Hardware / Firmware Resource Document

## Characterization Hardware

The hardware required for the Characterization Module is COTS, so there are many resources online to diagnose abnormal behavior if it occurs. Outlined below is the hardware setup used for development and testing.

Required Hardware:

Raspberry Pi 3 - Available on Amazon. Though it's not necessary to have the third iteration of the Pi, the CV (Computer Vision) module was written for the Raspberry Pi 3, which features bolstered CPU and hardware specs, speeding up the installation of required hardware and increased performance for CV.

>= 32 GB MicroSD - Available on Amazon. With the Raspbian 3 OS, 32 GB will provide a sufficient amount of memory to handle the OS and packages for OpenCV and other software required for the characterization module.

Any USB camera and Microscope combo - The idea for the camera setup is to get a view of droplets that are are less than 1 mm in diameter. Whether the camera is a USB Microscope in itself or a camera viewing into a microscope is irrelevant. An important thing to note is that the camera should be capable of recording at least 30 FPS (frames per second) for optimal CV processing. The higher the FPS, the lower the chance for error.

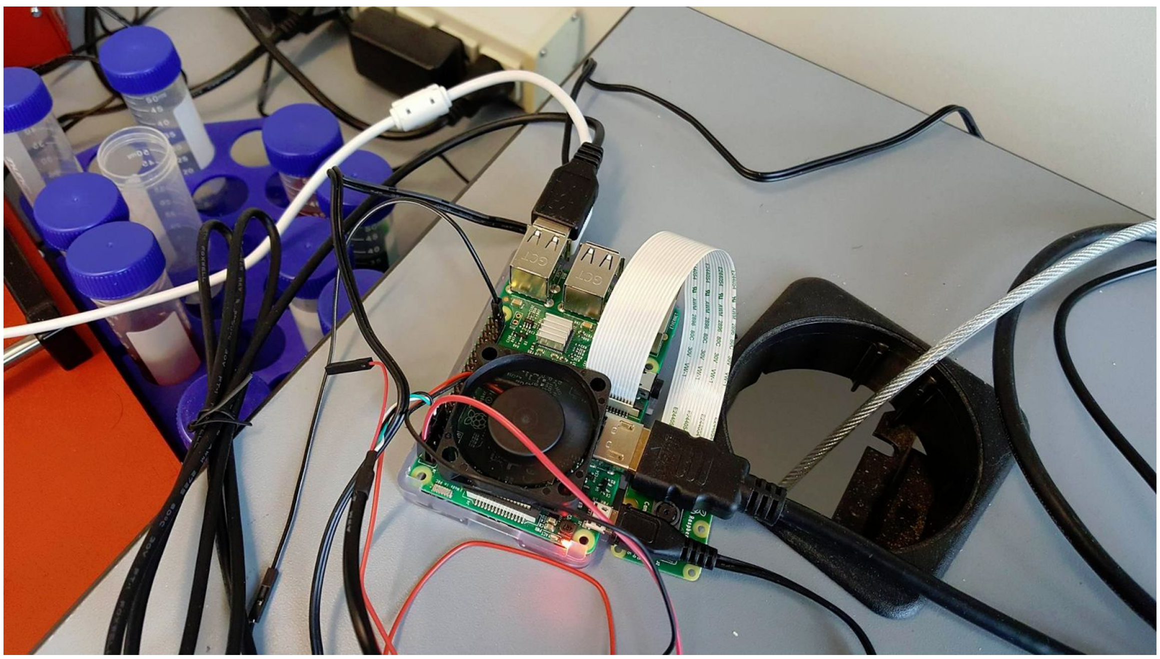
Raspberry Pi UART to USB Serial Cable - Available on Adafruit (https://www.adafruit.com/product/954) . This cable will allow the Raspberry Pi to interact with computers' COM ports without the need for complex kernel-level drivers to be written into the OS. ***If the Raspberry Pi is being powered by the standard 5V USB cable, DO NOT plug in the power wire to the Raspberry Pi's power header.***

Option Hardware (but nice to have):

5V Fan - Available for purchase on Amazon or Sparkfun. Placing the fan on the Pi (specifically above the CPU) will help cool the Pi down and reduce the chances of overheating (and therefore lower performance). Tests have not been executed to determine whether or not the CV stands to benefit from the cooling, but Pi 3's are known to run hotter than the Pi 2.

External Monitor (HDMI connection) - Available for purchase on Amazon, Newegg, or your favorite hardware company. Having a monitor to plug into the Pi provides a simple and direct interface to the Pi for development. Plugging the Monitor into the Pi will display the GUI for the OS and will circumvent the need to SSH or VNC to work on the Pi (but whatever is preferable, really).

Keyboard / Mouse - Available for purchase on Amazon, Newegg, or your favorite hardware company. Along the same lines as the monitor, attaching a keyboard and mouse to the Pi will provide a direct interface to interact with the Pi for development. If extra peripherals are not possible to acquire, interfacing through SSH or VNC are perfectly good options.



A Raspberry Pi with all above hardware connected

Important Notes:

Power On Sequence - Nothing particular, plugging in the 5V MicroUSB to the Pi will turn it on. Allow up to 20 seconds to boot, and watch for the blinking green LED on the Pi to indicate that everything is running smoothly. If this is not the case, consult (https://blog.adafruit.com/2013/02/15/raspberry-pi-status-leds-explained-piday-raspberrypi-raspberry_pi/) for more details.

Power Down Sequence - It is important that the Pi is programmatically shut down before cutting the power. To ensure this occurs, use the <poweroff> or <halt>

commands to turn off the Pi. Do not unplug the Pi until the green LED no longer blinks (should never be lit if the Pi is programmatically off).

Interfacing with the Pi - If the preferred interface with the Pi is ssh or vlc, configurations will need to be set on the Pi to enable these options. By entering <raspi-config> on the command line, a menu will appear with configuration options for the board. By navigating to *Interfaces*, the option to enable ssh, vnc, and other mediums of connections will be available. Enable the desired interface and restart the Pi afterward with <reboot>.

Adafruit Serial Cable - If the serial connection from the Pi to a computer's COM port is not functional, ensure that the SiLabs CP210X chip driver is installed on your computer. Specific set-up instructions for each OS is specified on Adafruit's page here: https://www.adafruit.com/product/954.

## PCR Hardware

Required Materials:

- 1 PCR PCB (printed out)
- 1 Arduino Uno (any)
- 2 thermocouples: https://www.adafruit.com/product/270
- 2 amplifiers: https://www.adafruit.com/product/269
- 1 N Channel MOSFET https://www.sparkfun.com/products/10213
- 1 barrel jack connector https://www.sparkfun.com/products/12748
- 1 10kOhm resistor (any)
- 1 diode (any)
- Breadboard wires (any)
- Female to male pin headers (any)
- Kapton Tape (any)
- Aluminum Insulating Tape (any)
- Nichrome wire http://jacobs-online.biz/nichrome_v_wire.htm

Chip Integration:

With the PCR compatible chip milled out, identify the snakeline path without control ports on the chip. Next, using the nichrome wire, cut out a length of wire that will fit in the path. (You should cut more than you need for ease of manipulating the wire. Bend the wire through the path. This is quite tricky, and you may want to tape down bends you have already done as you move through the path. Cut any excess. Once that wire has been manipulated into the path, solder the ends to two breadboard or soldering compatible wires. These will be the wires inserted into the PCB. Place the end of the top thermocouple (the one connected to the pins marked as top in the PCR_controller.ino code) onto the middle of the chip, close to the nichrome wire, but not touching. Tape the entire side with Kapton tape. Then apply two layers of insulating tape. Next, you can proceed to the normal microfluidic chip steps: applying PDMS and the other side, cleaning and sealing, and application of the control ports and tubes. Finally, tape down the bottom thermocouple to the bottom layer of the chip in the side position as the top thermocouple, just on the other side.

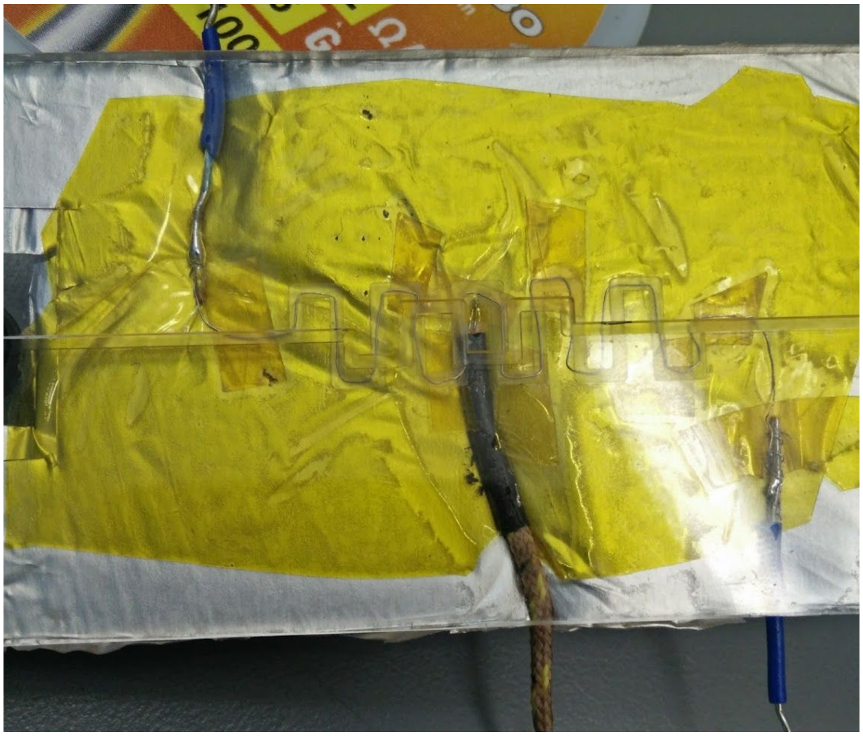
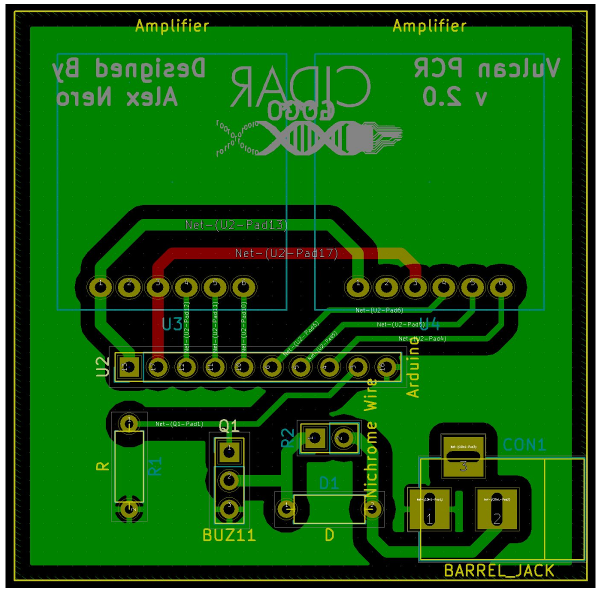


Image of the completed chip without the bottom sensor

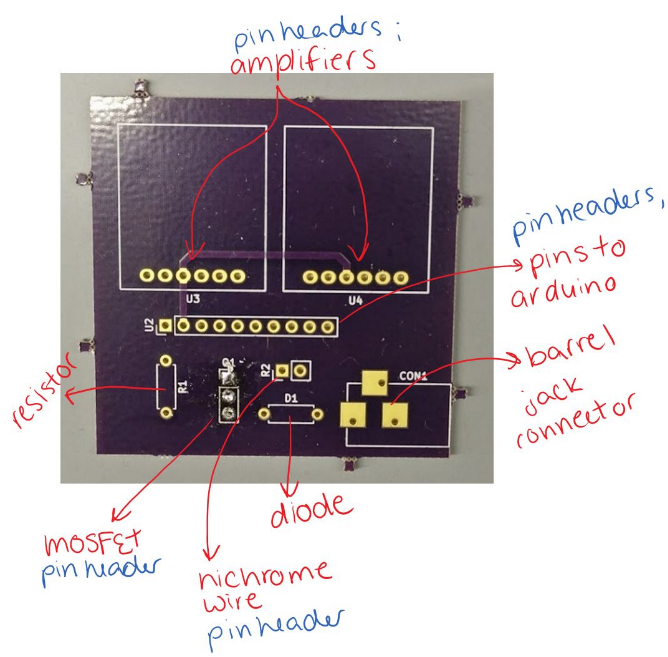
PCB:

Using the KiCad project, either mill out the PCB or send it out to be printed. Team 9 used OSH Park, [https://oshpark.com](https://oshpark.com). (This website will only need the file: PCR.kicad_pcb)




PCB Diagram

With the PCB, solder in a 10kOhm resistor and a diode into the R2 and D1 positions. Ensure the diode is oriented properly. The positive end should be connected to the trac directly connected to the barrel jack. Next, solder in the barrel jack connector. All that is needed is the ground and power. Finally, solder in pin headers to the rest of the circuit. (You may directly solder in the MOSFET as well.)



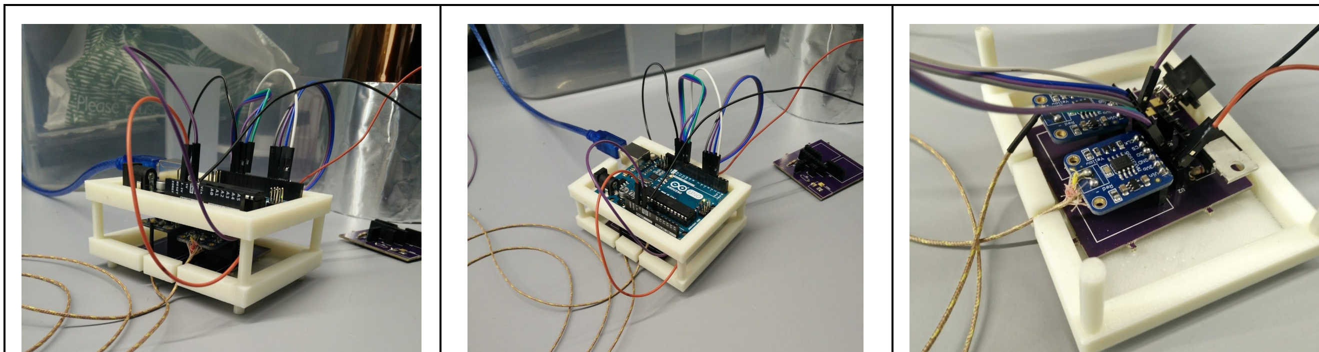

Labels for soldering

Assembly:

Using the pin numbers on the kicad schematic as a guide, insert male to male breadboard wires to pin headers and the other end to the labeled corresponding pins on the Arduino. Solder the thermocouple to the amplifier and solder male to male pin headers to the six pins on the amplifier (comes in kit). Make sure the red and yellow wires of the thermocouple match the red and yellow connections on the amplifier board. Insert the amplifier into the PCB. Insert the MOSFET is it has not been already soldered, and insert the two breadboard wires coming from the nichrome wire embedded in the chip.

3D printed case:

This portion is optional, but provides some organization. Print out the PCBHolder.stl and UnoHolder.stl. Simply connect them by inserting the rods from the PCBHolder into the UnoHolder. Place the Arduino in the Uno Holder and the PCB in the PCB Holder.



Images of PCR Module with 3D casing

With the Arduino connected to the computer, the 3D casing and the PCB, load up the PCR program and the Peripheral Manager program, and the PCR Module is complete.