An Open Platform Microcontrolled-pH Meter

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Hardware. Thermo Scientific Orion 9165BNWP Combination Sure-Flow pH electrodes were used in this laboratory, but any combination pH electrode with a BNC fitting should work. The *Excel* template has an offset to compensate for differences in the resistance across the pH glass membrane.

The *Eagle* file (mbedphv1.brd) necessary for ordering the PCB board from Sunstone (www.sunstone.com) is provided in the Supplemental Material. The latest revisions to the PCB will be available from KISScientific Instruments (www.kissinstruments.com).

Software. The supporting material contains necessary files, and updates will be supplied on-line. Updates for the *Excel* template for calibrating and measuring pH (pHv100.xls) will be posted at www.kissinstruments.com; and updates for *mbed* programs (pH-v12_LPC1768.bin) will be posted at https://developer.mbed.org/users/KISScientific/code/. The *mbed* USB driver is available at https://developer.mbed.org/handbook/Windows-serial-configuration.

PCB assembly. Instruments and materials needed for this exercise are listed in Table 1. The surface mount components, listed in Table 2, were obtained from DigiKey or Mouser. Students require fine tipped tweezers to place components on the PCB board. A single solder station and reflow oven can be used for an entire lab section. The reflow oven listed in the table has a default temperature profile program for the solder paste listed in the table. Reflow ovens are temperature-controlled infrared heaters. We selected this oven based on price, and it is unlikely that this specific model is required. The T-962 is easy to use and inexpensive. A multimeter is needed to check resistances and voltages on the PCB board. A digital oscilloscope, which is optional, is useful in trouble shooting boards.

Table 1. Instruments and materials needed to assemble PCB

Instrument	Part	Type	Source
Solder station	YiHua 968 DB	YiHua	Amazon.com
Infrared IC heater	T-962	Puhui Technology (Taian)	www.tech168.cn
Solder paste	SAC 305	ChipQuik	www.chipquik.com
Multimeter	Any type/model will suffice		

Table 2. Components needed for PCB				
Component	**Type**	**Part**	**Source**	**Quantity**
Circuit Board	See supplemental material		Sunstone	1
Microcontroller	Mbed LPC1768	OM11043	DigiKey	1
Power Supply	Murata	580-MEJ1D0512SC	DigiKey	1
Op Amp	TL082	497-2212-1-ND	DigiKey	1
Resistor	200K	CR0603-JW-204GLFCT-ND	DigiKey	1
Resistor	100K	CR0603-JW-104GLFCT-ND	DigiKey	3
Resistor	10	CR0603-JW-103GLFCT-ND	DigiKey	3
Resistor	1	CR0603-JW-102GLFCT-ND	DigiKey	3
Transistor	NPN	MMBT2222A-FDICT-ND	DigiKey	1
Capacitor	1uF	490-1543-1-ND	DigiKey	1
BNC	Molex	WM5514-ND	DigiKey	1
Cable/Headers	3" female cables	920-0005-01	SchmartBoard	1
Enclosure	3" x 2" x 1"	2701801	Radio Shack	1
IC Perf Board	6" x 8"	2761396	Radio Shack	1

Instructions for assembling the board are given in the student handout. After assembling the boards, make sure there are no solder bridges between pads (see Figure 1). Solder bridges are common when too much solder paste is applied to the board, and they are easily repaired (see instructional videos on www.kissinstruments.com). A solder bridge forms an electrical connection between pads on the circuit board and are usually visible without magnification. Another way to check for problems is to measure the resistance of all resistors using a multimeter.

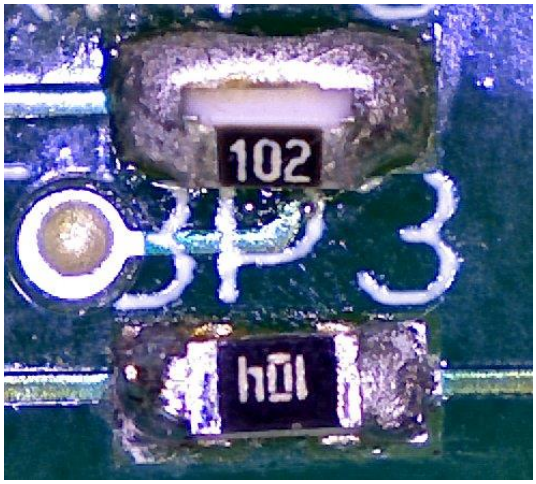


Figure 1. Top resistor illustrates solder bridge.

Power up the board using the microcontroller and ensure that there is power to the operational amplifier (–12V and pin 4, +12V at pin 8). **Make sure that there is no flux between pins 3 and 4.** Any residue between these pins will cause problems.

Enclosure. An enclosure, as listed in Table 2, can be used to protect the PCB from damage. A ¼" hole was drilled into one side of the enclosure to accommodate the BNC connector. The PCB was secured in place using the nut supplied with the threaded BNC connector (see Fig. 2).

Figure 2. Assembled PCB.

A new cover was constructed from perforated circuit board. A cover was cut to size (2” x 3”), and four holes were drilled into it, using the original enclosure lid as a template. Next, the *mbed* microcontroller was fed through the perforated board, and female jumper cables were attached to pin 1 (GND), pin 15 (AnalogIn, Signal input), pin 18 (AnalogOut, Offset), pin 39 (5V), and pin 40 (3.3V). The enclosure, cover, and PCB are illustrated in the Fig. 3. The microcontroller pin configuration is found on the *mbed* website: (https://developer.mbed.org/platforms/mbed-LPC1768).

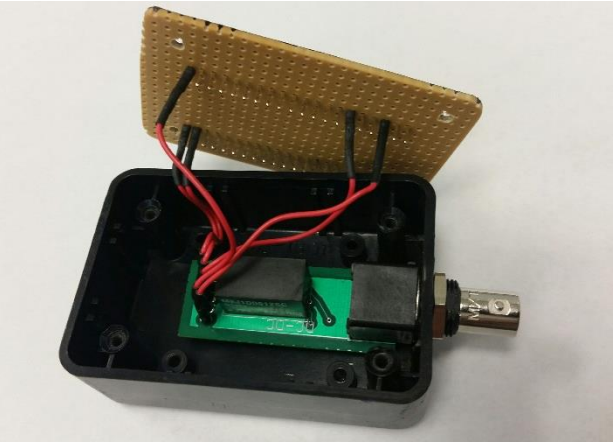
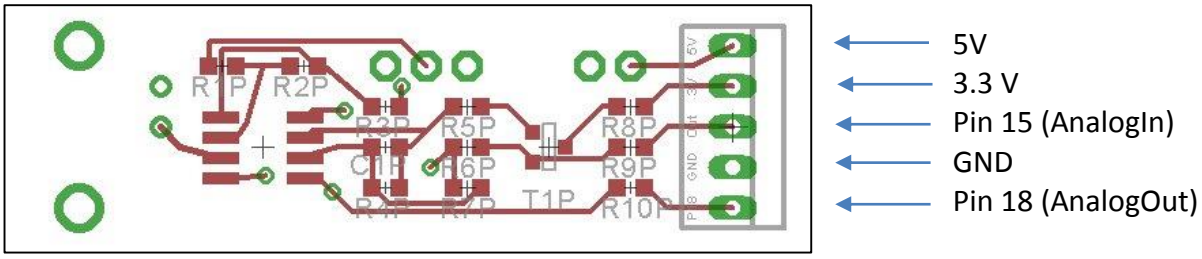


Figure 3. Assembled board in gadget box.

The other end of the jumper cables was attached to the appropriate header on the PCB as illustrated below:



It is critical that the jumper cables are attached to the correct pins in order for the pH meter to work!