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Capturing and Processing Air Data: Air Data System (ADS)

Berquó, Jolan Eduardo – Electronic Eng. (ITA)
Aerospace Product Certifier (DCTA/IFI)
Government Representative for Quality Assurance – RGQ (DCTA/IFI)
Post-graduated in Reliability Engineering and System Safety Engineering (ITA)
Specialization in Systems Engineering and Analysis (Italy)
jberquo@dcabr.org.br* /*jberquo@gmail.com

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We will present, that time, the fascinating process of capturing and processing air data, culminating in the presentation of important and vital information for the pilot, such as: altitude, airspeed, vertical speed, etc., on a display (PFD) in the cockpit; all done through the so-called Air Data System (ADS).
We begin by presenting the functions provided by the ADS, from the collection of air data to the sending of information to the display (PFD).

(F1) Provide data collection from external air pressure (Total Pressure - P_T and Static Pressure - P_S);

(F2) Provide capture of the Total or Measured External Air Temperature (T_M), transduction to electrical signal and sending it to ADC (Air Data Computer);

(F3) Provide P_T and P_S to the ASI (Air Speed Indicator);

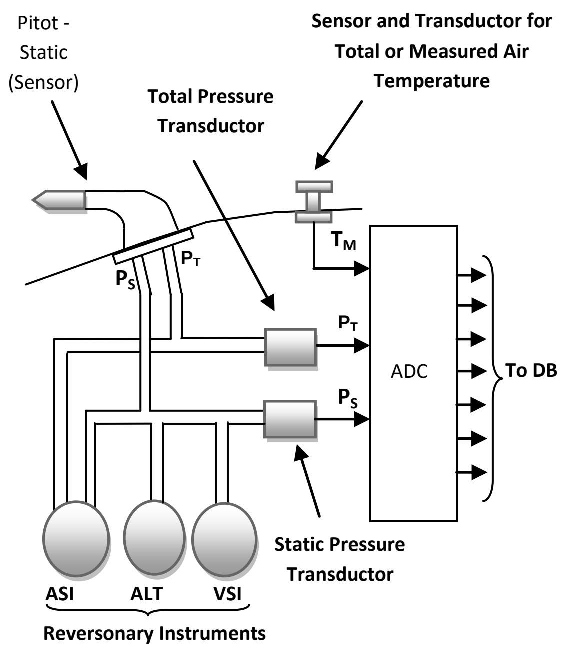
(F4) Provide P_S to ALT (Altimeter) and VSI (Vertical Speed Indicator);

(F5) Provide P_T and P_S data transduction for electrical signals and sending them to the ADC;

(F6) Provide the processing of the electrical signals of P_T, P_S and T_M in the ADC; and

(F7) Provide the routing of the digital signals processed in the ADC to the Electronic Display (PDF), in the cockpit, by means of a digital data bus.

The scheme of the system that performs the above functions is shown in Fig. 1. In this figure, each of the functions mentioned can be visualized. Check it out.



Obs.: "To DB" – To Digital Bus

Fig. 1 – Scheme of the ADS

The Reversionary Pneumatic Instruments are backup instruments, that is, backup of the PFD, in the information they can present. They are:

ASI - Airspeed Indicator ;
ALT - Altimeter; and
VSI - Vertical Speed Indicator.

The seven ADC output information are as follows:

- *Altitude (**H**);*
- *Vertical Seed ($\dot{\mathbf{H}}$);*
- *Calibrated Speed (V_C);*
- *Mach Number (M);*
- *True Airspeed (V_T);*
- *Static Air Temerature (T_S); and*
- *Relative Air Density (ρ/ρ_0).*

Let's go to the description of the process.

***(1) Sensor and Transducer of Total or External Air Temperature (T_M)**. It captures the external temperature (T_M) and converts it into an acceptable electrical signal for the ADC, which we will use as one of the variables; for example, in calculations for the presentation of the Mach Number (M) information.*

***(2) Pitot Tube Sensor.** It is a device already universally used in aircraft to capture the total pressure (P_T) of the external air through an orifice at the end of the tube, facing the air in air-relative movement.*

The total pressure of the air drawn is given by the sum:

$$P_T = P_I + P_S \;\therefore\; P_I = P_T - P_S \qquad (1)$$

where P_I is the impact pressure of the air in the tube, relative to the aircraft movement and P_S is the static pressure of the air surrounding the aircraft, at rest.

The consolidated Bernouille equation theoretically and mathematically explains the operation of the tube. It is given by:

$$P_T - P_S = = \frac{\rho V^2}{2} \;\therefore V = \sqrt{\frac{2(Pt - Ps)}{\rho}}$$ *. De (1) resulta que* $$V = \sqrt{\frac{2P_I}{\rho}} \qquad (2)$$

*where **V** is the relative speed of the fluid (liquid or air) at the inlet of the tube, and ρ is the density of the fluid at that point.*

However, this equation is strictly valid only for incompressible fluids. For aircraft flying at high speeds (above about 250 kt), the effects of compressibility must be considered. This is done in the ADC (Air Data Computer), from the data captured from the air.

The Pitot Tube captures total pressure through a hole at the end, routing it to the ASI and a transducer and from there to the ADC. But, the Pitot Tube can also incorporate a static pressure outlet (P_T), through a tube that coaxially wraps the Pitot Tube. This configuration is called the Pitot-Static Tube (Fig. 2).

The static outlet are holes placed on the sides of the tube surrounding the Pitot Tube, so that the relative wind speed does not interfere with the pressure measurement. This is important for aircraft that develop high speeds and are therefore indispensable for supersonic aircraft.

However, when the aircraft speed is not so high, this static pressure probe can be inserted into some other part of the fuselage.

The scheme of Fig. 1 is considering this coaxial configuration.

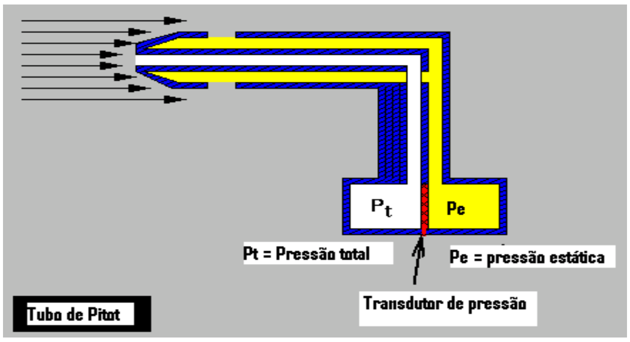


Fig. 2 – Pitot-Estatic Tube

Note, in Fig. 1, that the ASI is the only backup instrument that directly receives the total pressure (P_T) and the static pressure (P_S). The other instruments only receive the static pressure. So let's talk a bit about ASI.

*The P_S is conveyed into the box constituting the ASI, while the P_T is conveyed into an aneroid (transducer) diaphragm capsule contained also in the ASI, causing the capsule to expand. This movement of the capsule is transmitted to the instrument's hands by means of rods and gears, causing the pointer to present the sPSed of the aircraft, that is, the **indicated speed V_I (Fig. 3).***

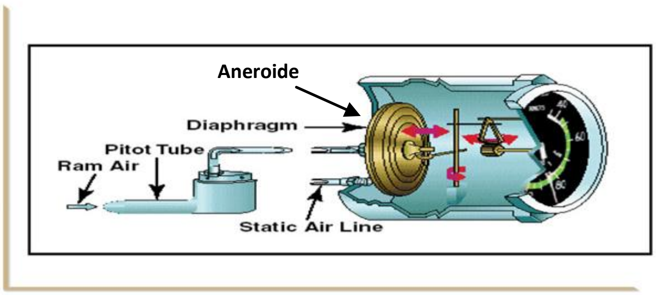


Fig. 3 - Arrangement inside the ASI

Note, however, that the ADC will forward to the PFD two values of aircraft forward speed: Calibrated Speed (V_C) and True Speed (V_T), that is, the ADC does not provide the Indicated Speed in the ASI. Let us then stretch a little further, to try to make the meaning of these speeds somewhat clearer.

The true speed (V_T), as the name says, is the actual speed of the aircraft's advance into the air. However, it should not be confused with another speed, the Groundspeed, which is the relative speed to the ground which would be that of a projection of the aircraft image on the ground, while traveling in air, calculated as the ratio between the distance traveled by that image, in the time unit.

On the other hand, the so-called Calibrated Speed (V_C) takes into account the indication ASI error, positioning error, maneuver error, etc.

However, in the comparison between True Speed (V_T) and Indicated Speed (V_I), at low altitudes, they are very close; but can vary widely as the aircraft flies higher. As a rough rule, we would say that the difference is about 2% for every 1,000 feet, up to about 10,000 feet, at which level a V_I of 150 kt would then equal a V_T of approximately 180 kt. This is the rarefaction effect of air with altitude.

***(1) Air Data Computer (ADC)** - We come to the "brain" of the system, a purely electronic equipment, the ADC; hence the ADS is a hybrid system (with mechanical and electronic parts) considered avionic, and a complex subsystem.*

The ADC receives signals from the transducers (P_T, P_S and T_M) in electrical form (i.e., analog signals) and converts them through internal converters to the digital form in order to perform its function.

The work of processing these signals in the ADC, based on a dedicated software schedule, is really noteworthy. From this input data, we develop the differential and integral calculus of the equations known theoretically for this purpose, to finally present, with a remarkable level of approximation, the information present at its output and sent to the PDF by the digital data bus.

If you want to take a look at these mathematical development equations on which the ADC is based, we recommend Chapter 7 of Reference 1.

Well, dear readers, let's interrupt here. We have already stretched well, in relation to the standard of the space of an MSC. We believe, however, that the presentation may have been of some value to them.

See you later

References:

(1) COLLINSON, R.P.G. - Introduction to Avionics Systems. Springer Dordrecht Heidelberg, 3. Ed., London (England) and New York (USA), 2011.

(2) HELBRICK, Albert D. - Principles of Electronics. Avionics Communications Inc., 4. Ed., Leesburg (USA), 2007.