Life Check: A Monitoring System for Patients Under Light Anesthesia

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I. Goal

The goal of this project was to design and develop a system which could be used to measure a biosignal and provide physiological information to clinicians.

II. Concept Development

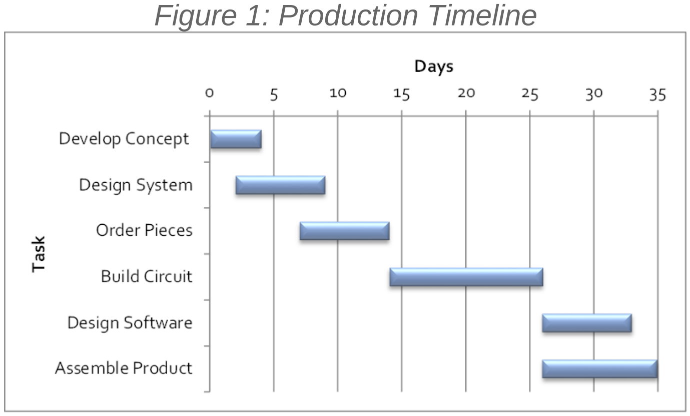
Our group decided to work with an anesthesiologist to develop a tool which is not currently available in the operating room. Dr. Mark Pinosky expressed a desire for an interactive tool to monitor patient alertness for patients under light sedation. After deciding to develop a tool to monitor patient alertness, we assessed the current methods used to monitor patients under light anesthesia. We discovered that airway, breathing, and circulation are monitored using pulse oximeters, electrocardiographs, and airway pressure monitors, but there is no standard method of monitoring awareness.

We discussed several ways to monitor patient alertness and ultimately decided to develop a handheld pressure sensor system. This system would include a hand held pressure sensor which is hooked up to a monitoring system with light and sound indicators. When the system was running, the patient would be instructed to squeeze a ball when they hear an audible noise. If the patient doesn't squeeze the ball within the allotted time period or if they do not squeeze the ball hard enough, an alarm would be sounded to alert the doctor of the need to reduce the rate of infusion of sedative.

With a clear outline of what we wanted to accomplish, we were able to develop a production timeline and proceed with device development.

III. Production Timeline

Figure 1: Production Timeline



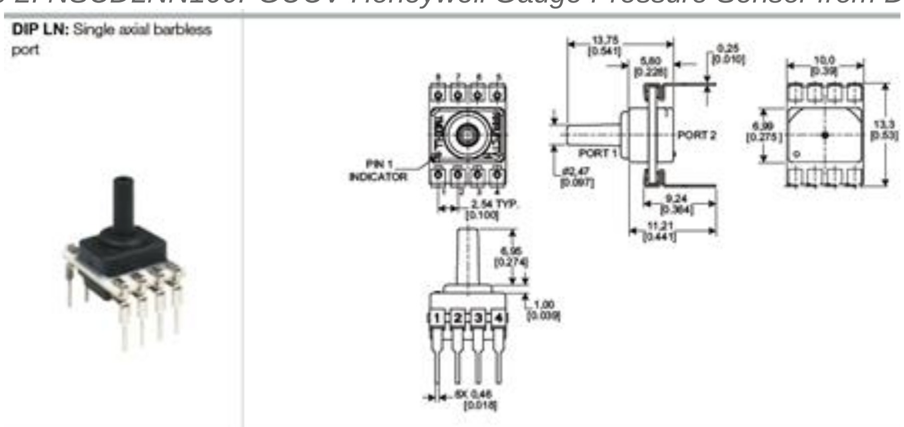
For this project, we were allotted only a month to produce a final product, so we decided to divide our time into six categories: concept development, system design, order pieces, circuit construction, software design, and product assembly. As shown in Figure 1 above, several categories overlapped slightly. During the circuit construction stage, we tested several circuits on a breadboard to ensure our design was the most effective and experienced much difficulty in getting the pressure sensor to produce readable voltage changes. Thus, the circuit construction stage took the longest to complete. Significant time was spent writing the software to not only control the LED indicators and to produce the different alert sounds, but to also read and analyze the input signals from the circuit board. As soon as this was complete, we were able to assemble the final product.

IV. Pressure Sensor

After deciding to develop a handheld pressure sensor, we consulted with Devin Hubbard about potential ways to develop this device. Initially, we looked into piezoresistive strain gauge sensors, load cells, gauge pressure sensors, and optical sensors. We decided against the strain gauge sensor because it would require developing a device to direct all of the force on the ball in a single direction. Using load cells seemed like a simpler option, but it would require money beyond the original budget as well as altering our original design by changing the pressure ball sensor to something flat like a button. Using the air pressure in a sealed ball seemed ideal, so we decided to use a gauge pressure sensor. We used optical sensors in a previous biomedical instrumentation lab, so we decided to reserve optical sensors as a backup sensor option if we could not get the gauge pressure sensor to work. The optical sensors would be blocked as an opaque plunger moved past them in an airtight chamber that provided resistance to assess the strength of pressure applied to the plunger.

We searched Digikey for the gauge pressure sensors available and decided to order a Honeywell 'TrueStability' gauge pressure sensor, part NSCDLNN100PGUCV. This sensor had an extrude which looked like it would be ideal for adding tubing to. This pressure sensor was also rated to measure up to 100 PSI. To determine the necessary PSI for our application, we used ranges of pressure that we were familiar with. Road bikes have a maximum of 80 to 120 PSI, and the internal pressure of a tire is greater than that created in our device by a human grip. Based off of that information, we selected the 100 PSI sensor. Figure 2 below shows a diagram of the sensor and its schematics.

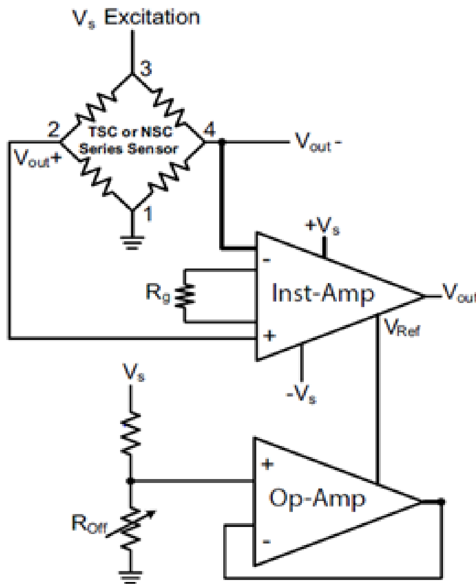
Figure 2: NSCDLNN100PGUCV Honeywell Gauge Pressure Sensor from Digikey



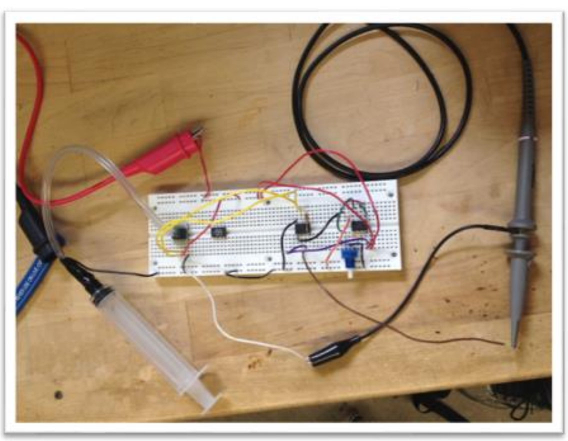
V. Circuit Development

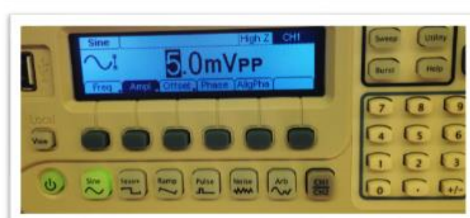
Initially, we used the circuit diagram from the datasheet with the sensor. This circuit diagram used the sensor, an instrumentation amplifier, and a voltage divider (*see Figure 3 below)*. The instrumentation amplifier IC used in this circuit was an INA221. We used a gain resistor, R_g of 200Ω. The voltage divider was built using a single supply operational amplifier, LM358. Initially, we tested the instrumentation amplifier and voltage divider with an input from the function generator. We tweaked the output until we got a good amplification on the output. To test the pressure sensor, we connected a stretch of Tygon tubing to the sensor, and connected a syringe full of air to the other end of the tubing. When we tested the pressure sensor with the voltage divider and the instrumentation amplifier, we did not obtain the signal we desired. After adjusting multiple components of the circuit and ensuring we had connected everything properly, we removed the voltage divider suggested in the datasheet, and the circuit worked as expected, producing an amplified signal directly related to the input pressure applied. Finally, we added an additional amplifier with a potentiometer in case at some point we want to adjust the amplification of the signal. *Figures 4, 5, and 6* below show images from the circuit testing stages.

Figure 3: Circuit Diagram From Datasheet



Figures 4, 5, 6: Testing the Sensor and Instrumentation Amplifier Output from 5mV Peak-to-Peak Input from Function Generator





VI. Software Development

We wanted a computer program to accompany the circuit, with the overall goal to make the program as user friendly as possible. Using LabView and the NI 6008 Data Acquisition device (DAQ), we designed a program that helped calibrate the device to each individual patient. The input controls allowed the operator to set an upper and lower threshold based off of the initial patient calibration. The program also allows the operator to change the time between each indicator beep and the time during which the patient must react and squeeze the ball. These controls were included to allow the operator to customize the alarm device to each procedure. For testing purposes, the computer program has virtual indicator lights that correspond to indicator lights on the device.

VII. Final Product

When building the final product, we replaced the syringe with a squeezable bulb and replaceable tubing. A luer lock was installed on the edge of the box to ensure that the inner tubing does not disconnect from the pressure sensor, but the outer tubing can be replaced if necessary. We also installed an on/off switch to control battery operation of the device. The LED display was built using transistors, resistors and LEDs, and this was installed on the front panel of the device. Figure 7 below shows the final product. Figure 8 below shows the internal circuitry. Figure 9 below shows the Labview program designed.

Figure 7: Final Product

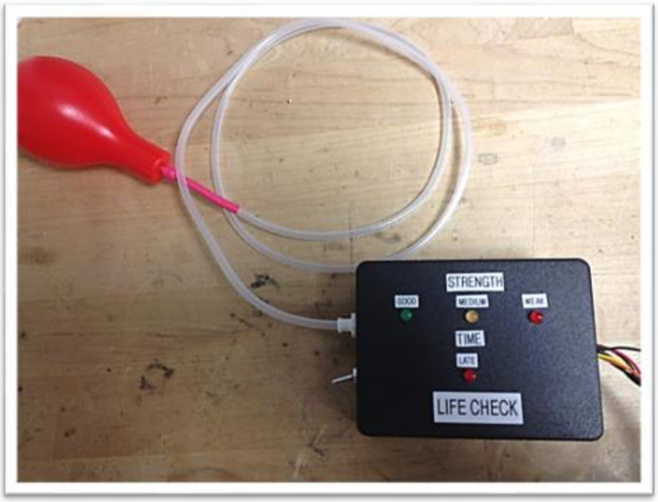


Figure 8: Internal Circuitry

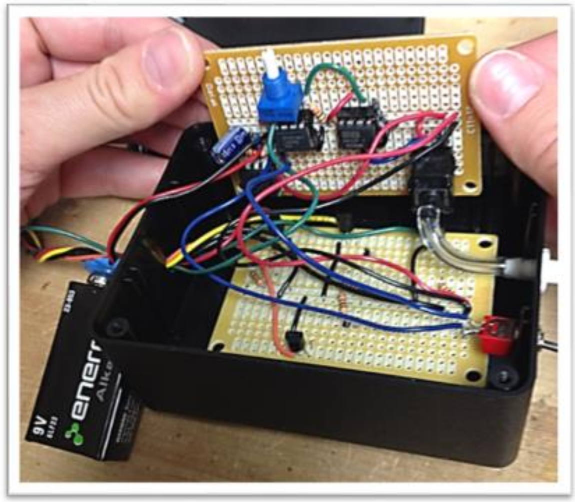
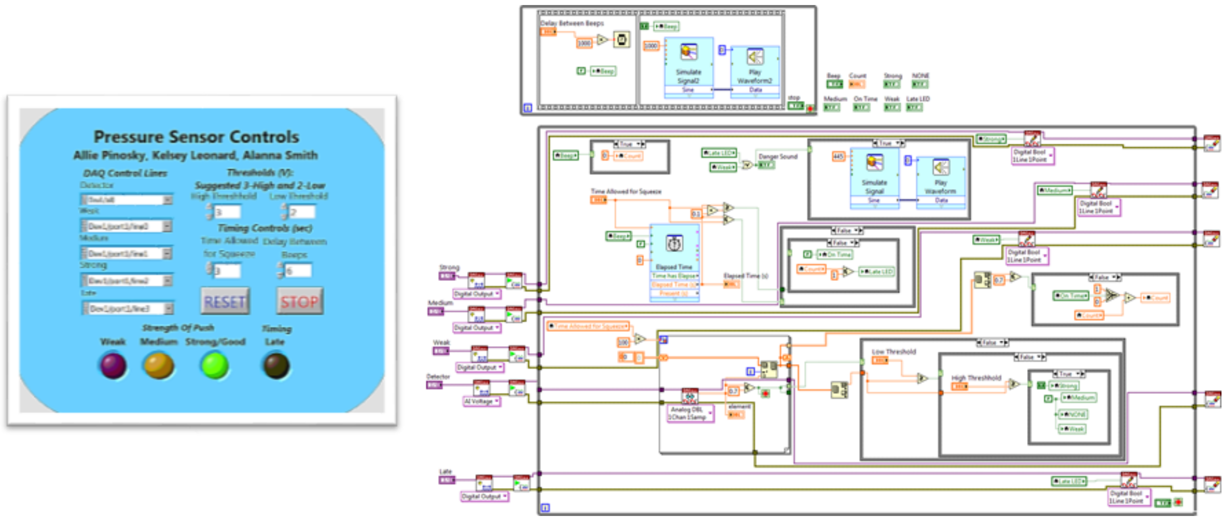


Figure 9: Labview Program to Control Life Check



VIII. Bill Of Materials

Thanks to spare supplies collected throughout the BME department, we were able to build this device at minimal cost. Assuming we had to purchase every component we used, we created a bill of materials to show the cost of the device. Figure 10 below shows the details of the expenses.

Figure 10: Bill of Materials

Item	Price each	Number of Items	Total Price
NSCDLNN100PGUCV (Pressure Sensor)	$1.190	1	$1.190
INA22 (Instrumentation Amplifier)	$4.370	1	$4.370
Resistors	$0.100	6	$0.600
5 V Voltage Regulator	$0.950	1	$0.950
5kΩ Potentiometer	$0.110	1	$0.110
Handheld bulb + plastic tubing	$1.000	1	$1.000
Heat Shrink Tubing	$2.040	1 kit	$2.040
Tygon Clear Plastic Tubing	$0.095	6"	$0.095
Luer Lock	$0.370	1	$0.370
Black Box +4 screws	$1.750	1	$1.750
LEDs	$0.480	4	$1.920
Transistors	$0.310	4	$1.240

Labels	$0.690	4"	$2.770
Device Subtotal			$18.405
NI 6008 Data Acquisition Device	$170.100	1	$170.100
Total Price			$188.505

IX. Future Improvements

While our device is fully functional and meets the requirements we developed, there is still room for improvement. In the future, we would like to design microcontroller interface to eliminate the need for a data acquisition device in order to decrease the cost of production. This would also necessitate a new computer interface system. We would also like to incorporate an internal buzzer into the device instead of a computer sound. Additionally, a hardwired reset button could be of use. We would incorporate an easier method of calibration. Finally, we hope to improve aesthetics.