AVIATION ENGINEERING

Airbus A320 Advanced Systems Guide: Engineering, Flight Controls, and Operational Mastery

Published: February 14, 2026 | Index ID: #955

The Airbus A320 family represents a watershed moment in aviation history, marking the transition from traditional mechanical linkages to the sophisticated realm of **Fly-By-Wire (FBW)**technology. For aviation students, line pilots, and maintenance engineers, mastering the A320 requires more than just a surface-level understanding of cockpit switches; it demands a deep dive into the integrated architecture of computers, sensors, and actuators that define modern flight. This guide provides a comprehensive technical analysis of the A320 systems, focusing on the intricate relationship between the pilot's sidestick and the aircraft's control surfaces.

The Core Philosophy: Fly-By-Wire and Electronic Control

At the heart of the Airbus A320 is the **Electronic Flight Control System (EFCS)**. Unlike traditional aircraft where cables and pulleys physically move the elevators and ailerons, the A320 uses electrical signals sent from the sidestick to a suite of flight control computers. These computers interpret pilot input through the lens of "Control Laws," which provide varying levels of protection and assistance depending on the health of the aircraft's sensors and systems.

Flight Control Computers (FCC) Architecture

The EFCS is managed by five primary computers that work in a redundant, high-availability configuration:

- ELAC (Elevator Aileron Computer): Two units responsible for pitch and roll control, including protection sensing.
- SEC (Spoiler Elevator Computer): Three units primarily managing spoiler control but capable of taking over elevator and standby pitch control in the event of ELAC failure.
- FAC (Flight Augmentation Computer): Two units handling rudder control (yaw), flight envelope protection (alpha-floor), and windshear detection.

The redundancy is designed such that even with multiple computer failures, the aircraft maintains **Mechanical Backup**for the stabilizer and rudder, allowing the pilot to maintain control until systems can be recovered or an emergency landing is performed.

Technical Analysis of Flight Control Laws

One of the most critical concepts for any A320 operator is the hierarchy of **Flight Control Laws**. These laws determine how the computers process sidestick inputs and what aerodynamic protections are active.

1. Normal Law

Under Normal Law, the A320 provides the highest level of safety. It operates on a G-load demand logic for pitch and a roll-rate demand logic for lateral control. In pitch, the sidestick commands a change in vertical acceleration; if the stick is neutral, the aircraft maintains 1G and automatically trims to maintain the flight path. Key protections include:

- High-Speed Protection: Prevents the aircraft from exceeding VMO/MMO by introducing a nose-up command.
- High Angle of Attack (Alpha) Protection: Known as Alpha-Prot, this prevents the aircraft from stalling. If the

angle of attack reaches a critical threshold, the computers override sidestick input to maintain a safe margin above the stall speed.

- Bank Angle Protection: Limits the bank angle to a maximum of 67 degrees (or 33 degrees if hands-off).

2. Alternate Law

If the aircraft loses multiple sensors (such as ADRs or IRUs) or computers, it degrades to Alternate Law. Here, the protections are significantly reduced. High-speed and Alpha protections are replaced by a simple stability warning. The aircraft no longer "auto-trims" for the pilot in the same way, requiring more manual monitoring. Depending on the severity of the failure, it can be **Alternate Law with Protections** or **Alternate Law without Protections**.

3. Direct Law

Direct Law occurs when the landing gear is extended while in Alternate Law, or in the event of total computer failure. In this state, there is a direct linear relationship between sidestick movement and control surface deflection. No protections are available, and the pilot must manually trim the aircraft using the trim wheel.

Feature	Normal Law	Alternate Law	Direct Law
Pitch Logic	Load Factor (G) Demand	Load Factor (G) Demand	Direct Surface Deflection
Roll Logic	Roll Rate Demand	Direct Surface Deflection	Direct Surface Deflection
Auto-Trim	Full Capability	Full Capability	None (Manual)
Stall Protection	Alpha-Prot / Alpha-Floor	Stability Warning Only	None
High Speed Prot.	Positive Nose-Up	Stability Warning Only	None

Hydraulic System Redundancy: Green, Blue, and Yellow

The A320 utilizes three independent hydraulic systems, uniquely identified by color. Unlike many aircraft that use a "System A and B" designation, Airbus uses a non-interchangeable fluid logic across **Green, Blue, and Yellow** systems to ensure that no single point of failure can lead to a total loss of flight control.

System Distribution and Power Sources

- Green System: Powered by Engine 1 or the Power Transfer Unit (PTU). It controls landing gear, flaps/slats, and major flight control surfaces.
- Blue System: Powered by an electric pump or the RAT (Ram Air Turbine) in an emergency. It provides emergency backup for flight controls and the emergency generator.
- Yellow System: Powered by Engine 2, an electric pump, or a manual hand pump (for cargo doors). It also provides power to the PTU.

The **Power Transfer Unit (PTU)** is a critical engineering component. It allows the Green system to pressurize the Yellow system (and vice versa) without the transfer of fluid. This happens automatically when a pressure differential of 500 PSI is detected between the two systems, ensuring that even if an engine fails, both major hydraulic circuits remain pressurized.

Flight Guidance and Management: The FMGS

The **Flight Management and Guidance System (FMGS)** is the brain of the A320. It consists of two **Flight Management and Guidance Computers (FMGCs)** and two **Multipurpose Control and Display Units (MCDUs)**. The FMGS manages four distinct functions:

1. Flight Management: Calculations of the flight plan, fuel predictions, and navigation performance.
2. Flight Guidance: Managing the Autopilot (AP) and Flight Director (FD) commands.
3. Flight Augmentation: Handled by the FACs for yaw damping and envelope monitoring.
4. Performance Optimization: Calculating the most efficient speeds and altitudes (Cost Index).

Vertical Navigation and Ceiling Altitudes

The A320's maximum certified ceiling is **39,100 feet (FL391)**. However, the FMGS calculates an "Optimum Altitude" (REC MAX) based on current weight, temperature, and cost index. Exceeding the REC MAX can significantly reduce the margin between the high-speed buffet and the low-speed stall (the "Coffin Corner").

For engineering and maintenance planning, the aircraft's weight and balance are governed by the **AIRCRAFT CHARACTERISTICS -- AIRPORT AND MAINTENANCE PLANNING (AC)** manual. This data is vital for determining the **ACN (Aircraft Classification Number)** which must not exceed the **PCN (Pavement Classification Number)** of the runway to prevent structural damage to the airport surface.

Traffic Collision Avoidance System (TCAS) Integration

Modern A320 aircraft utilize **TCAS II Version 7.1**, which is integrated directly into the flight guidance logic. In older versions, pilots had to manually fly the "Resolution Advisory" (RA) by following a green box on the Vertical Speed Indicator (VSI). In newer A320 configurations, the **AP/FD TCAS** capability allows the autopilot to automatically fly the RA maneuver, ensuring the most precise execution of collision avoidance instructions.

Mathematical Logic of TCAS RA

The TCAS computer calculates a "Tau" value, which represents the time to the closest point of approach (CPA). The formula is generally expressed as:

Tau = Range / Closure Rate

When Tau falls below a specific threshold (e.g., 25-35 seconds), an RA is issued. The A320 systems then coordinate with the intruder aircraft via Mode S transponder to ensure one aircraft climbs while the other descends.

Practical Implementation: Troubleshooting and Operational Challenges

Despite its advanced automation, the A320 requires pilots to be vigilant regarding "Automation Surprise." A common operational challenge is the transition from managed to selected modes. For example, if the **FCU (Flight Control Unit)** is set to a vertical speed that the aircraft cannot maintain without losing airspeed, the system may enter **Alpha Floor** protection, which automatically applies TOGA (Takeoff/Go-Around) thrust regardless of the thrust lever position.

Case Study: ADR / IR Discrepancies

The **ADIRS (Air Data Inertial Reference System)** provides critical speed and altitude data. If one of the three ADRs provides faulty data (e.g., due to a blocked pitot tube), the flight control computers may struggle to decide which data is correct. In some historical incidents, the system has "voted out" the good data, leading to a degradation to Alternate Law. Pilots are trained to identify these discrepancies through the "Unreliable Speed Indication" checklist, which involves setting a fixed pitch and thrust setting to maintain safe flight.

Summary and Broader Implications for Aviation Safety

The Airbus A320 is a masterpiece of systems engineering, balancing automation with redundant mechanical and electronic backups. Its design emphasizes "protection"—creating a safety bubble that makes it difficult for the pilot to inadvertently stall or overstress the airframe. However, this complexity requires a rigorous understanding of how the ELAC, SEC, and FAC computers interact with the Green, Blue, and Yellow hydraulic systems.

As aviation moves toward even higher levels of autonomy, the A320's legacy remains relevant. It taught the industry that the interface between human and machine must be clearly defined by logic laws and that redundancy is the ultimate safeguard against failure. For the student or professional, mastery of the A320 is not merely about learning which buttons to push; it is about understanding the underlying digital and physical architecture that allows this 70-ton machine to soar safely across the globe.

Baca Juga (Artikel Terkait)

- **[The Definitive Technical Guide to the Lycoming O-235 Series: Engineering Architecture, Operational Performance, and Maintenance Optimization]**
  URL: http://alaskawriters.com/lycoming-o-235-engine-technical-guide.pdf
- **[The Ultimate Technical Guide to the Cessna 206 and T206 Series: Maintenance, Documentation, and Engineering Architecture]**
  URL: http://alaskawriters.com/cessna-206-t206-technical-maintenance-guide.pdf
- **[Comprehensive Technical Guide to Boeing 737 Maintenance Manuals: Operational Procedures and System Standards]**
  URL: http://alaskawriters.com/boeing-737-maintenance-manual-technical-procedures-guide.pdf
- **[Comprehensive Technical Analysis of Boeing 737 Next Generation (NG) Maintenance and Operational Documentation]**
  URL: http://alaskawriters.com/boeing-737-ng-maintenance-operations-technical-guide.pdf

Tags: #Airbus A320 #Flight Control Laws #Fly By Wire #Aircraft Systems #Aviation Safety #TCAS