Mechatronics Term Project

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Outline

- Goal and motivation
- Description of components
- Mechanical system design
- Electrical system design
- Algorithm and operation instructions
- Mathematical modeling
- Conclusions

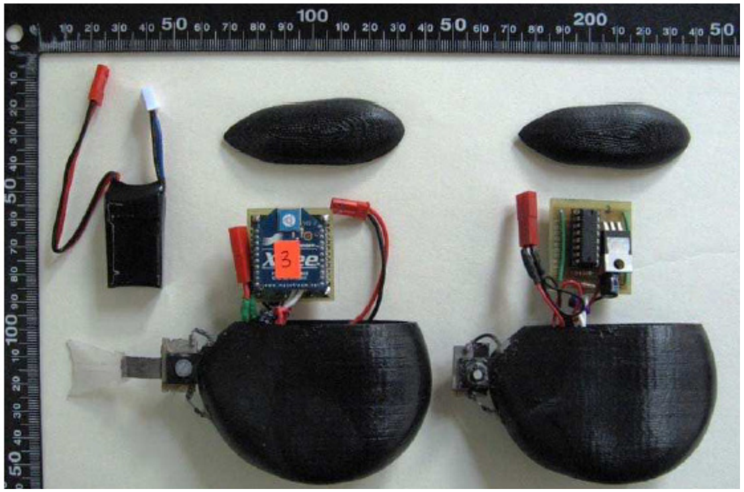
Robotic swimmer and school of golden shiner minnows in Dynamical Systems Laboratory (DSL) at NYU-Poly

Project goals

- Design a feedback controller to turn the shell of a swimmer at a variety of attack angles in a flow of constant rate
- Use the BS2 as controller
- Include user interface for monitor and control the device
- At least one actuator should be included.
- A sensory feedback loop will be used to control the actuator
- Utilize a digital and analog sensor

Motivation

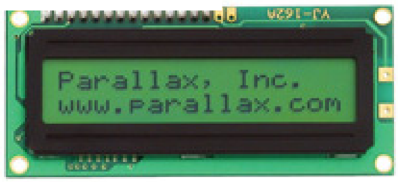
- Biomimetic, miniature robotic fish used to study schooling behavior of gregarious fish
- Uses ionic polymer metal composite, an electroactive material, as propulsor
- ABS plastic shell
- Requires optimization of shell shape to house on-board electronics and minimize drag

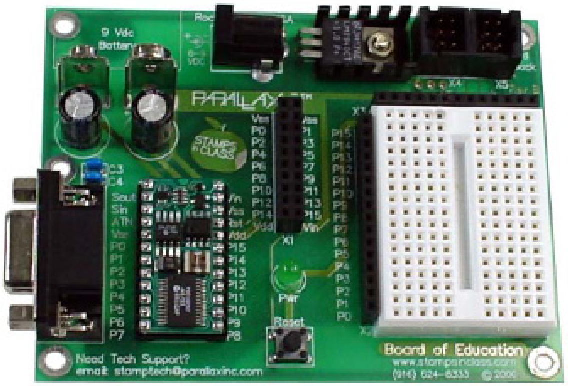


Robotic swimmers from DSL

Water tunnel in DSL

Component description





- Actuation
  - Jameco 12 Volt DC motor
- Sensing
  - Rotational potentiometers
  - Normally-open buttons
- User interface
  - Liquid crystal display
- Control
  - Basic Stamp microcontroller
- Structural
  - Assorted gears
  - Aluminum shaft

Component description

Item	Price
Box	$2
Screw	$2
Transistor	$4
Basic Stamp 2	$110
DC motor	$25

Item	Price
Plexiglass	$2
Batteries	$8
Switch	$4
Button	$4
Gears	$30

Total Cost: $191

Mechanical system design

- Low torque, high velocity DC motor requires internal transmission, external gear train to convert to high torque and low velocity

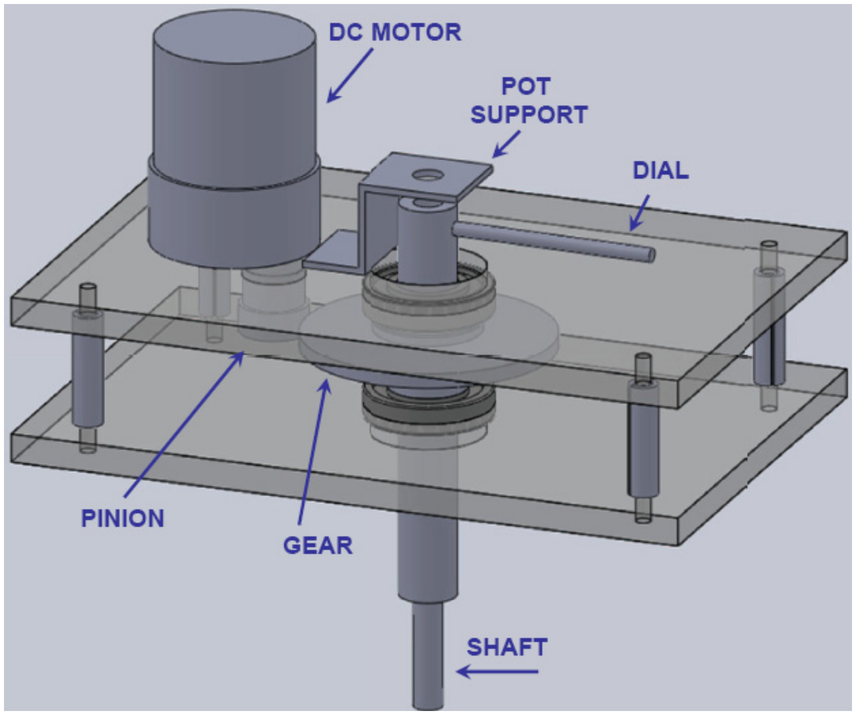
- Thrust bearings to withstand weight force

- Ball bearing to rotational force

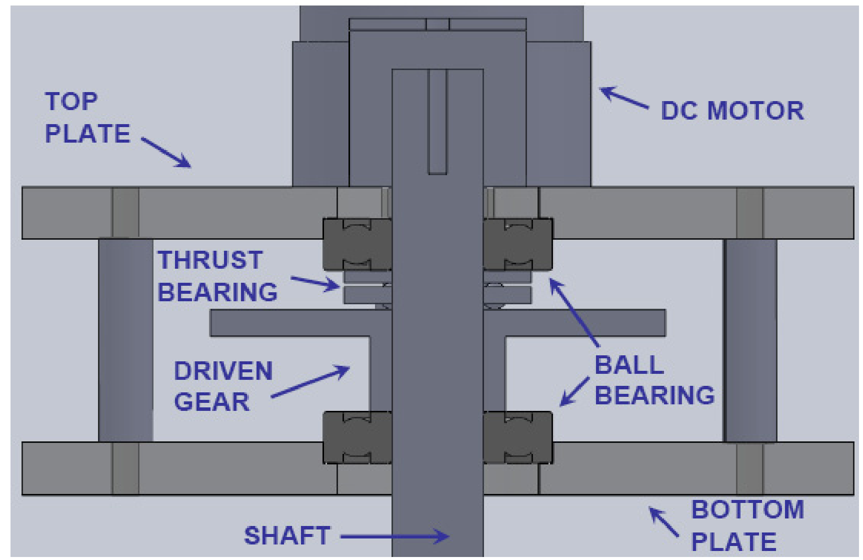
- Required to rest on top of water tunnel and position body in center of chamber to eliminate wall effects

- Automatic calibration of maximum range using sensor potentiometer and dial attached to rotating shaft

Mechanical system design



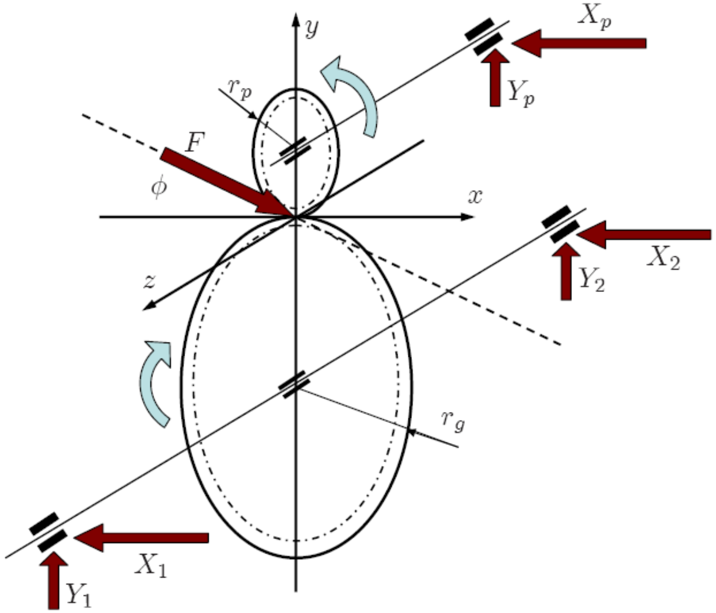
Mechanical apparatus with motor, gear train, shaft and support



Lateral view of structure

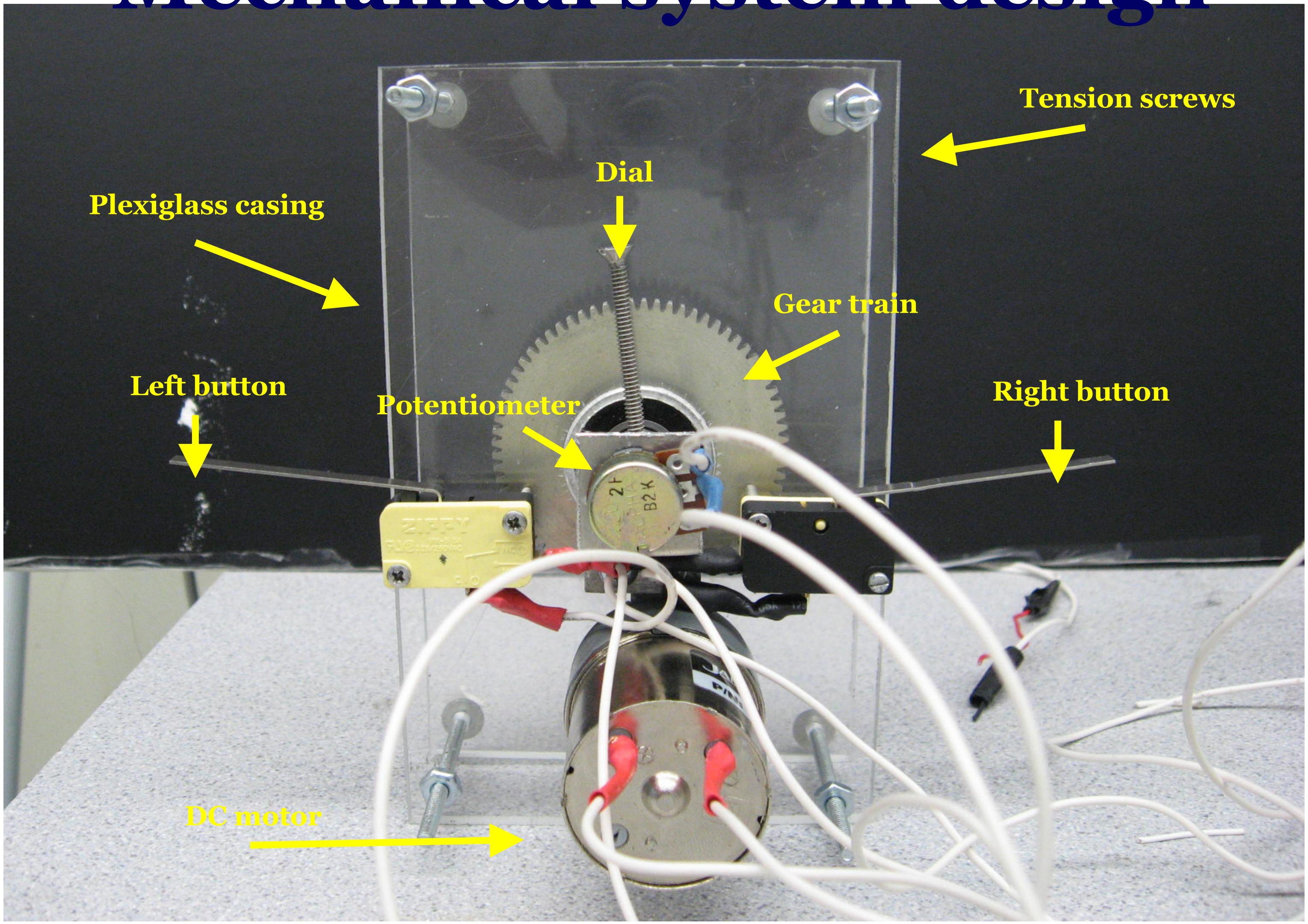
Mechanical system design

- Maximum efficiency speed: 35 rpm
- Maximum torque: 0.2325Nm
- Transmission ratio is 11 : 3
- Enhances the positioning precision and decrease the angular velocity of shaft



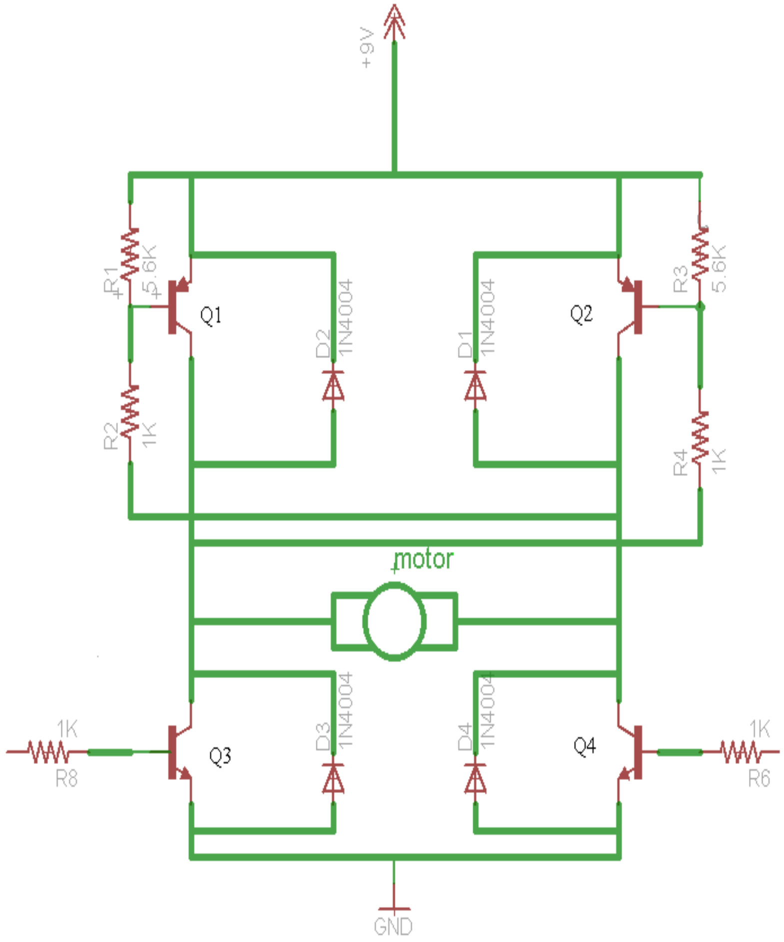
Schematic of gear train and forces

Mechanical system design



Bird's eye view of actuation device

Electrical system design

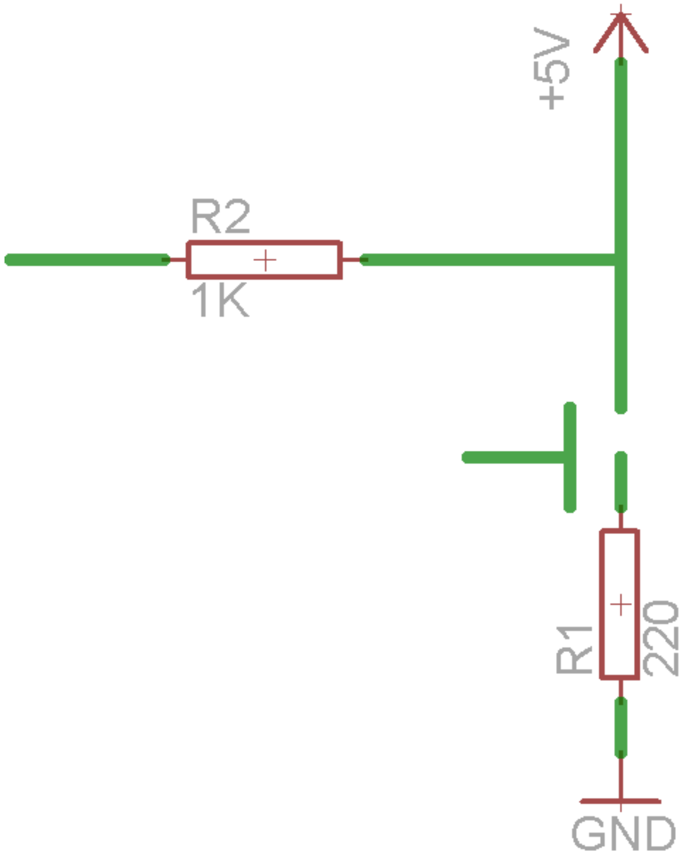


Schematic of H-bridge

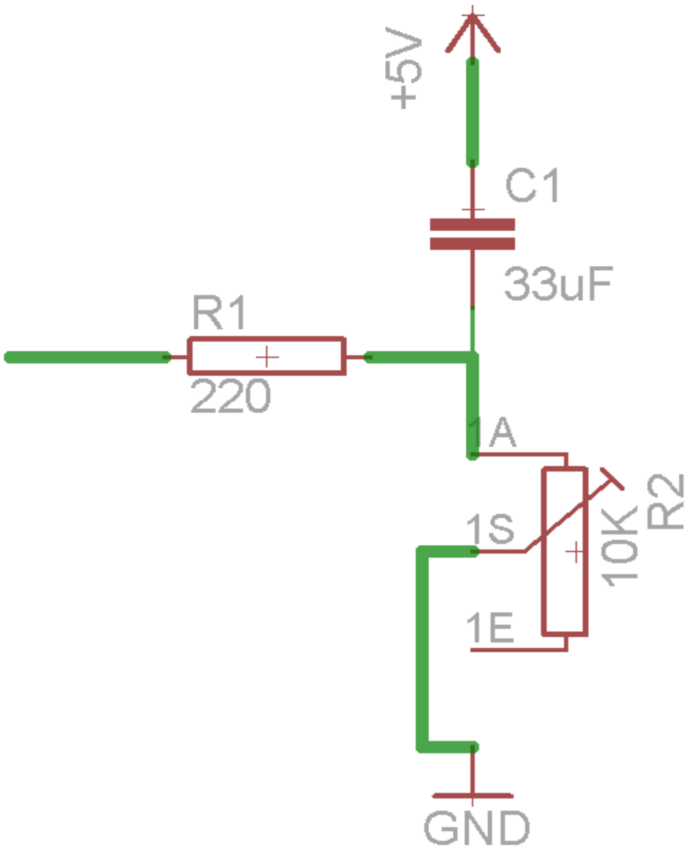
H-bridge for motor control

- Speed can be controlled via PWM
- High signal enters Q3's base, Q3 conducts, which allows Q2 to conduct
- Current flows from positive supply terminal through the motor from right to left (forward)
- To reverse the direction, low Q3 and high Q4

Electrical system design



Input button circuit schematic

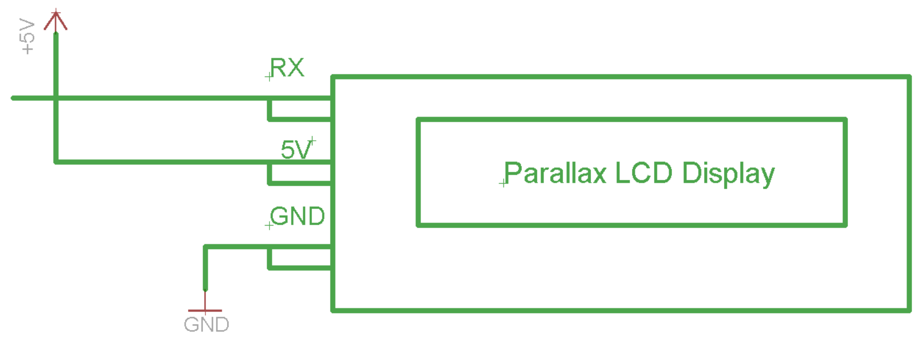


Input and sensor RC-potentiometer circuit schematic

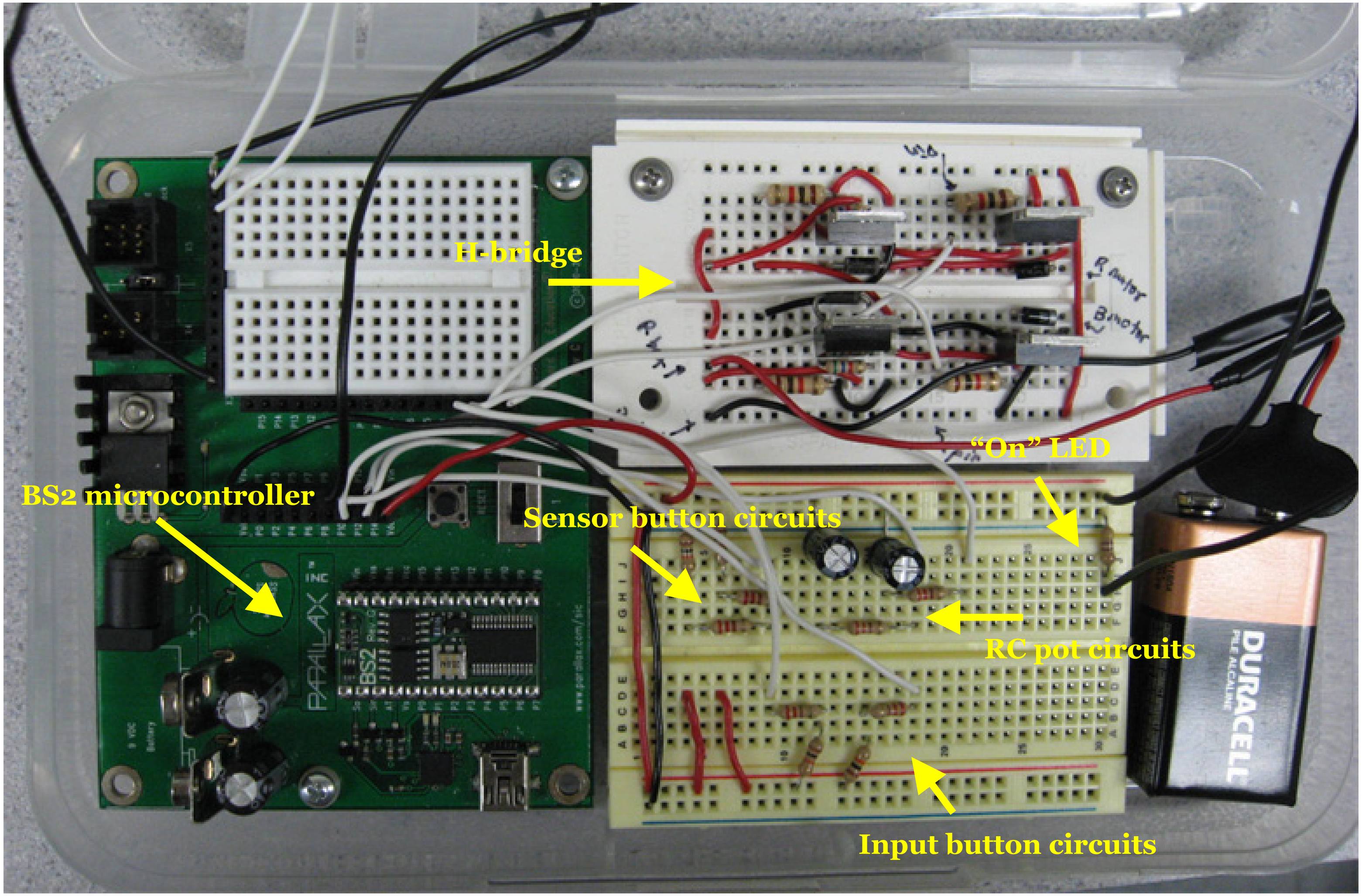
Electrical system design

LCD display

- Display measurement and status information
- Parallax 2×16 serial LCD
- 3-pin connection
- Used with PBasic SEROUT command

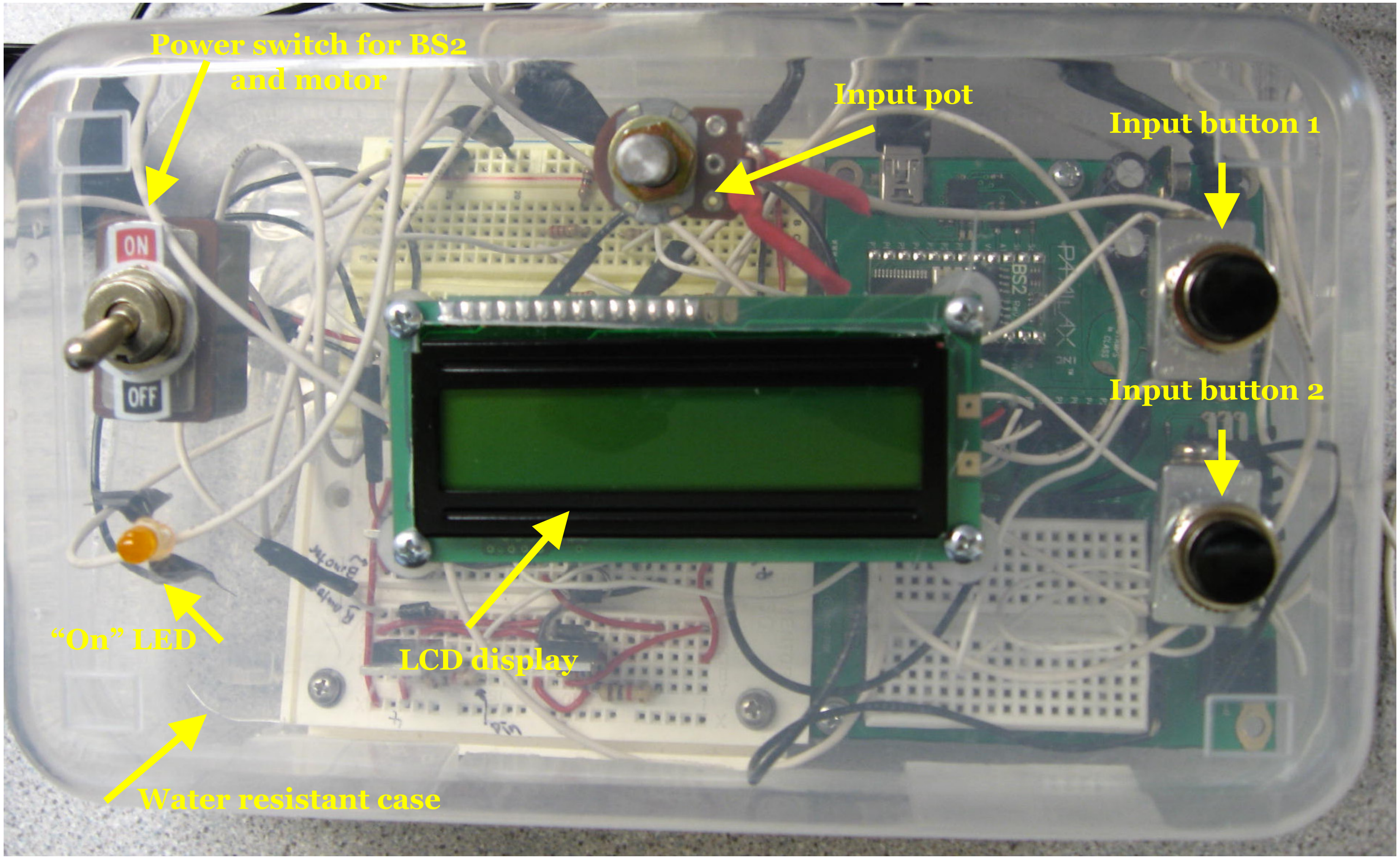


Electrical system design



Device circuitry without sensors connected

Electrical system design



User interface

Algorithm

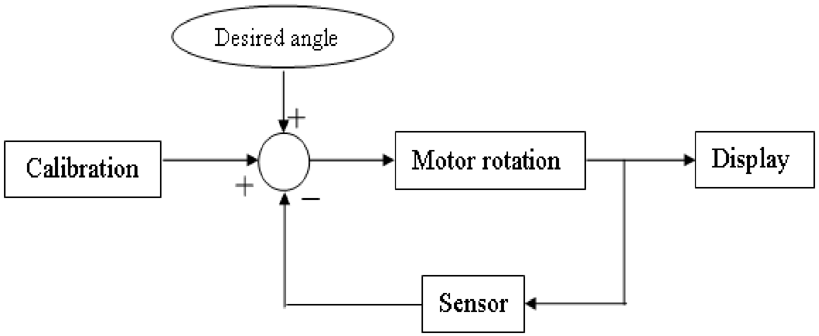
Calibration:

- Automatically moves dial to hit left endpoint button, then right endpoint button
- Uses RCtime command to record potentiometer position at each endpoint
- BS2 calculates middle position for potentiometer, uses PWM to track
- Scale range of dial in RCtime output with $\pm 90^{o}$

Algorithm

Input position and actuation:

- Input reference step or ramp, using button (discrete) or potentiometer (continuous)
- Input in degrees, which BS2 scales to RCtime, in 2 μs units
- Displayed on LCD, scaled to degrees
- Shaft position senses with RCtime command
- Feedback controller uses pulse width modulation

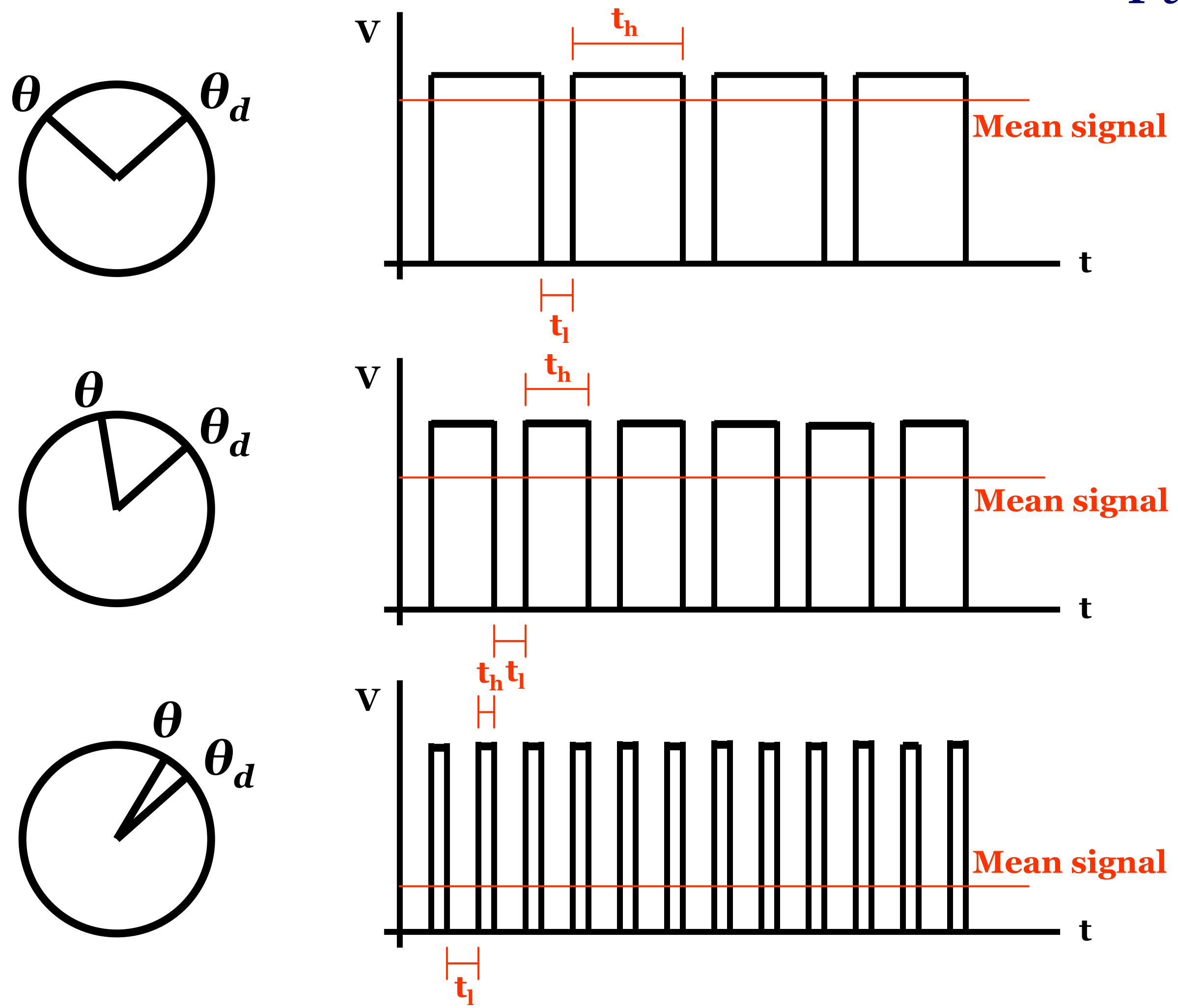


Block diagram of feedback control loop

Algorithm

Shaft position

PWM signal



Pulse width modulation-

- Low time, t_l, is constant

- High time, t_h, is proportional to the error:

$$t_h = K\,(\theta_d - \theta)$$

Operating instructions

- Start the Basic Stamp and motor using external on/off switch
  - This switch is the emergency shutdown, resetting and recalibrating system
- Wait as system calibrates automatically
- Button 1 pressed at any time after calibration to resets
- Select input mode
  - Button1: button input
  - Button2: potentiometer input
- If button input is selected, select position to the left or right of zero position, then degree value
- If potentiometer is selected, choose step or ramp intput
  - Button1: step input
  - Button2: ramp input
- If step input is selected, LCD displays reference position which shaft matches.
- If ramp input is selected, potentiometer selects grade of ramp
  - Steeper ramp to the left
  - Shallower ramp to the right

Modeling

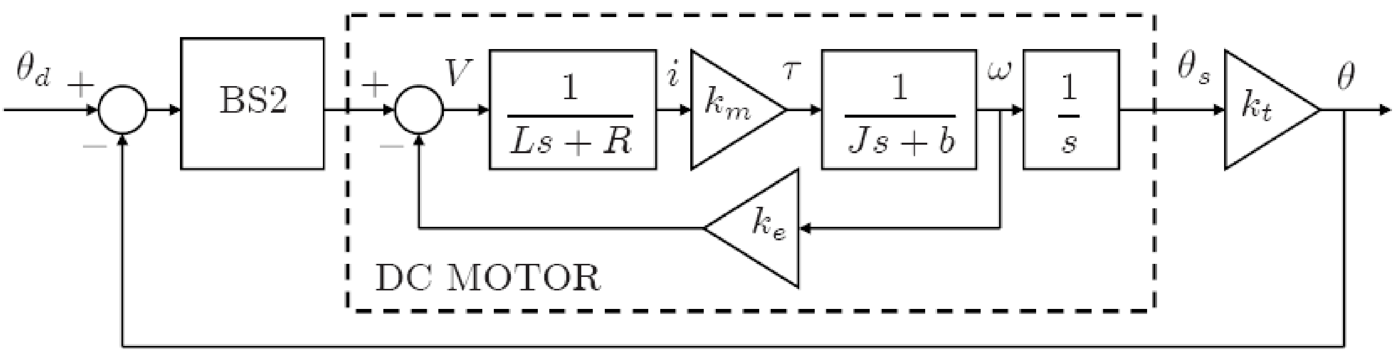
Electrical, mechanical subsystems can be described as the following ODE's:

$$L\frac{\mathrm{d}i(t)}{\mathrm{d}t} + Ri(t) = V(t) - V_b(t)$$
$$J\frac{\mathrm{d}\omega(t)}{\mathrm{d}t} + b\omega(t) = \tau(t)$$

- L = inductance of DC motor
- R = electrical resistance
- $i(t)$ = current
- $V(t)$ = voltage applied to DC motor
- $V_b(t)$ = back electromotive force
- J = moment of inertia of shaft
- B = viscous-type dissipative action
- $\omega(t)$ = angular velocity of motor shaft
- $\tau(t)$ = torque of motor shaft

Modeling

- Input is $V(t)$
- PI controller was implemented and found to lack any advantage over a strictly proportional control
- Proportional feedback control is implemented based on direct measurement of shaft angular position θ, and reference input θ_d
- PWM is used to control amplitude of driving voltage V supplied to DC motor.



Block diagram of feedback controller

Conclusions

- Angle of attack of the swimmer is input by the user
- A proportional feedback loop guarantees the desired position
- LCD display shows the reference step or ramp input

Future Work-

- Use strain gauge or composite beam to measure forces acting on body
- Consider roll and pitch motions of the body
- Implement PID control