

## Description of High Lift Control Systems

### RATIONALE

There is a need for a general overview of implementation of High Lift Systems as a source of information both for aircraft manufacturers specifying these types of systems as for systems suppliers designing them. This document meets this need.

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Table 1 System type and drive technology abbreviations used in overview



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## 1. SCOPE

This SAE Information Report (AIR) provides descriptions of High Lift Systems of commercial and military aircraft. The main focus is on mechanical systems which may be actuated hydraulically or electrically.

### 1.1 Purpose

The document is intended as an overview for those specifying or designing High Lift Systems in order to compare existing solutions as reference for implementation in new aircraft programs.

## 2. REFERENCES

### 2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The applicable issue of the publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

#### 2.1.1 EASA Publications

Available from European Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany (for visitors and for mail over 1 kg) and Postfach 10 12 53, D-50452 Cologne, Germany (for mail 1 kg or less); Tel: +49 221 8999 000, [www.easa.europa.eu](http://www.easa.europa.eu).

CS-23 Certification Specifications and Acceptable Means of Compliance for Normal-Category Aeroplanes.

CS-25 Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes.

#### 2.1.2 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, [www.faa.gov](http://www.faa.gov).

14CFR Part 23 Airworthiness Standards: Normal Category Airplanes

AC No: 23-17C Systems and Equipment Guide for Certification of Part 23 Airplanes and Airships

14CFR Part 25 Airworthiness Standards: Transport Category Airplanes

### 2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

#### 2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), [www.sae.org](http://www.sae.org).

AIR 4094 Aircraft Flight Control Systems Descriptions

AIR4253 Description of Actuation Systems for Aircraft with Fly-By-Wire Flight Control Systems

### 3. DESCRIPTION OF HIGH LIFT SYSTEMS

#### 3.1 General

High Lift Systems comprise Leading Edge Devices such as Leading Edge Slat Systems, Droop Nose Devices and Krueger Flap Devices, and Trailing Edge Devices such as Fowler Flaps and Simple Hinged Flaps.

Most applications on commercial or military aircraft use a central drive unit, distributing the power to the panels through a transmission shaft system with gearboxes adjusting driveline direction or avoiding obstacles in the driveline run to finally actuating the panel with different types of drive stations, possibly incorporating down drives, and driving the aircraft kinematic interface with ballscrews, lever or pinion outputs.

Alternatively there are systems operated by linear hydraulic actuators or electromechanical actuators (EMAs) directly acting on the aircraft kinematic interface point.

##### 3.1.1 Background on Top Level Requirements

Typical requirements for High Lift Systems include availability for each of the systems (Leading Edge and Trailing Edge) in the range of  $10^{-5}$  failures per flight hour, and there are much more stringent safety related requirements for asymmetry, disconnect or uncommanded movement.

In the civil airworthiness regulations, the following paragraphs are to be considered especially:

- 14 CFR/CS 25.697 (lift and drag devices, controls) (b) "Each lift and drag device control must be designed and located to make inadvertent operation improbable..."
- 14 CFR/CS 25.699 (lift and drag device indicator)
- 14 CFR/CS 25.701 (flap and slat interconnection) i.e., (a) "Unless the airplane has safe flight characteristics with the flaps or slats retracted on one side and extended on the other, the motion of flaps or slats on opposite sides of the plane of symmetry must be synchronized by a mechanical interconnection or approved equivalent means..."

The respective paragraphs are also included in regulatory documents of other nations.

A similar wording also is adopted for Normal Category Airplane in Advisory Circular 23-17C to 14 CFR23 and the guidance material to CS-23.

Tables 3 to 10 present overviews of High Lift Systems as they are in current production. In the later sections, the systems are presented in more detail with schematic diagrams.

Tables 1 and 2 provide the abbreviations that are used in overview.

**Table 1 - System type and drive technology abbreviations used in overview**

| System Type |                   | Drive Concept |                       | Drive Power |                                                         | Transmission |                       |     |                            |
|-------------|-------------------|---------------|-----------------------|-------------|---------------------------------------------------------|--------------|-----------------------|-----|----------------------------|
| S           | Slat              | C             | Central Drive Unit    | E           | Single Electric Drive                                   | TTA          | Torque Tube Aluminum  | STL | System Torque Limiter      |
| DN          | Droop Nose        | W             | Separate Wing Drives  | H           | Single Hydraulic Drive                                  | TTS          | Torque Tube Steel     | CF  | Compliance                 |
| K           | Krueger Flap      | M             | Multiple Panel Drives | EA/EA       | Duplex Electric Drive (Active/Active)                   | TTC          | Torque Tube Composite | CL  | Clutch                     |
| FF          | Fowler Flap       | P             | Single Panel Drives   | HA/HA       | Duplex Hydraulic Drive (Active/Active)                  | TTT          | Torque Tube Titanium  | ETL | Electronic Torque Limiting |
| SHF         | Single Hinge Flap | S             | Station Drives        | EA/HA       | Duplex Hybrid Drive (Active/Active)                     | TT           | Torque Tube general   | HR  | Hydraulic Flow Restrictor  |
|             |                   |               |                       | EA/EB       | Duplex Electric Drive (Active/Backup)                   | FS           | Flexible Shafts       |     |                            |
|             |                   |               |                       | HA/HB       | Duplex Hydraulic Drive (Active/Backup)                  | MC           | Mechanical Cables     |     |                            |
|             |                   |               |                       | HA/EB       | Duplex Hybrid Drive (Active/Backup)                     |              |                       |     |                            |
|             |                   |               |                       | PA/EB       | Duplex Hybrid Drive (Pneumatic Active/ Electric Backup) |              |                       |     |                            |

**Table 2 - Actuation and output abbreviations used in overview**

| Actuator Type |                                         | Actuator Torque Limiter |                | Output |                  | Safety System |                                        |
|---------------|-----------------------------------------|-------------------------|----------------|--------|------------------|---------------|----------------------------------------|
| BSAN          | Ballscrew Actuators - Translating Nut   | TL                      | Torque Limiter | C      | Carriage         | HOF           | Pressure-Off/ Brake applied            |
| BSAS          | Ballscrew Actuators - Translating Screw | LL                      | Load Limiter   | L      | Lever            | HON           | Pressure-On/ Brake applied             |
| ASA           | ACME Screw Actuators                    | SD                      | Shear Device   | P      | Pinion (Rack)    | EOF           | Electric Power-Off/ Brake applied      |
| GRA           | Geared Rotary Actuators                 |                         |                | MC     | Mechanical Cable | EON           | Electric Power-On/ Brake applied       |
| HA            | Hydraulic Actuator                      |                         |                |        |                  | CFB           | Constant Friction Brake                |
| EMBA          | Electromechanic Ballscrew Actuators     |                         |                |        |                  | UCFB          | Unidirectional Constant Friction Brake |
| EMRA          | Electromechanic Rotary Actuators        |                         |                |        |                  | NB            | Actuator Noback                        |
|               |                                         |                         |                |        |                  | Brk           | Other Type of Brake                    |
|               |                                         |                         |                |        |                  | HL            | Hydraulic Lock                         |

## 3.2 Leading Edge Systems

Tables 3 to 6 summarize the Leading Edge Systems described in this report.

## 3.2.1 Leading Edge Systems - Airbus

**Table 3 - Leading edge systems - Airbus - overview**

| Para  | Aircraft          |                     | Panels      |                 | Type of Actuation |                | Transmission                      |                    |                                          |
|-------|-------------------|---------------------|-------------|-----------------|-------------------|----------------|-----------------------------------|--------------------|------------------------------------------|
|       | Manu-<br>facturer | Type                | Type        | Number/<br>Wing | Drive<br>Concept  | Drive<br>Power | Type                              | Limiting<br>Device | Comment                                  |
| 4.1.1 | Airbus            | A300 (B2)<br>(B4)   | S<br>K/S    | 3<br>1/3        | C                 | HA/HA          | TTS                               | CL/STL             | Rivetted                                 |
| 4.1.2 |                   | A300-600            | K/S         | 1/3             | C                 | HA/HA          | TTS                               | CL/STL             | Rivetted                                 |
| 4.1.3 |                   | A310                | K/S         | 1/3             | C                 | HA/HA          | TTS                               | CL/STL             | Rivetted                                 |
| 4.1.4 |                   | A320<br>Family      | S           | 5               | C                 | HA/HA          | TTS                               | None               | Welded                                   |
| 4.1.5 |                   | A330/A340<br>family | S           | 7               | C                 | HA/HA          | TTC/ TTT/TTS                      | CF/STL             | Ti for Compliance,<br>Short Steel Shafts |
| 4.1.6 |                   | A380                | DN/S        | 2/6             | C                 | EA/HA          | TTC/ TTT/TTS                      | CF/STL/<br>ETL     | Ti for Compliance,<br>Short Steel Shafts |
| 4.1.7 |                   | A400M               | N/A         | -               | -                 | -              | -                                 | -                  | -                                        |
| 4.1.8 |                   | A220                | S           | 4               | C                 | HA/HA          | TTS                               | -                  | -                                        |
|       |                   |                     |             |                 |                   |                |                                   |                    |                                          |
| Para  | Aircraft          |                     | Actuators   |                 |                   |                | Safety System                     |                    |                                          |
|       | Manu-<br>facturer | Type                | Type        | Number/<br>Wing | Limiter           | Output         | Comment                           | Type               | Comment                                  |
| 4.1.1 | Airbus            | A300 (B2)<br>(B4)   | HA/<br>BSAS | 1/6             | TL                | L              |                                   | NB                 |                                          |
| 4.1.2 |                   | A300-600            | HA/<br>BSAS | 1/6             | TL                | L              |                                   | HL/NB/<br>UCFB     | Noback for Extend<br>UCFB for Retract    |
| 4.1.3 |                   | A310                | HA/<br>BSAS | 1/6             | TL                | L              |                                   | HL/HON             |                                          |
| 4.1.4 |                   | A320<br>Family      | GRA         | 10              | TL                | P              |                                   | HON                |                                          |
| 4.1.5 |                   | A330/A340<br>family | GRA         | 14              | TL                | L/P            | inb'd slat lever<br>others pinion | HOF                |                                          |
| 4.1.6 |                   | A380                | GRA         | 16              | TL                | L/P            | DN lever<br>others pinion         | HOF                |                                          |
| 4.1.7 |                   | A400M               | N/A         | -               | -                 | -              | -                                 | -                  |                                          |
| 4.1.8 |                   | A220                | GRA         | 8               | TL                | L              | -                                 | HOF                | Skew detection<br>system                 |

## 3.2.2 Leading Edge Systems - Boeing

**Table 4 - Leading edge systems - Boeing - overview**

| Para  | Aircraft                |       | Panels       |                 | Type of Actuation                          |                | Transmission                                    |                    |                                                                        |
|-------|-------------------------|-------|--------------|-----------------|--------------------------------------------|----------------|-------------------------------------------------|--------------------|------------------------------------------------------------------------|
|       | Manu-<br>facturer       | Type  | Type         | Number/<br>Wing | Drive<br>Concept                           | Drive<br>Power | Type                                            | Limiting<br>Device | Comment                                                                |
| 4.2.1 | Boeing                  | 717   | S            | 5               | C (Control)<br>W (Drive)                   | HA/HA          | MC                                              | HR                 |                                                                        |
| 4.2.2 |                         | 737   | K<br>S       | 2<br>3          | C (Control)<br>P (Drive)                   | HA/HB          | -                                               | -                  |                                                                        |
| 4.2.3 |                         | 747   | K<br>S       | 3<br>10         | M<br>4 per wing                            | PA/EB          | TTA                                             |                    | Riveted or EMF                                                         |
| 4.2.4 |                         | 757   | S            | 5               | C                                          | HA/EB          | TTA                                             | CF                 | Shock Absorber                                                         |
| 4.2.5 |                         | 767   | K<br>S       | 1<br>6          | C (I/B slat<br>and Kruger)<br>C (O/B slat) | HA/EB          | TTA                                             |                    | I/B 1 slat and<br>1 Kruger seal flap,<br>5 O/B slat separate<br>drives |
| 4.2.6 |                         | 777   | K<br>S       | 1<br>7          | C                                          | HA/EB          | TTA                                             | STL                | Half System Torque<br>Limiter                                          |
| 4.2.7 | (McDonnell-<br>Douglas) | MD-11 | S<br>D       | 8<br>1          | C (I/B+D)<br>M (O/B)                       | HA             | MC                                              |                    |                                                                        |
|       |                         |       |              |                 |                                            |                |                                                 |                    |                                                                        |
| Para  | Aircraft                |       | Actuators    |                 |                                            |                |                                                 | Safety System      |                                                                        |
|       | Manu-<br>facturer       | Type  | Type         | Number/<br>Wing | Limiter                                    | Output         | Comment                                         | Type               | Comment                                                                |
| 4.2.1 | Boeing                  | 717   | HA           | 4               | -                                          | MC             |                                                 | HOF                | Mechanical Latch                                                       |
| 4.2.2 |                         | 737   | HA           | 5               | -                                          | L              |                                                 | HL                 |                                                                        |
| 4.2.3 |                         | 747   | GRA/<br>BSAN | 26/0<br>20/3    | -                                          | L              | Kruger alt. w/<br>duplex Rotary<br>or Ballscrew | EOF                |                                                                        |
| 4.2.4 |                         | 757   | GRA          | 10              | TL                                         | P              |                                                 | NB                 |                                                                        |
| 4.2.5 |                         | 767   | GRA          | 13              | T/L in Offset<br>GB                        | L              | Kruger with 1<br>actuator                       | NB                 |                                                                        |
| 4.2.6 |                         | 777   | GRA          | 15              | TL                                         | P<br>L         | Kruger w/ lever                                 | NB                 |                                                                        |
| 4.2.7 | (McDonnell-<br>Douglas) | MD-11 | HA           | 3               | -                                          | MC             |                                                 | N/A                |                                                                        |

## 3.2.3 Leading Edge Systems - Bombardier

**Table 5 - Leading edge systems - Bombardier - overview**

| Para  | Aircraft          |                   | Panels    |                 | Type of Actuation |                | Transmission |                    |         |
|-------|-------------------|-------------------|-----------|-----------------|-------------------|----------------|--------------|--------------------|---------|
|       | Manu-<br>facturer | Type              | Type      | Number/<br>Wing | Drive<br>Concept  | Drive<br>Power | Type         | Limiting<br>Device | Comment |
| 4.3.1 | Bombardier        | CL300             | N/A       | -               | -                 | -              | -            | -                  | -       |
| 4.3.2 |                   | CL600             | N/A       | -               | -                 | -              | -            | -                  | -       |
| 4.3.3 |                   | Global<br>Express | S         | 4               | C                 | EA/EA          | TTA          | -                  | -       |
|       |                   |                   |           |                 |                   |                |              |                    |         |
| Para  | Aircraft          |                   | Actuators |                 |                   |                |              | Safety System      |         |
|       | Manu-<br>facturer | Type              | Type      | Number/<br>Wing | Limiter           | Output         | Comment      | Type               | Comment |
| 4.3.1 | Bombardier        | CL300             | N/A       | -               | -                 | -              | -            | -                  | -       |
| 4.3.2 |                   | CL600             | N/A       | -               | -                 | -              | -            | -                  | -       |
| 4.3.3 |                   | Global<br>Express | BSAS      | 8               | TL                | L              | -            | EOF                | -       |

## 3.2.4 Leading Edge Systems - Dornier, Embraer, Gulfstream, Lockheed, Sukhoi, Syber Jet

**Table 6 - Leading edge systems - other aircraft - overview**

| Para  | Aircraft          |                   | Panels    |                 | Type of Actuation |                | Transmission |                    |             |
|-------|-------------------|-------------------|-----------|-----------------|-------------------|----------------|--------------|--------------------|-------------|
|       | Manu-<br>facturer | Type              | Type      | Number/<br>Wing | Drive<br>Concept  | Drive<br>Power | Type         | Limiting<br>Device | Comment     |
| 4.4.1 | Dornier           | Do-228            | N/A       | -               | -                 | -              | -            | -                  | -           |
| 4.4.2 |                   | Do-328            | N/A       | -               | -                 | -              | -            | -                  | -           |
| 4.5.1 | Embraer           | ERJ 145<br>Family | N/A       | -               | -                 | -              | -            | -                  | -           |
| 4.6.1 | Gulfstream        | G200              | S         | 1               | C                 | E              | FS           | CF/ETL             |             |
| 4.7.1 | Lockheed          | L1011             | S         | 7               | C                 | HA/HA          | TT           | CF/STL             | riveted     |
| 4.8.1 | Sukhoi            | SJ100             | S         | 4               | C                 | EA/EA          | TTS          | ETL                | welded      |
| 4.9.1 | Syber Jet         | SJ30-2            | N/A       | -               | -                 | -              | -            | -                  | -           |
| Para  | Aircraft          |                   | Actuators |                 |                   |                |              | Safety System      |             |
|       | Manu-<br>facturer | Type              | Type      | Number/<br>Wing | Limiter           | Output         | Comment      | Type               | Comment     |
| 4.4.1 | Dornier           | Do-228            | N/A       | -               | -                 | -              | -            | -                  | -           |
| 4.4.2 |                   | Do-328            | N/A       | -               | -                 | -              | -            | -                  | -           |
| 4.5.1 | Embraer           | ERJ 145<br>Family | N/A       | -               | -                 | -              | -            | -                  | -           |
| 4.6.1 | Gulfstream        | G200              | BSAS      | 3               | TL                | L              |              | NB/EOF             |             |
| 4.7.1 | Lockheed          | L1011             | BSAN      | 7               | TL                | L              |              | Brk                | centrifugal |
| 4.8.1 | Sukhoi            | SJ100             | GRA       | 8               | TL                | P              |              | EOF                |             |
| 4.9.1 | Syber Jet         | SJ30-2            | N/A       | -               | -                 | -              | -            | -                  | -           |

### 3.3 Trailing Edge Systems

Tables 7 to 10 summarize the Trailing Edge Systems described in this report:

#### 3.3.1 Trailing Edge Systems - Airbus

**Table 7 - Trailing edge systems - Airbus - overview**

| Para  | Aircraft          |                     | Panels    |                 | Type of Actuation |                | Transmission |                    |                                          |
|-------|-------------------|---------------------|-----------|-----------------|-------------------|----------------|--------------|--------------------|------------------------------------------|
|       | Manu-<br>facturer | Type                | Type      | Number/<br>Wing | Drive<br>Concept  | Drive<br>Power | Type         | Limiting<br>Device | Comment                                  |
| 4.1.1 | Airbus            | A300                | FF        | 3               | C                 | HA/HA          | TTS          | CL/STL             | Rivetted                                 |
| 4.1.2 |                   | A300-600            | FF        | 3               | C                 | HA/HA          | TTS          | CL/STL             | Rivetted                                 |
| 4.1.3 |                   | A310                | FF        | 2               | C                 | HA/HA          | TTS          | CL/STL             | Rivetted                                 |
| 4.1.4 |                   | A320<br>Family      | FF        | 2               | C                 | HA/HA          | TTS          | None               | Welded                                   |
| 4.1.5 |                   | A330/A340<br>family | FF        | 2               | C                 | HA/HA          | TTC/TTT/TTS  | CF/STL             | Ti for Compliance,<br>Short Steel Shafts |
| 4.1.6 |                   | A380                | FF        | 3               | C                 | HA/HA          | TTC/TTT/TTS  | CF/STL/E           | Ti for Compliance,<br>Short Steel Shafts |
| 4.1.7 |                   | A400M               | SHF       | 2               | C                 | HA/HA          | TTC          | None               |                                          |
| 4.1.8 |                   | A220                | FF        | 2               | C                 | HA/HA          | TTS          |                    |                                          |
| Para  | Aircraft          |                     | Actuators |                 |                   |                |              | Safety System      |                                          |
|       | Manu-<br>facturer | Type                | Type      | Number/<br>Wing | Limiter           | Output         | Comment      | Type               | Comment                                  |
| 4.1.1 | Airbus            | A300                | BSAN      | 6               | TL                | C              |              | NB                 |                                          |
| 4.1.2 |                   | A300-600            | BSAN      | 6               | TL                | C              |              | NB                 |                                          |
| 4.1.3 |                   | A310                | BSAN      | 4               | TL                | C              |              | HON                |                                          |
| 4.1.4 |                   | A320<br>Family      | GRA       | 4               | TL                | L              |              | HON                | Panel connection w/<br>skew detection    |
| 4.1.5 |                   | A330/A340<br>Family | GRA       | 5               | TL                | L              |              | HOF                | Panel connection w/<br>skew detection    |
| 4.1.6 |                   | A380                | GRA       | 6               | TL                | L              |              | HOF                | Panel connection w/<br>skew detection    |
| 4.1.7 |                   | A400M               | BSAN      | 4               | TL                | L              |              | HOF                |                                          |
| 4.1.8 |                   | A220                | GRA       | 4               | TL                | L              |              | HOF                | Skew detection                           |

## 3.3.2 Trailing Edge Systems - Boeing

**Table 8 - Trailing edge systems - Boeing - overview**

| Para  | Aircraft                |       | Panels    |                 | Type of Actuation        |                | Transmission |                    |                                         |
|-------|-------------------------|-------|-----------|-----------------|--------------------------|----------------|--------------|--------------------|-----------------------------------------|
|       | Manu-<br>facturer       | Type  | Type      | Number/<br>Wing | Drive<br>Concept         | Drive<br>Power | Type         | Limiting<br>Device | Comment                                 |
| 4.2.1 | Boeing                  | 717   | SHF       | 1               | C (control)<br>S (drive) | H              | -            |                    |                                         |
| 4.2.2 |                         | 737   | FF        | 2               | C                        | HA/EB          | TTA          |                    |                                         |
| 4.2.3 |                         | 747   | FF        | 2               | C for I/B<br>C for O/B   | HA/EB          | TTA          |                    |                                         |
| 4.2.4 |                         | 757   | FF        | 2               | C                        | HA/EB          | TTA          |                    |                                         |
| 4.2.5 |                         | 767   | FF        | 2               | C                        | HA/EB          | TTA          |                    |                                         |
| 4.2.6 |                         | 777   | FF        | 2               | C                        | HA/EB          | TTA          |                    | EMF torque tubes                        |
| 4.2.7 | (McDonnell-<br>Douglas) | MD-11 | FF        | 2               | C (control)<br>S (drive) | H              | -            |                    |                                         |
|       |                         |       |           |                 |                          |                |              |                    |                                         |
| Para  | Aircraft                |       | Actuators |                 |                          |                |              | Safety System      |                                         |
|       | Manu-<br>facturer       | Type  | Type      | Number/<br>Wing | Limiter                  | Output         | Comment      | Type               | Comment                                 |
| 4.2.1 | Boeing                  | 717   | HA        | 4               | -                        | L              |              | -                  |                                         |
| 4.2.2 |                         | 737   | BSAN      | 4               | T/L                      | L              |              | NB (partly)        | Noback only on I/B station of each flap |
| 4.2.3 |                         | 747   | BSAN      | 4               | TL                       | C              |              | NB (partly)        | Noback only on I/B station of each flap |
| 4.2.4 |                         | 757   | BSAN      | 4               | TL/SD                    | C              |              | NB                 |                                         |
| 4.2.5 |                         | 767   | GRA       | 4               | TL                       | L              |              | NB                 |                                         |
| 4.2.6 |                         | 777   | BSAN      | 4               | TL                       | L              |              | NB/UCFB            | 1 noback brake per wing + act. NB       |
| 4.2.7 | (McDonnell-<br>Douglas) | MD-11 | HA        | 8               | LL (hyd)                 | L              |              |                    |                                         |

## 3.3.3 Trailing Edge Systems - Bombardier

**Table 9 - Trailing edge systems - Bombardier - overview**

| Para  | Aircraft          |                | Panels    |                 | Type of Actuation |                | Transmission |                    |                                       |
|-------|-------------------|----------------|-----------|-----------------|-------------------|----------------|--------------|--------------------|---------------------------------------|
|       | Manu-<br>facturer | Type           | Type      | Number/<br>Wing | Drive<br>Concept  | Drive<br>Power | Type         | Limiting<br>Device | Comment                               |
| 4.3.1 | Bombardier        | CL300          | FF        | 1               | C                 | HA/HB          | FS/TTS       | CF                 | First shaft flexible                  |
| 4.3.2 |                   | CL600          | FF        | 2               | C                 | EA/EA          | FS           |                    |                                       |
| 4.3.3 |                   | Global Express | FF        | 3               | C                 | EA/EA          | TTA          | Electric           | Interconnection of panels at BSAs     |
|       |                   |                |           |                 |                   |                |              |                    |                                       |
| Para  | Aircraft          |                | Actuators |                 |                   |                |              | Safety System      |                                       |
|       | Manu-<br>facturer | Type           | Type      | Number/<br>Wing | Limiter           | Output         | Comment      | Type               | Comment                               |
| 4.3.1 | Bombardier        | CL300          | BSAN      | 2               | TL                | C              |              | HOF                |                                       |
| 4.3.2 |                   | CL600          | BSAN      | 4               | TL                | L              |              | EOF                |                                       |
| 4.3.3 |                   | Global Express | BSAS      | 4               | TL                | C              |              | EOF                | Skew detection w/<br>position sensors |

## 3.3.4 Trailing Edge Systems - Dornier, Embraer, Gulfstream, Lockheed, Sukhoi, Syber Jet

**Table 10 - Trailing edge systems - other aircraft - overview**

| Para  | Aircraft          |                | Panels    |                 | Type of Actuation |                | Transmission   |                                   |                                                    |
|-------|-------------------|----------------|-----------|-----------------|-------------------|----------------|----------------|-----------------------------------|----------------------------------------------------|
|       | Manu-<br>facturer | Type           | Type      | Number/<br>Wing | Drive<br>Concept  | Drive<br>Power | Type           | Limiting<br>Device                | Comment                                            |
| 4.4.1 | Dornier           | Do-228         | FF        | 1               | C                 | E              | FS             | STL                               |                                                    |
| 4.4.2 |                   | Do-328         | FF        | 1               | P                 | H              | TTC            |                                   | Interconnection of panels                          |
| 4.5.1 | Embraer           | ERJ 145 Family | FF        | 2               | C                 | EA/EA          | FS             | CF/ETL                            |                                                    |
| 4.6.1 | Gulfstream        | G200           | FF        | 2               | C                 | E              | FS             | CF/ETL                            |                                                    |
| 4.7.1 | Lockheed          | L1011          | FF        | 4               | C                 | HA/HA          | TT             | STL                               |                                                    |
| 4.8.1 | Sukhoi            | SJ100          | FF        | 2               | C                 | EA/EA          | TTS            | ETL                               | Welded                                             |
| 4.9.1 | Syber Jet         | SJ30-2         | FF        | 1               | C                 | E              | TTA            | CL                                | Magneformed                                        |
| Para  | Aircraft          |                | Actuators |                 |                   |                |                | Safety System                     |                                                    |
|       | Manu-<br>facturer | Type           | Type      | Number/<br>Wing | Limiter           | Output         | Comment        | Type                              | Comment                                            |
| 4.4.1 | Dornier           | Do-228         | BSAN      | 2               |                   | L              |                | EOF                               |                                                    |
| 4.4.2 |                   | Do-328         | HA        | 1               |                   | L              |                | NB                                | Hydraulic lock                                     |
| 4.5.1 | Embraer           | ERJ 145 Family | BSAN      | 4               | TL                | C              |                | EOF                               |                                                    |
| 4.6.1 | Gulfstream        | G200           | BSAS      | 3               | TL                | C              |                | NB/EOF                            |                                                    |
| 4.7.1 | Lockheed          | L1011          | BSAN      | 8               | TL                | C              | telescoping    | Brk                               | Centrifugal                                        |
| 4.8.1 | Sukhoi            | SJ100          | BSAN      | 4               | TL                | C              |                | EOF                               |                                                    |
| 4.9.1 | Syber Jet         | SJ30-2         | GRA       | 2               | TL                | L              | Worm/<br>Wheel | Complex<br>Electronic<br>Hardware | Irreversible Worm<br>Position Monitoring<br>System |

#### 4. DETAILED SYSTEM DESCRIPTION

In the following sections, the detailed systems schematics are presented as they were made available by aircraft manufacturers or system suppliers.

##### 4.1 Airbus

##### 4.1.1 Airbus A300 B2/B4

##### 4.1.1.1 A300 Aircraft Characteristics

The aircraft family consists of the A300B1, A300B2, and A300B4 and was the first aircraft designed by the Airbus company. It is a Wide Body Aircraft with medium range and a typical capacity between 250 and 300 passengers.

##### 4.1.1.2 A300 System Characteristics

The leading edge incorporates three slat panels per wing, being operated through Ballscrew actuators acting on a guided track panel and one inboard Kruger Flap on A-300B4 being operated with a single hydraulic RAM. The trailing edge comprises of two double slotted Fowler panels per wing being guided through a track and aft linkage system in Main-Vane Configuration.

The High Lift Systems (Leading and Trailing Edge) are controlled through a mechanical input which controls the manifolds of two hydraulic motors on each Power Drive Unit with integrated Pressure-Off brakes and coupled by a speed summing differential gearbox. Excessive torque is limited by a slipping clutch. Each Power Drive Unit is operated in an active/active mode.

Hydraulic control is performed through the mechanical cable input from the cockpit control lever. Sequencing of the slat and flap control is achieved through a cam box which itself changes the input from the mechanical cable into the mechanical signal operating a hydro-mechanical control valve connected to the 3000 psi (20690 kPa) systems.

Power to the panels is transmitted with a rigid torque tube steel shaft transmission also serving as a mechanical interconnection for all stations. A torsion bar torque limiter stopping the system through a wedged roller design limits the output torque to each wing's driveline. The transmission also includes shock absorbers.

There are two linear actuators per panel partly incorporating no back devices. The slat actuators are of translating screw design incorporate torque limiters, a torsion bar design torque limiter acting on wedged rollers and a single stage grease lubricated gear. The flap actuators include an offset gearbox, a torque limiting device and a dual stage grease lubricated gearbox. Flap actuators number 2 to 6 include the no-back device. The number 3 actuator acts in tension direction only and the number 2 actuator incorporates a lifter to reduce the drag.

Safety against shaft rupture and back driving is achieved with the help of nobacks in each ballscrew actuator.

The system monitors for asymmetry using Syncro type sensors and stops operation in case of failure.

## 4.1.1.3 A300 Equipment Details

**Table 11 - Airbus A300 B2/B4 equipment overview**

| Equipment Name                                | Number Off | Details                                                                                                                                                                                                   |
|-----------------------------------------------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| High Lift System General                      |            |                                                                                                                                                                                                           |
| Cockpit Lever                                 | 1          | 1 Lever assembly with 5 detent positions                                                                                                                                                                  |
| Leading Edge Slat System                      |            |                                                                                                                                                                                                           |
| Power Drive Unit<br>(named Slat Control Unit) | 1          | 2 hydraulic motors with pressure off brakes<br>2 manifolds controlled with central mechanical input<br>Speed summing differential gearbox<br>Central output<br>Dual channel sensor for cockpit indication |
| Transmission System                           | 1          | Rigid steel shafts<br>Articulating spline joints and universal joints<br>1 T-Gearbox<br>2 Half system torque limiter<br>2 Bevel gearboxes<br>4 Line gearboxes                                             |
| Ball screw Actuators                          | 12         | Translating screw shaft<br>Single load path<br>Single acting noback preventing unwanted extension<br>Incorporating station torque limiting                                                                |
| Wing Tip Brakes                               | 2          | Unidirectional friction brakes preventing retraction                                                                                                                                                      |
| Asymmetry Sensors                             | 2          | Dual channel potentiometer-type                                                                                                                                                                           |
| Krueger Actuators (A300B-4 only)              | 2          | Single load path hydraulic actuators<br>Hydraulic lock preventing unwanted extension                                                                                                                      |
| Trailing Edge Flap System                     |            |                                                                                                                                                                                                           |
| Power Drive Unit<br>(named Flap Control Unit) | 1          | Same concept as for leading edge slat system<br>Difference: dual output                                                                                                                                   |
| Transmission System                           | 1          | Rigid steel shafts<br>Articulating spline joints and universal joints<br>2 Half system torque limiter<br>6 Bevel gearboxes<br>2 Line gearboxes<br>Shock absorbers                                         |
| Ball screw Actuator Stations                  | 8          | Translating ballnut<br>Double load path (Fail Safe)<br>Nobacks (on station 2 and 4 to 6 double acting, only in tensile direction on station 3)<br>Incorporating down drives and station torque limiting   |
| Asymmetry Sensors                             | 2          | Dual channel Synchro type                                                                                                                                                                                 |

## 4.1.2 Airbus A300-600

## 4.1.2.1 A300-600 Aircraft Characteristics

The aircraft is a derivative of the A300-B2/B4 aircraft with a modernized High Lift system partly based on the Airbus A310 system developed some years earlier incorporating the fly-by-wire control (electrically signaled and controlled).

## 4.1.2.2 A300-600 System Characteristics

The panel layout is identical to that of the A300 B2/B4 aircraft. The difference in the system is mainly based on some advantages originally introduced in the Airbus A310 system (see below).

## 4.1.2.3 A300-600 Equipment Details

**Table 12 - Airbus A300-600 equipment overview**

| Equipment Name                                | Number Off | Details                                                                                                                                                                                                                                        |
|-----------------------------------------------|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>High Lift System General</b>               |            |                                                                                                                                                                                                                                                |
| Cockpit Lever                                 | 1          | 1 Lever assembly with 5 detent positions                                                                                                                                                                                                       |
| Control Computers                             | 2          | Control/monitor architecture<br>Processor operated, software based                                                                                                                                                                             |
| <b>Leading Edge Slat System</b>               |            |                                                                                                                                                                                                                                                |
| Power Drive Unit<br>(named Slat Control Unit) | 1          | 2 Hydraulic motors with pressure off brakes applied<br>2 Manifolds controlled with central mechanical input<br>Speed summing differential gearbox<br>Central output<br>2 Dual channel sensor, one each for loop closure and cockpit indication |
| Transmission System                           | 1          | Rigid steel shafts<br>Articulating spline joints and universal joints<br>1 T-Gearbox<br>2 Half system torque limiter<br>2 Bevel gearboxes<br>4 Line gearboxes                                                                                  |
| Ballscrew Actuators                           | 12         | Translating screw shaft<br>Single load path<br>Noback preventing unwanted extension<br>Incorporating station torque limiting                                                                                                                   |
| Wing Tip Brakes                               | 2          | Unidirectional friction brakes preventing retraction                                                                                                                                                                                           |
| Asymmetry Sensors                             | 2          | Dual channel Synchro-type                                                                                                                                                                                                                      |
| Krueger Actuators                             | 2          | Single load path hydraulic actuators<br>Hydraulic lock preventing unwanted extension                                                                                                                                                           |
| <b>Trailing Edge Flap System</b>              |            |                                                                                                                                                                                                                                                |
| Power Drive Unit<br>(named Flap Control Unit) | 1          | Same concept as for Leading Edge Slat System<br>Difference: dual output                                                                                                                                                                        |
| Transmission System                           | 1          | Rigid steel shafts<br>Articulating spline joints and universal joints<br>2 Half system torque limiter<br>6 Bevel gearboxes<br>2 Line gearboxes                                                                                                 |
| Ballscrew Actuator Stations                   | 8          | Translating ballnut<br>Double load path (Fail Safe)<br>Nobacks (on station 2 and 4 to 6 double acting, only in tensile direction on station 3)<br>Incorporating down drives and station torque limiting                                        |
| Asymmetry Sensors                             | 2          | Dual channel Synchro type                                                                                                                                                                                                                      |

#### 4.1.2.4 A300-600 System Schematics

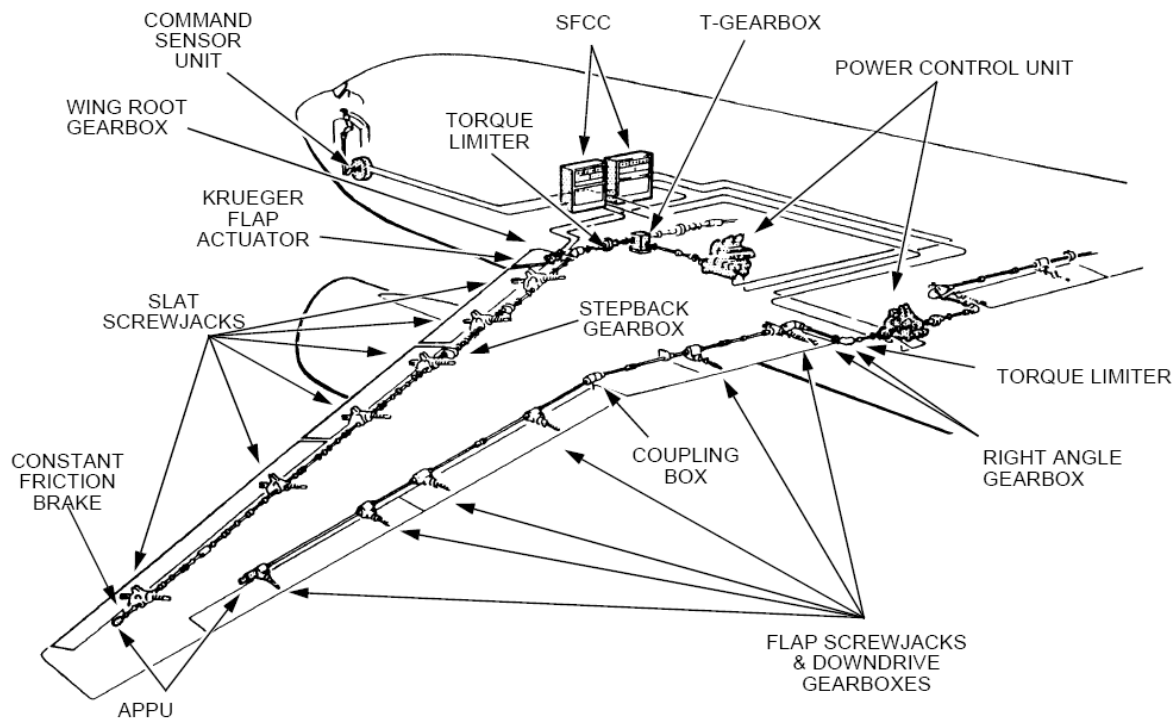


**Figure 1 - Airbus A300-600 highlift system**

#### 4.1.3 Airbus A310

##### 4.1.3.1 A310 Aircraft Characteristics

The aircraft was developed based on the same fuselage as the Airbus A300, but with a reduced size and an improved wing design to be optimized mainly for extended medium range. The aircraft type was later certified for ETOPS and has a capacity of approximately 200 passengers.

##### 4.1.3.2 A310 System Characteristics

The panel layout is identical to that of the A300 B2/B4 aircraft. The High Lift system has been modernized as it was completely changed over into an electrically signaled and controlled layout, even though some units are based on those installed on the A300 aircraft. Also the application of active Wing Tip Brakes for the fulfillment of the safety concept was new.

## 4.1.3.3 A310 Equipment Details

**Table 13 - Airbus A310 equipment overview**

| Equipment Name                                 | Number Off | Details                                                                                                                                                                                                                           |
|------------------------------------------------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>High Lift System general</b>                |            |                                                                                                                                                                                                                                   |
| Cockpit Lever                                  | 1          | 1 Lever Assembly assembly with 5 detent positions                                                                                                                                                                                 |
| Control Computers                              | 2          | Control/monitor architecture<br>Processor operated, software based                                                                                                                                                                |
| <b>Leading Edge Slat System</b>                |            |                                                                                                                                                                                                                                   |
| Power Drive Unit<br>(named Power Control Unit) | 1          | 2 Hydraulics motors with pressure off/brake applied<br>2 Manifolds controlled with solenoid valves<br>Speed summing differential gearbox<br>Central output<br>2 Dual channel sensors, one for loop closure and cockpit indication |
| Transmission System                            | 1          | Rigid steel shafts<br>Articulating spline joints and universal joints<br>1 T-Gearbox<br>2 Half system torque limiter<br>2 Bevel gearboxes<br>4 Line gearboxes                                                                     |
| Ballscrew Actuators                            | 12         | Translating screw shaft<br>Single load path<br>Incorporating station torque limiting                                                                                                                                              |
| Wing Tip Brakes                                | 2          | Hydraulic safety brakes of pressure on/brake applied type                                                                                                                                                                         |
| Asymmetry Sensors                              | 2          | Dual channel Synchro type                                                                                                                                                                                                         |
| Krueger Actuators                              | 2          | Single load path hydraulic actuators<br>Hydraulic lock preventing unwanted extension                                                                                                                                              |
| <b>Trailing Edge Flap System</b>               |            |                                                                                                                                                                                                                                   |
| Power Drive Unit<br>(named Power Control Unit) | 1          | Same concept as for Leading Edge Slat System<br>Difference: dual output                                                                                                                                                           |
| Transmission System                            | 1          | Rigid steel shafts<br>Articulating spline joints and universal joints<br>2 Half system torque limiter<br>4 Bevel gearboxes<br>2 Line gearboxes<br>2 Kink steady bBearings                                                         |
| Ballscrew Actuator Stations                    | 8          | Translating ballnut (screw shaft is connected with universal joint to jackhead on station 2 to 4)<br>Double load path (failsafe type)<br>Incorporating down drives and station torque limiting                                    |
| Wing Tip Brakes                                | 2          | Hydraulic safety brakes of pressure on/brake applied type                                                                                                                                                                         |
| Asymmetry Sensors                              | 2          | Dual channel Synchro type                                                                                                                                                                                                         |

#### 4.1.3.4 A310 System Schematics

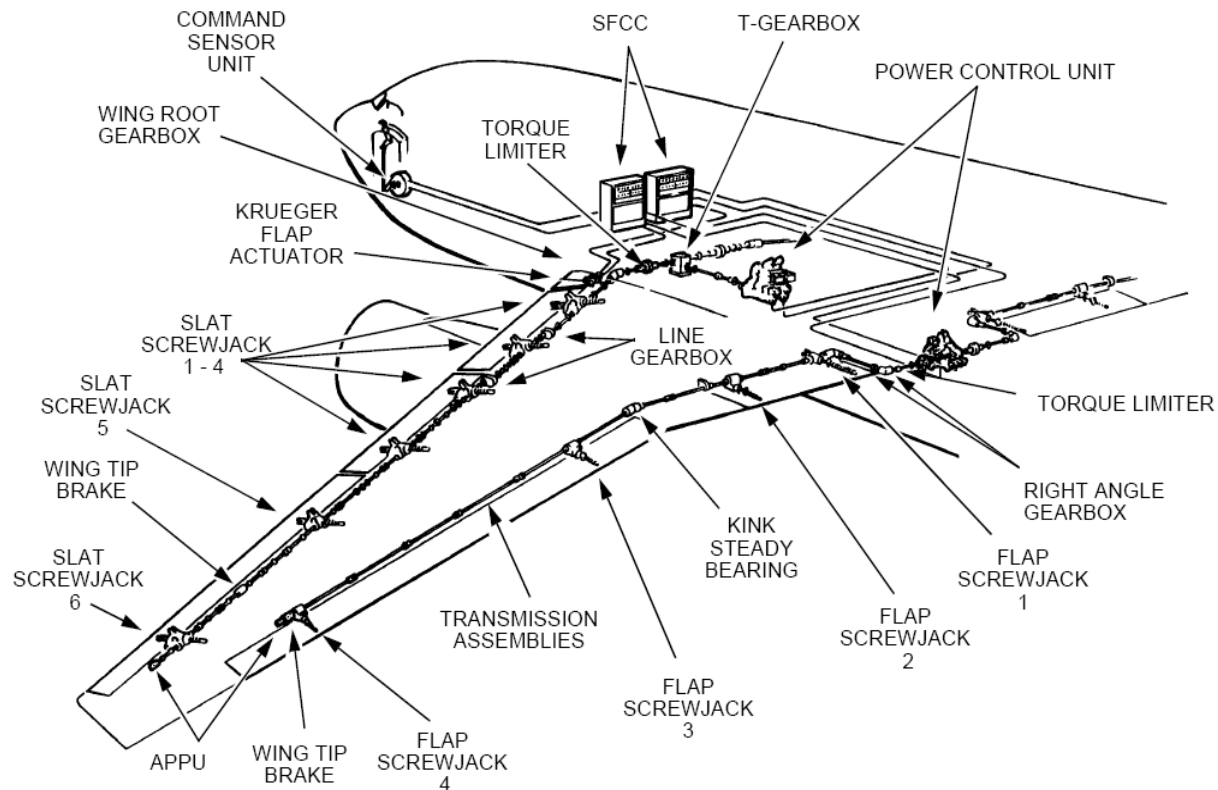


**Figure 2 - Airbus A310 high lift system**

#### 4.1.4 Airbus A320 Family

##### 4.1.4.1 A320 Family Aircraft Characteristics

The aircraft family consists of the following aircraft: A318, A319, A320, and A321 and their variations designated by dash numbers. The A320 family was designed as a single aisle, short to medium range aircraft with a typical seating capacity between 107 and 220 passengers. There are also long range and business jet versions on the market.

##### 4.1.4.2 A320 Family System Characteristics

The leading edge incorporates five slat panels per wing, being operated through a rack and pinion drive. The trailing edge comprises of two Fowler panels per wing being guided through a front link and track system. For the A321 the flaps are designed in a double slotted Main-Vane Configuration. For all other family members, only single slotted flaps were used.

The High Lift Systems (Leading and Trailing Edge) is fully electrically signaled, controlled and monitored by two software based two channel controllers. They control two hydraulic motors on each Power Drive Unit with integrated Pressure-Off brakes coupled by a speed summing differential gearbox. Each Power Drive Unit is operated in an active/active mode. Hydraulic control is performed through solenoid valves operating a hydro-mechanical control valve connected to the 3000 psi (20690 kPa) systems.

Power to the panels is transmitted with a rigid torque tube steel shaft transmission also serving as a mechanical interconnection for all stations.

There are two rotary actuators per panel without Nobacks which incorporate a ball ramp design torque limiter acting on friction discs. The slat actuators drive through a set of grease lubricated planetary gears arranged around the through shaft. The flap actuators include an offset gearbox, and a dual stage grease or Semi-Fluid lubricated gearbox.

Safety against shaft rupture, overspeed and back driving is achieved with the help of dual channel (fail operational) Redundant Wing Tip Brakes working in the pressure-on/brake applied mode.

The system electronically monitors for asymmetry, overspeed, uncommanded motion and jam conditions.

#### 4.1.4.3 A320 Equipment Details

**Table 14 - Airbus A320 family equipment overview**

| Equipment Name                                 | Number Off | Details                                                                                                                                                                                                                        |
|------------------------------------------------|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>High Lift System general</b>                |            |                                                                                                                                                                                                                                |
| Cockpit Lever                                  | 1          | 1 Lever assembly with 5 detent positions (1 gated)                                                                                                                                                                             |
| Control Computers                              | 2          | Control/monitor architecture<br>Processor operated, software based                                                                                                                                                             |
| <b>Leading Edge Slat System</b>                |            |                                                                                                                                                                                                                                |
| Power Drive Unit<br>(named Power Control Unit) | 1          | 2 Hydraulic motors with pressure off brakes<br>2 Manifolds controlled with solenoid valves<br>Speed summing differential gearbox<br>Central output<br>2 Dual channel sensors, one each for loop closure and cockpit indication |
| Transmission System                            | 1          | Rigid shafts<br>Articulating spline joints and universal joints<br>1 T-Gearbox<br>5 Bevel gearboxes                                                                                                                            |
| Plug-In Type Geared Rotary Actuators           | 20         | Single load path<br>Incorporating station torque limiting                                                                                                                                                                      |
| Wing Tip Brakes                                | 2          | Dual channel - hydraulically powered - solenoid operated<br>Pressure on - brake applied type                                                                                                                                   |
| Asymmetry Sensors                              | 2          | Dual channel Synchro-type                                                                                                                                                                                                      |
| <b>Trailing Edge Flap System</b>               |            |                                                                                                                                                                                                                                |
| Power Drive Unit<br>(named Power Control Unit) | 1          | Same concept as for Leading Edge Slat System<br>Difference: dual output                                                                                                                                                        |
| Transmission System                            | 1          | Rigid shafts<br>Articulating spline joints<br>6 Bevel gearboxes<br>2 Line gearboxes                                                                                                                                            |
| Ballscrew Actuator Stations                    | 8          | Single load path<br>Incorporating station torque limiting                                                                                                                                                                      |
| Wing Tip Brakes                                | 2          | Dual channel - hydraulically powered - solenoid operated<br>Pressure on - brake applied type                                                                                                                                   |
| Asymmetry Sensors                              | 2          | Dual channel                                                                                                                                                                                                                   |
| Interconnection Links                          | 2          | Secondary load path<br>Skew detection through proximity switches                                                                                                                                                               |

## 4.1.4.4 A320 Family System Schematics

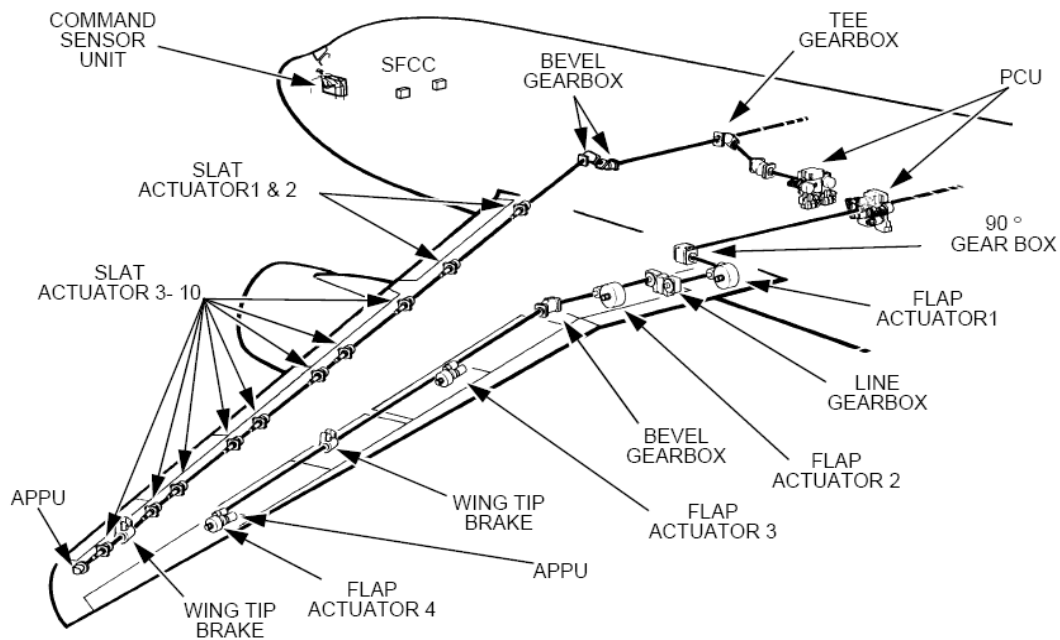


**Figure 3 - Airbus A320 family aircraft - high lift system (aircraft view)**

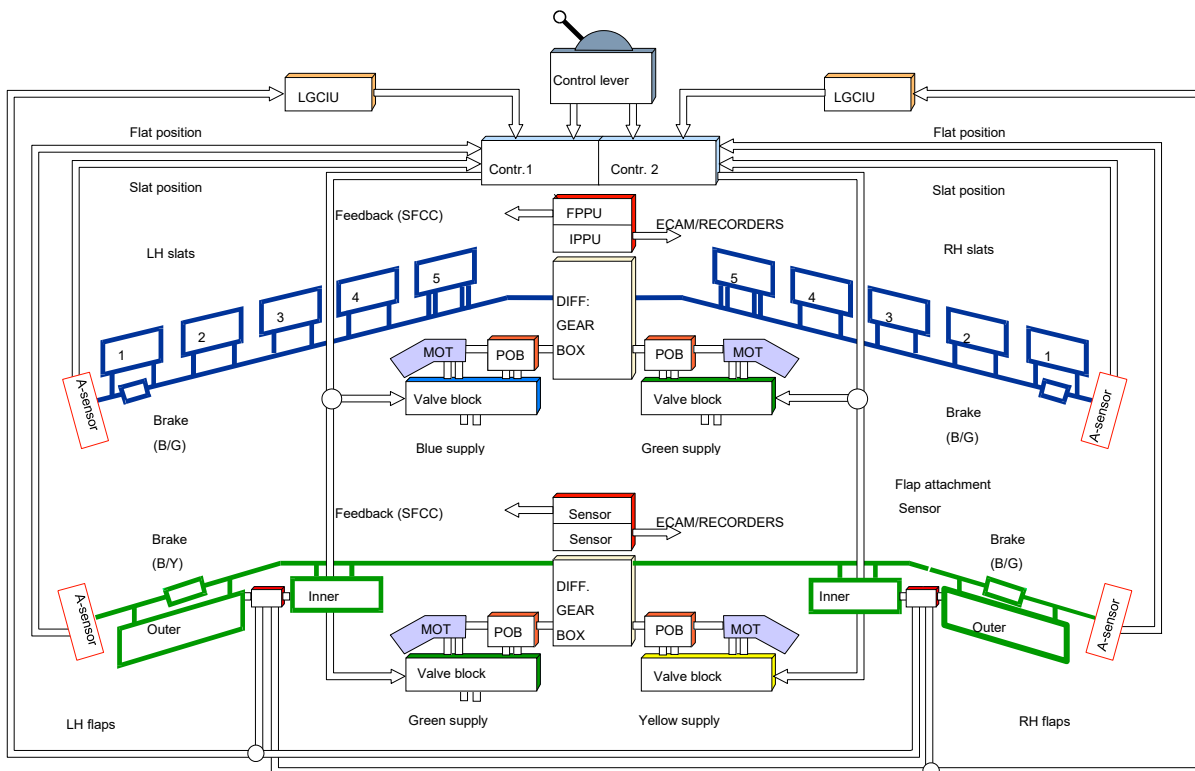


**Figure 4 - Airbus A320 family aircraft - high lift system (signal view)**