AIR DATA SYSTEM

By
Paul Infant Teenu Mohan Das
07\textsuperscript{th} February 2011
Our Adventure today

• Traditional Pitot tube
• Introduction to the Integrated Electronic Standby Instrument (IESI) and Air Data System (ADS)
• Architecture of ADS
• Modeling and Calculation of parameters
• Design of Air Data System
The Ancestor (Pitot tube)

- The Pitot tube compares the pressure outside an aircraft to the pressure inside it (static).
- Used to be a complete analog system.
- Modern aircrafts still use it with help of pressure transducer.
The Physicist…

- **Point I**: Pressure $= P_s$ (static), $v_1$ = random
- **Point II**: Pressure $= P_t$ (total), $v_2$ = 0
- **Point III**: Pressure $= P_s$ (static), $v_3$ = $v_1$
- **Dynamic pressure** $q = P_t - P_s$

Figure 2. Cross-section of a Typical Pitot Static Tube
The digital trend...

• The ADS is currently used as a standby system.
• Measure Outside pressure and temperature and calculates Altitude, Airspeed and Mach number.

• Components:
  • Embedded Computer(686CORE)
  • Inertial Measurement Unit(IMU)
  • Two Pressure Sensors/Transducers
  • Temperature sensor
  • Digital Compass
  • Algorithms like Strapdown Inertial Navigation System(SINS)
Lets be an System Architect

• Has two precision pressure transducers (PPT), forming a Pressure Measurement Unit (PMU).
• A temperature module (Ti Module).
• Core Microprocessor (686CORE).
• An LCD display (AMLCD).
• Control Panel.

Figure 1. Architecture of the ADS
The Mathematician

• International Standard for Atmosphere (ISA) given by International Civil Aviation Organization (ICAO).
  • *Altitude Equation*
    • *Atmospheric pressure reduces with Altitude.*

\[
\frac{dp}{p} = -\frac{g}{RT}\,dh
\]

Where,
• \(P\) = Pressure at altitude \(h\).
• \(g\) = Gravitational Constant (9.8 m/s\(^2\)).
• \(R\) = Universal gas Constant (287.3 J/kg).
• \(T\) = Air Temperature at Altitude \(h\).
ISA has several altitude regions in which air temperature is defined.

- Sea-level temperature 288.15K or 15 degree Celsius
- Varies linearly till 11km from sea level to 216.65K
- From 11km to 20km constant temperature of 216.65K

\[
T_h = \begin{cases} 
T_0 - \beta_0 \cdot h & -2000\,m \leq h \leq 11000\,m \\
T_{11} & 11000\,m < h \leq 20000\,m 
\end{cases}
\]

(2)

Where,

- \( T_h \) = Temperature at altitude \( h \).
- \( T_0 \) = Temperature at sea-level.
- \( \beta_0 \) = Temperature gradient = 0.0065
- \( T_{11} \) = Temperature at 11km from sea-level.
Some Fluid Mechanics?

Types of fluid flows
- Incompressible ($v < 30\% \text{ of sonic velocity}$)
- Subsonic Compressible ($30\% \text{ sonic velocity} > v < \text{sonic velocity}$)
- Supersonic ($v > \text{Sonic velocity}$)
- Fluid speed given as Mach numbers

$$M = \frac{v}{c}$$

Where,
- $M =$ Mach number
- $v =$ Velocity of the fluid
- $c =$ Velocity of sound
Being a Mathematician is not easy.

- **Perfect Gas Equation**
  - Relates pressure, temperature and Density of Fluid

\[ \rho = \frac{p}{RT} \]  \hspace{1cm} (5)

Where,
- \( \rho \) = Density of fluid
- \( P \) = Pressure given by fluid
- \( T \) = Temperature of fluid
- \( R \) = Universal Gas Constant
Maths! Maths! Maths!

- The speed of sound varies with altitude

\[ c = \sqrt{k \frac{p_s}{\rho_s}} = \sqrt{kRT_s} \]  \hspace{1cm} (6)

\[ v = M \cdot c = M \cdot \sqrt{kRT_s} \]  \hspace{1cm} (7)
Design time...

- Ring Network protocol used.
- RS-232 used for communication
- Master-Slave relation between CORE and PPT.
- Each module has its own ID.

Figure 3. RS-232 PPT Ring Network
Algorithm

Figure 4. Application Software Modules of the ADS
Conclusion

• ADS makes flying more safer.
• It is reliable even to be made a primary system for Air Data Collection.
• The ADS includes Altimeter, Airspeed, Mach number and Temperature sensor all in one system.
• Avoid: