Flow-Controlled Irrigation Pump for Neuroendoscopy

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Abstract

Neuroendoscopy is a minimally-invasive surgical procedure that uses tube-like instruments, or endoscopes, to gain access to the inner structures of the brain, spinal cord, and peripheral nervous system. During these procedures a non-peristaltic flow of saline is necessary to permit visualization and navigation of the surgical field. At present, a pressurized bag of saline is utilized to irrigate the surgical field but provides no means to maintain a constant flow rate when instruments are introduced to and removed from the endoscope. The objective of this project is to design a circuit that modifies pre-existing cardiac pump technology from Medtronic to be suitable for providing this irrigation during Neuroendoscopy as well as negative feedback to maintain a continuous flow rate throughout the procedure. To address this goal, the final design incorporates a series of operational amplifiers that appropriately scale the flow sensor and controller voltages followed by a differential amplifier to compare them and send an adjustment signal to the centrifugal pump. Formalized testing of the prototype revealed that the constructed circuit successfully attenuated the maximum rpm of the Bio-Pump from 4550 to 600, corresponding to the desired maximum flow of 0.150 mL/min. Additionally, the system responds accordingly to changes in input voltages and flow resistance. Future work on the design will include adjusting the sensitivity of the circuit to better respond to more minute changes in flow as well as miniaturizing the prototype to the microscale.

Project Description

Objective

To design a circuit that adapts the Medtronic Bio-Console and centrifugal pump for use as a source for saline irrigation during neuroendoscopic procedures by attenuating and continuously adjusting the output flow with negative feedback from a flow sensor.

Background

- Neuroendoscopy is a minimally-invasive procedure using tube-like instruments, or endoscopes, to gain access to the inner structures of the brain, spinal cord, and peripheral nervous system [1].
- For the procedure, a continuous flow of saline is necessary to visualize and navigate the surgical field.

- Pre-existing system for cardiac applications, marketed by Medtronic [2].

Current System

- At present, Dr. Medow employs hanging saline bags as a source of irrigation during surgical procedures.
- However, this solution possesses numerous limitations:
  - Insertion of instruments into endoscope causes flow reductions up to 75%.
  - As a result, visibility can be limited at times during the procedure.
  - During lengthy surgeries, the set-up must be replaced each time the saline bag becomes empty.

Design Criteria

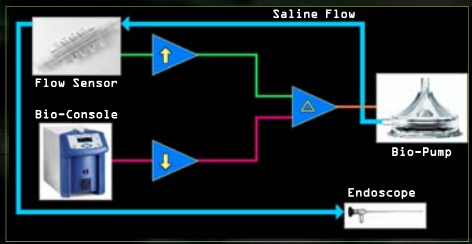
The designed circuitry must:

- Integrate with existing Medtronic system.
- Incorporate negative feedback to adjust the irrigation following insertion and removal of instruments into and from the endoscope.
- Allow for adjustment to occur as rapidly as possible.
- Be adjustable during and between surgical procedures.

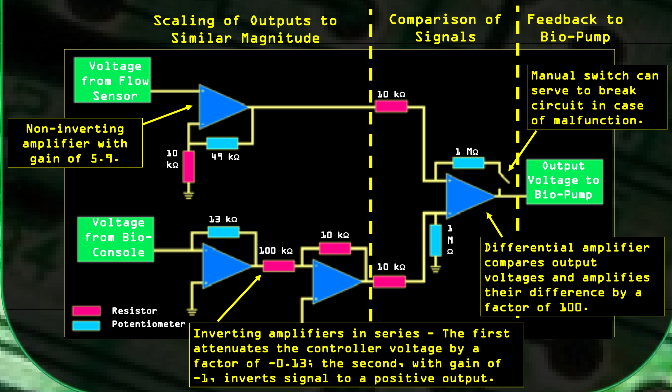
Final Design

Approach in Concept:

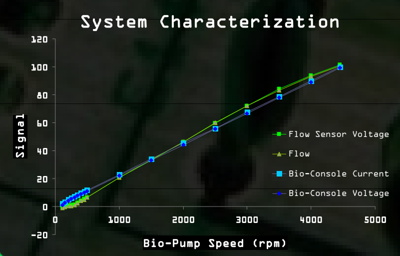
To supply negative feedback to the Bio-Pump, the controller voltage of the Bio-Console must be compared to the output voltage of the flow sensor. Discrepancies in these values caused by insertion and removal of instruments into and from the endoscope can then be compared and a voltage tailored to this difference is sent to the pump to make the adjustment.



Implemented Design:

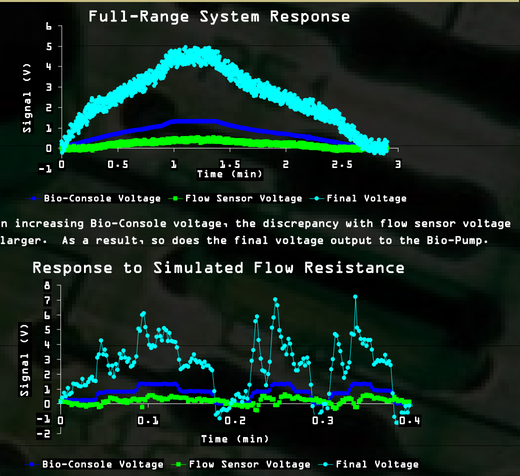


Prototype Validation



- System exhibits an overall linear response.
- With different scaling factors, outputs have a comparable slope:
  - Bio-Console Voltage = 0.15
  - Flow sensor Voltage = 6
  - Flow = 50

Prototype Validation



- With an increasing Bio-Console voltage, the discrepancy with flow sensor voltage becomes larger. As a result, so does the final voltage output to the Bio-Pump.

- Increasing the resistance to saline flow decreased the flow sensor voltage, resulting in marked increases in the final voltage supplied to the Bio-Pump.

Future Work

- Incorporate a current-controlled circuit breaker in place of the manual switch.
- Continue to simplify and miniaturize the circuit, eventually to the microscale.
- Conduct testing of the circuit integrated within the Medtronic system in an animal model.
- Develop a system independent of Medtronic technology specific to the neuroendoscopy application.

References

[1] P. Cappabianca, G. Cinalli, M. Ganegam *et al*, "Application of neuroendoscopy to intraventricular lesion." *Neuroendoscopy*, vol. 62, pp. 575-97, Feb. 2008.

[2] Medtronic, Inc. (2004). *Cardiovascular Surgery Products*. [Online]. Available: http://www.medtronic.com/cardsurgery.html.

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