AVDASI2 Actuation & Control

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Outline

- Requirements
- Timeline
- Considerations (non-exhaustive)
- Suggested approach
- Suggested work plan

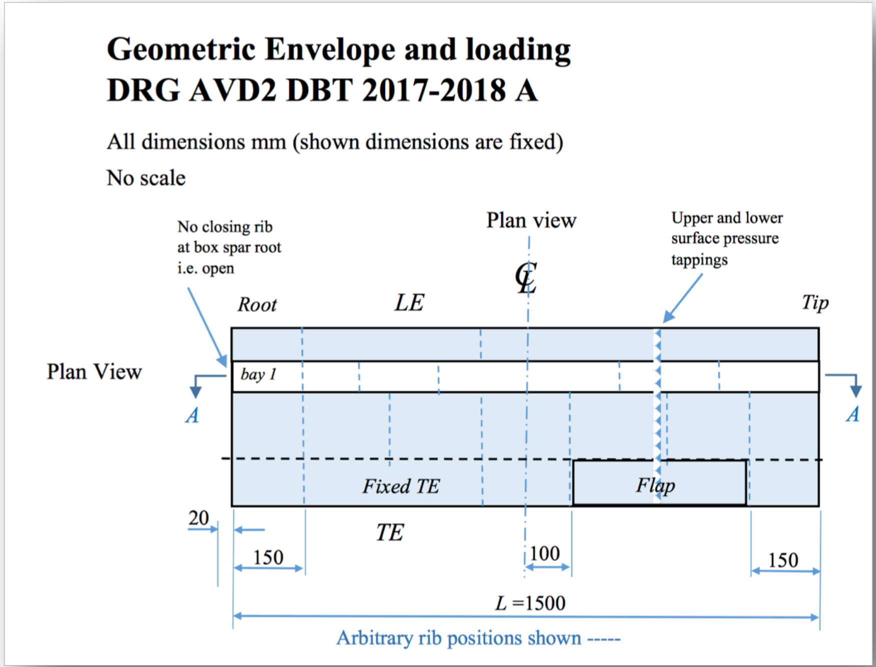
Requirements

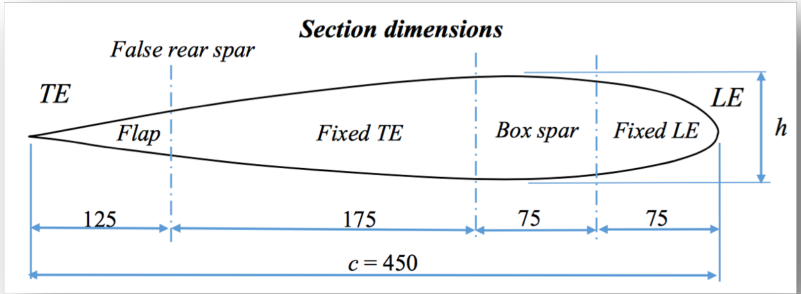
- From reqs doc:
  - The flap must be electronically actuated and capable of achieving and holding precise positions under normal flight conditions and up to the ultimate design load. Indications of actuation and achieved positions must be provided.
  - To prove the flap control deployment shall be demonstrated in the wind tunnel at various wind speeds and angles of attack and in the structural test up to ultimate loading.

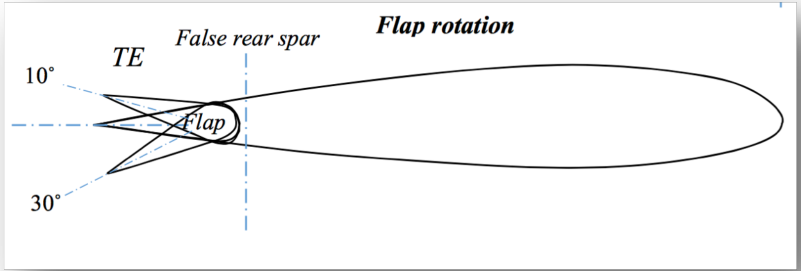
Requirements

- Elaboration/specifics:
  - The flap actuation system shall operate correctly under expected aerodynamic and structural loads
  - An indicator shall be shown when the flap reaches within ±5° of the commanded position
  - The flap shall automatically stop in at least two locations: fully retracted and fully deployed
  - The control system shall not require additional support equipment
    - i.e. it shall be possible to control the flap without an external computer

Requirements







Timeline

Intro and inductions
- Wk3-4

Comms reports
- Wk9

Working demonstrator
- Friday wk12

Deliver wing
- Wk17

Assess against reqs
- During aero & strucs tests wk19-20

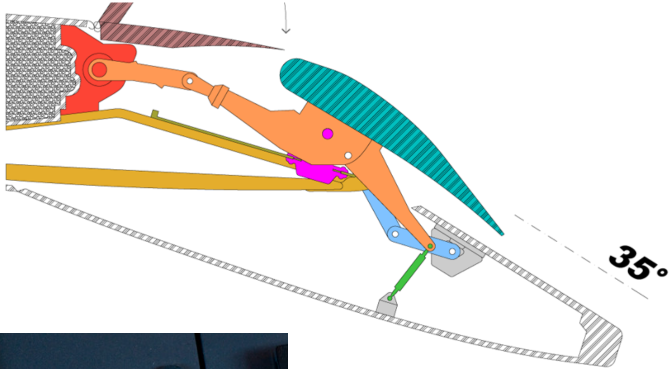
Requirement 1: Operation Under Loads

"The flap actuation system shall operate correctly under expected aerodynamic and structural loads"

- Hinge moments
  - Aerodynamic loads
  - Actuator's control power
  - Mechanism design
- Span-wise bending
  - Mechanism should continue to run freely at ultimate load

Requirement 2: Position Indicators

"An indicator shall be shown when the flap reaches within ±5° of the commanded position"

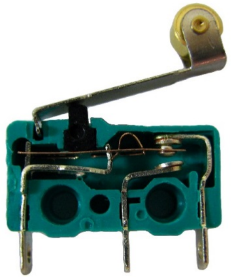


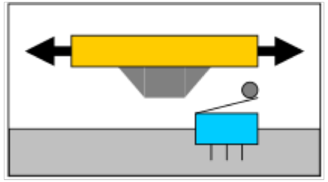
- Aero testing for different flight phases, probably want 4 positions
- Requires **sensing** of position
  – Could be a potentiometer
- Probably an LED indicator
- Think about verification
  – Accuracy and precision

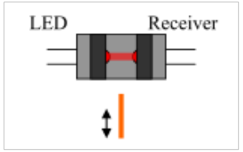
Requirement 3: Automatically Stop

"The flap shall automatically stop in at least two locations: Fully retracted and fully deployed"

- At least two locations
  - Failsafe / prevents damage
  - *Could* include intermediate points
- Automatically stop
  - Reliable sensing + suitable control







Requirement 4: Support Equipment

"The control system shall not require additional support equipment"

- Additional = not delivered with your wing
- Must be able to drive flap in your absence, i.e. without your laptop etc.
- Probably driven from a control panel on the end of lead
  - Could hold push buttons, actuator stops upon release
  - Many push buttons - e.g. one for each position
  - One multi-way switch to select flap position

Up

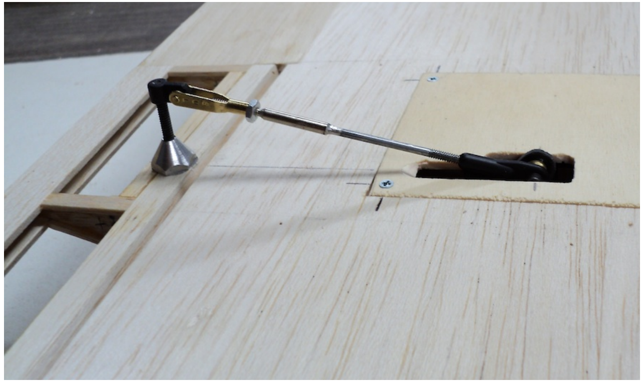
Down

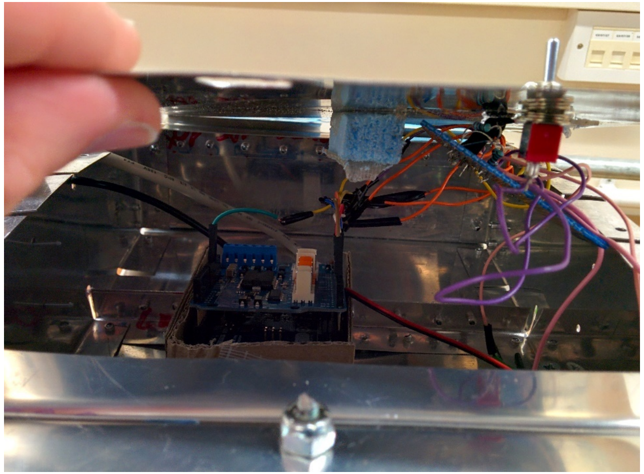
Considerations

- Key components
  - **Mechanism** design and manufacture
  - **Actuator** sizing and integration
  - **Sensing** solution(s)
  - **Control** hardware and software

Mechanism Integration

- Choice of materials
  - 3D printers, laser cutter available, suitable?
- Strength and stability
- Tolerances and friction
- Packaging - inside wing more efficient
- Location of electronics



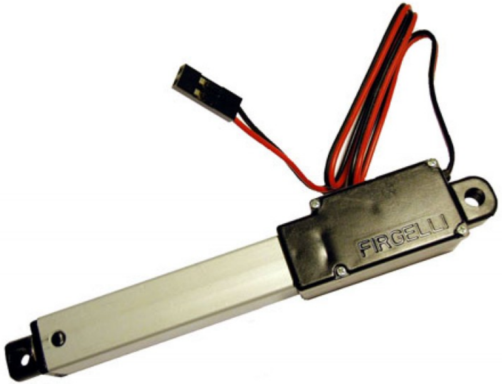


Actuator Examples

- Varying advantages/disadvantages
- Check datasheets, online tutorials

Servo

DC Geared motor



Firgelli linear actuator

Actuator Examples

DC Geared motor

never before been combined in a device of this size. These small linear actuators are a superior alternative to designing with awkward gears, motors, servos and linkages.

Firgelli's L series of micro linear actuators combine the best features of our existing micro actuator families into a highly flexible, configurable and compact platform with an optional sophisticated on-board microcontroller. The first member of the L series, the L12, is an axial design with a powerful drivetrain and a rectangular cross section for increased rigidity. But by far the most attractive feature of this actuator is the broad spectrum of available configurations.

Benefits

- Compact miniature size
- Simple control using industry standard interfaces
- Low voltage
- Equal push / pull force
- Easy mounting

Applications

- Robotics
- Consumer appliances
- Toys
- Automotive
- Industrial automation

L12 Specifications

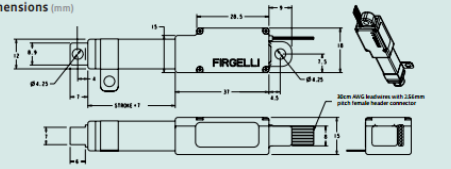
Gearing Option	50	100	210
Peak Power Point [1]	12 N @ 11 mm/s	23 N @ 6 mm/s	45 N @ 2.5 mm/s
Peak Efficiency Point	6 N @ 16 mm/s	12 N @ 8 mm/s	18 N @ 4 mm/s
Max Speed (no load)	23 mm/s	12 mm/s	5 mm/s
Backdrive Force [2]	43 N	80 N	150 N

Stroke Option	10 mm	30 mm	50 mm	100 mm
Weight	28 g	34 g	40 g	56 g
Positional Accuracy	0.1 mm	0.2 mm	0.2 mm	0.3 mm
Max Side Force (fully extended)	50 N	40 N	30 N	15 N

Mechanical Backlash	0.1 mm
Feedback Potentiometer	2.75 kΩ/mm ± 30%, 1% linearity
Duty Cycle	20 %
Lifetime	1000 hours at rated duty cycle
Operating Temperature	–10°C to +50°C
Storage Temperature	–30°C to +70°C
Ingress Protection Rating	IP–54
Audible Noise	55 dB at 45 cm
Stall Current	450 mA at 5 V & 6 V, 200 mA at 12 V

[1] 1 N (Newton) = 0.225 lb_f (pound-force)
[2] a powered-off actuator will statically hold a force up to the Backdrive Force

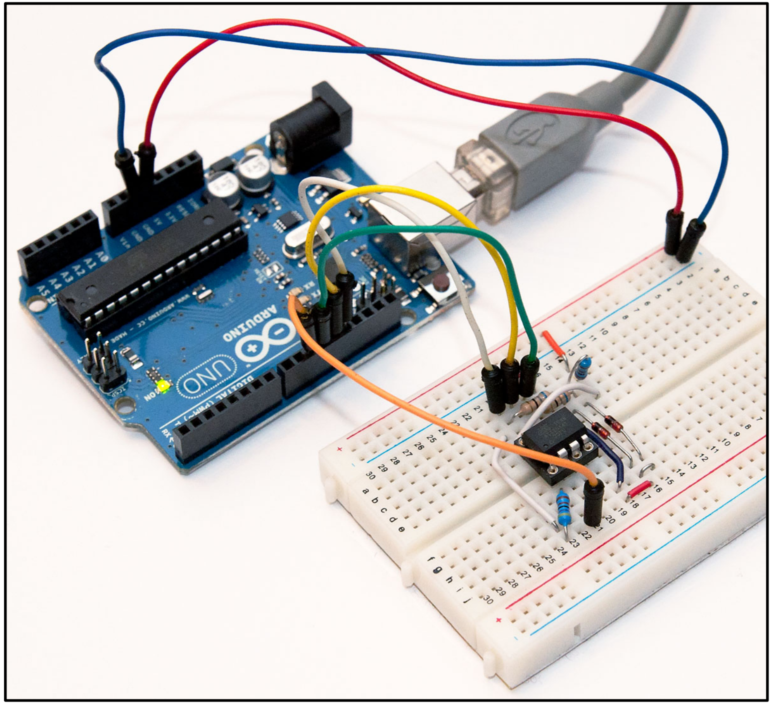
Dimensions (mm)



Firgelli linear actuator

Electronics: Arduino

- Microcontroller prototyping platform
- Interacts with world through I/O, e.g.
  - Read analog voltages, digital signals
  - Blink LEDs, drive motors
- 'Shields' for hardware prototyping
- Behaviour programmed in 'Arduino-flavoured' C
  - From simple to quite complex

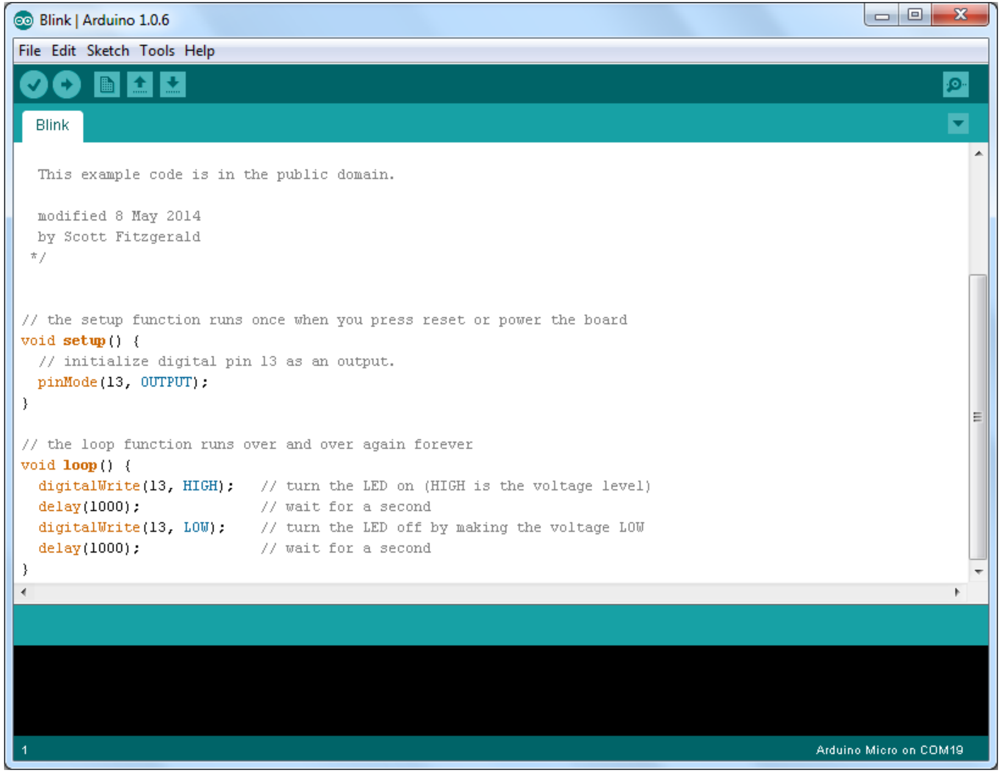


Electronics: Arduino Programming

Arduino IDE:

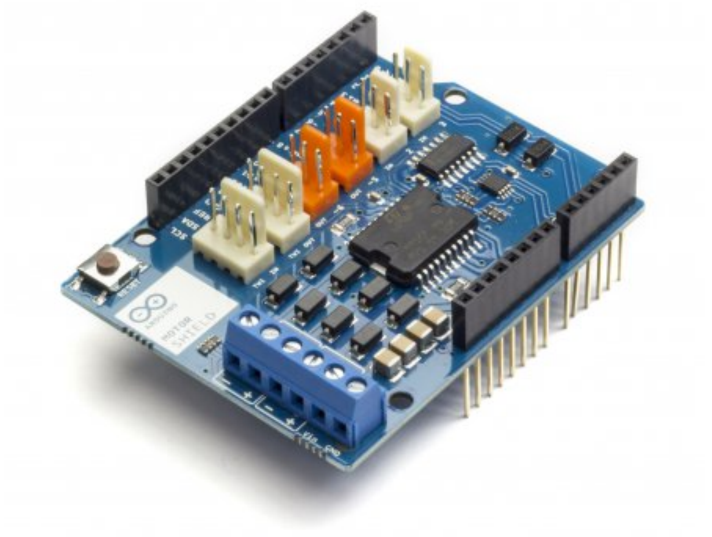
- Write the program “sketch”
- Compile it
- Upload it
- Monitor operation

- Many examples included



Electronics: Arduino Motor Shield

- “Shields” for common task
- Stacks on top of Arduino
- Motor shield handles power for driving motors
  - Arduino pins cannot handle motor currents directly



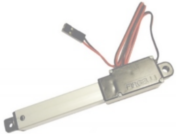
Taking things further

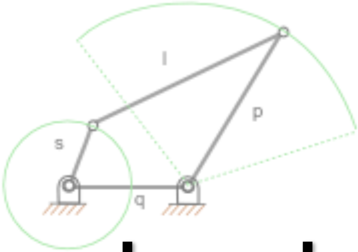
- More ambitious mechanisms?
- Redundancy?
- Fail-safe?
- Wireless comms?
- Integrated power?
- Simplified digital hardware – custom PCB?
- BUT start simple, then address stretch goals.
  - Simple hinged flap will meet requirements!!!

Actuation Task Recap: Building Blocks

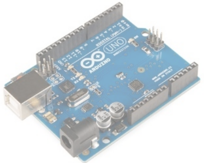
Sensing

Actuation





Control



Mechanism

Ordering Kit

- Standard list of components available
  - See Blackboard – wk5
- Many other options for 'sale'
  - Enquire with TAs

Design - Mechanisms ...

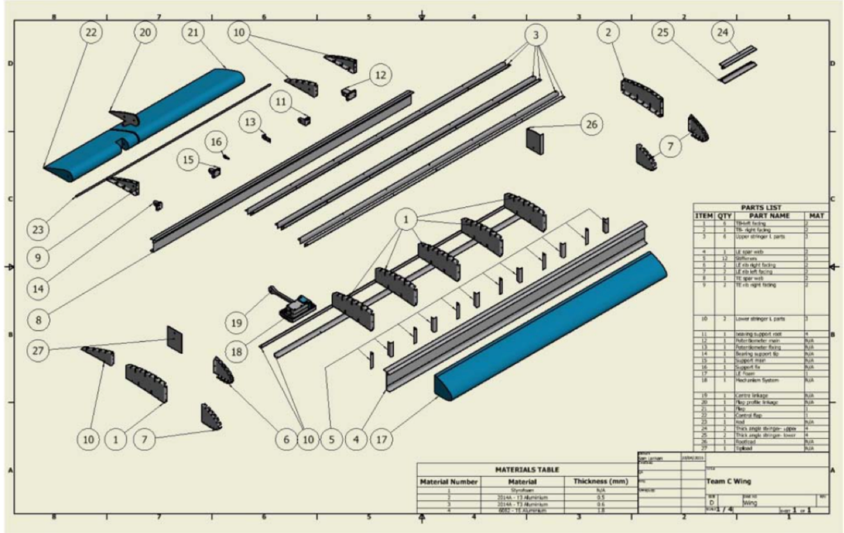
Approach:

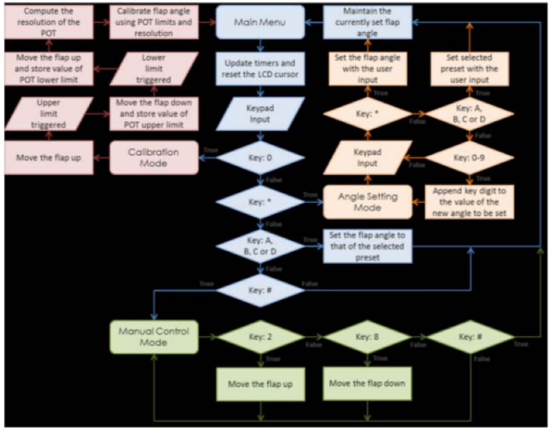
- Scheme hinges and basic linkages to obtain required flap deployment.
- For initial design consider hinge lines and trajectory of flap for continuity of profile using CAD and check animation.
- For refined design check stiffness, strength and stability of linkage elements and supporting structure and consider accurate positioning (indexing?) and locking. Consider alignment, friction and losses in deformed loaded structure.

… Actuation & Control

<u>Approach:</u>

- Scheme actuation motors and gearing
- Scheme position sensing method and stops
- Scheme control logic
- Animate using CAD
- Bench test





2.3 Mechanism

2.3.1 Mechanical

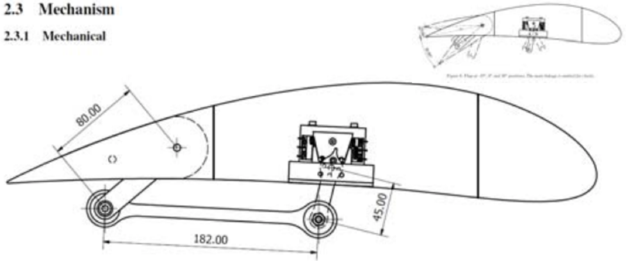
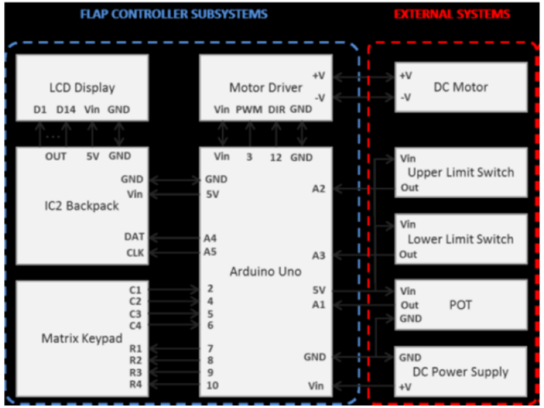
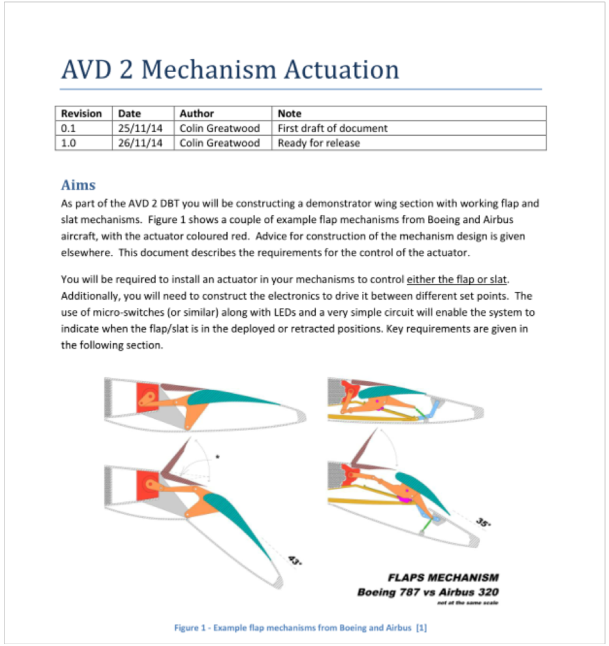


Figure 5: Mechanism drawing, showing the lengths of key linkages, and the location of the motor box within the wing torque box.



Further Guidance

- Check docs in A&C folder on Bb
- Self taught
  - www.arduino.cc
- Mechanisms lectures
- Labs
  - TAs



AVD 2 Mechanism Actuation

Revision	Date	Author	Note
0.1	25/11/14	Colin Greatwood	First draft of document
1.0	26/11/14	Colin Greatwood	Ready for release

Aims

As part of the AVD 2 DBT you will be constructing a demonstrator wing section with working flap and slat mechanisms. Figure 1 shows a couple of example flap mechanisms from Boeing and Airbus aircraft, with the actuator coloured red. Advice for construction of the mechanism design is given elsewhere. This document describes the requirements for the control of the actuator.

You will be required to install an actuator in your mechanisms to control either the flap or slat. Additionally, you will need to construct the electronics to drive it between different set points. The use of micro-switches (or similar) along with LEDs and a very simple circuit will enable the system to indicate when the flap/slat is in the deployed or retracted positions. Key requirements are given in the following section.

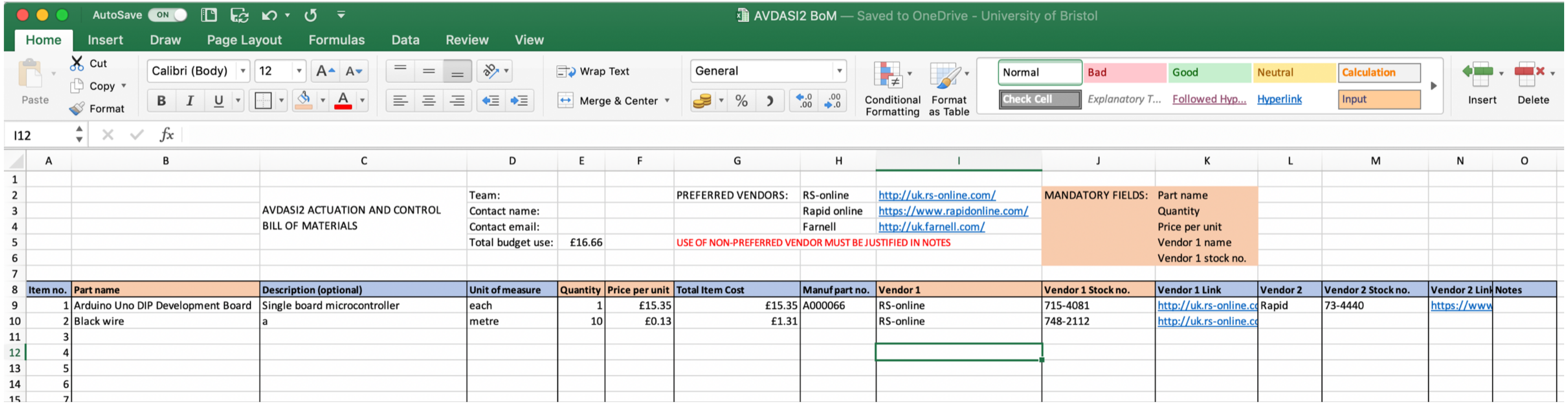
Figure 1 - Example flap mechanisms from Boeing and Airbus [1]

Learning

- Mechanisms lectures, also:
  - http://507movements.com
  - http://www.mechanisms.co
  - https://www.youtube.com/user/thang010146/videos
  - https://en.wikipedia.org/wiki/Four-bar_linkage, http://dynref.engr.illinois.edu/aml.html
  - https://en.wikipedia.org/wiki/Flap_(aeronautics)#Types_of_flap
- Arduino starter kit (1-2 per team)
  - www.arduino.cc/en/Guide/HomePage
  - www.oomlout.com/a/products/ardx/

Ordering

- Bill of Materials – ‘BoM’
  - Submit for demonstrator and for final wing – one order for each
  - Lists components, ordering details, costs
  - INCOMPLETE BoMs WILL CAUSE DELAYS
  - NON-PREFERRED SUPPLIERS MAY CAUSE DELAYS



AVDASI2 ACTUATION AND CONTROL
BILL OF MATERIALS

Team:
Contact name:
Contact email:
Total budget use: £16.66

PREFERRED VENDORS: RS-online http://uk.rs-online.com/ ; Rapid online https://www.rapidonline.com/ ; Farnell http://uk.farnell.com/

USE OF NON-PREFERRED VENDOR MUST BE JUSTIFIED IN NOTES

MANDATORY FIELDS: Part name, Quantity, Price per unit, Vendor 1 name, Vendor 1 stock no.

Item no.	Part name	Description (optional)	Unit of measure	Quantity	Price per unit	Total Item Cost	Manuf part no.	Vendor 1	Vendor 1 Stock no.	Vendor 1 Link	Vendor 2	Vendor 2 Stock no.	Vendor 2 Link	Notes
1	Arduino Uno DIP Development Board	Single board microcontroller	each	1	£15.35	£15.35	A000066	RS-online	715-4081	http://uk.rs-online.co	Rapid	73-4440	https://www	
2	Black wire	a	metre	10	£0.13	£1.31		RS-online	748-2112	http://uk.rs-online.co				
3														
4														
5														
6														
7														

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Suggestions

- Consider interfaces – within A&C sub-group and with wider team
  - Physical dimensions and attachment
  - Wiring, power, actuators, linkages – check full range of movement
  - Communicate changes, regular checks
  - Tradeoffs – weight, aerodynamics, space, loads…
- Split tasks appropriately
  - **Mechanism** design and manufacture
  - **Actuator** sizing and integration
  - **Sensing** solution(s)
  - **Control** hardware and software
  - **Purchasing** and receipt

Questions?