HEG Open Hardware Designs

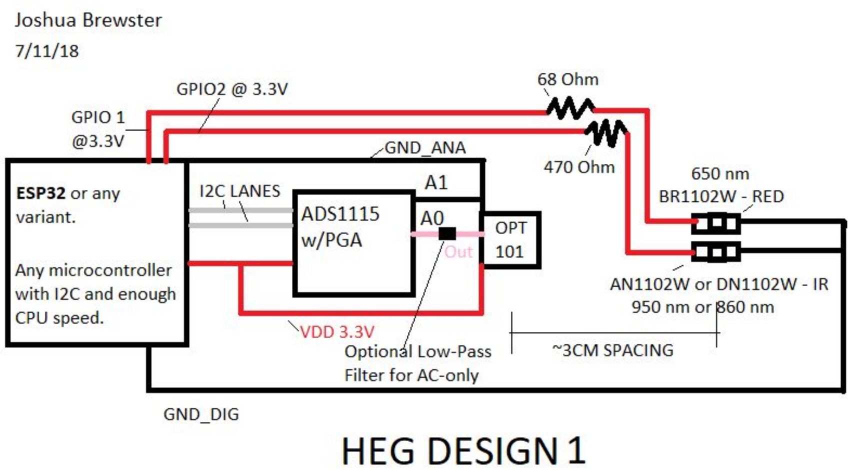
HEGduino kit

This design is based off the original, now-expired HEG patent 5995857 by Hershel Toomim and Bob Marsh. The original sensor design is simply an OPT101 spaced at 3cm from 2 50mA LEDs - one in the Red spectrum and one in the Infrared spectrum. The Red LED is set at 650nm and the Infrared LED is set at either 850nm or 950nm. 850nm provides more linear scaling for blood flow ratio, while 950nm is the industry standard for pulse oximetry.

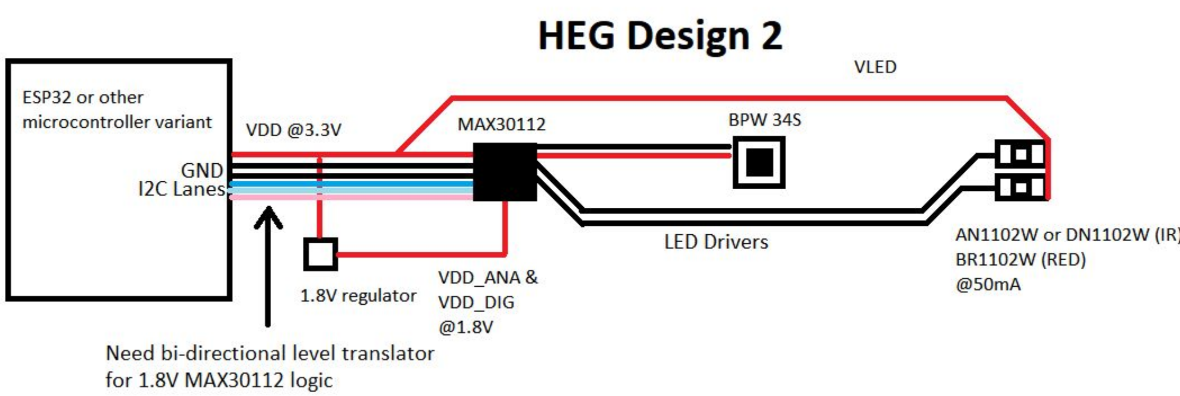
Our microcontroller of choice is the Espressif ESP32 using Arduino libraries, available for ~5 dollars on average, with our firmware available for free under the MIT license at https://github.com/moothyknight/HEG_ESP32. We also originally accomplished it with an Arduino Nano v3 which we purchased for 1 dollar apiece plus shipping. We are utilizing the ESP32 for its IoT capabilities which allows full interaction via a local webserver on the device itself. It also can connect online for remote data collection abilities or use bluetooth as well as traditional serial methods. None of our work is original on this in the sense that we used wholly open source libraries to develop the software solution, aside from our own simple method for driving the LEDs and timing the readings.

Continue below for multiple designs.

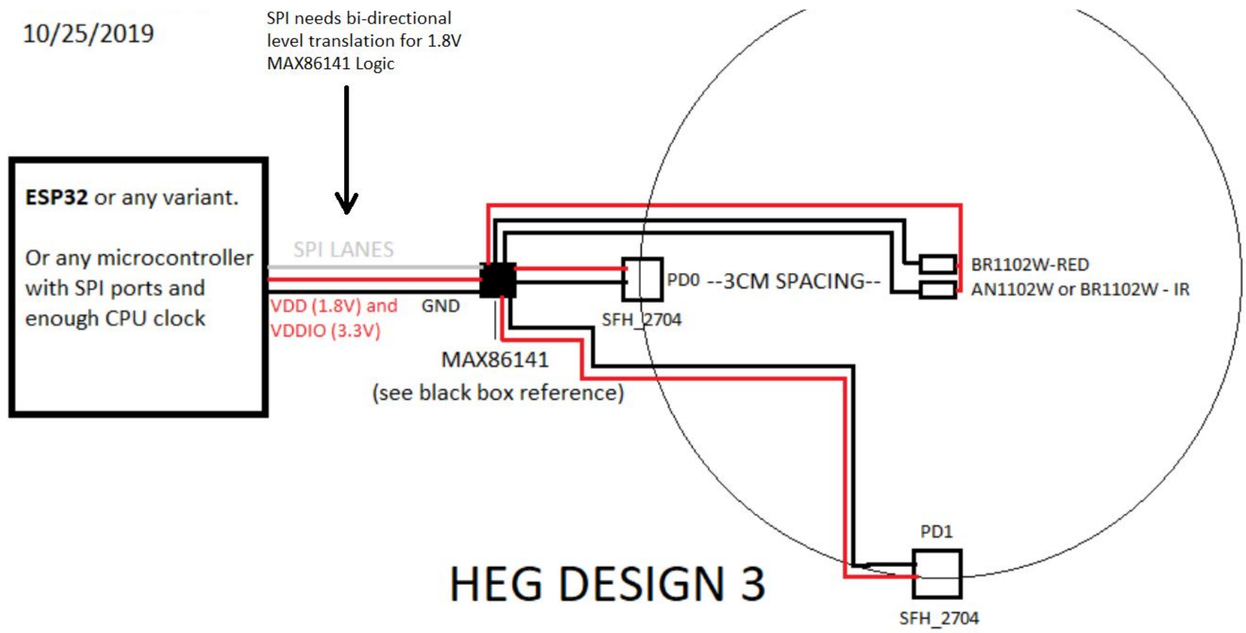
Varied designs (thereby classifying them under the MIT License for open source use):



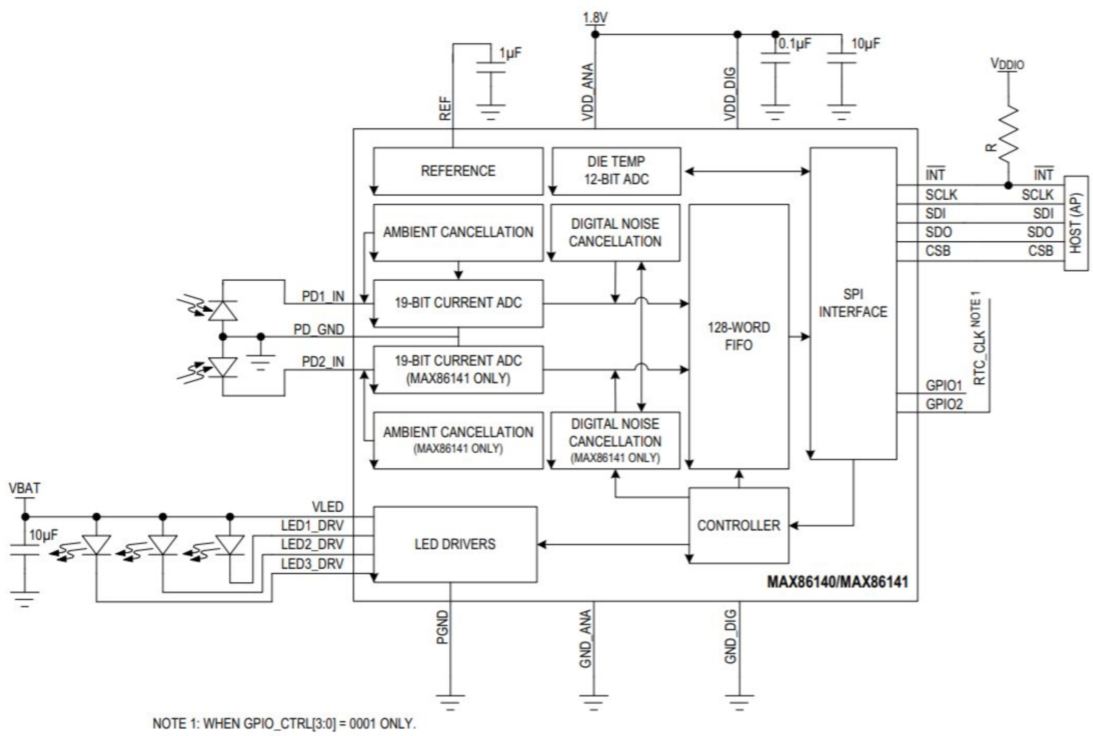
Design 1 as described above, in simplified form. The OPT101 has a built in transimpedance amplifier and the ADS1115 has up to 16X programmable gain.



Experimental Design 2 with a MAX30112, enabling up to 3200sps via I2C. BPW34 is a highly sensitive photodiode. We followed the datasheet recommendations for decoupling capacitors and grounding. Drivers coming soon.



Experimental Design 3 with MAX86141. The wiring follows the 2-sensor recommendations in the datasheet by MAXIM to the T (see below), with our novel sensor spacing and these photodiodes. This allows for 4200 samples per photodiode per second at 18-bit resolution, opening up the possibility of Fast Optical Signal methodologies and at a highly affordable rate. Needs a 1.8v voltage regulator and bi-directional logic translation for 1.8V logic. Drivers coming soon.

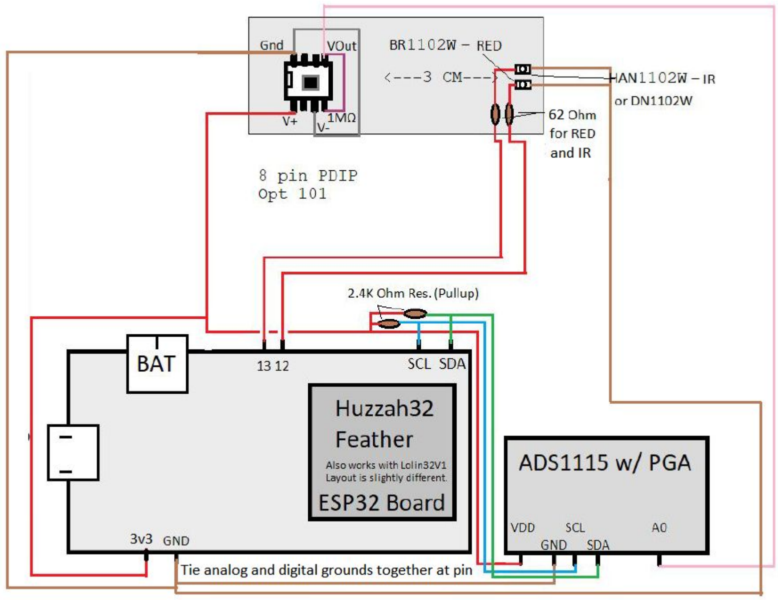


Above is the reference sheet provided by MAXIM, we followed this exactly and included ground planes wherever possible for improved isolation and decoupling. The MAX86141 should be as close to the photodiode site as possible.

As you can see, it’s fairly easy to design these things, the key is finding the best and most affordable parts - which improve year to year. These are a solid foundation to begin from. And yes, I used Paint for these diagrams… but I recommend EAGLE or KiCAD for some of the better PCB design tools.

More design notes on next page...

More detailed view of Design 1, minus the optional GND_ANA to A1 on the ADS1115 (for differential output):



Design notes:

There are several key design ideas to keep in mind when developing the sensor.

1st: The sensor distance tells you roughly how deep of a signal you are reading. You are measuring an arc that is a slice of a field generated by each LED flash, the distance of that arc depending on the distance of the sensor from the photodiodes. The distance limit is based on safe LED intensity as well as tissue absorption, enabling up to about 5cm deep of penetration according to Event Related Optical Signal tests in nIR light penetration. Toomim and Marsh recommend 2.2 to 3.5cm with the LEDs used in these designs according to patent 5995857.

2nd: The analog and digital components need separate ground lines/planes from the sensor to prevent feedback from the LED voltages. The analog output should also be shielded with copper planes to minimize noise.

3rd: The closer you can get the ADC to the signal output the better, movement can generate static and add noise if there is more wire between the ADC and sensor.

4th: You don't need more than 100 samples per second and 16 bits for good signal fidelity. We demonstrated this with a minimum-bar ADS1115, which includes PGA and differential modes to get pretty decent signal. We also recommend the MCP3424, an 18-bit, 240sps sigma-delta ADC which is more than enough for pulse oximetry, and simultaneous sensor data. These are both available as arduino kit-styled components.