (multi-channel)

Given the GPIOs that can be arbitrarily controlled through MethodSCRIPT on the Pico, users will be able to integrate simple multiplier designs to enable multichannel feature. This is a useful feature for Bio-FET sensor as it comes naturally with high throughput demand due to its small-scale. Figure 3 shows an example of 16 duo-channel/32 single-channel. Treating each Bio-FET as a pixel while the current readings are mapped to a heatmap matrix, frame per second (fps) becomes a critical SPEC for this application as it determines how many sensors can be driven by Pico within a whole sweep interval. Alternatively, the GPIO pins can be saved by adding a ripple counter IC for MUX address. The PWM from Pico will be used instead to drive the ripple counter IC as clock.

3 Work with Bio-FET as a linear device

While some Bio-FET applications are dedicated to the sensitivity for qualitative decisions, there are others, such as for sensing pH, glucose, lactate etc., would rather to obtain good accuracy and to avoid efforts for calibration.

3.1 Hardware connections for single channels

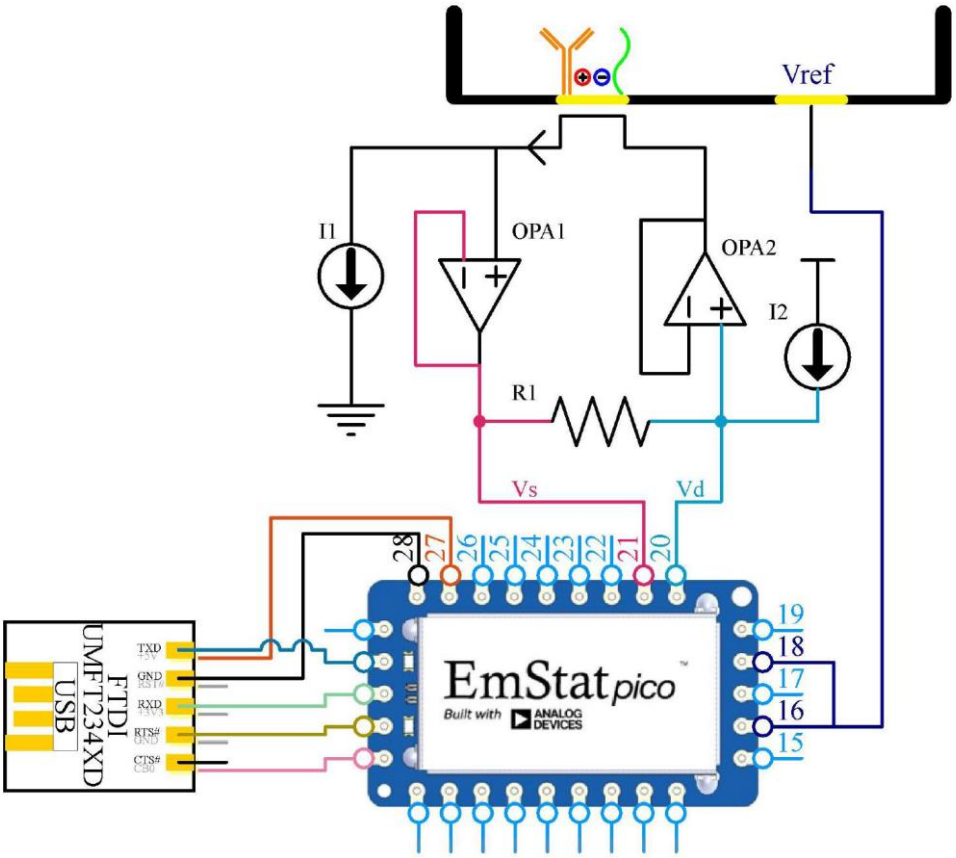

Figure 4: EmStat Pico for Bio-FET in linear mode

Figure 4 illustrates a circuitry works with Pico to measure Bio-FET as a linear device. A source-drain follower is introduced for this purpose. In this case, both drain-source current as well as drain-source voltage are locked by I1, I2 and R1, where Vds= I2×R1. Vs is, therefore, linearly proportional to the equivalent potential change at the gate of Bio-FET. Pico can measure both Vd and Vs with its voltage channels. One of the RE/CE channel can be used to drive reference voltage in the electrolyte.

3.2 Hardware connections for multi-channels (32 channels)

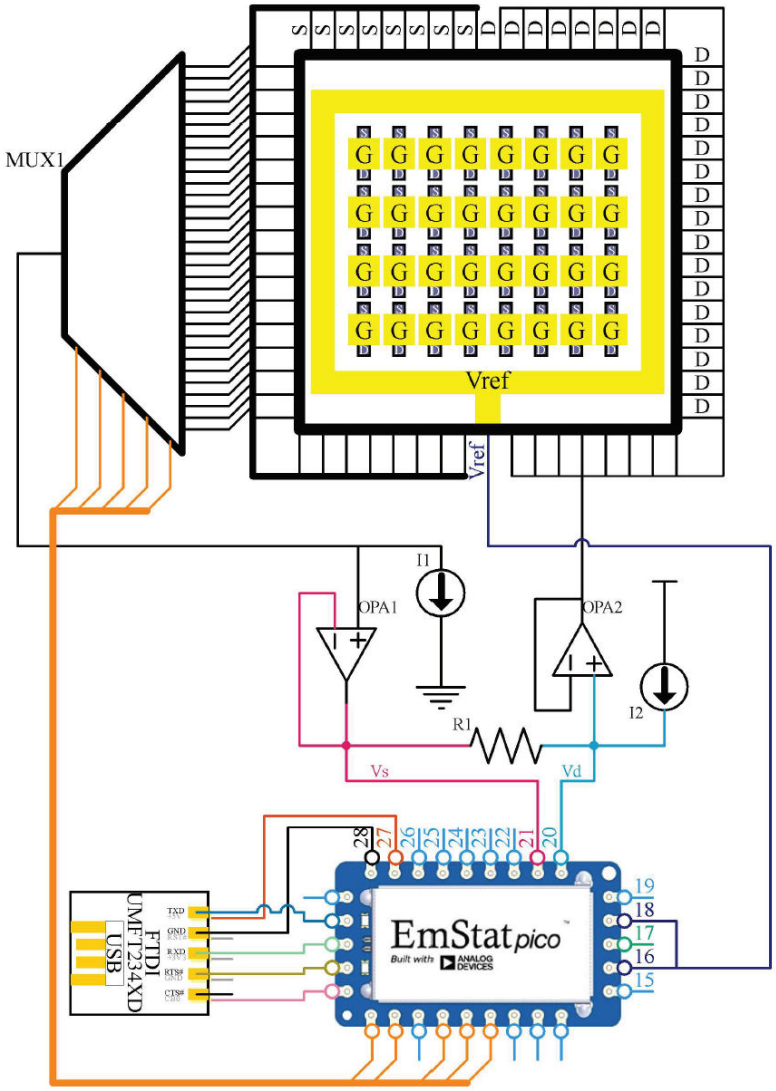

Figure 5: EmStat Pico for Bio-FET in linear mode (multi-channel)

Just like what's shown in previous section, EmStat Pico can enable multichannel feature with extra multiplexer. Alternatively, ripple counter can be added for mux address to reduce the usage of GPIOs and for applications with hundreds or thousands of channels.

4 Discussion

Bio-FET is a representative application with multidisciplinary ideas in combine. For research groups have Very-large-scale Integration (VLSI) design background, on-chip design might be interesting at first glance however too costly for disposable sensors in practice. EmStat Pico can fit well as OEM for portable/wearable biomedical applications and fills gap in the electronics. Bio-FET manufacture can be as simple as it can, since it has simple stackup, relatively high tolerance on mask alignment and straightforward mask design. This makes researchers without VLSI background more accessible.

5 References

1. https://en.wikipedia.org/wiki/Bio-FET

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4. Duarte-Guevara, Carlos, Vikhram Swaminathan, Bobby Reddy Jr, Chin-Hua Wen, Yu-Jie Huang, Jui-Cheng Huang, Yi-Shao Liu, and Rashid Bashir. "Characterization of a 1024× 1024 DG-BioFET platform." *Sensors and Actuators B: Chemical* 250 (2017): 100-110. https://www.sciencedirect.com/science/article/abs/pii/S0925400517307074