飞行技术专业系列教材
FEIXING JISHU ZHUANYE XILIE JIAOCAI

Avionics for the Air Transport Pilot

Compiled by He Xiaowei Xiang Shulan

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Preface

Over the past 30 years, advanced avionics have progressed to the stage where they are now standard equipment in all modern airline transport aircraft and many general aviation aircraft. As a result, one of the most difficult tasks faced by flight training staff, is training pilots to operate aircraft equipped with such equipment.

The pilot must have a thorough knowledge of the operation of each individual component that makes up the system (e.g. autopilot, autothrottle and EFIS), and understand fully the inter-relationship among these individual components and how they interface together. In addition, the base-line knowledge of pilots aspiring to operate these aircrafts must be enhanced to ensure a sound basic knowledge of the normal and non-normal procedures, and the operational limitations of such equipment.

With the enormous amount of data that can be displayed by these systems, pilots must develop new flight management skills so that they can interpret and use the information in such a way that the overall operation of the aircraft is enhanced from both safety and economic viewpoint.

In producing this book, our aim has been to provide a basic understanding of the avionics used in modern transport category airplane. The main avionics are included here, and have been into 16 chapters. They are Chapter 1, Air Data Computer System; Chapter 2, Electronic Instrument Systems; Chapter 3, Automatic Flight Control Systems; Chapter 4, Flight Data Recording & Airplane Condition Monitoring System; Chapter 5, Airborne Weather Radar System; Chapter 6, Secondary Surveillance Radar and Transponder; Chapter 7, Traffic Alert and Collision Avoidance System; Chapter 8, Ground Proximity Warning System; Chapter 9, Enhanced Ground Proximity Warning System; Chapter 10, Runway Awareness and Advisory System; Chapter 11, Predictive Windshear System; Chapter 12, Radio Altimeter; Chapter 13, Inertial Navigation System; Chapter 14, Inertial Reference System; Chapter 15, Global Positioning System; Chapter 16, Flight Management Computer System.

The book was compiled by He Xiaowei and Xiang Shulan. He Xiaowei was responsible for Chapters 1,2,3,4,5,6,7,8,9,10,11,12,16, and Xiang Shulan for Chapters 13,14,15.

This book can be used as a text book by students of flight, we wish it also is a good reference to ATPL students and other qualified pilots who want to improve their knowledge on the subject of avionics.

In editing this book, we have been greatly assisted by the Department of Education and College of Flight Tech. of CAFUC. And therefore, we would like to express our gratitude for all the collaboration that we have received from them.

He Xiaowei

May 2012

CONTENTS

Chapter 1 Air Data Computer System

1.1 Introduction

Many of the primary flight instruments on an aeroplane are dependent on pressures transmitted from the pitot/static probes through a system of pipelines before reaching the sensors in the instruments. Larger aeroplanes require longer pipes, which results in increased lag errors and greater risk of breakage/leakage. To overcome these, and to create other benefits, most modern transport category aeroplanes use Air Data Computers (ADC).

Air data computers are usually of the digital type; that is, they transmit data in digital format which is compatible with other computer-based systems. Analogue air data computers, which transmit their output data to servo-operated devices, are less common, although a few are still in existence.

1.2 The Basic Principle

The ADC takes inputs from the pitot and static pressure sources, converts them to electrical signals, and then transmits them via a data bus to the various flight instruments. In addition, input from the outside air temperature probe is used to calculate the true airspeed. In some later models of ADC, the angle of attack (alpha) sensor inputs are also provided. Normally there will be two ADCs to provide redundancy, each pilot is able to switch to the output of the other ADC. See Figure 1.1.

Figure 1.2 is a block diagram showing the data inputs and outputs of a typical ADC. Output signals are transmitted as electronic data to operate the pilots' air data instrument displays, plus TAS, TAT and SAT (static air temperature) displays.

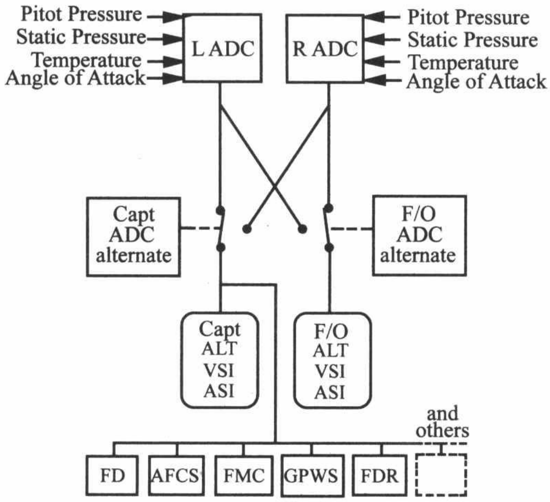

Figure 1.1 Air Data Computer Interface Schematic

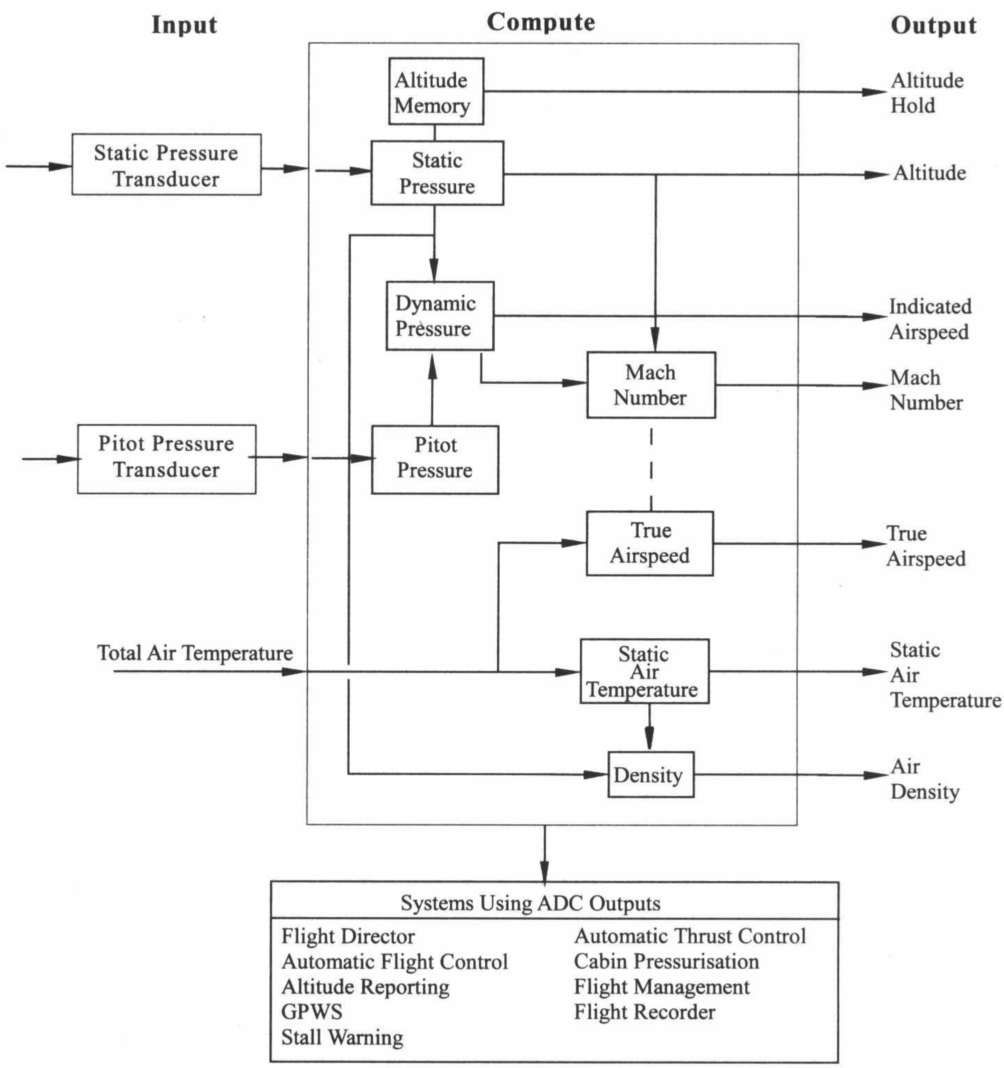

Figure 1.2 Inputs and Outputs of an Air Data Computer

In addition, outputs are fed to such systems as the flight director (FD), automatic flight control system (AFCS), flight management computer (FMC), ground proximity warning system (GPWS), the flight data recorder (FDR) and others.

Loss of air data input activates a warning logic circuit within the ADC, which causes warning flags to appear on the associated indicators and annunciators to illuminate on the computer control panel.

SAT (Static Air Temperature)

Static air temperature is the temperature of the air at the surface of the aircraft as if there were no compression effects due to the aircraft's movement. At very low airspeeds, these effects are negligible, but for most transport, aircraft normal flight speeds are such high that the direct measurement of SAT is virtually impossible. SAT is also known as outside air temperature (OAT).

TAT (Total Air Temperature)

Total air temperature is the temperature of the air when it has been brought completely to rest, as in the pitot tube. The ram rise, that is the temperature increase due to compression, can then be subtracted from TAT to give corrected outside air temperature (COAT). The value of ram rise can be calculated for any given mach number, so clearly the air data computer can be programmed to make this correction.

1.3 Temperature Measurement Probes

Aircraft that operate at low airspeeds, such as some helicopters and light aircraft, usually employ a simple bimetallic thermometer shown in Figure 1.3, which operates a rotary pointer against a temperature scale to indicate static air temperature.

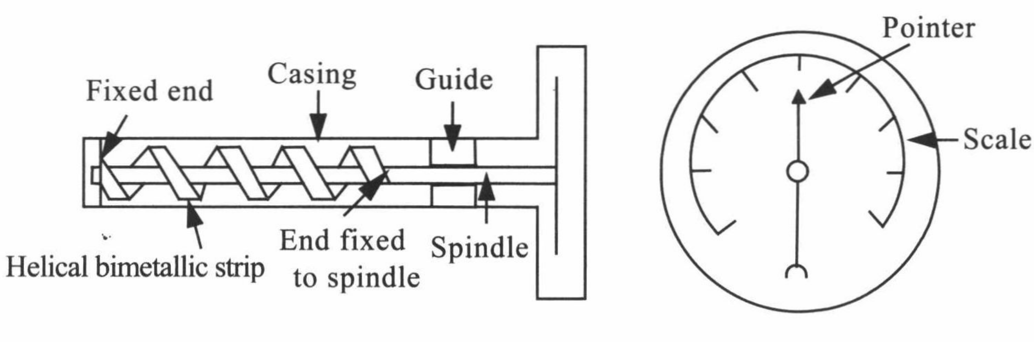

Figure 1.3 Bimetallic Thermometer

TAT sensors are more complex because they must, as far as possible, recover the temperature rise due to adiabatic compression of the air as it is brought to rest; what is known as the 'ram rise'. To do this it is necessary to use sophisticated probes to capture and slow the air and then convert the air temperature to an electrical signal for transmission to the ADC.

The sensitivity of the probe is known as recovery factor. For example, a probe that senses SAT plus 85% of the ram rise in temperature would be said to have a recovery factor of 0.85.

TAT probes are typically contained within an aerodynamically shaped strut with an air intake mounted on the outer end, to keep clear of any boundary layer air. Air is drawn into the hollow strut, through the air intake, where it is brought virtually to rest. Its temperature is sensed by a platinum resistance-type element mounted within the strut, which produces an electrical signal proportional to the temperature. Most modern TAT probes have a very high recovery factor, usually very close to unity (1.0).

An alternative type of probe uses engine bleed air to create a reduction of pressure within the casing of the probe. This has the effect of drawing air into the hollow strut at a higher rate, so that the de-icing heating element within the strut cannot affect the sensed temperature of the indrawn air.

Figure 1.4 is a diagram of an air temperature measurement probe.

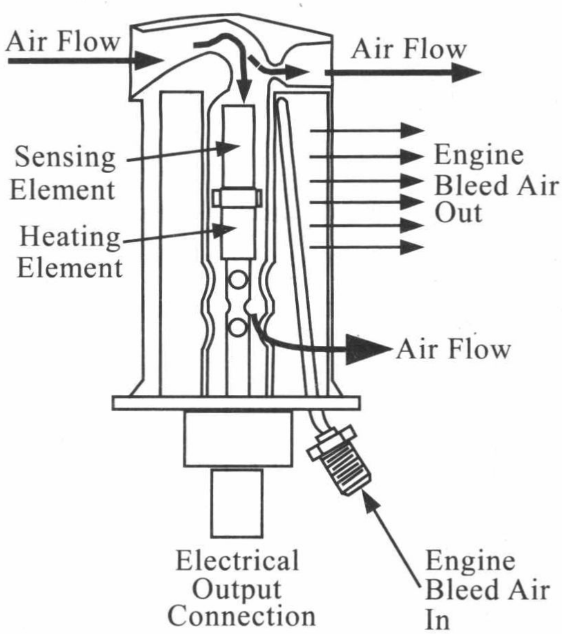

Figure 1.4 TAT Measuring Probe

1.4 Pressure Transducers

Pressure transducers convert pitot and static pressure into suitable electrical signals for transmission to the air data computer. In the case of analogue ADCs, the transducer is often of the electro-magnetic type, the amplified output of which drives a servomotor and operates a synchro system, which in turn operates the analogue instrument displays.

Digital ADCs more commonly utilize piezoelectric transducers that form part of a solid-state circuit. Some crystalline materials, such as quartz, can be made to generate varying electrical signals when subjected to pressure. A diaphragm composed of thin quartz discs impregnated with metallic particles is subjected to pitot or static pressure and the subsequent flexing of the diaphragm creates an electrical charge in the discs, the polarity of which is dependent upon the direction of flexing. Thus a signal proportional to increasing or decreasing pressure is generated.

1.5 Air Data Instruments

1.5.1 Mach/airspeed Indicator

The Mach/airspeed indicator (MASI) shown at Figure 1.5 combines the functions of both a conventional airspeed indicator and Machmeter. The instrument receives information from its associated air data computer, and presents airspeed against a single needle, and both Mach and airspeed are in digital displays.

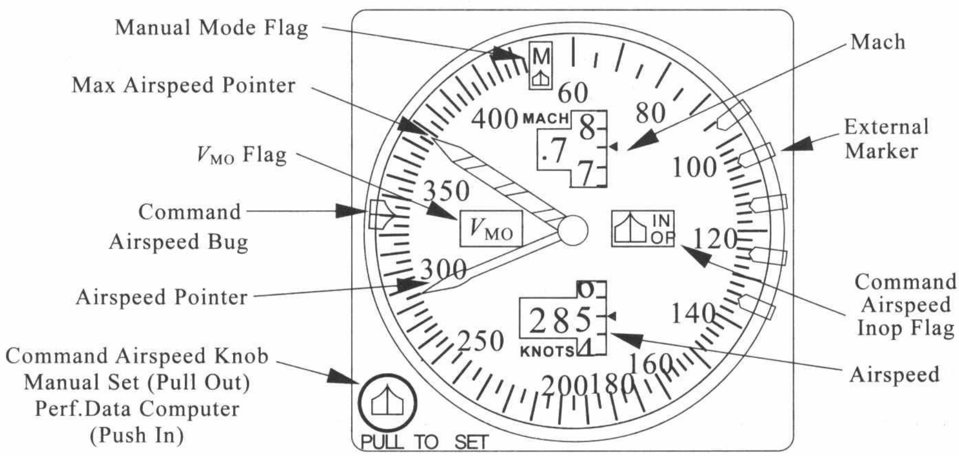

Figure 1.5 Mach/Airspeed Indicator

The striped needle (barbers pole) shows the maximum permitted airspeed (V_{MO}). The Mach display is normally blanked out at low Mach numbers, typically below M 0.4. The five little bugs mounted on the external face of the instrument are manually positioned, and are used to remind the pilot of various significant speeds, such as V_1, V_2, V_R and so on.

The command airspeed knob sets the commanded airspeed bug, to which the autothrottle will respond when engaged; this command airspeed is also fed to the air data computer, to govern the FAST/SLOW display on the attitude indicator. If the ADC fails, the digital readouts of Mach number and airspeed will be covered by a flag, and the airspeed pointer will read zero.

1.5.2 Altimeter

The electric servo altimeter is driven by its associated air data computer. The display has both a needle and a digital readout; the needle turns once per thousand feet as shown in Figure 1.6. The digital display is blanked if the ADC information is unreliable or the power is lost.

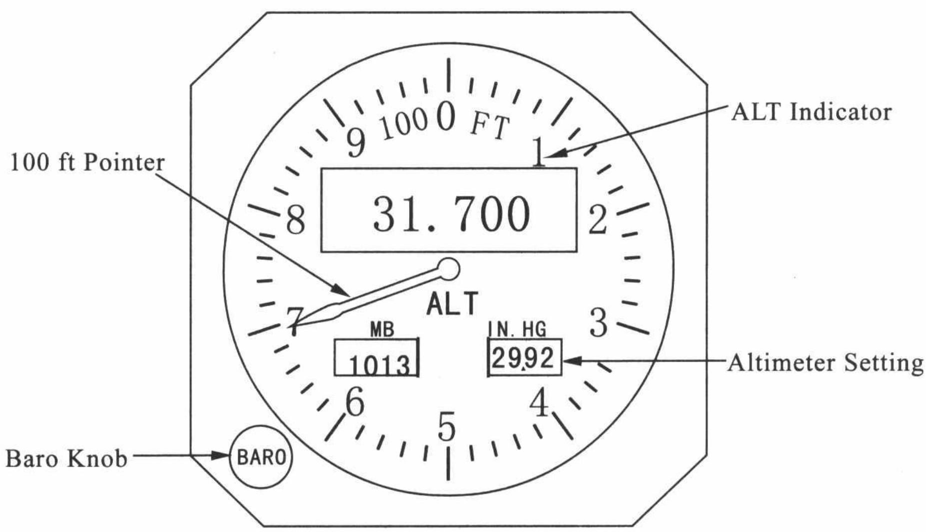

Figure 1.6 Altimeter

Where the captain has an electric servo altimeter, then either the other pilot's altimeter must be pneumatic, that is an altimeter driven directly by static pressure, or a standby pneumatic altimeter must be provided.

These pneumatic instruments are usually fitted with a motor driven vibrator to reduce the effects of hysteresis, or lag, during rapid changes in height such as an abnormal descent. Under these conditions the indicated altitude will lag behind the correct value, and the aircraft will be lower than the altimeter reading.

1.5.3 Vertical Speed Indicator

The vertical speed indicator (VSI) receives its information from its associated air data computer, and may show an OFF flag if the data is unreliable or the power is lost (Figure 1.7).

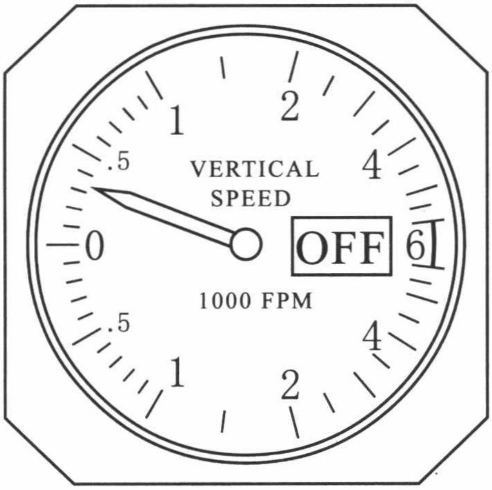

Figure 1.7 Vertical Speed Indicator

Modern VSIs, called IVSIs, are fitted with an inertial mechanism to improve response times.

1.5.4 TAS/TAT/SAT Indicator

The TAS/TAT/SAT indicator receives its information from its associated air data computer. TAS/TAT/SAT indicator is shown in Figure 1.8. TAS is displayed in the left window, SAT or TAT is displayed in the right window. The display in the right window is switched from SAT to TAT or back again by alternate presses of the TEMP SEL button.

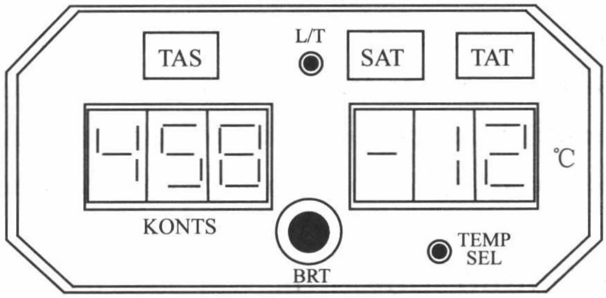

Figure 1.8 TAS/TAT/SAT Indicator

On the modern airplane, altitude, airspeed and vertical speed are displayed on the Primary Flight Display, SAT and TAT on the System Display.