Experiment A9
Practical Implementation of Sensors
Procedure

Deliverables: Checked lab notebook, printed plots with captions

Overview
In this laboratory exercise, you will examine the practical use and calibration of several sensors in a couple of everyday devices such as a popular party game and a Play Station 3 game consol. These sensors include an RTD, thermistor, photodiode, and strain gauges. Data sheets for each of these sensors can be found on the course website. Various signal processors for the sensors will be used, including the sensor interface box(SIB), which has a power supply and digital voltmeter for the various transducers. The course website has links to videos demonstrating the sensor and SIB.

Part I: Beerless Pong
Single-handedly responsible for the loss of countless engineers to another "unnamed" college, beerless pong is one of the most widely played games among college students today. However, despite its mass appeal the game has not changed much over the past two decades… until now. Using a cantilever mass measurement system based on strain gages and a Wheatstone bridge, you will perform a proof-of-concept experiment for a Beer Pong 2.0 system, specifically demonstrating a new key design feature, automatic scoring.

Setup and Data Acquisition

1. Sketch a schematic of the cantilever beam setup in your lab notebook and write a brief description of the apparatus.

2. The cantilever apparatus is shown in Figure 1. It consists of a cantilever beam affixed with strain gages, an amplifier, and a integrated voltmeter that reads the output voltage from the bridge. The bridge has already been configured as a full bridge in deflection mode. To set the input voltage to the Wheatstone bridge, set the "Signal Select" button to "Bridge Excite". The red LED display should indicate now the bridge excitation voltage. Set it to 5 V using the turning knob in the upper left corner. To read the bridge output voltage, set the "Signal Select" button to "Amplifier Out". The LED display now shows the output bridge voltage, which has been amplified by an operational amplifier that is inside the voltmeter box.

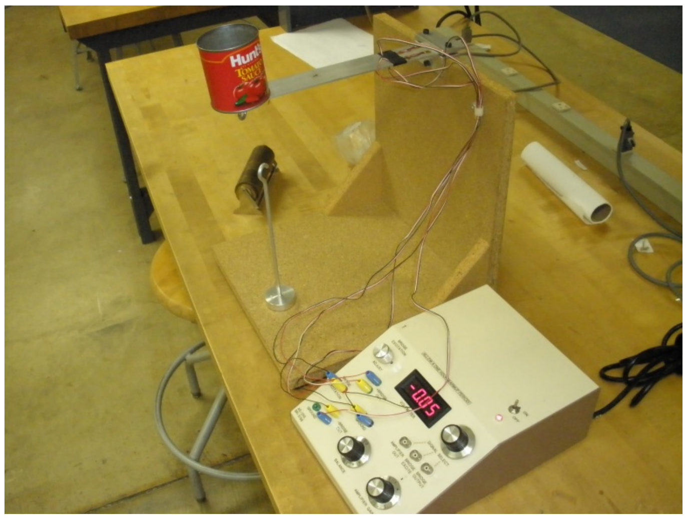


Figure 1 - Cantilever beam and Wheatstone bridge apparatus

3. Balance the Wheatstone bridge so that the output voltage is ~0 V. Make sure that there is no weight attached to the beam. The range of measured masses should be up to 50 g. Take your calibration weights and place 50 g in the Red Dixie Cup. Then change the amplification factor so that the output voltage is ~2 V.

4. Remove the weights and balance the Wheatstone bridge again. At this point, the settings on the voltmeter should not be modified (the amplification, the bridge balance resistance, or the input voltage) because the calibration will only be valid for these settings.

5. Calibrate the force balance by sequentially adding known weights and recording the resultant voltage in a table in your lab notebook. Because ping-pong balls are light, it is suggested to start at no weight and increase in small increments (5-10 g). At least 5 data points are required to generate the calibration curve.

6. Sequentially add ping-pong balls to the cup while recording the resultant voltage after adding each ball in another table in your lab notebook. Using this data and the actual weight (published value) of one ping-pong ball, one can estimate the accuracy of the measurement system.

Part II: Signal Amplification Study – Beerless Pong 3.0

Recall that a measurement device that measures mass served as inspiration for our Beer Pong 2.0 system. However, while this approach would be sufficient for automatic scoring, it does not provide a mechanism for team recognition. So for Beer Pong 3.0, we will take an optical approach. Rather than attempting to measure the mass, we will measure whether the balls actually make it into the cup using the photoconductive sensor. Further, we will try to distinguish between teams using red balls and those using blue balls.

The photoconductive sensor uses a semi-conductor whose resistance changes upon exposure to light. Importantly, though, they respond differently to different parts of the electromagnetic spectrum – the photocells used in this lab are more sensitive in the visible spectrum as opposed to the infrared and ultraviolet spectrums. Referring to the photocell data sheet, it is clear that a CdS photocell is more sensitive for certain wavelengths than others. Since red and blue are at different wavelengths, a CdS photocell should be able to distinguish between them when they are in the cup.

NOTE: The Op-Amp box is powered by a V_{cc} = 5 V. The maximum amplifier output 4.9 V. Any theoretical output greater than 4.9 V will be clipped to 4.9 V. Notify the TA if the output voltage is clipped.

Setup and Data Acquisition

1. For the next four instructions, refer to Figure 2. Be sure to record BOTH sensor interface box channels when making measurements. Use a descriptive label for both channels (voltages) in your lab notebook.

2. Connect the photocell to the Sensor Interface Box. Recall from the YouTube tutorials that all the sensors in this lab require three things: power, signal and ground. The photocell sensor uses the red wire for power(5V), blue wire for signal and black for ground

3. Connect the black wire on the red dual Op-Amp box (channel A) to GND on the sensor interface box.

4. Connect the red/white wire on the Op-Amp box (channel A) to +5V on the sensor interface box.

5. Connect the output of the sensor interface box to the input of channel A(the remaining solid color wire).

6. Connect the output of the Op-Amp box (stripe color wire) to the input of the second channel of the sensor interface box.

7. Make sure the dual Op-Amp box gain switch is set to #2, which gives a gain of G = 10.

8. Measure the dark and light voltage by covering the sensor with your finger and holding the sensor to the overhead light, respectively. Record these values in your lab notebook. This is

essentially a two point calibration.

9. Tape the photocell inside the cup (about midway) facing the bottom of the cup and record a baseline reading. Be sure not to move the cup too much, as a subtle change in lighting will affect the data.

10. Insert the red ball and record a baseline voltage in your lab notebook. Repeat for the blue ball. Note that these measurements are not too different and that our signal needs to be conditioned to make these two readings more distinguishable.

11. In your lab notebook, record the base photocell readings and amplified readings for the following cases: no ball in cup, red ball in cup, white ball in cup and blue ball in cup.

(Note: Experience has taught us that a gain on the order of 10 is necessary to see a difference in the red and blue signals.)

Switch Setting	Gain
0	100.
1	20
2	10
3	7
4	5
5	4.2
6	3.4
7	3
8	2.0
9	1.9

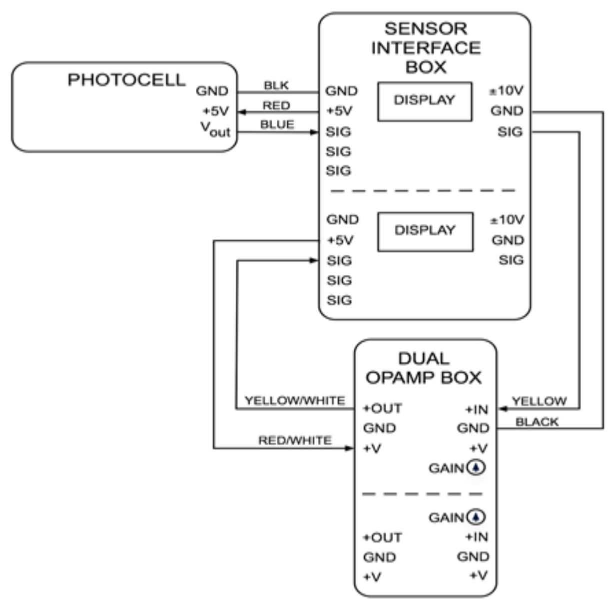


Figure 2 - Wiring Diagram of photocell and red dual operational amplifier box.

Part III: PS3 Hot Shot

In the fast paced industry of console gaming, advanced graphics are pushing hardware to design limits. The result is increased heat production and shorter product lifecycle. You will record the internal temperature, while utilizing the photocell to simultaneously demonstrating proof-of-concept for a fan speed measurement system.

You will need two LabQuests, 1 and 2, for this experiment. LabQuest 1 is the original aqua colored one. LabQuest 2 is the black rectangular one. There is a stylus on the bottom of both LabQuests.

A. Temperature

Recall from the YouTube tutorials that all of the sensors in this lab require 3 things: 1) Power (Red), 2) Ground (Black), and 3) Signal (Blue), where on the LabQuest Connector, orange is power (5V), black is ground and red is the signal. You will need to use the male-to-male connectors (color of the connector is irrelevant) as shown in Fig. 7.

1. Open the lid to the PS3, place the RTD inside the PS3 between the power supply unit and blue ray player as shown in Fig. 5. The power supply is on the left. The blue ray player is on the right. The RTD uses convection to measure the internal temperature of the PS3. The thermistor has already been placed directly on the CPU heat sink and will serve as a warning if core temperature reaches critical levels. The thermistor uses conduction to measure CPU temperature.

2. Sketch a schematic of the PS3 depicting the location of the various sensors.

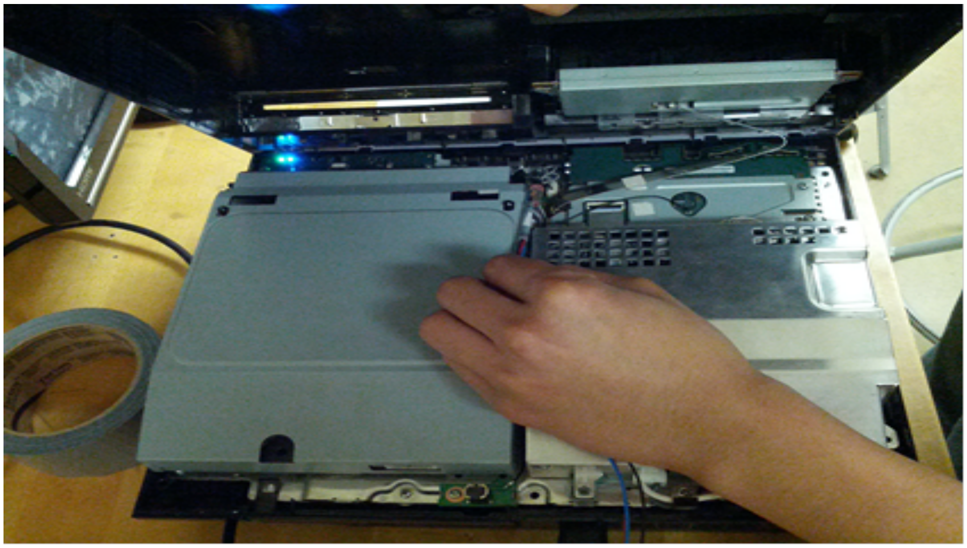
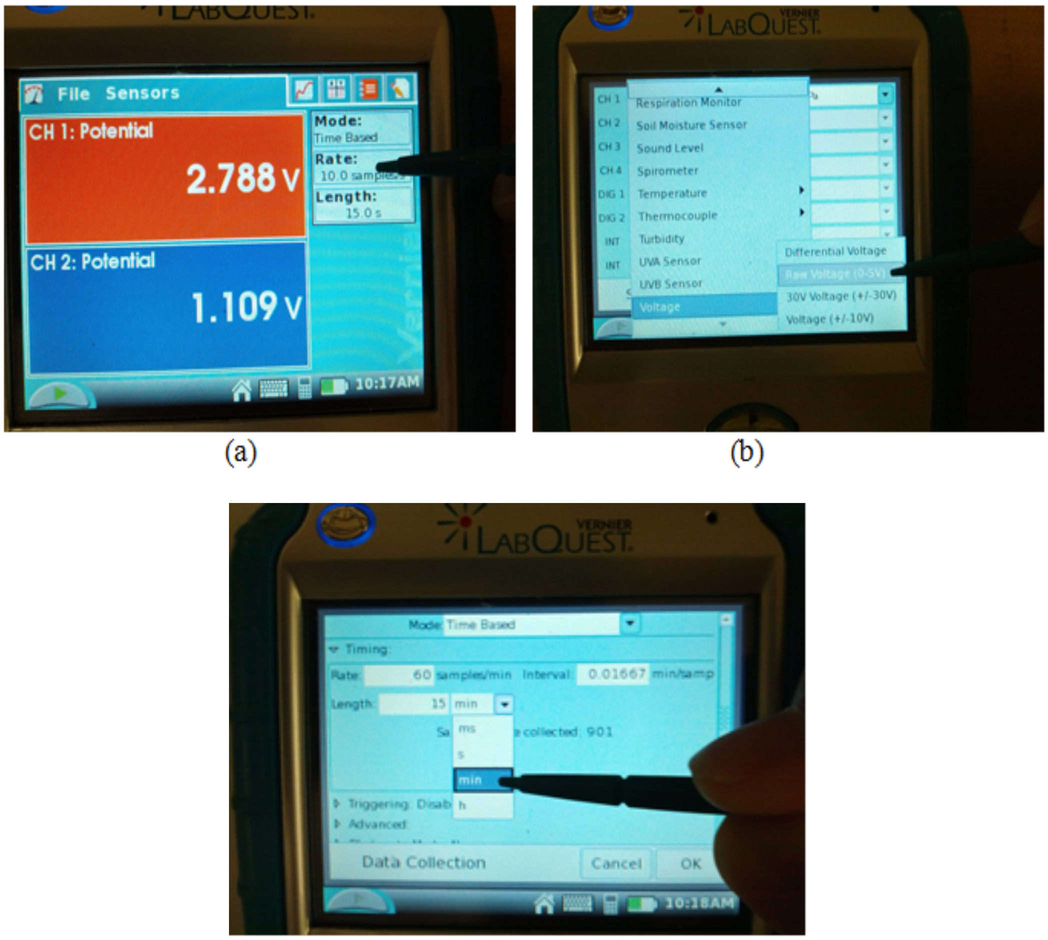


Figure 5 - Placement of the RTD in the PS3.

3. Replace PS3 cover.

4. Configure the older aqua colored LabQuest for two sensor channels (Channel 1 and Channel 2). Each channel should be configured for **Raw Voltage [0-5V]** by tapping the **Sensors** tab (Figure 6a) at the top of the screen, then (Figure 6b) **Sensor Setup** then **Voltage** on the drop down menus. Finally tap **OK.** Tap the **Rate** window (Figure 6a) on the right side of the screen to access the "Data Collection" window. This will allow you to set the sample rate and duration. Set the data acquisition rate to **60 samples/min for 10 min**. (Figure 6c)



(a) (b)

(c)

Figure 6 – (a) Set the sampling frequency in the LabQuest, (b) configure the channels, and (c) set the sampling duration.

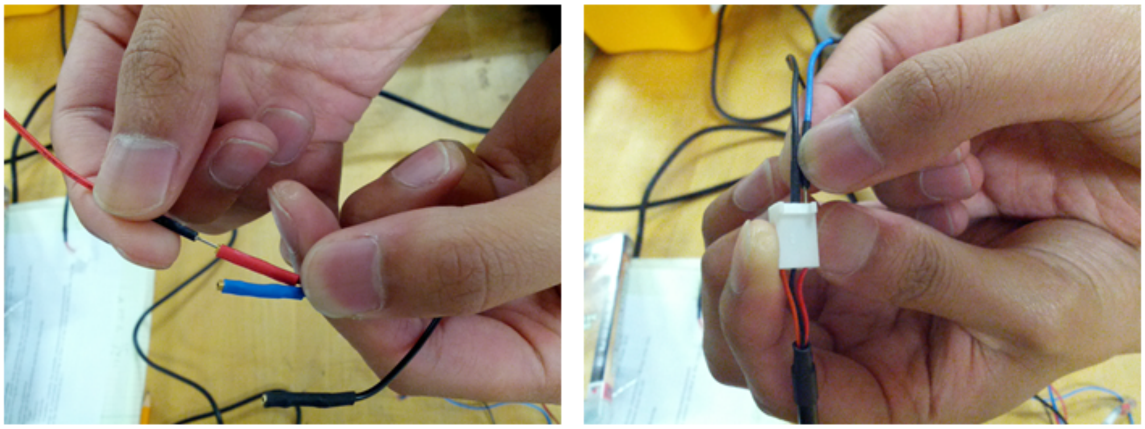


Figure 7 - Procedure to connect sensor wires to male-to-male connector.

5. As shown in Fig. 7, connect the Thermistor (wires labeled "TH" coming from the PS3) to Labquest 1, Channel 1.

6. As shown in Fig. 8, connect RTD to the sensor interface box (SIB) Channel 2.

7. Connect output of SIB Channel 2 to Red Op-Amp Box. Use solid color wires. Red is power. Black is ground. Yellow is signal.

8. Connect output of the Red Op-Amp Box (striped wires) to the Sensor Interface Box in Channel 1.

9. Connect output of the Sensor Interface Box Channel 1 to Labquest 1 Channel 2. Refer to Appendix B.

10. Sketch wiring diagrams for these circuits in your lab notebook.

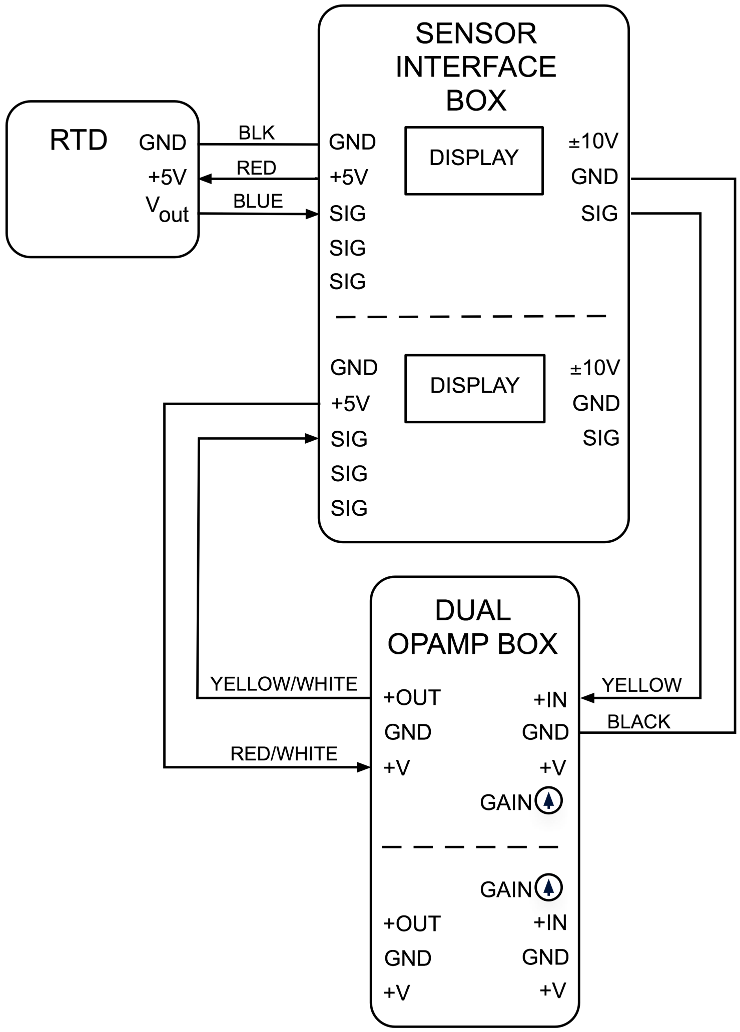


Figure 8 - Wiring diagram for RTD and Red op-amp box.

Switch Setting	Gain
0	100.
1	20
2	10
3	7
4	5
5	4.2
6	3.4
7	3
8	2.0
9	1.9

Figure 9 - Switch settings for ROAB

11. Set Gain on the Op-Amp Box to switch setting #3, which corresponds to a gain of 7. Refer to Figure 9.

12. Then connect the LabQuest cable to the LabQuest as shown in Fig. 10.

13. Record Gain of the Op-Amp in your lab notebook. **Caution: Do not confuse the switch setting # with the actual gain**.

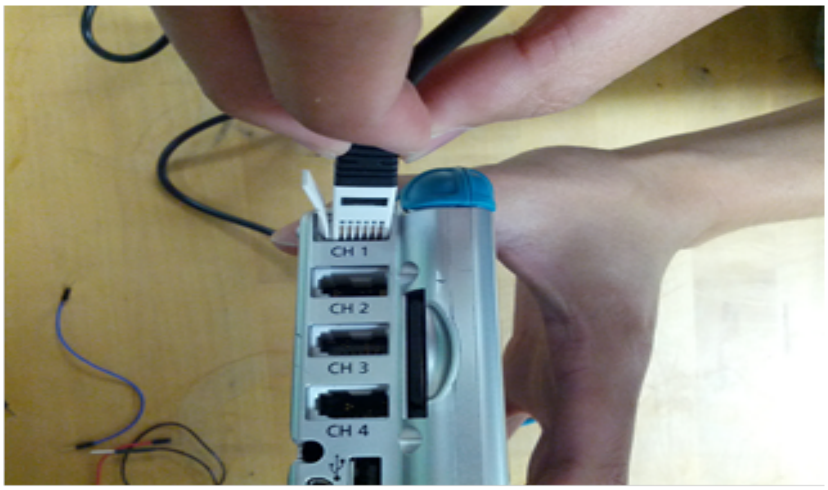


Figure 10 - Procedure to connect LabQuest cable to the LabQuest.

B. Photocell

The photocell has already been installed in the PS3. It's mounted directly above the fan, pointing down. Refer to Appendix B for wiring diagram.

1. Connect the Photocell to LabQuest 2, Cannel 1. Configure Channel 1 for **Raw Voltage [0-5]** by tapping the **Sensors** tab(Figure 6a) at the top of the screen, then (Figure 6b) **Sensor Setup** then **Voltage** on the drop down menus. Finally tap **OK**. Tap the **Rate** window (Figure 6a) on the right side of the screen to access the "Data Collection" window. This will allow you to set the sample rate and duration. Set the data acquisition rate to **20,000 samples/sec for 0.1 sec**.

2. Align the laser and photocell and fix the position with the clamp. The final setup should look like Figure 11.

3. Start a new run (click the file cabinet icon on the graph screen) every time you hear the fan speed increase while noting the approximate starting time at which this occurs.

4. Connect Laser to bench power supply. Red to Red. Black to Black.

5. Turn on Power Supply. Set output Voltage to 6V.

6. Try to adjust the laser such that the photocell output is greater than 0.3V.

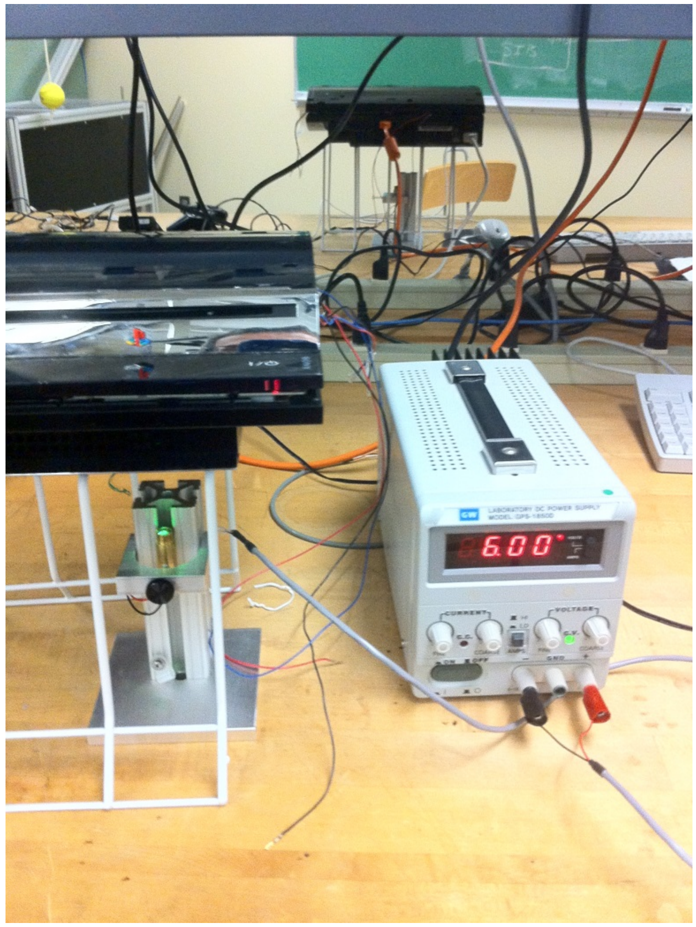


Figure 11 - Clamping and alignment of laser for photocell measurements of fan speed.

C. The PS3

Caution: You will be operating the PS3 at temperatures near the upper design limit, failure to follow these steps correctly will damage the console!

1. **DO NOT POWER ON THE PS3 UNTIL A TA HAS CHECKED YOUR SET-UP.**

2. Power on the PS3 and load the game.

3. Start data acquisition simultaneously on both LabQuests at mission start. Once started, LabQuest 1 (heat sensors) will run unattended until the experiment is completed. LabQuest 2 (photocell) will sample data for 1 seconds then stop. When the PS3 fan increases speed, tap the file cabinet icon in the upper right of the screen. When the fan speed increases next tap play (green arrow). This will start sampling for the next run. Power off the unit either at 10 min. or when the core temperature reaches 170 degrees F, whichever happens first. There should be 6 - 7 fan speed changes.

4. When data acquisition is complete, save your data on each LabQuest by tapping **FILE** (upper left corner) then **SAVE**. Use the appropriate file names:

(Eg.1) staXYYYZZZPC, (Eg. 2) staXYYYZZZTH

File Name Key
- X – Station number; eg. 2
- YYY – Day of week; eg. Thu
- ZZZ – Time of class; eg. 3:30
- PC – Photocell
- TH – Thermistor

NOTE: **Save** will create a file with an extension of QMBL. QMBL is a proprietary format that can be read by Logger Lite. Load the QMBL files into Logger Lite by clicking **File,** then **LabQuest Browser** to find the file, and then use **File Export** to change to CSV format. MatLab can read a CSV file.

5. Write down the name of the file in your lab notebook.

6. Tap **File New** on the LabQuest.

7. Sign the sheet of paper with your **STATION *NUMBER***, name and email address. Please disconnect all wires and connectors and replace them as they were found for the next lab session.

Fan Speed: There are **15 blades** on the fan of the PS3. As each blade eclipses the laser beam, the photocell voltage will drop. Plot the response of the photocell as a function of time. From the oscillations in the signal, deduce the speed of the fan in RPMs.

Temperature: You must use the RTD and Thermistor calibration sheet from the lab webpage to convert your raw voltages to temperatures.

Deliverables – Create plots listed below. Save the plots as PDFs, import them into either Microsoft Word or LaTeX, and add an intelligent, concise caption. Make sure the axes are clearly labeled with units. Plots with multiple data sets on them should have a legend. **Additionally, write a paragraph for each plot (separate from the caption) describing what you did in lab to obtain the plot.**

1. A plot of the calibration data (mass as a function of voltage) for the cantilever beam with the linear equation of best fit.

2. Make plot of measured mass vs. the discrete number of ping pong balls. (Use your calibration equation from deliverable #1 to convert the voltages to mass.) Apply a linear curve fit to the data and use the slope to estimate the mass of a single ping pong ball. Plot the curve fit on top of the data as a continuous line.

3. A table containing the raw photocell voltages and amplified voltages for the different colored balls and the empty cup.

4. For one of the PS3 fan speed measurements, make a plot of the photocell output voltage vs. time for several periods of oscillation. Draw lines on the graph to indicate one full period of oscillation. In your paragraph, explain how this was used to determine the fan speed.

5. A single plot containing *both* the temperature vs. time for both the RTD and thermistor (on the left scale) *and* the fan speed in RPMs vs. time (on the right scale). Use either the ‘plotyy’ or ‘yyaxis’ command in MATLAB to do this.

   NOTE: You must use the RTD and Thermistor calibration sheet from the lab webpage to convert your voltages to temperatures.

   NOTE: The fundamental frequency of the photocell output is essentially the “blade passage rate”, and there are **15 blades** on the fan of the PS3.

Suggested Talking Points – Please address the following questions in your paragraphs.

- Estimate the relative error of your measurement in the mass vs. number of ping pong balls. What does this suggest if this configuration were used in the automatic scoring feature on the beer pong 2.0 system? (Would this feature work? Does this signal need amplification? Is the system sufficiently sensitive? Is the calibration sufficient?)

- Qualitatively discuss the relationship between the temperature and fan speed. In particular, why did the engineers at Sony, design the PS3 with variable fan speeds?

- Look up the processor specifications for the PS3. How much heat (in watts) does the processor typically produce?

Appendix A

Equipment

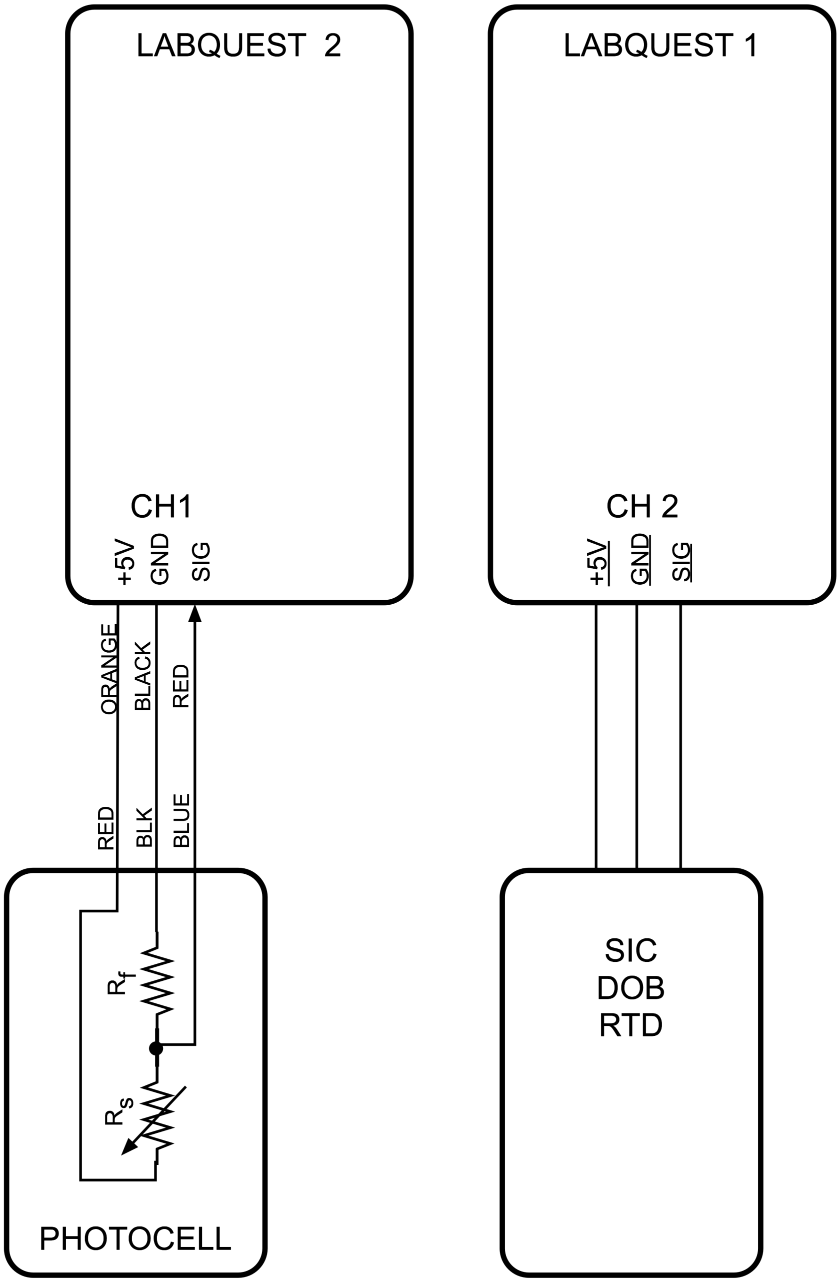
Beerless Pong

- Cantilever Apparatus: (includes mounted strain gages with wire leads, an amplifier, and an integrated voltmeter, configured to read output voltage from full Wheatstone Bridge in deflection mode
- 10 - Ping Pong Balls: (both white, dark blue and colored)
- 1 g – 50g slotted weight set
- Pill bottle with 1 g and 2 g weights
- Sensor Interface Box (SIB) w/ 9V battery and 9V power supply
- 1 roll scotch tape on counter
- Red opamp box with 2 sets of leads
- photocell
- Gray extension cable for photocell

PS3 Hot Shots

- PS3 Hot Shot: (Thermistor w/ wire leads already mounted in unit heat sink; Photocell w/ wire leads already mounted directly above fan) (female end connectors)
- Orange HDMI Video cord, 6' length(from PS3 to monitor)
- PS3 controller w/ white extension cable, 6' length(from controller to PS3)
- White wire support Rack(supports PS3 over laser assembly)
- LabQuest 1 w/stylus: aqua color, w/ DC Power Supply
- LabQuest 2 w/stylus: black color, w/ DC Power Supply
- LabQuest connector cable w/ 3-wire leads(female connector ends) (Qty. 3)
- RTD Sensor w/3-wire leads(female connectors)
- RTD Sensor 3–wire Extension Cable, 24 AWG – 18" length(male to female connector ends)
- Sensor Interface Box (SIB), w/ 9V battery and 9V power supply
- SIB cable w/3 – prong plastic-snap connector to 3-wire leads(male connectors); (Qty. 2)
- Red -Amp Box
- Set of 3 - Leads (12"- red, yellow , black)(3 – prong plastic-snap connector to 3-wire leads(female end connector – for Red Op-Amp Box)
- Set of 3 - Leads (12"- red and white striped, yellow and white striped , black and white striped)(3 – prong plastic-snap connector to 3-wire leads(female end connector– for Red Op-Amp Box)
- Laser pointer w/ 24" cable lead ending in 1 black and 1 red (m/f)banana fitting
- 80/20 - Laser Clamp Stand w/ aluminum slide bracket and plastic mounting screw
- GW Power Supply GPS – 1850D – used to supply power for laser
- USB to USB cord – 4' length(data from Labquest to computer)
- Stopwatch

Appendix B


LABQUEST 2
LABQUEST 1
CH1
+5V
GND
SIG
CH 2
+5V
GND
SIG
ORANGE
BLACK
RED
RED
BLK
BLUE
Rf
Rs
PHOTOCELL
SIC
DOB
RTD