HVAC Vent Control

Final Design Review

Project Definition

- Remote control of airflow through HVAC registers
- Balance airflow manually or automatically
- Reduce monthly energy bill and carbon footprint
- Low cost, modular unit

Why Balance Airflow?

- Most current households have inefficient systems
  - Rooms don't get equal airflow
  - Rooms receive too much or too little heat/ AC
- Some rooms in use only for part of the day
  - Energy wasted if air is directed to a room not in use

Environmental Impact

- Approximated average NC house and used 10 yr average NCDC heating and cooling degree data
- Energy savings per year
  - 96.2 gal. heating oil
  - 221.4 kWh
- CO_2 savings per year
  - 72 kg CO_2 from cooling
  - 976 kg CO_2 from heating

$$\dot{Q} = \Delta T \frac{A}{R}$$

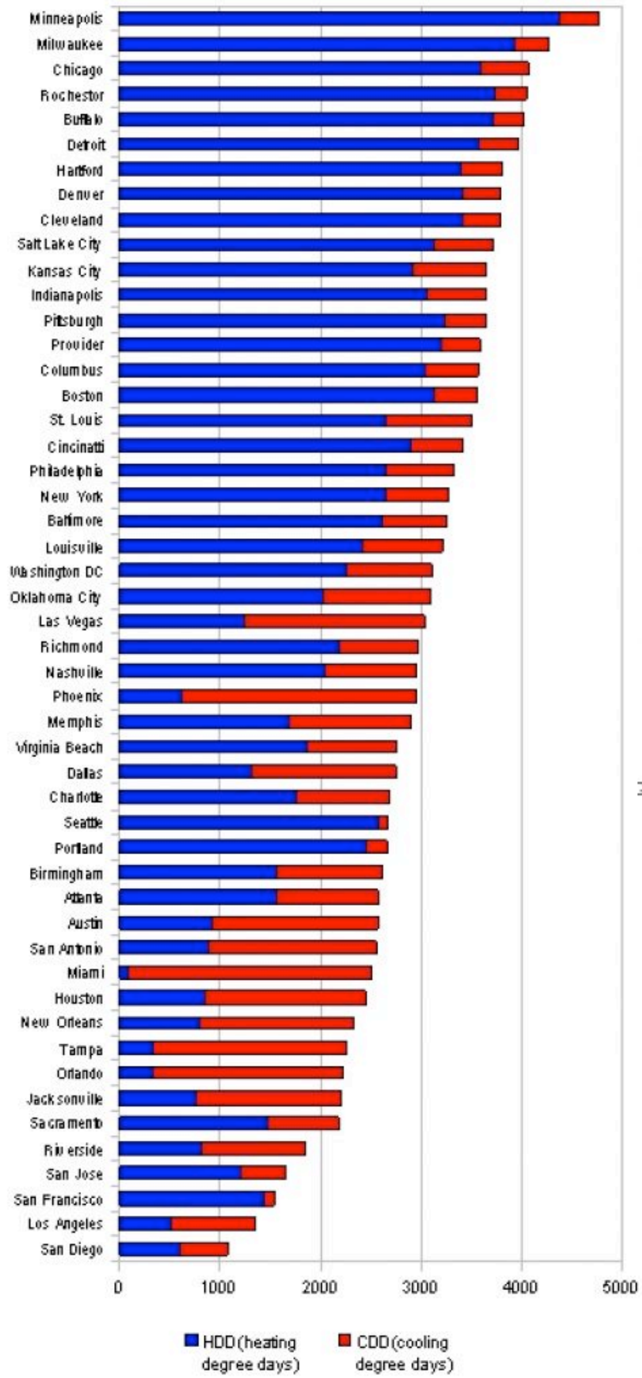
$$\dot{Q}_{tot} = \dot{Q}_{wall} + \dot{Q}_{window}$$

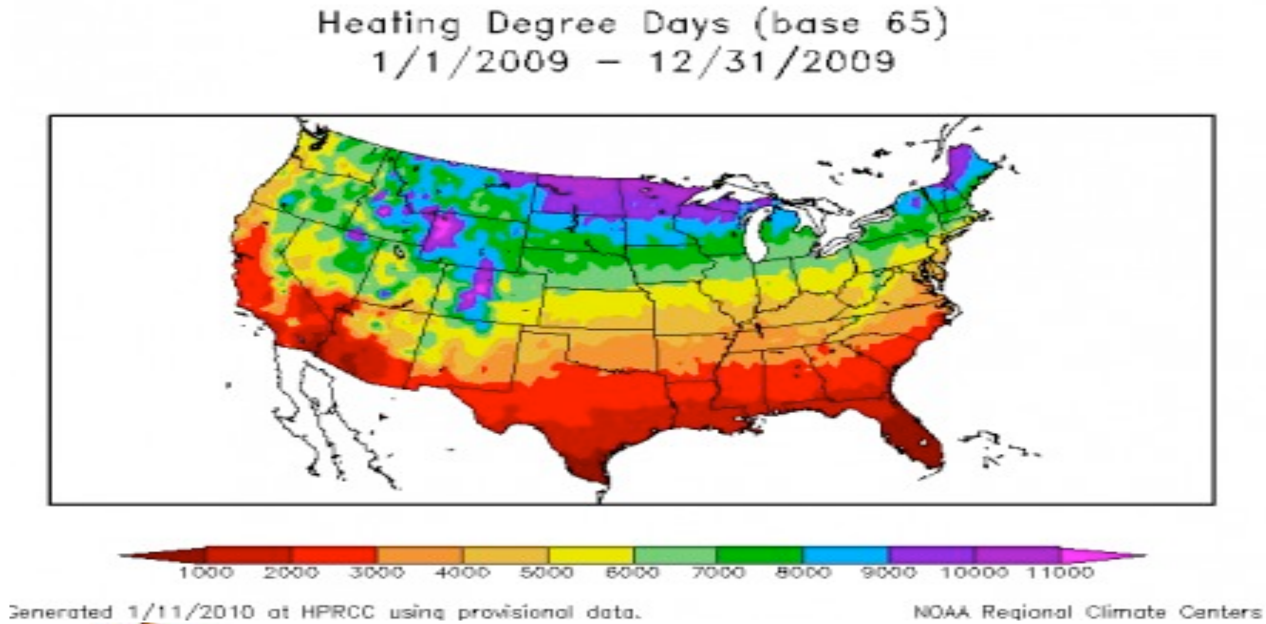
$$\frac{.8\ kg_C}{32620\ kJ} * \frac{3600\ kJ}{kWh} * \frac{44\ kg_{CO_2}}{12\ kg_C} = \frac{.3237\ kg_{CO_2}}{kWh}$$

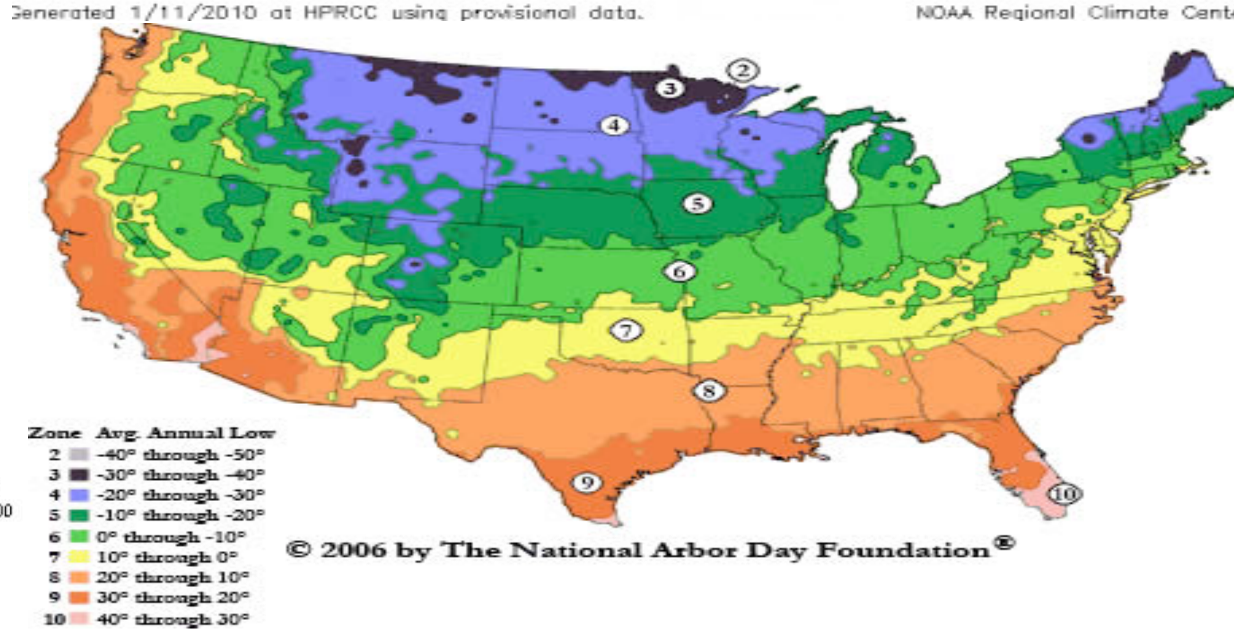
$$\frac{.3237\ kg_{CO_2}}{kWh} * 221.4 \frac{kWh}{yr} = 71.67\ kg_{CO_2}$$

$$\frac{10.15\ kg_{CO_2}}{gal.} * 96.2\ gal. = 976.43\ kg_{CO_2}$$

Areas in Need







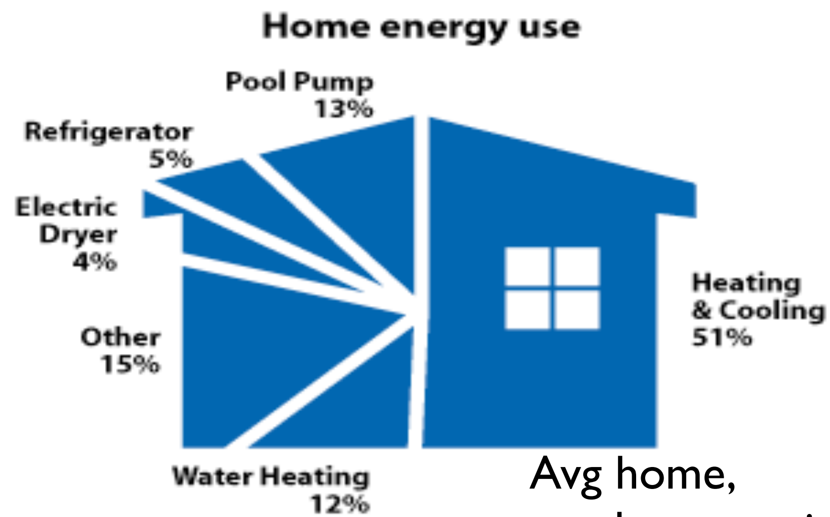
How can we help?

- HVAC systems generally inefficient due to varying register distances from the airflow source and poorly balanced ventilation systems.

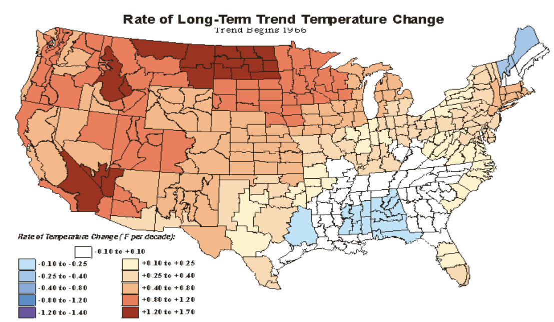
- Annually the average NC household spends $1,100 on heating and cooling. Our system can save nearly $350 in heating and cooling costs each year.

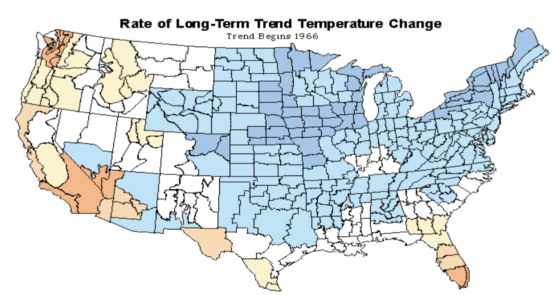
Marketability

- Target
  - New-home "green" construction
  - Areas with high HDD/CDD
- Benefits
  - Heating/cooling energy cost savings
  - Increased home comfort
  - Home climate customization
  - Lower energy use (less carbon emissions)

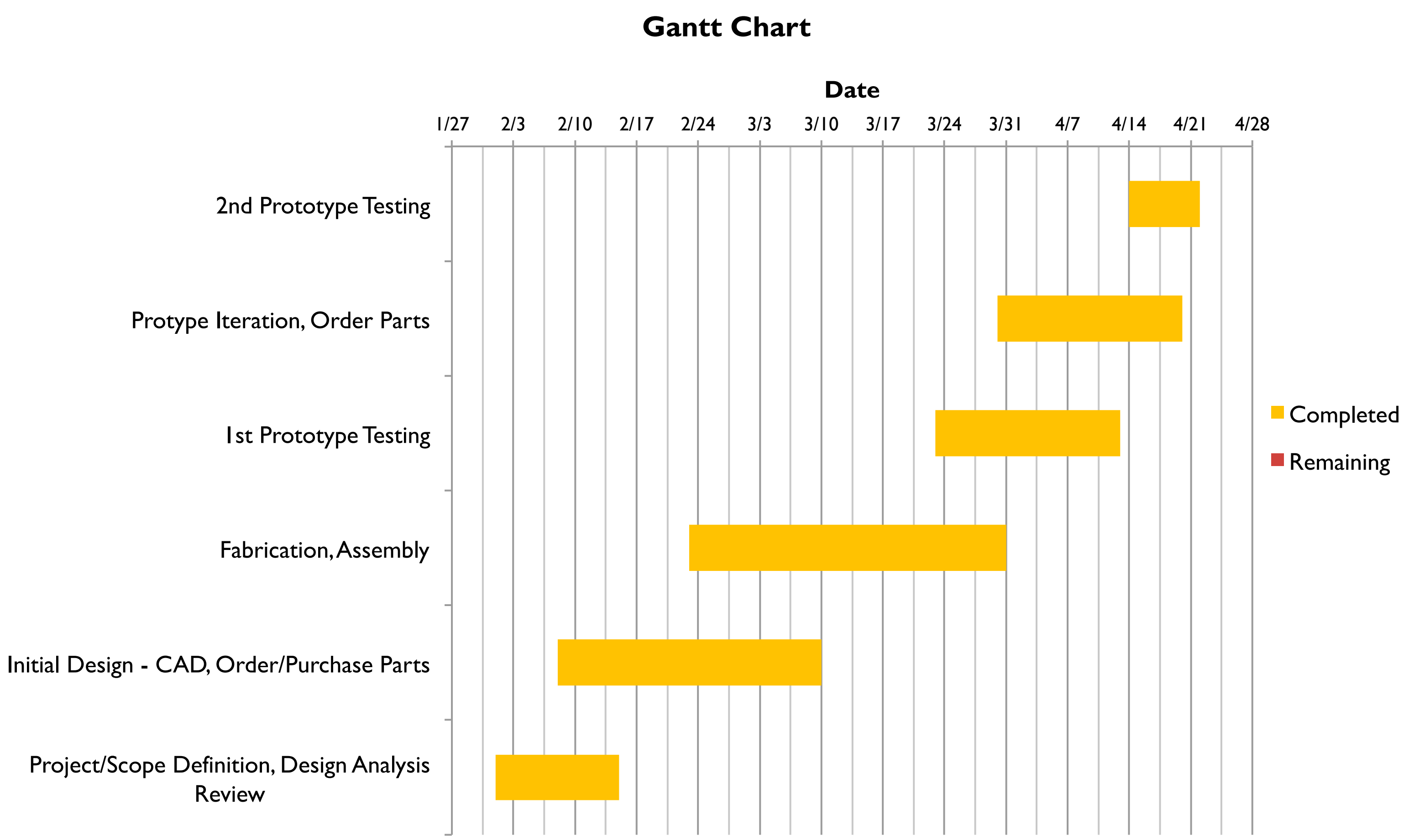


Avg home, southwest region





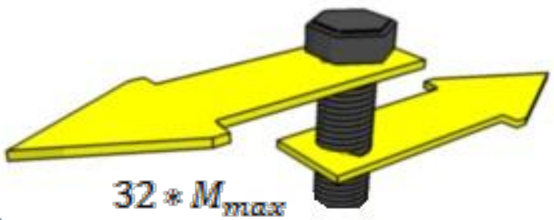
Gantt Chart


Gantt Chart
Date
1/27
2/3
2/10
2/17
2/24
3/3
3/10
3/17
3/24
3/31
4/7
4/14
4/21
4/28
2nd Prototype Testing
Protype Iteration, Order Parts
1st Prototype Testing
Fabrication, Assembly
Initial Design - CAD, Order/Purchase Parts
Project/Scope Definition, Design Analysis Review
Completed
Remaining

Budget

#	Item	Cost
3	Firgelli Linear Actuators	$720
3	Firgelly Actuator Controllers	$180
	Test Rig Materials	$260.78
2	Metal Adhesive	$11.82
1	Powered USB Hub	$36.99
3	Battery Holders	$2.91
3	Cooling Fans	$20.97
4	Motors	$43.30
1	Poster	$55
	TOTAL	$1,332

Actuator Pin Stress Calculation



$$\sigma_{max} = \frac{32 * M_{max}}{\pi d^3}$$

$$d_{min} = \sqrt[3]{\frac{32 * M_{max}}{\pi * \sigma_{max}}}$$

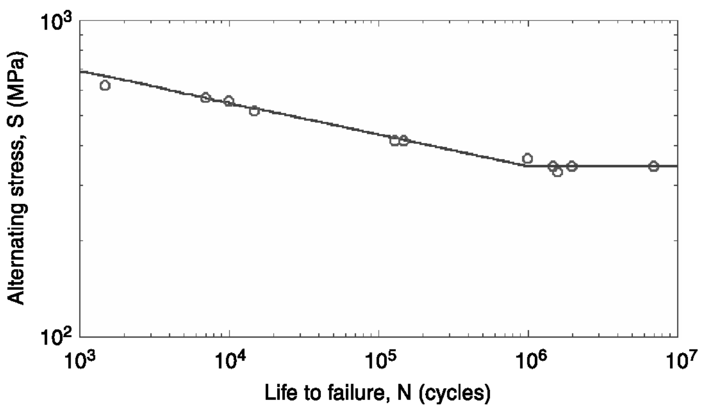
- Pin connecting actuator to louver arm must be able to handle stress of opening and closing vent
- Assume worst case scenario of 15 lb
- Min pin diameter 0.0757 in.
- Actutator pin diameter 0.167 $\longrightarrow$ n ≈11

Actuator Pin Fatigue Calculation

$$S_f = k_\infty S_f'$$

$$\sigma_a' = k_{fb}\frac{32 * M_{max}}{\pi d^3}$$

$$\frac{1}{n_d} = \frac{\sigma_a'}{S_f} + \frac{\sigma_m'}{S_{ut}}$$

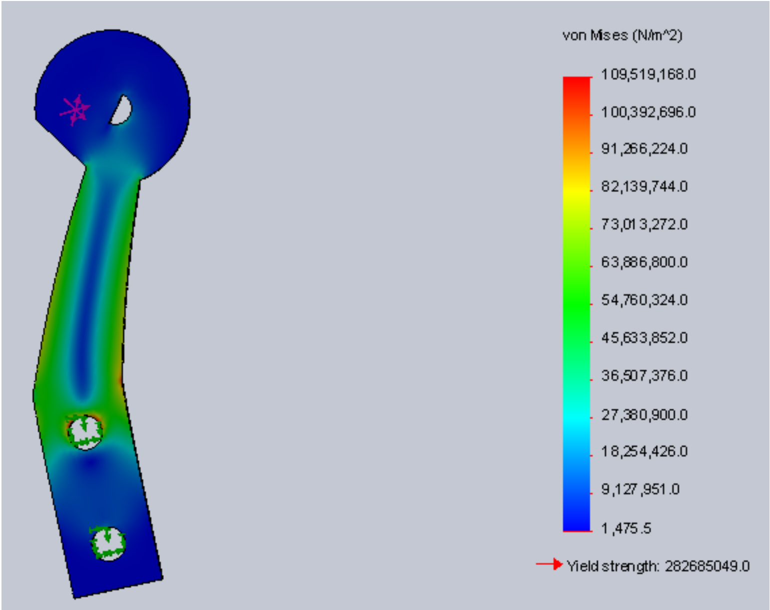


Source: Bannantine *et al.* (1990)

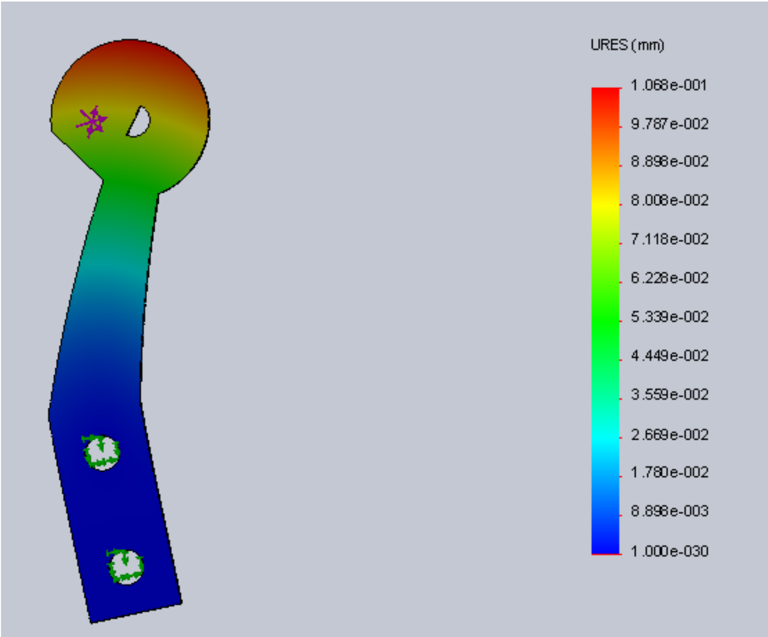
- Goal of infinite cycles under worst case scenario of 15 lb of applied force
- Resulted in
  - Infinite Life
  - Factor of safety of 3.6

Register Lever

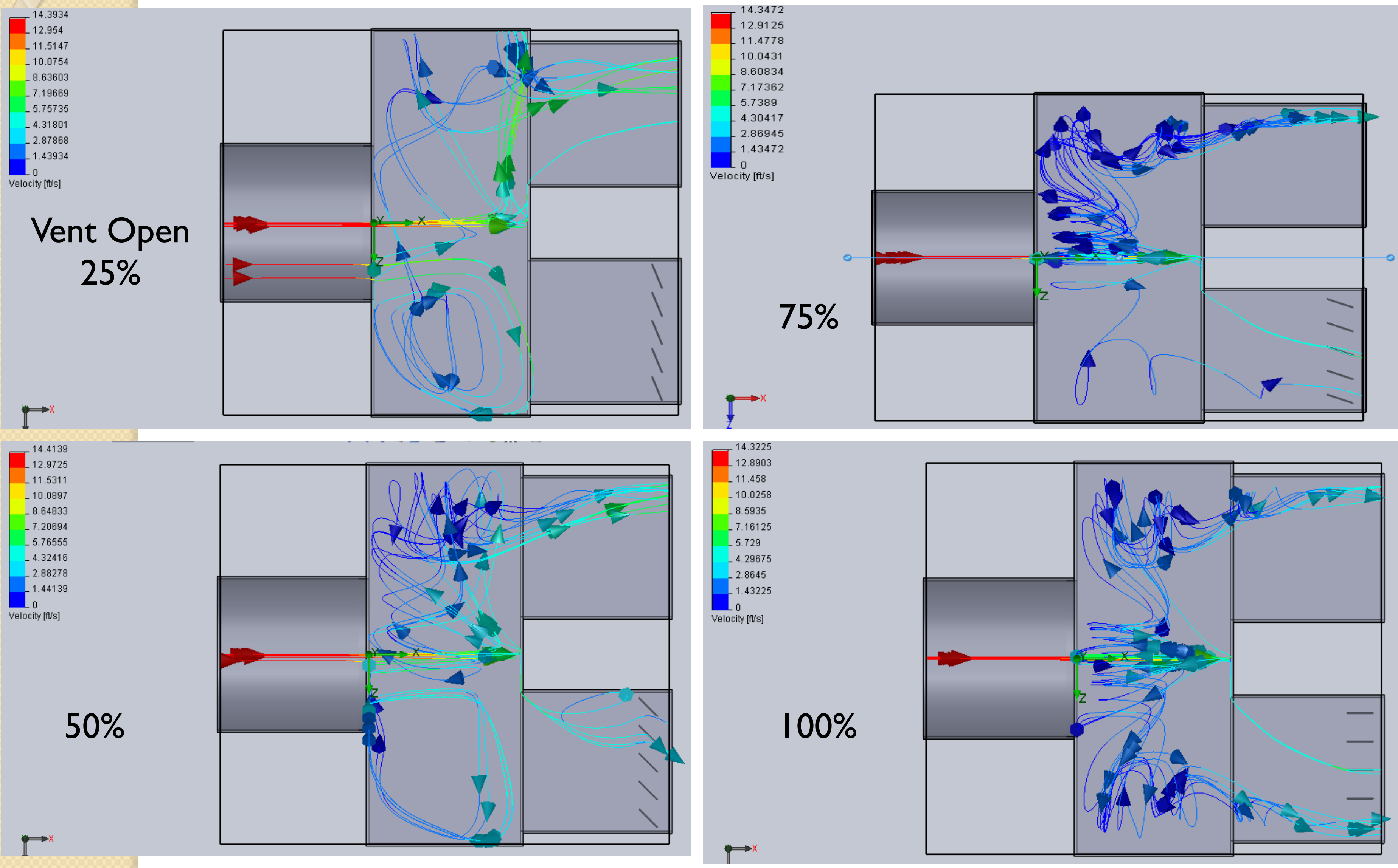
- Stress Plot



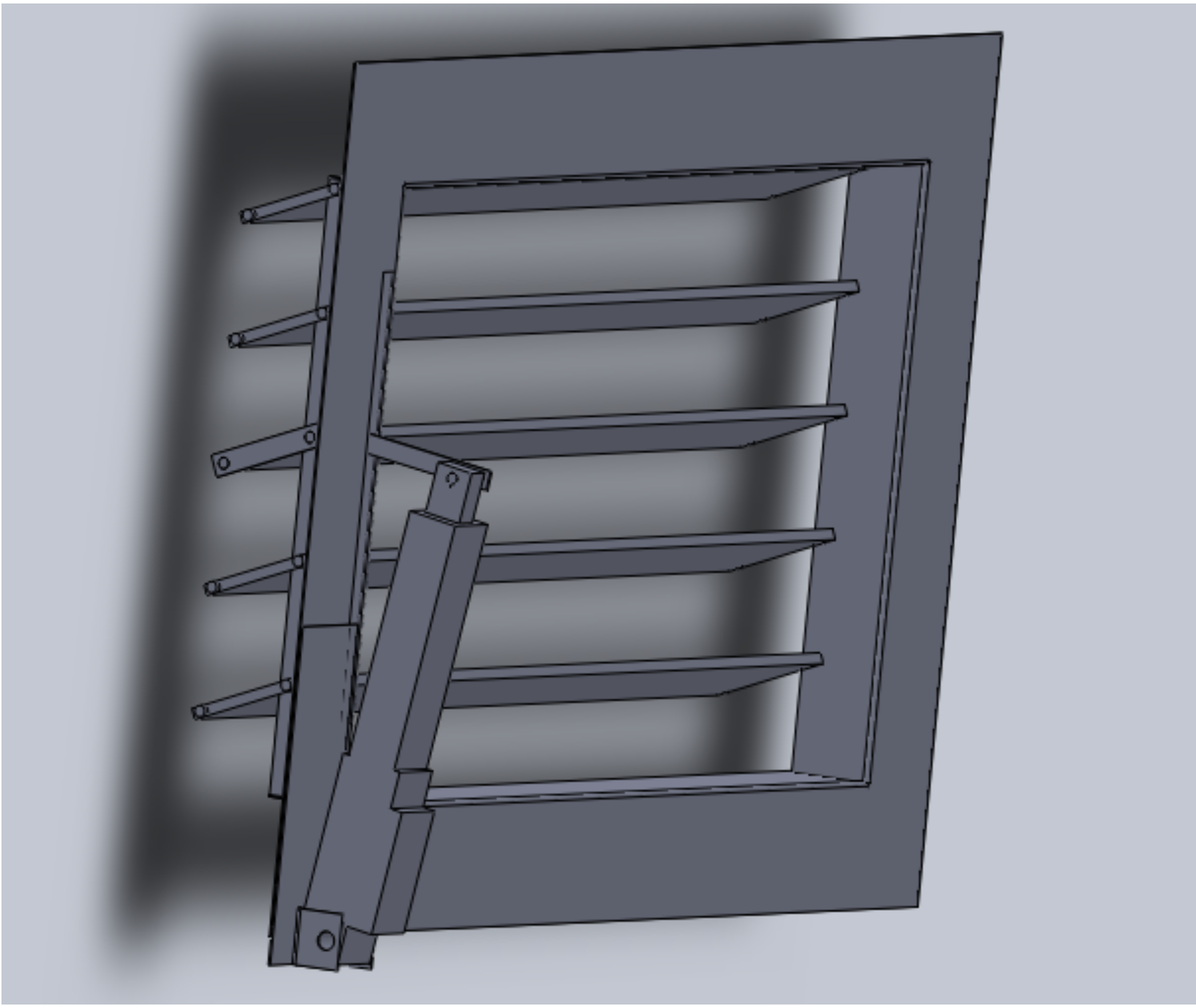
- Displacement Plot



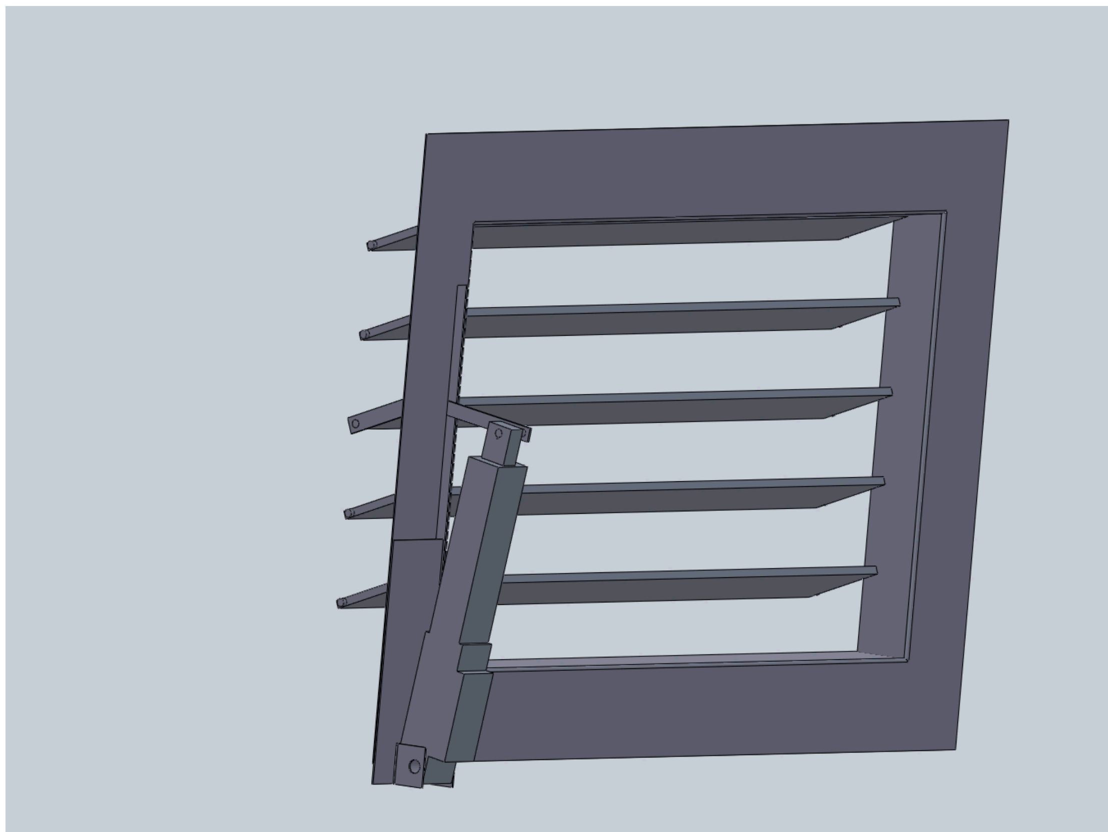
FlowWorks Simulation



Vent Design

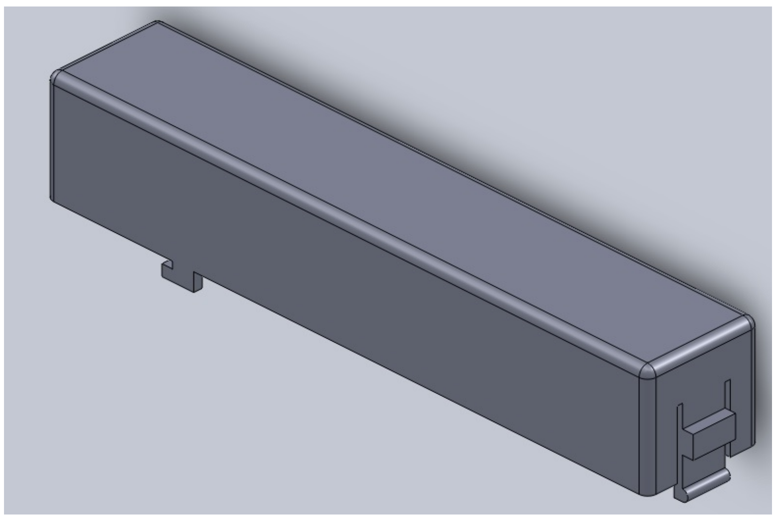


Linear Actuator Hinge Design

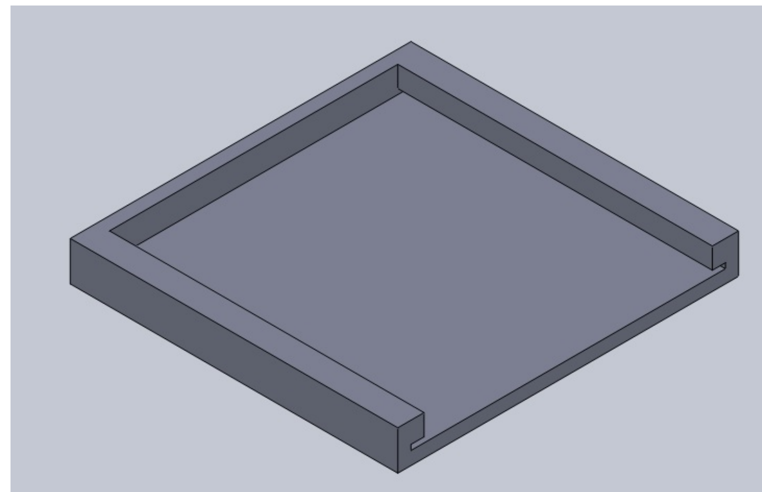


Protection

- Linear Actuator Cover



- Actuator Controller Dish



Innovation

Modular Design

- Design is modified off the-shelf register
- Replaces standard house vent with little modification of current structure
- Easy renovation and system expansion

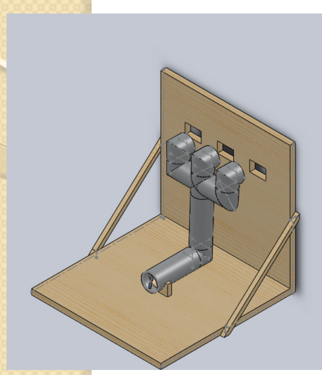
Mechanics

•Back of actuator hinged to face of vent

•Piston end of actuator mounted on pivot to lever arm for louver control

•Unit protected by easily detachable casing

HVAC Test Rig



Conceptual Design

- Simulates ventilation system in a typical household
- Air flow supplied by two in-line duct fans
- Registers have average air speed of 1.1 m/s (3.6 ft/s)when 100% open

Actual Rig

Control System

LabVIEW Control System

•Manual position control of actuators by user
•Timer function permits automatic position control depending on time and date

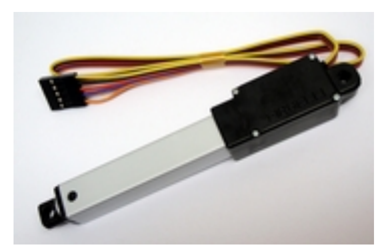
Linear Actuator Control Board

•Stand alone closed loop control board
•Controlled via USB
•On board/computer adjustment of speed, sensitivity, and stroke limits
•Position feedback
•Battery powered

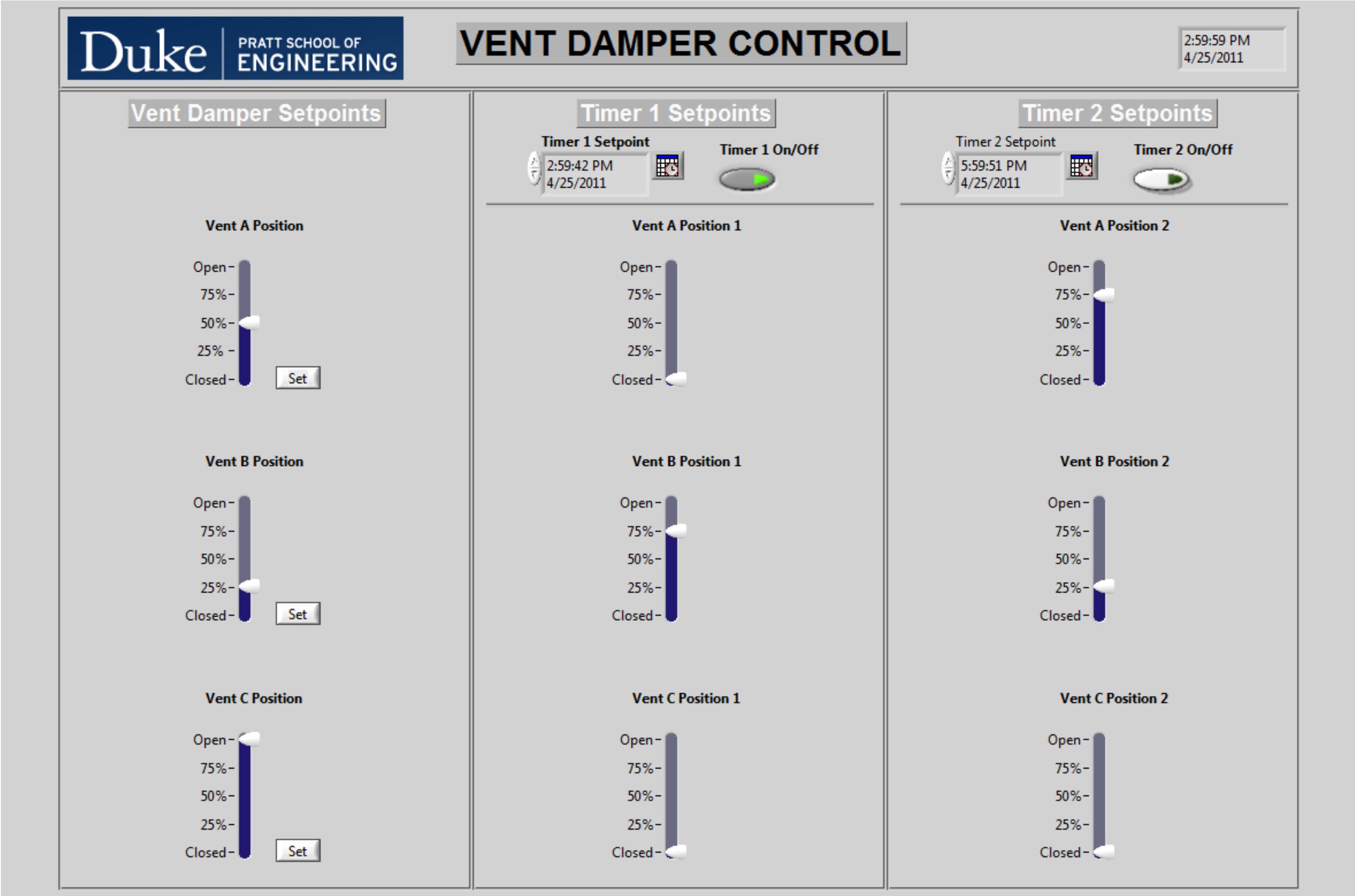
Firgelli Linear Actuator

•Specified force output of 15 lbs
•Lifetime = 1000 hrs
•Internal potentiometer for position feedback
•Stroke length= 50mm
•Gear Ratio= 50:1
•Voltage= 6 volts

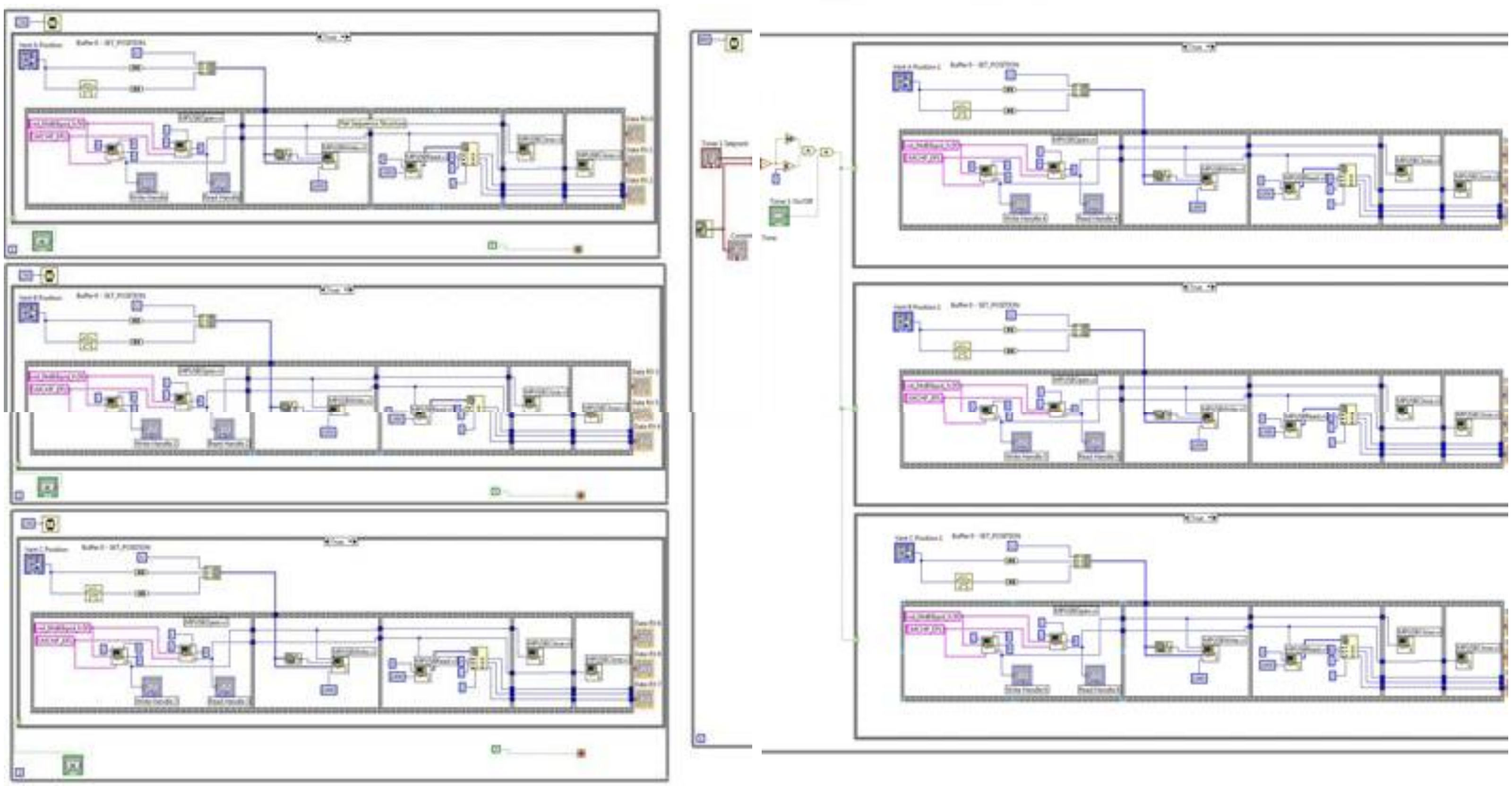
NATIONAL INSTRUMENTS LabVIEW



Vent Damper Control



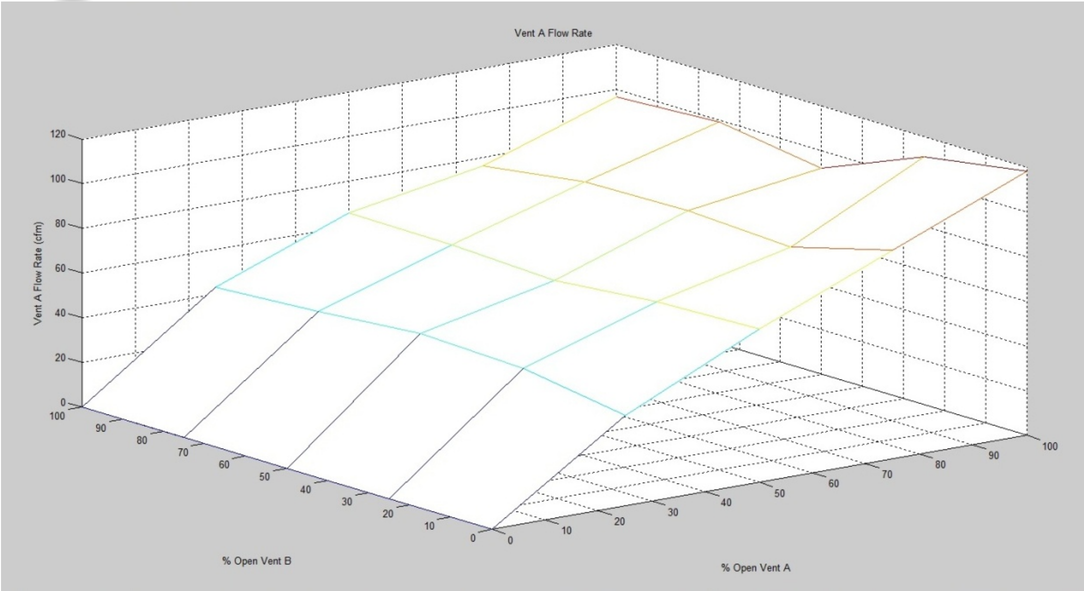
Controller Block Diagram

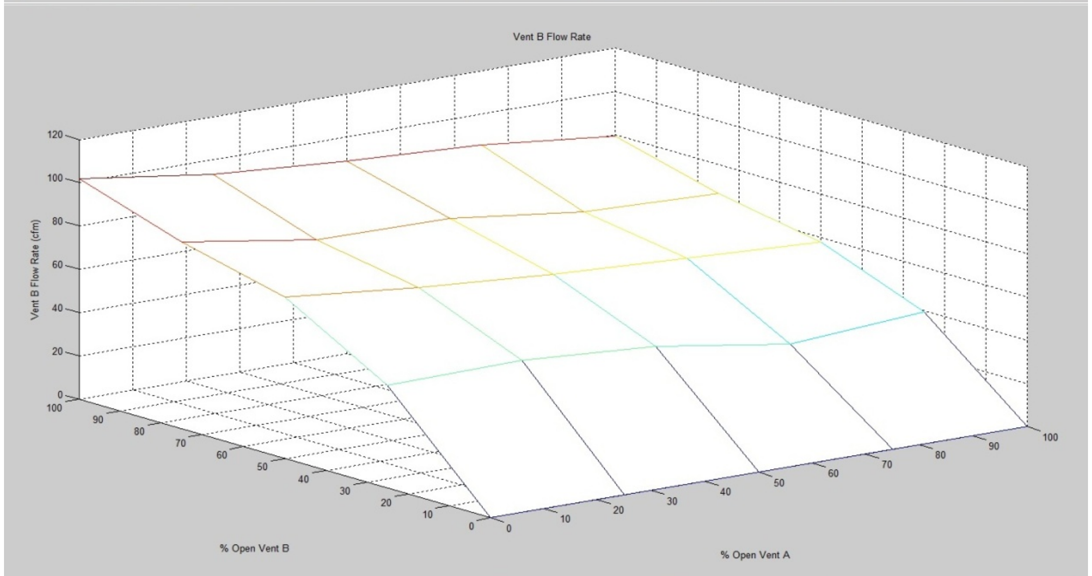


Testing

- Need to verify ability to balance flow and increase or decrease flow through any given vent
- Test with two vents cycling through all possible positions
- Measure air velocity exiting vent perpendicular to direction of travel

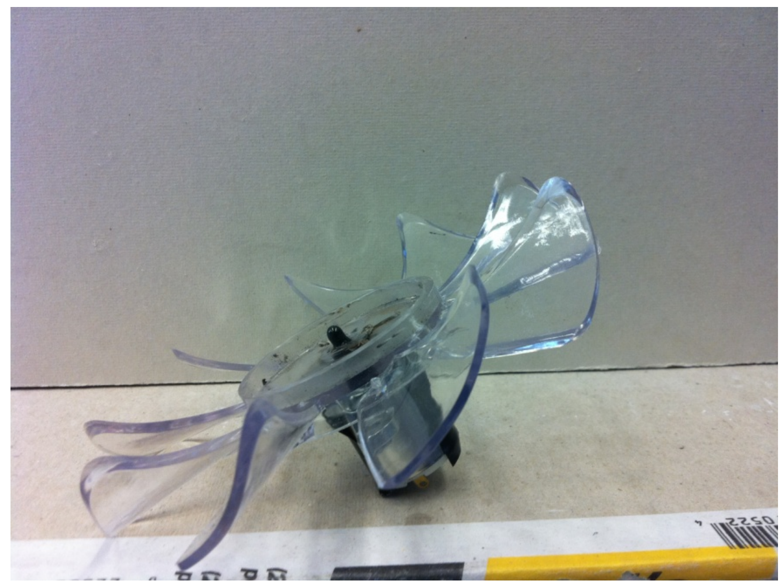
Testing Results





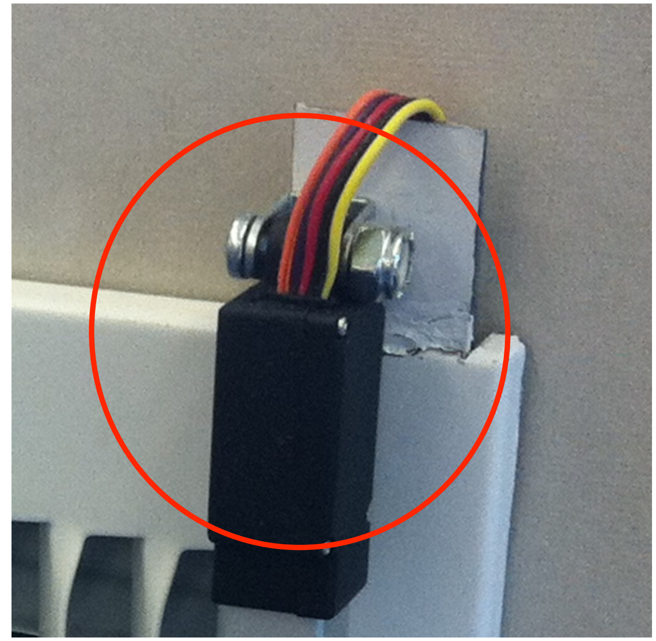
Trouble Areas

- Desire to have closed-loop system with anemometers providing feedback
- Purchasing anemometer would be too expensive ~$400 ea.
- Could not make anemometer sensitive enough for low air flows < 1 m/s



Prototype to Production

- Linear Actuator:
  - Use actuator with 30mm stroke length instead of 50mm to avoid modifying vent
- Control Software:
  - More visually appealing
  - Integrate room temperature sensors
  - Integrate vent anemometer inputs
  - Software can be obtained for free on all computers
- Control Board:
  - Use wirelessly controlled boards OR boards that rely on USB power



Product Future

- Use Bluetooth instead of USB for communication.
  - Requires solving power problems
- Use thermocouples to measure temperature in each room
  - Adjust louver position based on room temperature rather than CFM

Conclusion

Recommended for production

- System payback period of 5 years
- System easily upgradeable and expandable
- Easy installation
- Large target market
- Environmentally-friendly