12 October 2007

To Whom It May Concern:

We are undergraduate biomedical engineering majors at the University of Wisconsin-Madison working on our senior capstone project. We are interested in designing and building a prototype for the Gas Pressure Meter project through Engineering World Health. This device will be kit-able because of the advanced electronic parts needed. The attached document contains a detailed description of our proposed design and budget. Our advisor is Professor Naomi Chesler and our local Engineering World Health contact is Professor John Webster. Along with these two great resources, we are able to work with a variety of biomedical and electrical/computer engineering professors at our university. We are very interested in this project because of the potential impact our device could have on medical care in developing countries.

If funded, a prototype check should be made out to Ksenija Bujanovic.

Contact information for the team members is as follows:

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Thank you for your consideration,

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Goals

Our goal is to design and build a gas pressure meter that meets the specifications of the Engineering World Health design program in order to improve medical care in developing countries. The gas pressure meter would be used to measure pressures at the outlet of anesthesia and ventilation machines. It is important that the pressure is measured precisely, accurately, and easily to ensure proper medical treatment of adults and children (1).

Approach

Our design is based on the principle of pressure transduction through a strain gauge. A Wheatstone bridge within the strain gauge produces a voltage that corresponds to a change in pressure. Our device will then amplify this signal and display the calibrated pressure value using light-emitting diodes (LED). The LED display will be controlled using a peripheral interface controller (PIC).

Prior Work

We have performed prior research in this area that will be very beneficial in meeting our goals this year. Last semester we designed, built, and tested a “proof-of-concept” prototype gas pressure meter. The prototype consisted of a circuit that converted pressure into voltage using a strain gauge. As noted above, the central component to the pressure transduction circuit is the Wheatstone bridge. The Wheatstone bridge resides within the strain gauge, and is usually made of a piezoelectric material that responds to changes in pressure by changing its resistance (2). The corresponding change in voltage is linearly related to the change in pressure. Figure 1 shows the schematic of our pressure transduction circuit from last semester. In our design, the current first passed through a buffer to prevent a high source resistance from being loaded by a low-impedance input (2). Once the voltage had been established through the strain gauge, it was sent through an inverting amplifier. To test the accuracy of our circuit we used known pressure values and compared the voltage output of our device. The measurements from the prototype pressure gauge were compared to those obtained using a KAL84 pressure calibrator, which has an accuracy of within 0.1 mmHg. By trial and error, we found that 30kΩ

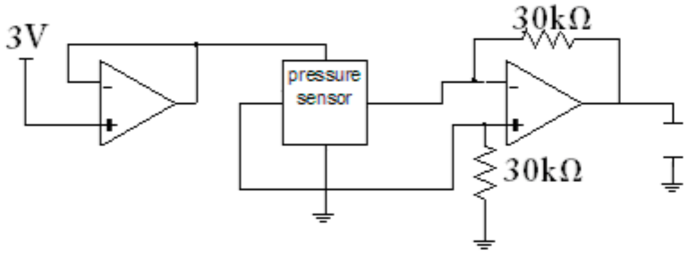

Figure 1 – Preliminary circuit design used in the first iteration of the prototype. A buffer reduces loading on the strain gauge. The final stage is an inverting amplifier with two 30k resistors.

resistors showed the most consistently accurate voltage readings (lowest standard deviation (1.67×10^{-4})) of all resistor pairs tested with the inverting amplifier. The source and indicator were borrowed from Professor Chesler's lab. Figure 2 shows the linear relationship between the pressure input and the voltage output, acquired through preliminary testing. Because the relationship is linear, the algorithm necessary to convert this voltage to the displayed pressure value (in mmHg) on the two LEDs will be straightforward, as proposed in this year's design and testing section.

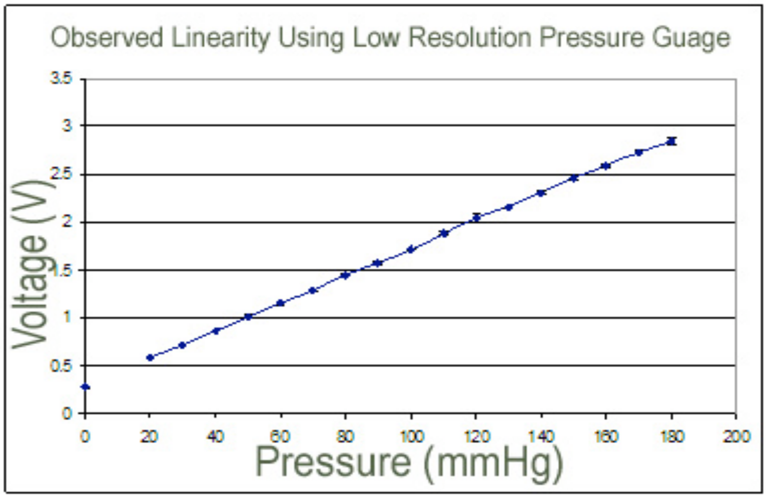

Figure 2 – Voltage output vs. pressure input as transduced by the first generation prototype displaying linearity from 0 to 200mmHg.

Design and Testing

Our proposed design for this year will contain the circuit described in the prior work section, which converts pressure input to a voltage output. In addition, the new prototype will contain a peripheral interface controller (PIC) and two 7-segment light emitting diodes (LED) for digital display. The final circuit design will be assembled on a printed circuit board (PCB). The PIC will be programmed to display numerical values in millimeters of mercury (mmHg) which correspond to the final output voltage of the circuit, and therefore to the pressure input. The values will then be displayed on the seven-segment numeric panels to be read by the user.

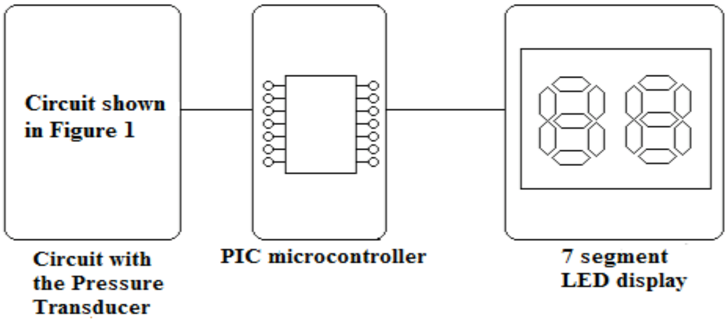

Figure 3- Block diagram of the final system. A pressure source will enter the system through the circuit appearing in Figure 1. The voltage exiting the circuit will enter the microcontroller which will power the LED display, showing a corresponding pressure input in the form of mmHg.

Another facet of the design that will be addressed is the connection of the device to the ventilator or anesthesia machine. To accomplish this we will use a Y-connector, a component common to ventilators, to connect our device to the machine. This will reduce the cost of the device because the part will be

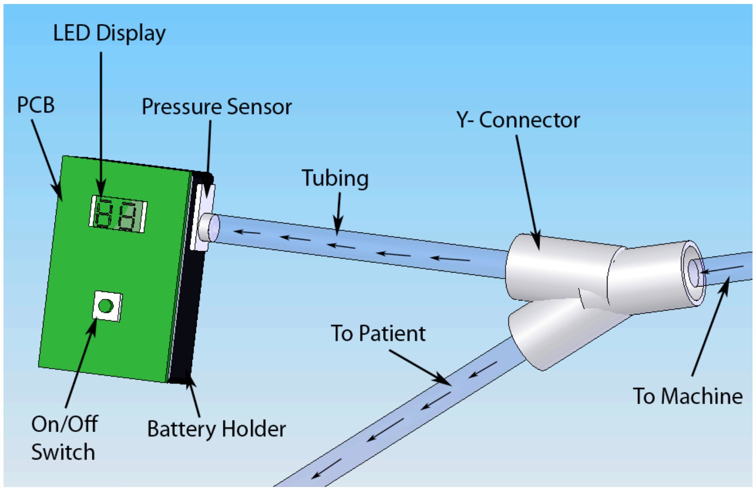

Figure 4- Schematic of proposed design, showing couplings, directions of air flow, and attached pressure sensor device.

locally available. As shown in Figure 4, one pathway leads to the normal ventilation path, the other to the pressure transducer. Because the diameter of the output tube is different than the pressure sensor input, a rubber sleeve will be used to connect the tubes. The system schematic can be seen in Figure 3. This semester we will focus on programming the PIC and testing the preliminary prototype of the new design. We will be able to test our device with ventilation and anesthesia machines at the UW- Hospital.

The range of pressures that the device needs to be able to measure is between zero and 75 mmHg (3). Our pressure transducer will work in this range, as it can measure up to 300 mmHg. We have designed and built a preliminary pressure- transducing system and have achieved pressure measurements with 99% precision. After calibration, it will be equally accurate. Since the transducer used in the completed device will be less accurate than that used for testing the accuracy of the completed device may be reduced. However, it will still satisfy the 90% accuracy requirement.

Our proposed design is a kit-able device that will meet the specifications put forth by Engineering World Health, as it will be able to measure oxygen, medical air, or carbon dioxide in medically useful ranges to within 10% of the true value.

Budget

We estimated the budget necessary for this device based on three units and 500 units. Three units were chosen because PCBs must be ordered a minimum of three at a time. As shown in Table 1, the PCB unit cost dropped considerably when the quantity was increased to 500 units. Also, part of the price calculated in the three-unit cost consists of shipping charges. Those costs would be essentially negligible when parts are ordered in mass quantity.

Some assumptions had to be made in our calculations. Because cost per PCB can vary based on the layout, the $1.60 is based on the budgets of several past EWH final project reports. Second, we don't know which PIC microcontroller we are going to purchase, but based on our research they can cost anywhere from $0.30 to $2.50 per unit in mass quantity. In our cost calculations we erred on the safe side and assumed $1.75 per unit. However, notice that if we are able to purchase the $0.30 per unit device our total unit cost drops to $4.76.

Based on our calculated costs we request $120 to build our initial three prototypes. We calculated that the initial prototypes will cost $105.95; the remaining $14.05 is for unexpected costs that accrue over the course of the year.

Table 1 – Proposed budget for first three prototypes and projected budget for mass production

Part Description	Seller	Part Number	Unit Cost (per 3)	Total Cost (Unit x3)	Unit cost (per 500)	Total Cost (Unit x500)
Pressure Sensor	Electronic Goldmine	G15473	$ 3.91	$ 11.73	$ 1.51	$ 755.00
Battery Holder	All Electronics	BH-32	$ 3.09	$ 9.27	$ 0.52	$ 260.00
PCB	Express PCB		$ 17.00	$ 51.00	$ 1.60	$ 800.00
Display	Electronic Goldmine	G4031	$ 2.66	$ 7.98	$ 0.24	$ 120.00
Peripheral Integrated Controller			$ 3.00	$ 9.00	$ 1.75	$ 875.00
Resistors (two per unit)	Digikey	Varies Based on Size	$ 0.70	$ 2.10	$ 0.06	$ 30.00
Operational Amplifier	Allied Electronics	LM358ADE4	$ 2.43	$ 7.29	$ 0.11	$ 55.00
Low Battery light	Digikey	67-1102-ND	$ 0.10	$ 0.29	$ 0.08	$ 39.00
Tubing	US Plastics	54044	$ 2.03	$ 6.09	$ 0.09	$ 50.43
Button	All Electronics	PB-151	$ 0.40	$ 1.20	$ 0.25	$ 125.00
Total			**$ 35.32**	**$ 105.95**	**$ 6.21**	**$ 3,109.43**

References

1. Keidan, H., (2001) Pressure versus volume-controlled ventilation with a laryngeal mask airway in pediatric patients. *Pediatric Anesthesia (691-694)*
2. Webster, J. G. , *Medical Instrumentation.* (1998) Canada: John Wiley and Sons.
3. C. D. Ray, *Medical Engineering*, (1974) Chicago: Year Book Medical Publishers, Inc.