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CONTENTS

Chapter 1

SEMI-CONDUCTORS

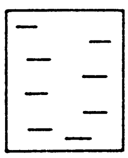
This section provides some explanation and introduces the terminology associated with the more common semi-conductors.

Semi-conductors are another class of materials with important electrical characteristics and uses. In their normal state and as their name implies, these materials have resistance values that fall between those of conductors and insulators.

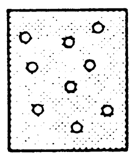
The usefulness of devices made from semi-conductor materials, such as silicon and germanium, results from manufacturing processes that enable their resistance to be changed instantly from a high resistance value to a low resistance value.

Good conductors are materials possessing atoms that have an excess of electrons. When a voltage is applied, the readily available electrons allow a current flow to occur quite easily. An insulator on the other hand, possesses atoms with a shortage of electrons and as it is much more difficult for electrons to move, so the insulator represents a very high resistance.

Semi-conductor materials are selected from the group which are neither good conductors nor good insulators and commonly germanium or silicon is used. These materials are not used in their raw state as they are doped with designer impurities to artificially create an excess of electrons to become donor 'N' type materials, or a deficiency of electrons to become acceptor 'P' type materials.



N type materials have an apparent excess of electrons that are normally free to drift among the atoms of the materials.

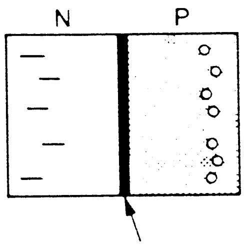


P type materials have an apparent deficiency of electrons. An area that is electron deficient is represented by a hole which normally drifts among the atoms of the material.

Both N type and P type materials are electrically balanced with equal numbers of protons and electrons. In N type materials, there are free electrons, and in P type materials, there are free holes. When P type and N type materials are joined together, a PN junction is formed. Free electrons from the N type material, cross the junction and are accepted into the free holes in the P type material. This causes the previously electrically balance N type material to become positively charged and the P type material to become negatively charged.

The remaining free electrons in the N type material are repelled away from the junction by the negative charge of the P type material and the remaining free positive holes in the P type material are also repelled away from the junction by the acquired positive charge of the N type material. Conduction across this junction is difficult because the resistance is high.

The overall negative charge of the P type materials repel the free electrons in the N type materials to this end.

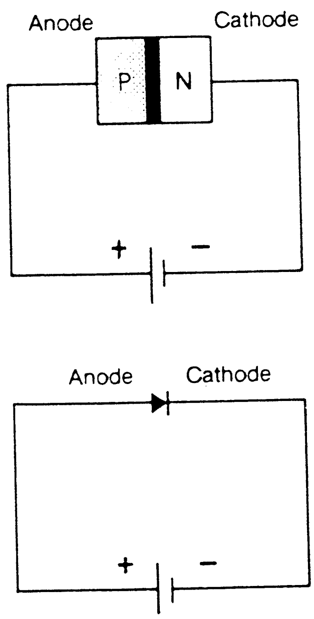


The overall positive charge of the N type materials repel the free holes in the P type materials to this end.

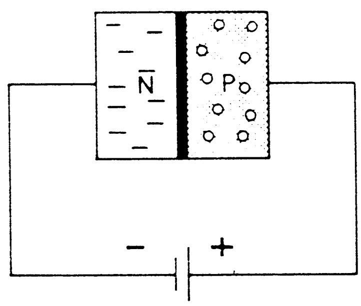
In this state, the PN junction does not seem particularly interesting. However, should a voltage be applied across the junction, its behaviour is quite remarkable and this device is the very useful and important solid state diode.

FORWARD BIAS

If voltage is applied to the junction with positive to P type material and negative to N type material, conduction is assisted as resistance is low.



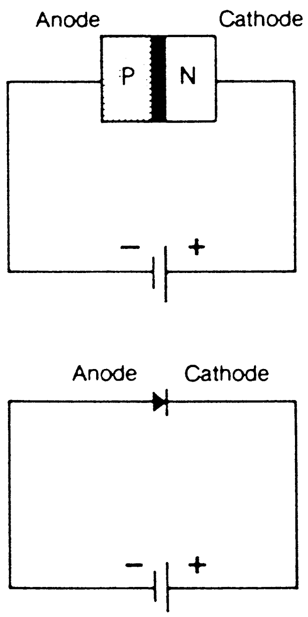
Forward biasing a diode puts it into its conducting state.



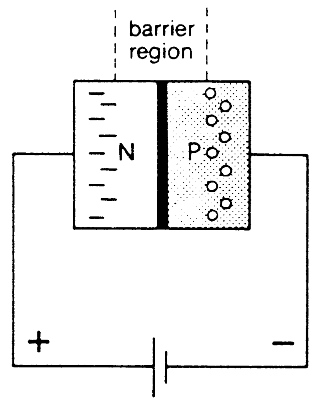
Forward biasing a pn junction narrows the barrier region and thus reduces the resistance to current.

REVERSE BIAS

Should a voltage be applied to the junction, positive to the N-type material and negative to the P-type, the barrier region of the junction widens (resistance is high) and little or no current flows.



Reverse biasing a diode puts it into its non-conducting or high-resistance state.



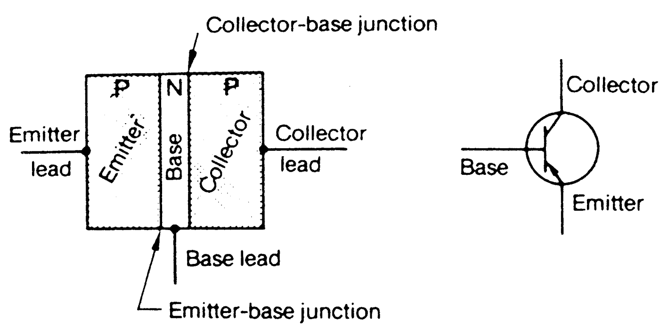
Reverse biasing a pn junction widens the barrier region and thus increases the resistance to current.

Diodes can be used as larger high power rectifiers in power supply systems or small, very low current gates in computers and other sensitive electronic equipment.

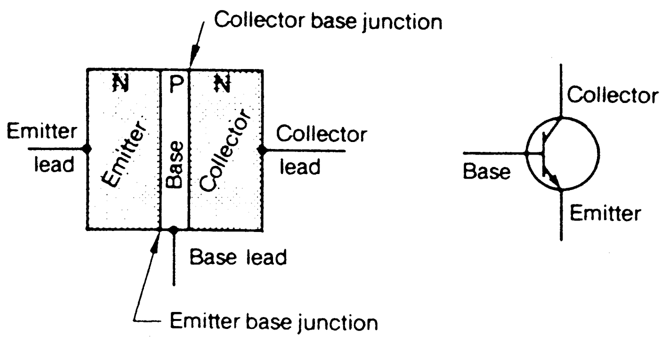
TRANSISTORS

When three pieces of semi-conductor material are joined, two junctions are formed on the now single piece 'solid' device. The types of materials joined, determine whether the junctions are NPN or PNP combinations. This device is the original transistor which lends itself to be used in many electronic circuit application.

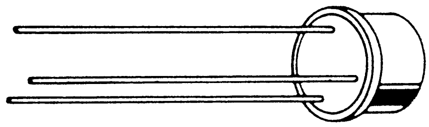
When compared to the original vacuum tubes or valves, which could be used for similar functions, transistors are much smaller, lighter, cheaper and more reliable.



A PNP JUNCTION



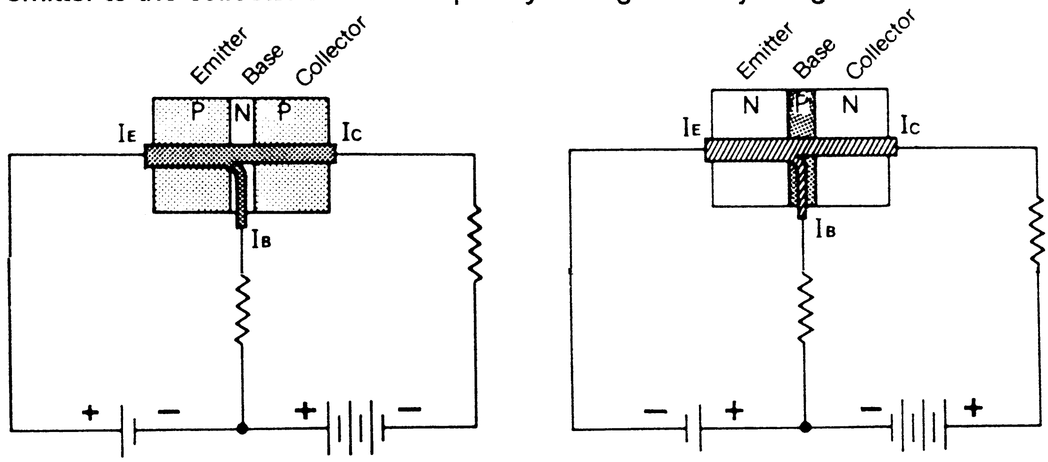
AN NPN JUNCTION



TRANSISTOR:

TRANSISTOR OPERATION

The behaviour of the transistor junction is quite different from the expected behaviour of an interconnected pair of diodes. To operate, there needs to be a voltage of the appropriate polarity, applied across the emitter-collector and a forward bias voltage between the emitter and base. When these conditions are met, current will flow from the emitter to the collector and consequently through the adjoining circuit.



The current in the emitter-base-collector circuit is 20 or more times greater than the current in the emitter-base circuit.

Transistors are very sensitive to temperature, and they are easily destroyed by excessive heat. Silicon types will withstand higher temperatures than germanium types. The maximum junction temperature for silicon is 200°C, but for germanium it is only 90°C. If a transistor is required to carry a large amount of current it will get hot.

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To reduce the risk of failure at the junction, heat sinks are often fitted to dissipate the heat.

Uses

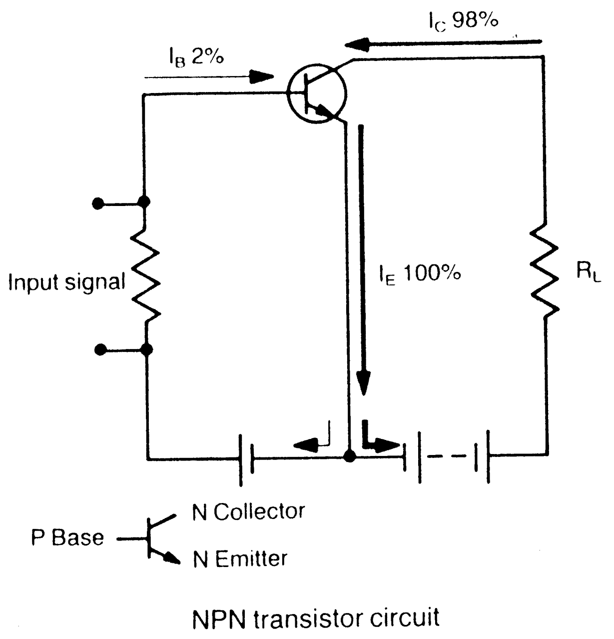
Transistors are set to operate in two ways:

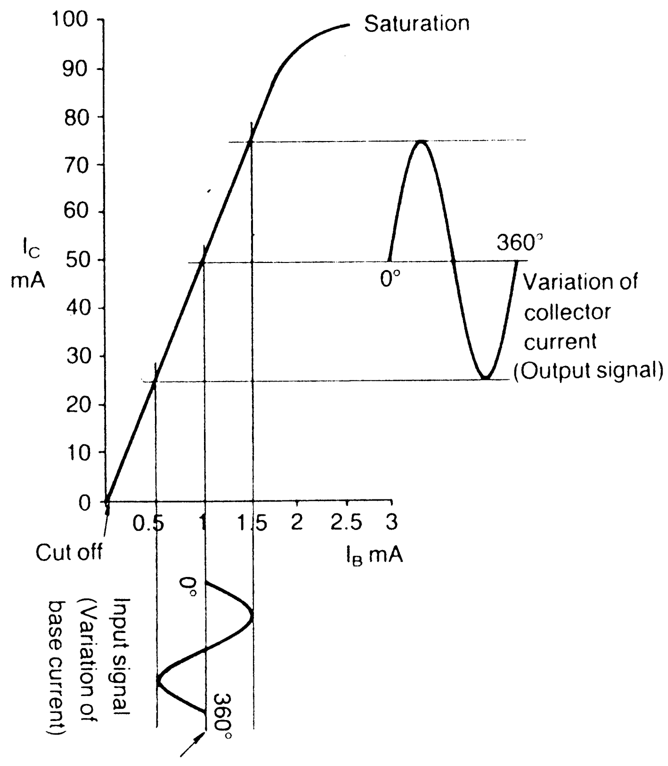
a) as amplifiers, and

b) as electronic switches.

Amplifiers

The diagram below shows a transistor circuit as an amplifier. The small analog input signal fed to the base is amplified about 50 times by one transistor. Should a greater amplification be required, transistor amplifiers can be coupled in series.

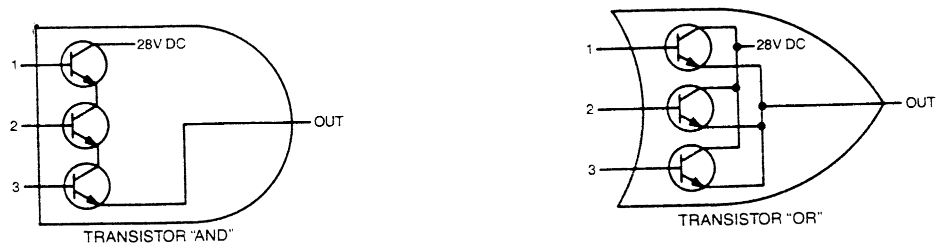




A TRANSISTOR AMPLIFIER

Switches

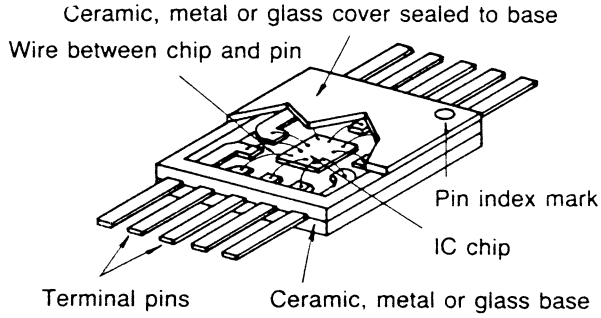
By controlling the base potential at either 5V or 0V (DC) the transistor can be turned ON or OFF. When it is on, a current flows and a voltage will appear elsewhere in the circuit. This type of switching is used in digital computers where the 5 volts is designated a value of one (1) and the 0 volts a value of zero (0). Digital computers use this zero and one system to produce a binary number system. Binary number systems and computer logic functions are presented in the next chapter.



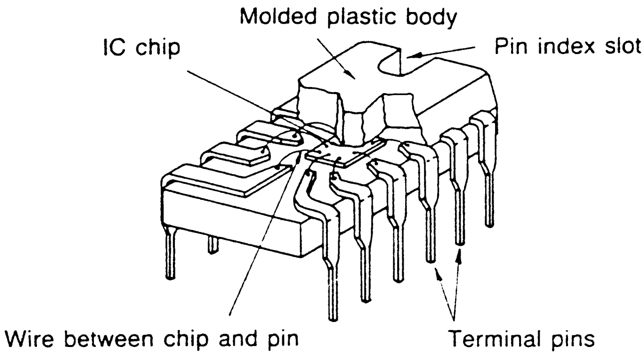
TRANSISTOR SWITCHES USED TO FORM LOGIC GATES

Transistors are now rarely used as stand alone devices. Modern engineering allows electronic components to be 'grown' in extremely miniature form. The 'integrated circuits' used in computer chips can consist of thousands of transistors (switches) capacitors and resistors. A semi-conductor (silicon base) material about 3mm square can support the remarkable amount of electronic components needed to become a pentium computer chip. It is not easy to imagine how this is done and you may be relieved to know that it is a three dimensional process.

The following diagrams are for general information only.



INTEGRATED CIRCUIT



INTEGRATED CIRCUIT: COMPUTER CHIP

The semi-conductors mentioned here are only some of the 'solid state' devices used today. Some of those not discussed are:

Silicon Controlled Rectifiers (SCRs)
Thermistors
Hall Generators
Field Effect Transistors (FETs)
Zener Diodes
Thyristors
Semi-conductor Lasers
Solar Cells
and there are more!

Chapter 2

BASIC LOGIC FUNCTIONS

The complex electrical control systems in modern aircraft are made up of various solid-state components such as resistors, capacitors, diodes, transistors and integrated circuits, which achieve the required sequential operation of each system.

Many stand alone computers capable of performing a vast range of dedicated functions are used. It is normal practice to depict these complex functions symbolically in the form of logic gates, rather than as complex electronic circuit diagrams.

BINARY SYSTEMS

Before looking at the basic computer logic functions, a short review of binary number systems is appropriate.

Digital Computers use the most simple of numeric codes possible 'ones and zeros'. The OFF condition is a '0' and the ON condition a '1'. In terms of voltage the nominal value of 5V DC represents a '1' and a lower value or no voltage represents a '0'. On their own, these 0's and 1's do not really mean anything, but couple an output line voltage with a timing device or computer clock and now a zero or a one is generated each period as determined by the clock. Using integrated circuits or memory chips, the computer can store these zeros and ones by having little transistors switched off or on. It is common for computers to use the binary code in sets of 8, 16 or 32 bits. However, any number of bits can be used to generate a number that means something to the computer by perhaps representing a letter of some text, a position on the screen or an ON or OFF command for an external piece of equipment.

Binary To Decimal

To convert binary code to decimal numbers it is a simple matter of understanding that binary is a code for a number system to the base two. By setting out a conversion table so that each digit of binary code represents a power of two, the code begins to make sense.

BASE	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
DECIMAL VALUE	128	64	32	16	8	4	2	1	
BINARY CODE	1	0	1	0	1	1	0	1	=10101101
DECIMAL NUMBER	128	0	32	0	8	4	0	1	=173

There is no point in remembering the decimal equivalents when it is easy to work out. The following list shows binary to decimal equivalents to 32.

Binary	Decimal
1	1
10	2
11	3
100	4
101	5
110	6
111	7
1000	8
1001	9
1010	10
1011	11
1100	12
1101	13
1110	14
1111	15
10000	16
10001	17
10010	18
10011	19
10100	20
10101	21
10110	22
10111	23
11000	24
11001	25
11010	26
11011	27
11100	28
11101	29
11110	30
11111	31
100000	32

LOGIC GATES

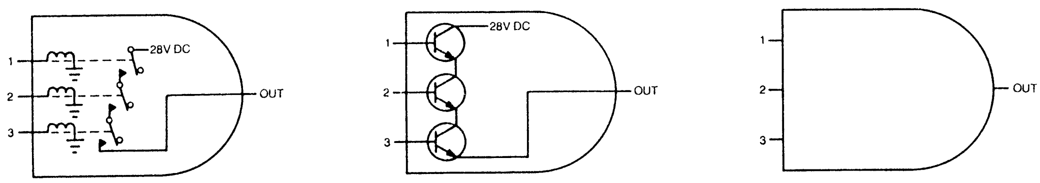
Logic diagrams are made up of a series of logic gates based on BOOLEAN LOGIC, and permit one of two possible outcomes. Thus, the logic of complex switching circuits can be represented diagrammatically.

Logic Gates take three basic forms; AND, OR and NOT.

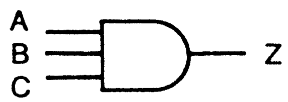
The AND Gate

The AND gate symbolizes a situation where all inputs to the gate must be ON to produce output. Since binary logic is used, ON is represented by 1, OFF by 0. Hence, both inputs (A and B) must be 1 for the output (C) to be 1. If either A or B is 0 the output at C will be 0. Because the AND gate will only produce an output when both inputs are in the logic 1 state, it is sometimes referred to as the "all or nothing" gate.

The functions of the various logic gates are shown in "Truth Tables", which show the binary logic output for each combination of inputs. The logic symbol, truth table, and an example of a simple electrical circuit which could represent an AND gate are shown below.



INPUTS			OUT PUT
A	B	C	Z
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

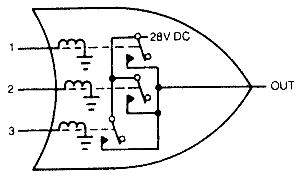


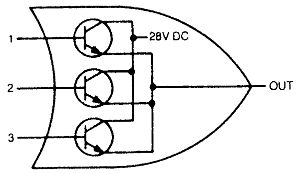
AND GATE

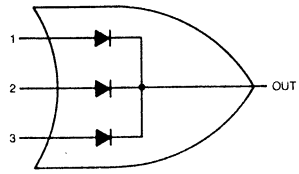
The OR Gate

The OR gate symbolizes a situation where any input (A or B) being in logic state 1 (ON) will produce an output - that is to say, a logic 1 output. Only if all inputs are logic state 0 will the output be 0. Because the OR gate will produce an output if any, or all, inputs are in logic state 1, it is sometimes referred to as an "any or all" gate.

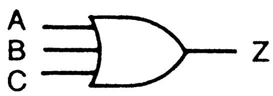
The logic symbol, truth table, and a simple electrical circuit which could be represented by an OR gate are shown below.







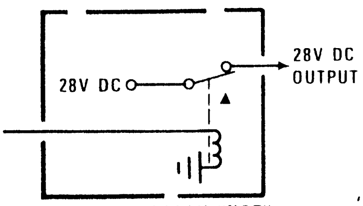
INPUTS			OUT PUT
A	B	C	Z
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1



OR GATE

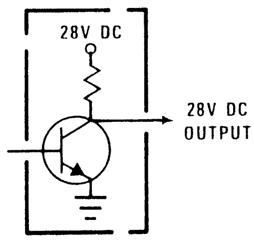
The NOT (Inverter) Gate

The third of the three basic logic gates, the NOT, or INVERTER, gate has only a single input and output and is used to invert a function. If the input is logic state 1, the output will be 0, and vice versa. The logic symbol, truth table and a simple electrical circuit which could be represented by a NOT gate are shown below.



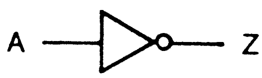
RELAY "NOT"

"NOT" Equivalents



SOLID STATE "NOT"

IN PUT	OUT PUT
A	Z
0	1
1	0



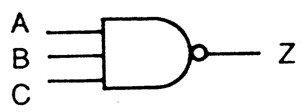
NOT GATE

The NOT gate is generally used in conjunction with other gates, rather than on its own, to invert their basic functions.

The NAND Gate

The NAND gate is an AND gate with an inverted output; in other words it is an AND gate with a NOT gate added on the output side (the term NAND is diminutive of NOT AND). Thus, the normal output of the AND gate will be inverted. The symbol for a NAND gate, and its truth table, are shown in the diagram below. The symbol is abbreviated and rather than show an AND gate with a NOT gate added, the NOT function is symbolized by a small circle on the output line of the AND gate. Similarly, the truth table is abbreviated, as shown:

INPUTS			OUT PUT
A	B	C	Z
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

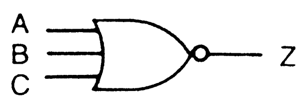


NAND GATE

The NOR Gate

As with the NAND gate, a NOR gate is an OR with a NOT added; a NOT OR gate. The normal output of the OR gate will be inverted and the symbol and truth for the NOR gate are shown below.

INPUTS			OUT PUT
A	B	C	Z
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0

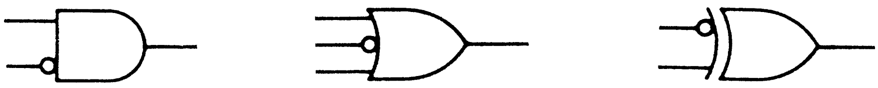


NOR GATE

Inhibited or Negated Gates

The basic logic gates can be used in a wide range of combinations to symbolize sequential functions. Having seen how a NOT gate can be added to the output of an AND or OR gate to invert the output, it follows that the functions of these two gates could be changed further by adding a NOT gate to one or other of the inputs.

The diagram below shows the two basic gates modified in this manner, the NOT gate position being shown by a small circle in each case.

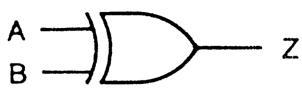


NEGATED INPUTS

The Exclusive OR Gate

The exclusive OR gate symbolizes a situation in which similar inputs produce a 0 output and dissimilar inputs produce a 1 output. The symbol and truth table for an exclusive OR gate are shown below.

INPUTS		OUT PUT
A	B	Z
0	0	0
0	1	1
1	0	1
1	1	0



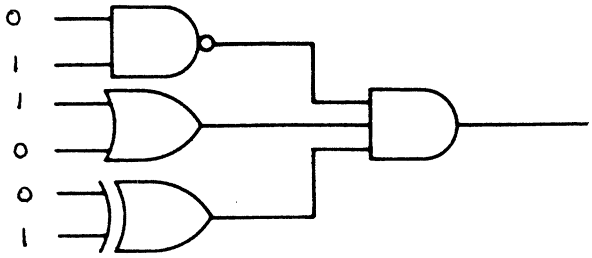
EX-OR GATE

Positive and Negative Logic

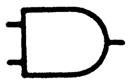
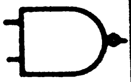
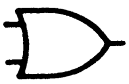
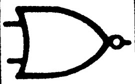
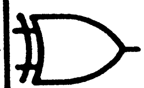
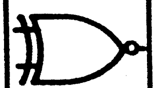
As previously stated, logic circuit signals are at two levels, referred to as binary 1 and binary 0. In simplistic terms these may be regarded as ON or OFF, but in reality they represent voltage levels.

Positive logic circuits are those in which binary 1 represents a higher voltage level and binary 0 a lower one. The actual voltage values may be both positive, both negative or one positive and the other negative. Negative logic circuits, in which binary 1 always represents the low voltage level, are not commonly used and then only when system design parameters demand it.

It is possible to evaluate the function of a logic circuit using the truth tables for the appropriate gates. Test yourself with the logic circuit diagram below with the inputs as shown. Will the final output be 0 or 1?



Truth Table Summary

INPUTS	A B	 (1)	 (2)	 (3)	 (4)	 (5)	
A	**B**	**AND**	**NAND**	**OR**	**NOR**	**Exclusive OR**	**Exclusive NOR**
0	0	0	1	0	1	0	1
0	1	0	1	1	0	1	0
1	0	0	1	1	0	1	0
1	1	1	0	1	0	0	1

Application

In modern aircraft, logic functions are applied to almost every operation. For example, flaps can be prevented from being lowered if the airspeed is above a certain value. If the maximum flaps operating speed was 200 kt, above this speed the computer (via the ADC) would present a 'NO' condition, at or below 200 kt when flaps selection was made a 'YES' condition is presented. The flaps would be deployed should any other 'OR' or 'AND' conditions be met.

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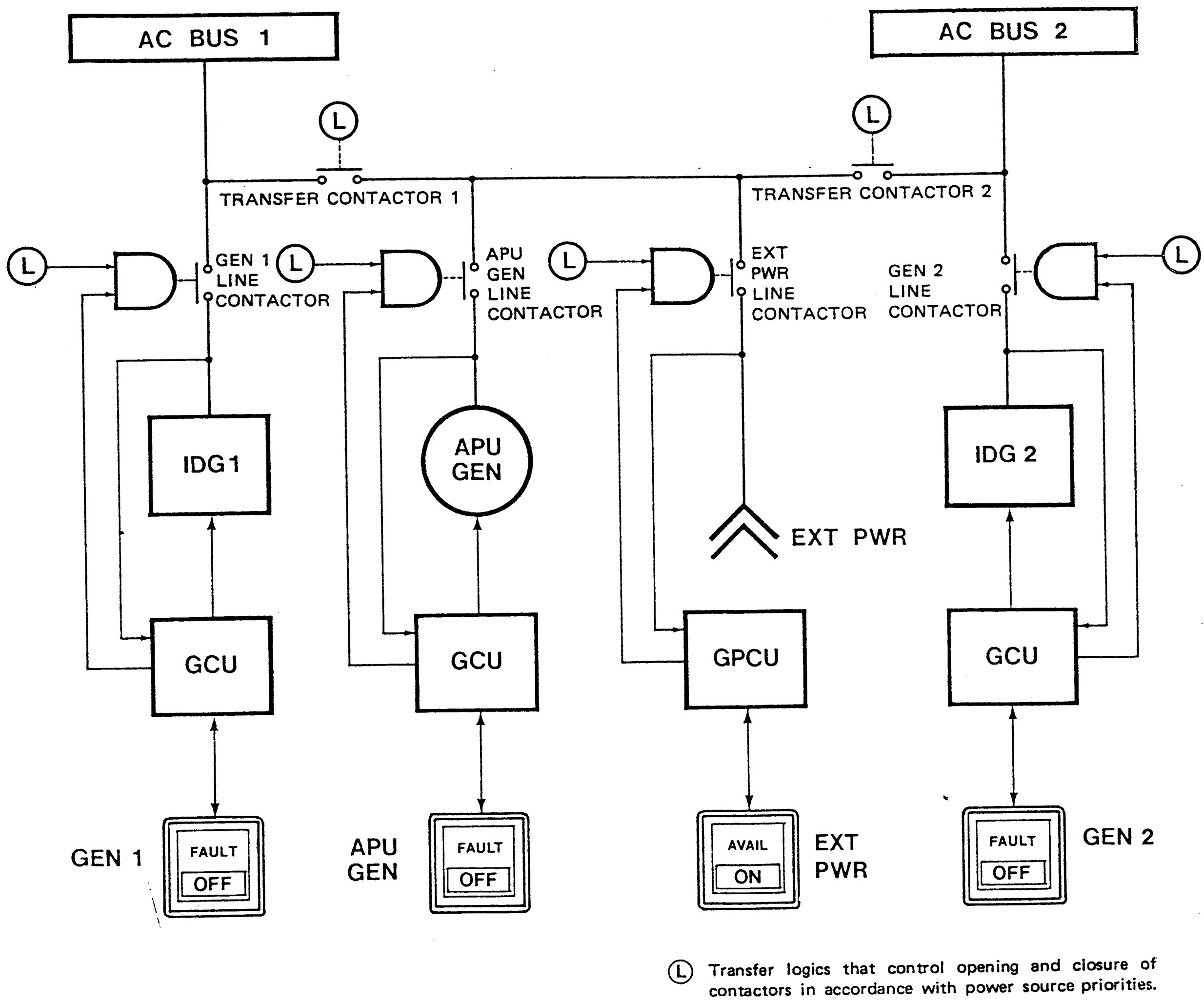
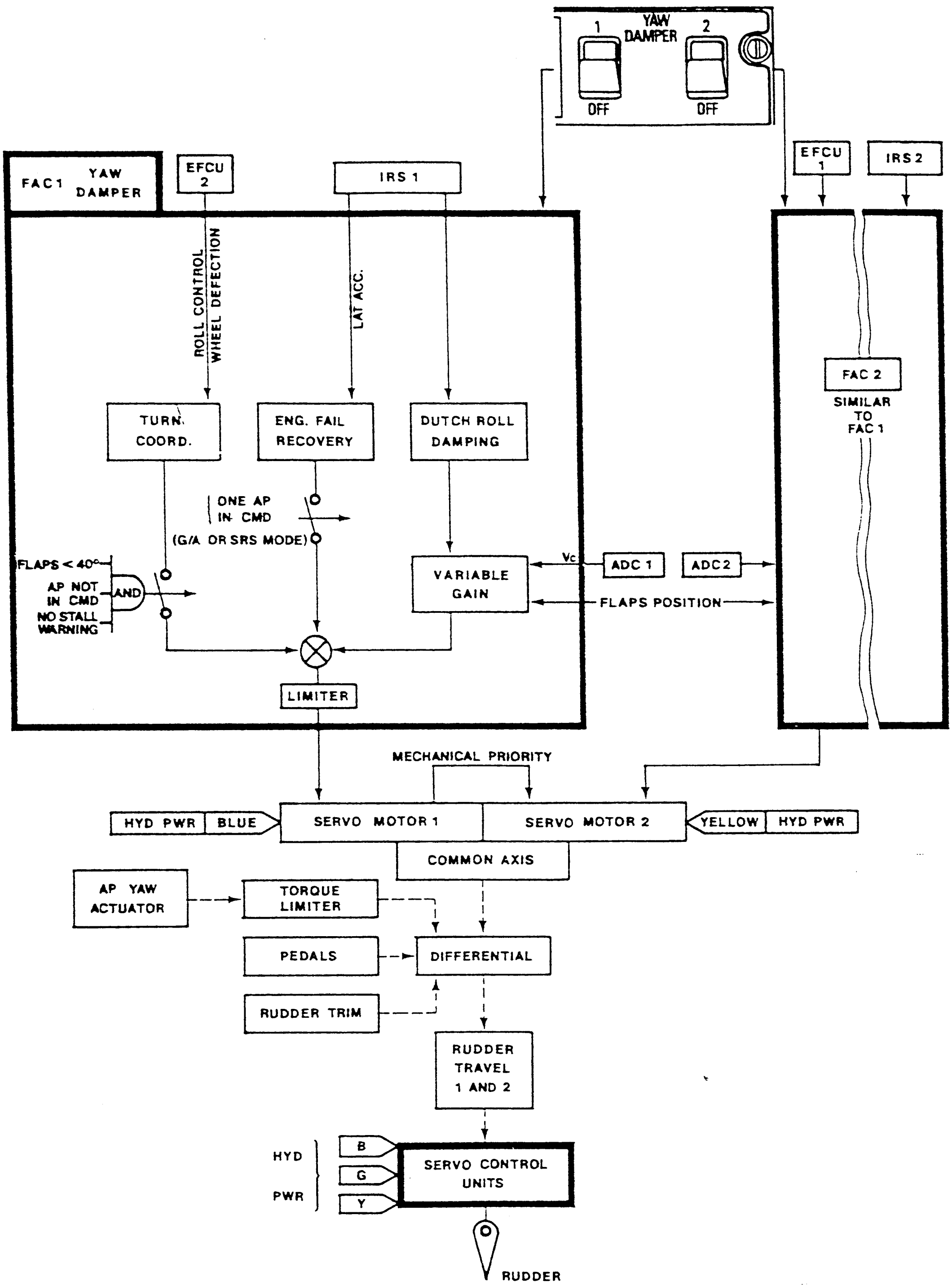
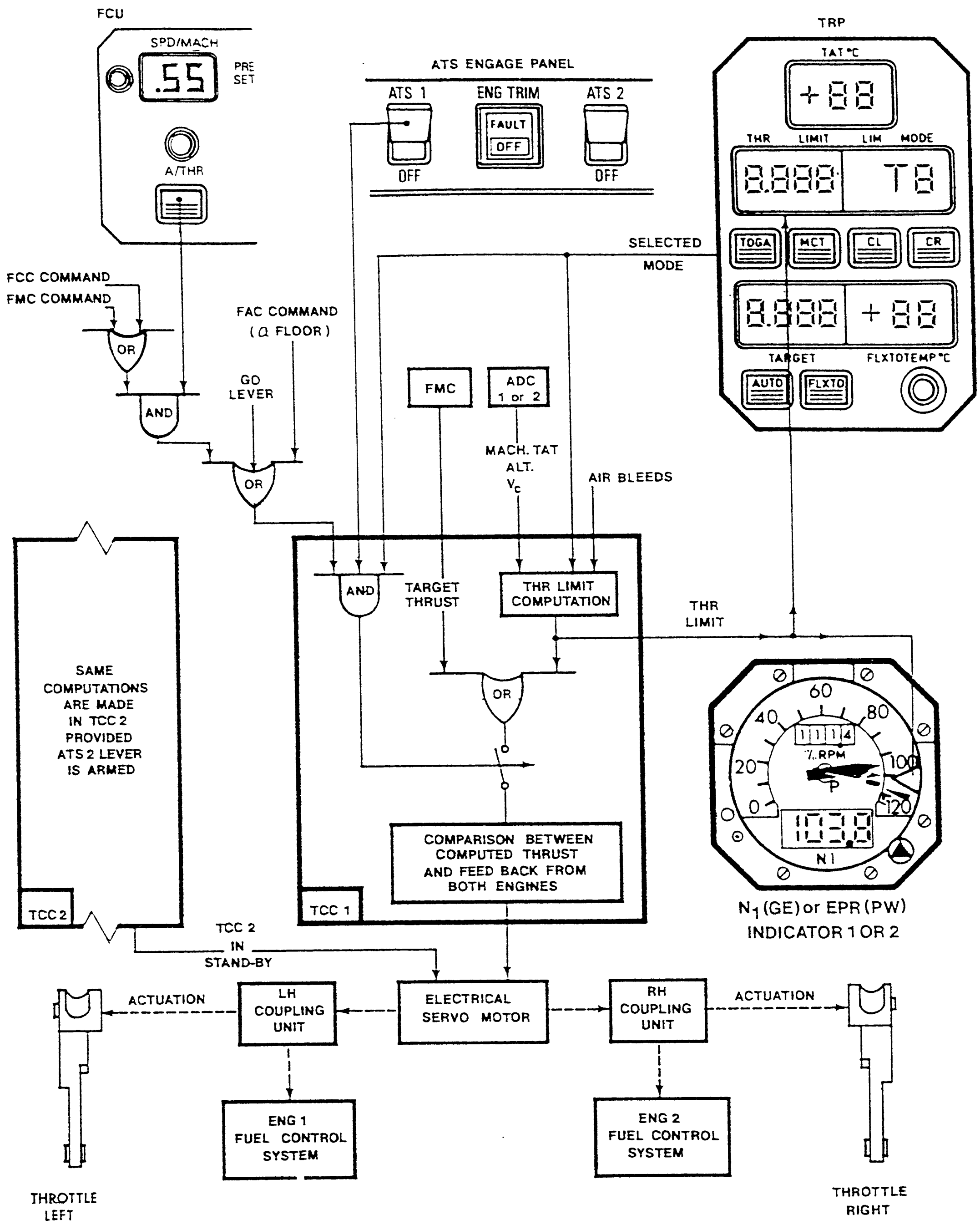


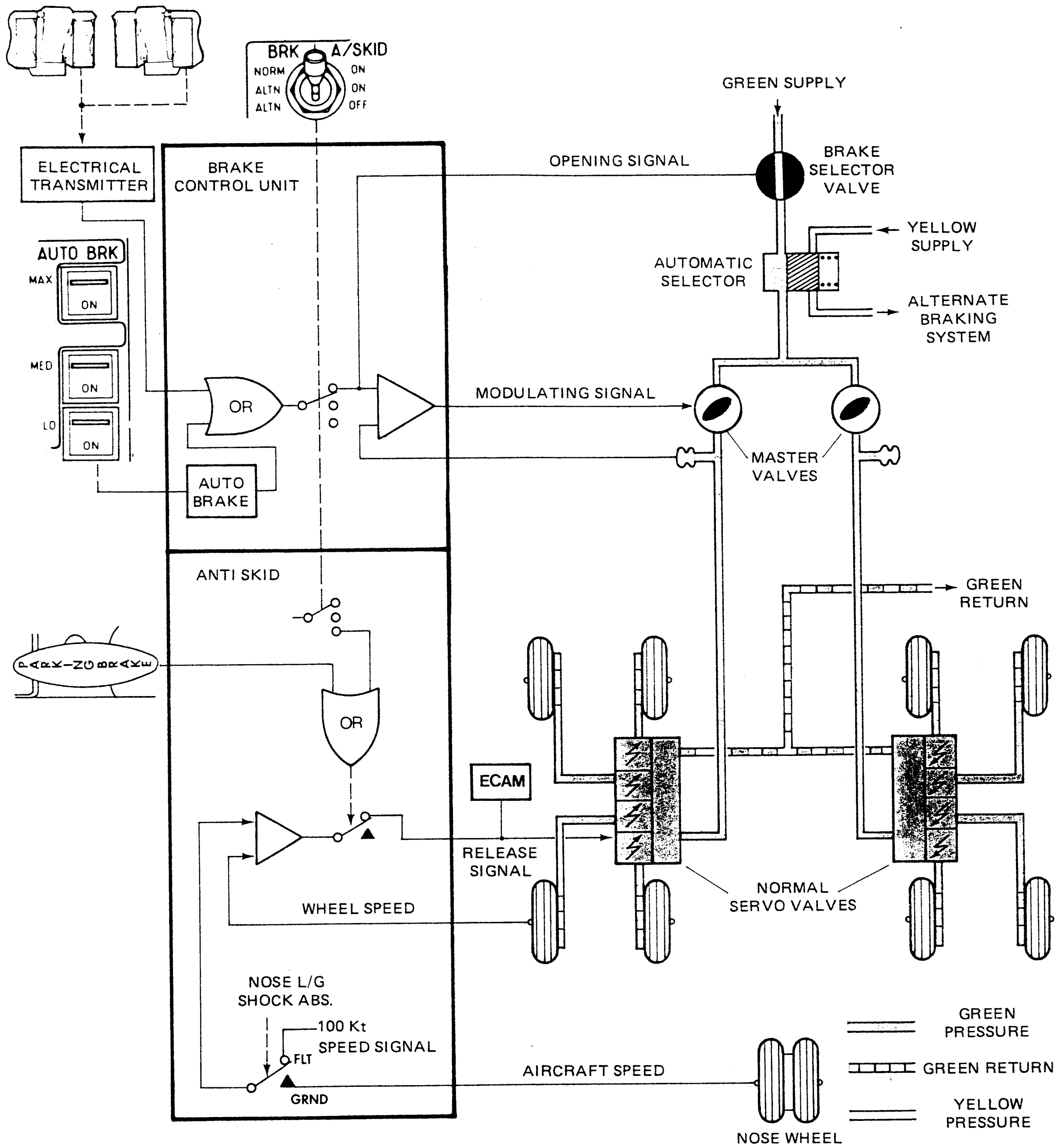
AC POWER GENERATION AND TRANSFER



YAW DAMPER SYSTEM



ATS THRUST MODE



NORMAL BRAKING SYSTEM

Chapter 3

INTRODUCTION TO AUTOMATIC SYSTEMS

This chapter is designed to have you think about the function and action of computers, sensors, local information transmission and the devices or servos that do the physical work. To understand aircraft automatic systems, a pilot must have some idea of the basic engineering concepts which provide high quality and reliable aircraft performance.

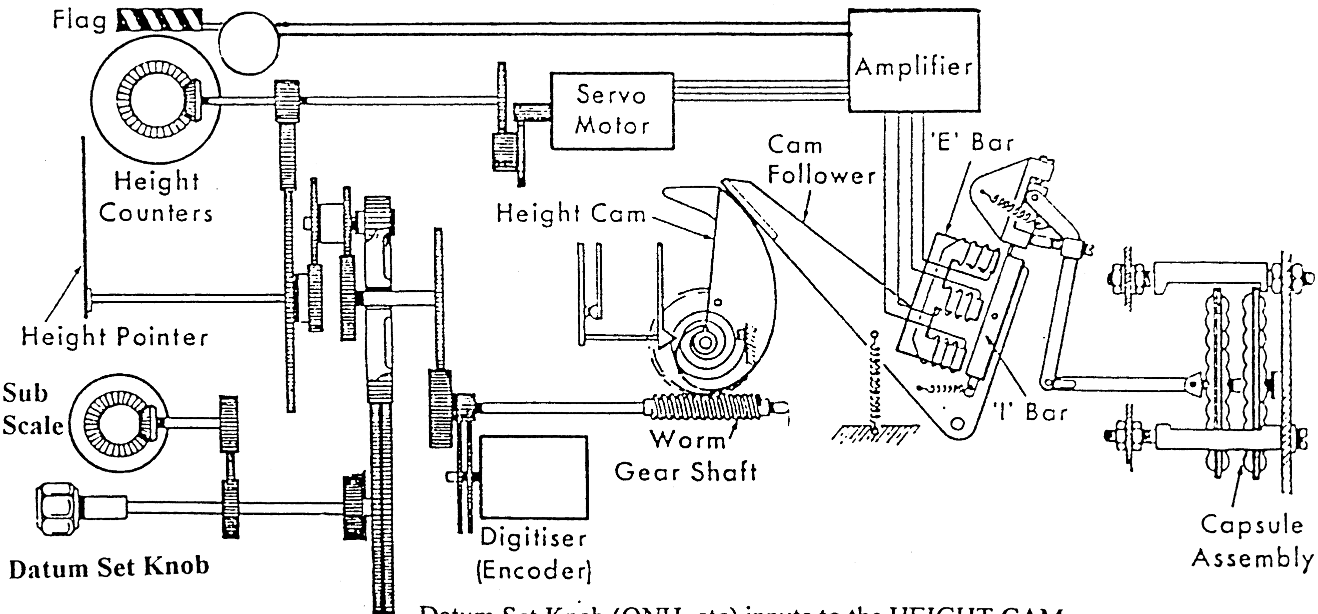
COMPUTERS

All modern aircraft have equipment that could be classified as a computer or performs a computing function. These devices are either Analog computers, Digital computers or can be a 'hybrid' where they are used to combine the operation of both types.

Analogue Computers

Analogue computers perform dedicated functions, often very well and in real time. However, they are mostly mechanical devices which require a high degree of maintenance and can be used for no other function than that for which they are designed.

The flight instruments, Altimeter, Airspeed Indicator, Vertical Speed Indicator, Machmeter, etc., are all analogue devices. They accept Static and Pitot pressure which cause the physical movement of a sensing capsule. The amount of movement which occurs is an analogue of the input pressure. This input is amplified mechanically by gears and levers and used to position pointers which can be read against the face of an indicator. Engine oil pressure and temperature indicators are also analogue devices. Undercarriage up, not up, down and not down micro switches, are an example of digital sensors or switches being used with Binary system logic to indicate undercarriage up, in transit or down.



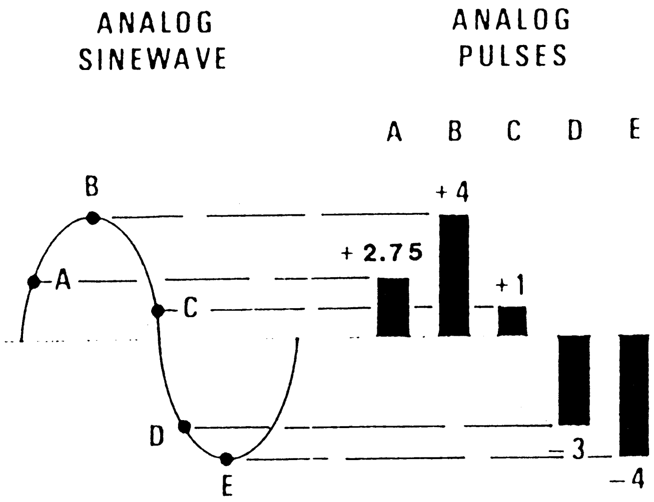
Datum Set Knob (QNH, etc) inputs to the HEIGHT CAM.
Encoder provides altitude output for transponder

SERVO ASSISTED ALTIMETER

The servo assisted altimeter is an example of an alternating current analogue device, where the movement of the capsule determines the phase of the error signal produced by an E.I. transformer. It is also an example of the 'loop' principle, where the error signal is amplified electrically and connected to a servo motor which drives to reposition the E frame (stator) of the E.I transformer to the null or cancel the error signal. In driving to the null, the motor positions the pointer or counters to indicate the new altitude.

Analog is the most convenient method in our everyday lives, but it is not very efficient or precise when compared with digital in the realm of aircraft avionics. An analog display provides a physical representation of information which bears an exact relationship to the original information.

The following illustrates a sine wave such as A, B, C, D and E. The measured values are a direct representation of the continuous values along the sine wave. Analog data is represented in a continuous form by physical variables, such as voltage, resistance, capacitance, and angle of rotation.



ANALOG SIGNAL

DIGITAL COMPUTERS

Digital computers are usually capable of many different tasks but can also be dedicated devices which perform only one function. The digital watch and electronic calculator are examples. The term digital comes from the binary code 0's and 1's used in these devices. Digital functions are occurring on an increasing number of modern aircraft. The parameters of pressure, temperature etc., can be digitally coded, sometimes from an analog sensor, so that from this point, a digital parameter is available to the central computer for use anywhere on the aircraft.

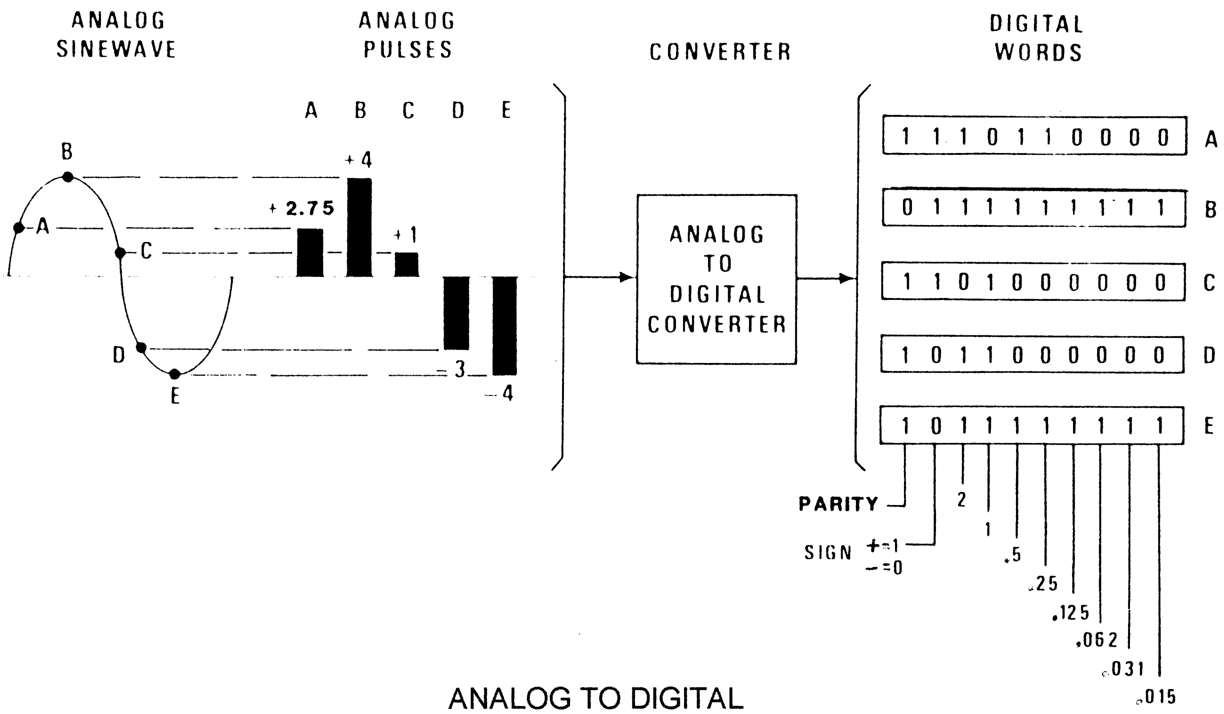
Modern, high capacity digital computers are driven by 'software'. Should some device be required for a different aircraft which operates at different speeds, the existing airspeed indicator may not function well enough in the new range. Where analog systems are used, new instruments may have to be researched, developed and manufactured. In a digital computer system, a programme adjustment is the likely change being a quicker and cheaper option.

The advantage of converting data into a digital representation, is that the components are more economical, lighter and provide a higher degree of resolution. Digital data is also much easier to transmit without loss of data detail with the added advantage that more than one user can use the same information. By having the data coded, more than one data group can be transmitted along a cable by multiplexing (time or frequency sharing) the data. Such a cable is called a data bus (short for busbar).

Digital data is represented in discrete or discontinuous form. In this case by a series of ones and zeros. A one represents the presence of a value or expression, while a zero represents the absence of that value or expression.

The following diagram represents analog to digital conversion, and analog measurement at point A has a value of +2.75 volts. The output of the converter consists of a digital word of ten bits (ones and zeros) which represents the analog value of measurement A. A parity bit is added to verify the reliability of data transmission and reception.

Depending upon the usage, coding and required resolution, the length of digital words may be anywhere from 8 to 64 bits. A bit is defined as a single binary decision such as a '1' or '0'.



ANALOG TO DIGITAL

SENSORS

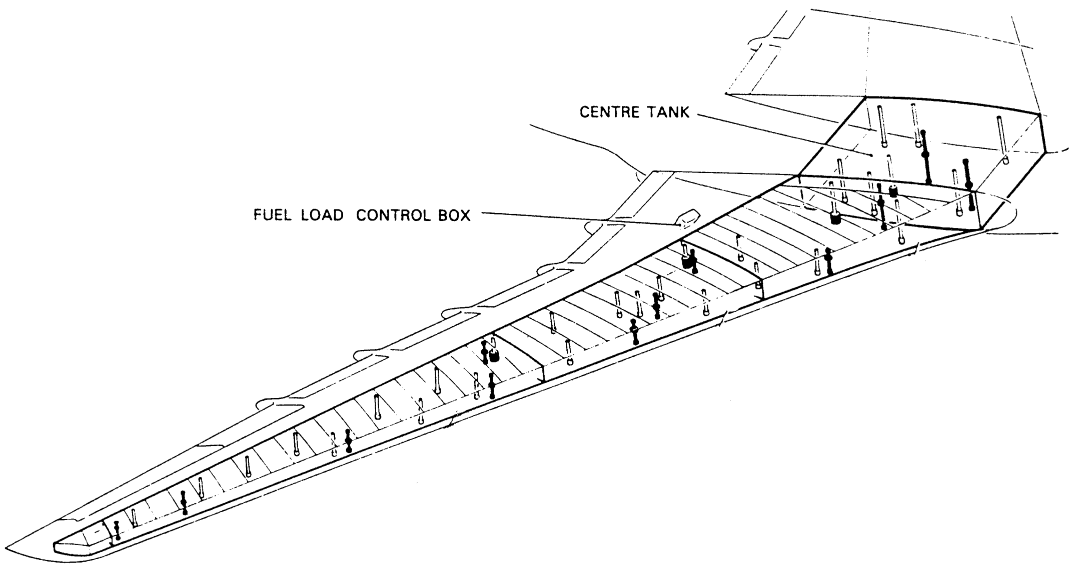
Temperature and pressure sensors, and micro switches, have already been mentioned, but other fairly common analog devices include potentiometers and rheostats when used as fuel level sender units in small aircraft. The up or down position of the float, produces an analog voltage (DC) which is used to drive an indicator to a calibrated position.

CAPACITIVE TANK UNITS

In large aircraft, capacitive tank units are used to measure fuel quantity in terms of weight. This is because the total power developed by an engine, depends not on the volume of fuel but on the energy it contains. Since each fuel molecule has some weight and also because one kilogram of fuel has the same number of molecules regardless of temperature and therefore volume, the total number of molecules or total available energy, is best indicated by measuring the total fuel weight.

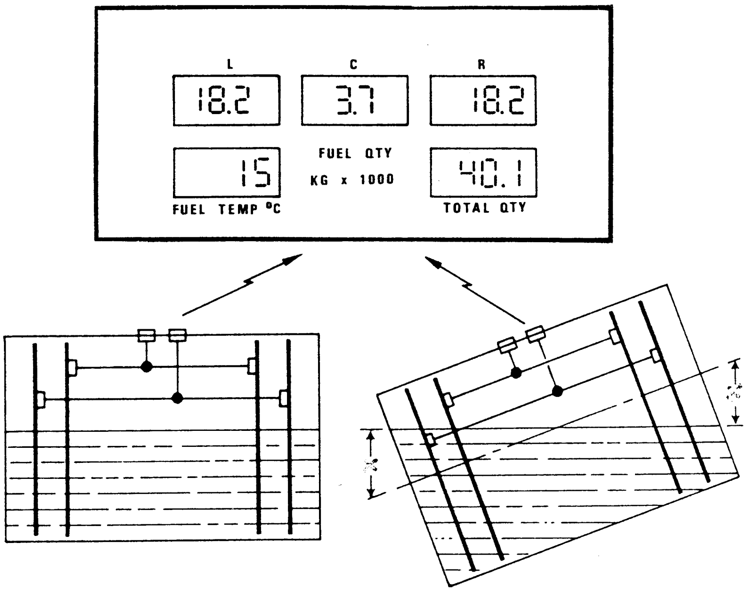
The measuring device must therefore be sensitive to both changes in volume and density so as to eliminate the undesirable effects due to temperature. For this purpose, density compensating devices are placed in the bottom of main tanks to provide the correct density input to the system for each fuel load.

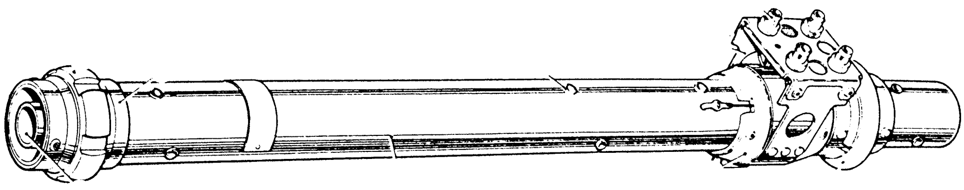
In capacitance type fuel quantity indicating systems, a large number of tank units are in the fuel tanks. The reasons for this are to ensure that indications remain the same, regardless of the attitude of an aircraft and its tanks and also of any surging of the fuel.



CAPACITIVE TANK UNITS IN WING

The following diagram shows a schematic, two unit system and how aircraft attitude has no effect on the indication. If the tank is half-full and in a level attitude, each tank unit will have a capacitance of half its maximum value, and since they are connected in parallel the total capacitance measured will produce a 'half-full' indication. When the tank is tilted, and because the fuel level remains the same, the total capacitance remains the same as for the level-tank attitude and the indication is unchanged.



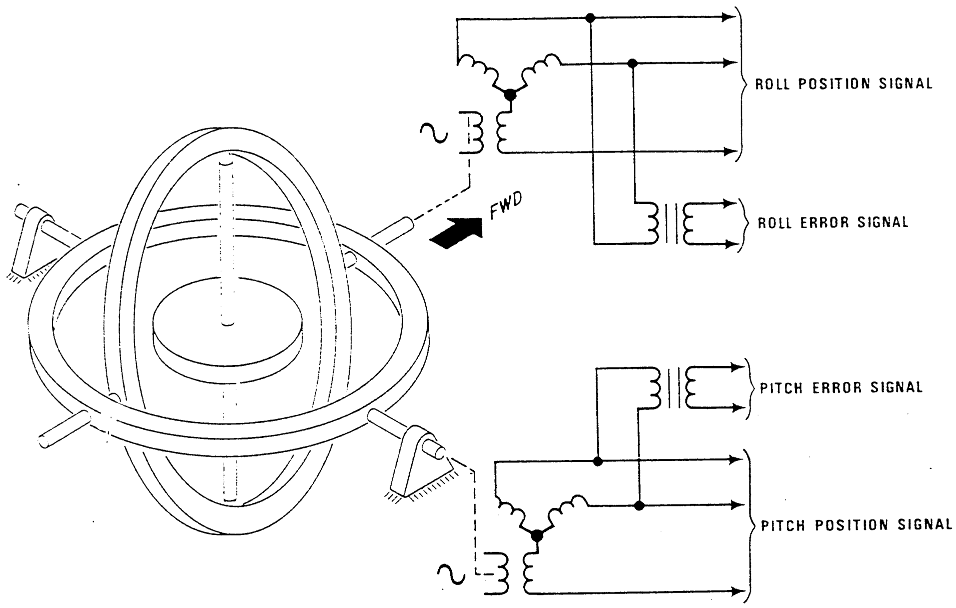


A CAPACITIVE TANK UNIT

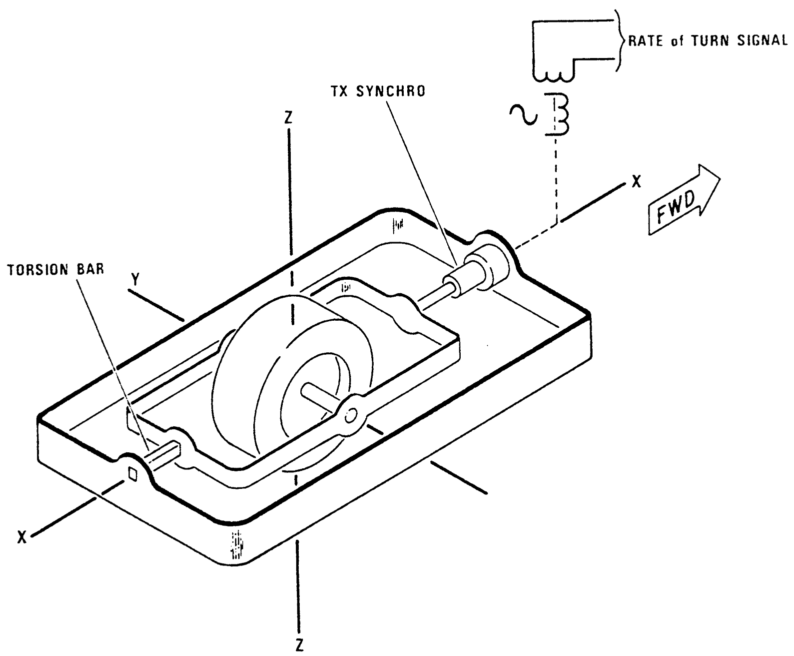
A **Fuel Quantity** indicator shows the fuel remaining, in kilograms.

GYROSCOPIC SENSORS

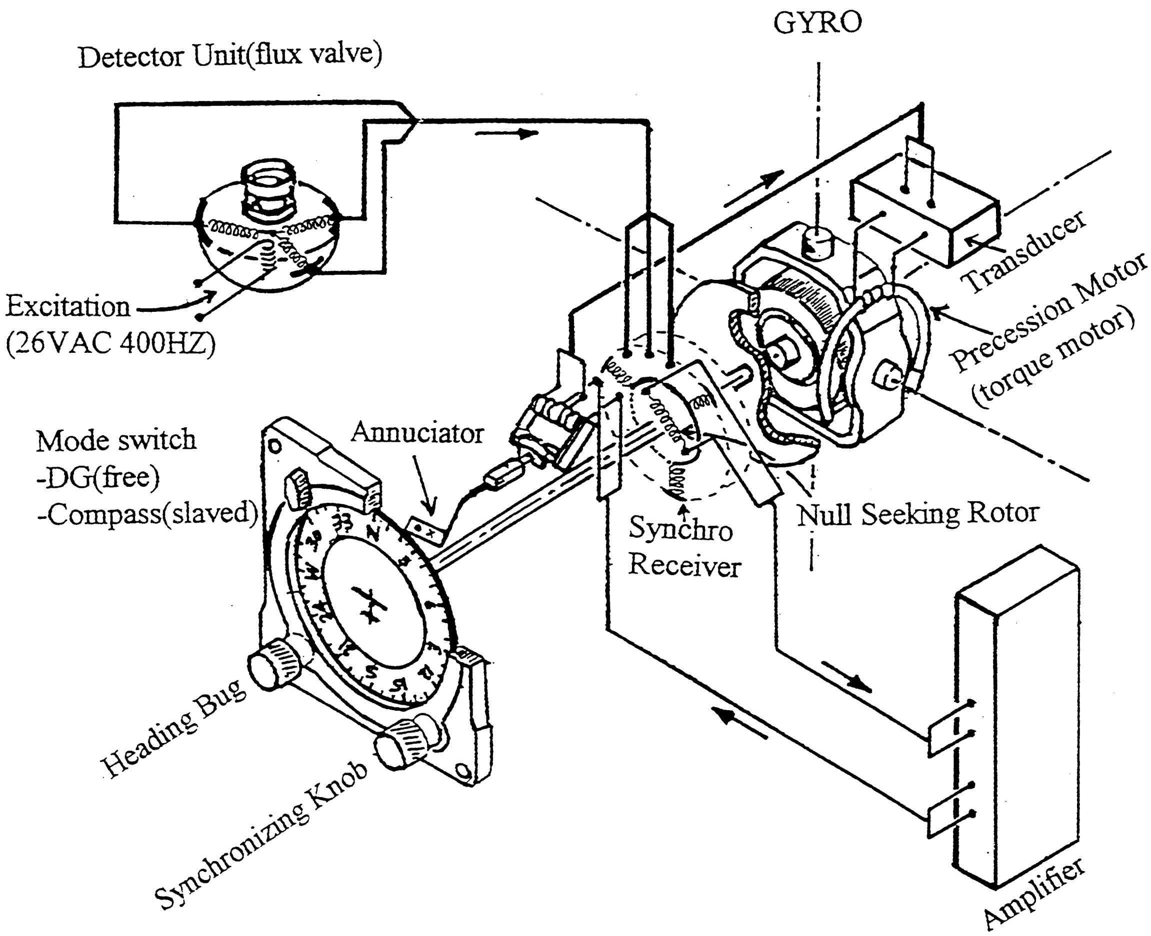
In small aircraft, the attitude indicator (AI) uses a displacement gyroscope with a vertical axis. This device can be powered by vacuum air pressure, but AC driven AI's are becoming more common. Because the axis is kept vertical by some type of gravity sensing, this instrument provides a quality horizontal reference. Against this reference, pitch and bank information is indicated to the pilot.
Should this pitch or roll information be required for an automatic system, the information would need to be output by some type of electronic device.



VERTICAL GYRO: ANALOG OUTPUT FROM SYNCHRO TRANSMISSION SYSTEM



RATE GYRO: ANALOG OUTPUT FROM RESOLVER TRANSMISSION SYSTEM

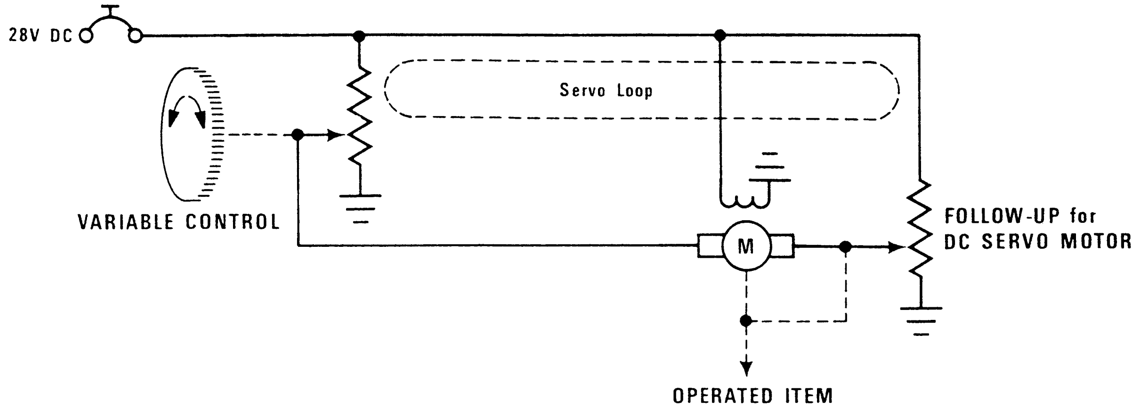


REMOTE INDICATING COMPASS SYSTEM

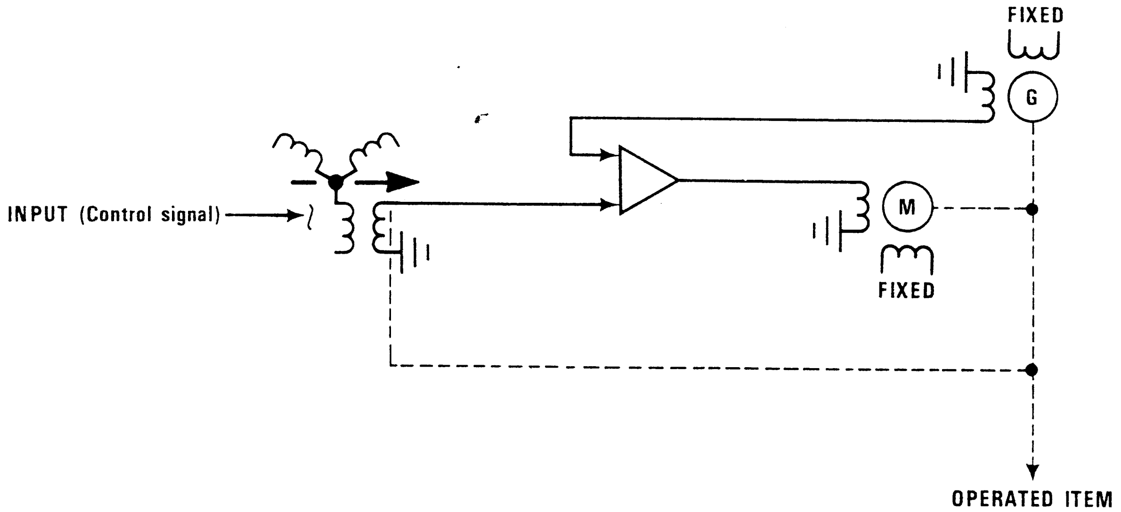
Large aircraft do not have remote indicating compass systems because the INS (IRS) can provide a TRUE NORTH reference and a computer can supply magnetic variation from a magnetic map and hence a magnetic reference is readily available. The remote indicating compass is an excellent example of how a small but complete system functions.

The remote indicating compass system uses a self synchronous transmission system known as SELSYN.

Both DC and AC transmission systems are used in aircraft.



A DC CONTROL LOOP



A TACHO GENERATOR FEEDBACK LOOP

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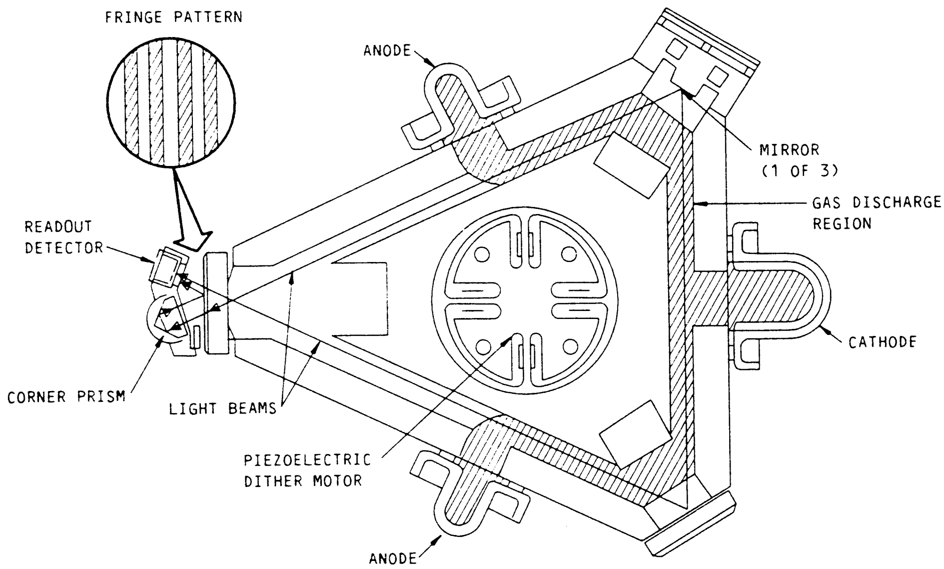
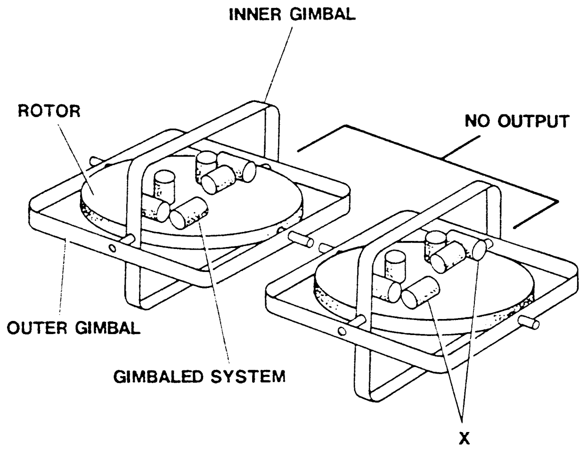
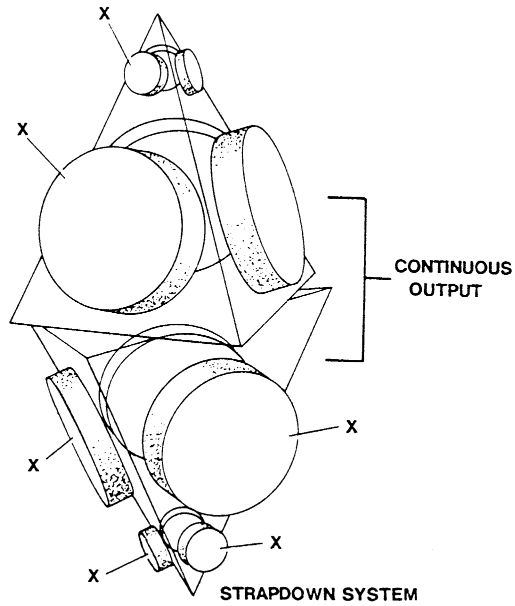
Digital technology has allowed many developments in gyroscopic systems. On large aircraft, only standby gyros are mechanical. Inertial navigation systems that use 'stable platforms' to hold their accelerometers in exact alignment will eventually age out. Solid state laser gyros fitted in a 'strap down' system now perform far more accurately and are more reliable.



LASER GYRO





STABLE PLATFORM

STRAPDOWN SYSTEM

Chapter 4

AUTOMATIC FLIGHT

Automatic flight encompasses those systems that assist the pilot in the safe and efficient operation of aircraft. These systems include autopilots and flight directors which are presented firstly in the context of small aircraft systems.

Later in this section automatic flight control systems of modern large airline aircraft are presented and include:-

a) Multiple Automatic Pilots and Flight Directors with Autoland
b) Auto Throttle
c) Automatic Trim and Yaw damper systems

BASIC AUTOPILOTS

The automatic pilot is designed to ease the pilot's workload, allowing more time to concentrate on communication, lookout and system monitoring. An autopilot is required to meet three basic functions. These are:-

- stability augmentation
- manoeuvre control
- system coupling

Attitude Sensing

Using the level attitude as the standard reference, attitude sensing is roll sensing or roll error about the aircraft longitudinal axis and pitch sensing or pitch error about the aircraft lateral axis. Attitude sensing is achieved by comparing aircraft attitude to a gyroscopic reference.

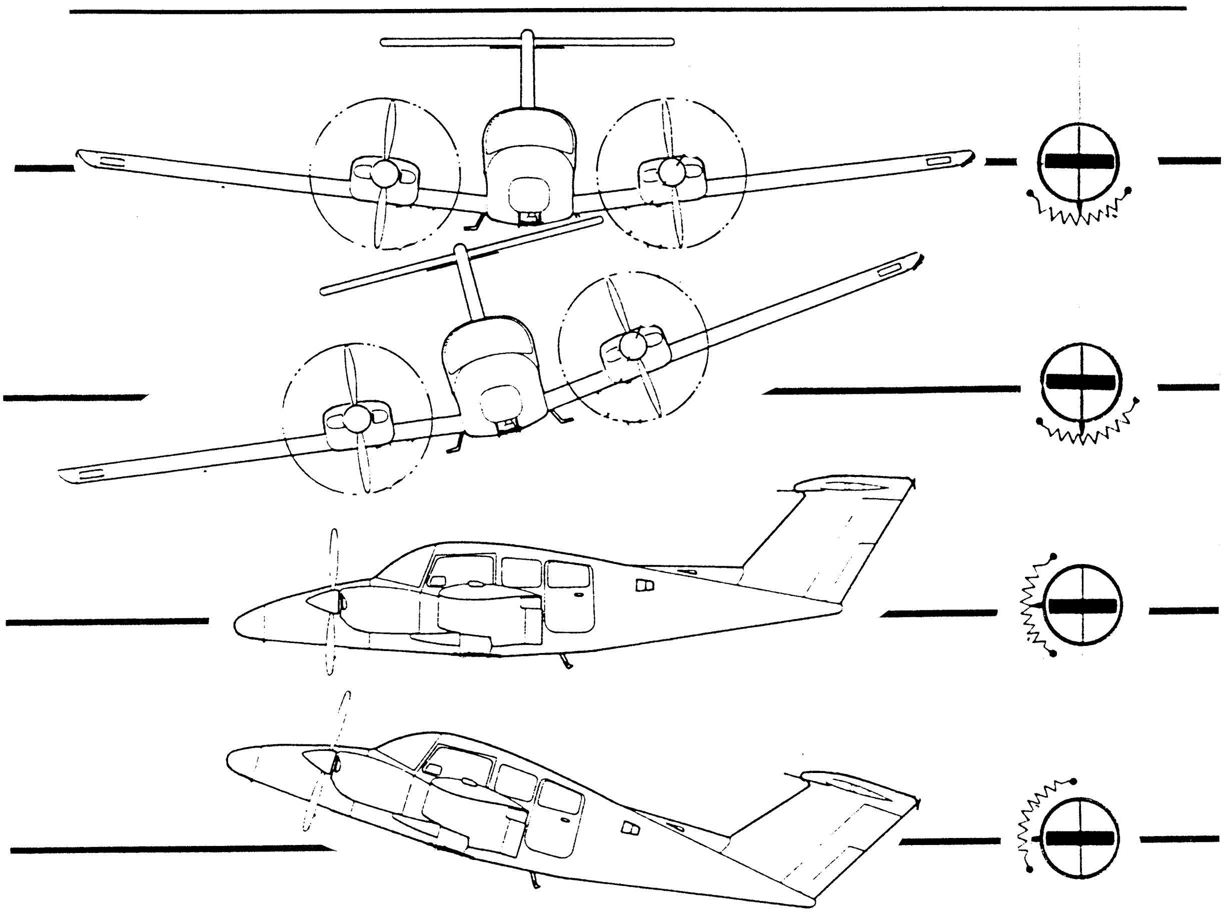
Many light aircraft autopilots use the attitude indicator vertical gyro to generate pitch and roll error signals.

A rate gyro is used to sense rate change about a single axis. The rate gyro in the turn indicator, senses turn movement or yaw about the aircraft's vertical axis.

Rate sensing can also be achieved by using 'accelerometers'. Some single channel wing leveller systems use accelerometers in conjunction with an inclined rate gyro. An inclined rate gyro, used in a turn coordinator, senses yaw and roll.

A transducer is a device which is used to convert a physical reference to an electrical signal. There are many types of transducers and the types encountered in this subject include the EI transformer, potentiometer and SELSYN. Light sensitive semiconductors are also used for both analog and digital sensing.

All of the above are methods of sensing (hence the term Sensor) aircraft attitude and generating an Error signal when the aircraft departs from its required attitude.



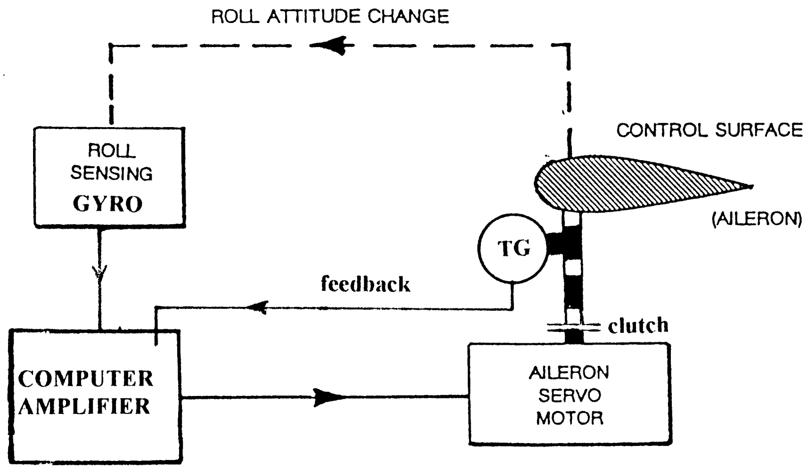
VERTICAL GYRO ATTITUDE SENSING

STABILISATION (the INNER LOOP)

Regardless of which type of sensing is employed, once an ERROR SIGNAL has been determined, an appropriate response must occur. The computer amplifies the signal and sends it to electric or hydraulic servos. If engaged, these servos will cause a control surface displacement , the aircraft responds and when straight and level, the error signal is cancelled. While this is correct, the process is not quite that simple.

The error signal causes control surface displacement but by how much and at what rate? The autopilot will have calibrated or set responses matched to the aircraft. Heavy aircraft have air data computers to feed the autopilot as control input is related to variables such as altitude and airspeed. When the control surface is moved, a feedback signal is generated by its movement, and is of opposite polarity to the error signal. The autopilot uses this feedback signal to modify displacement of the control surface and to return the control surface to its neutral position, when the aircraft responds and returns to its straight and level attitude.

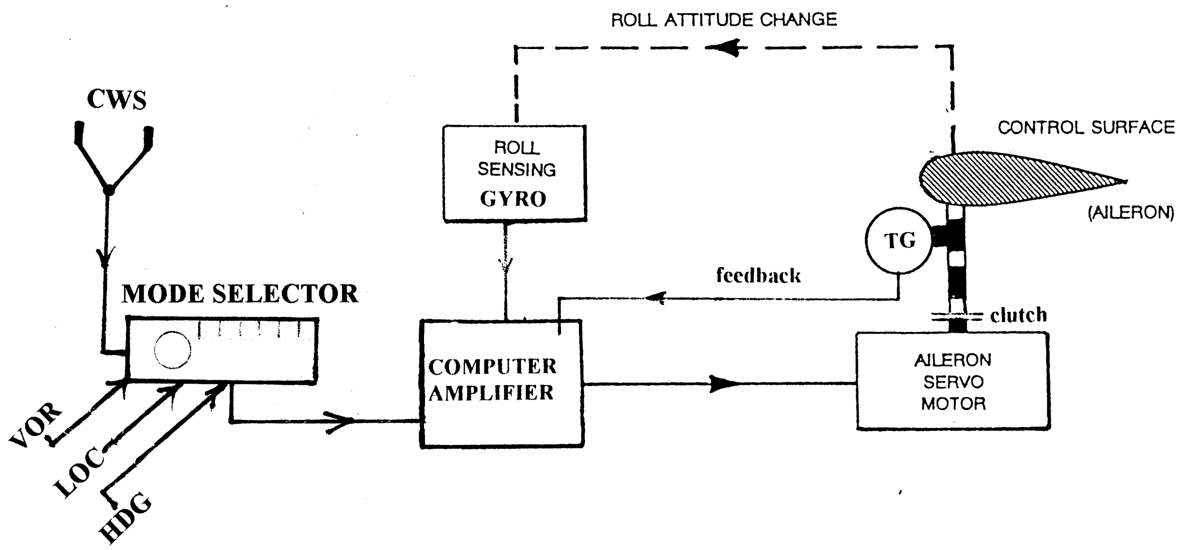
Consider a basic single channel wing leveler autopilot. Some form of gyroscopic sensing is required to sense roll movement about the longitudinal axis. Traditionally a vertical gyroscope is used as the reference. Should roll occur, an electronic error signal is generated, amplified and fed to a servo motor to position the ailerons. This is the inner or closed loop which is a basic stabilization system. As the ailerons move, the aircraft rolls back towards wings level and a feedback signal is generated to cancel the original error signal.



INNER LOOP SINGLE CHANNEL

CONTROL (the OUTER LOOP)

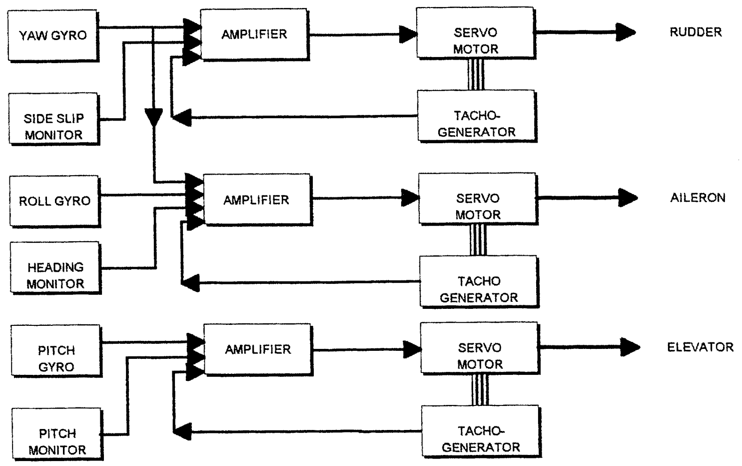
The inner loop has provided the aircraft with an automatic flight stabilization system. Should the aircraft be displaced from its gyroscopic reference, it will be returned to that reference. The outer loop now must 'interfere' with the inner loop if it is to allow appropriate control surface movements to induce required manoeuvres. If the pilot inputs to the autopilot to turn left, the autopilot produces an error signal which tells the inner loop that the aircraft is turning right. The inner loop reacts by turning the aircraft left. The outer loop has thus caused the correct response to the pilot's control input.



INNER AND OUTER LOOP SINGLE CHANNEL

Modern computers allow the error and feedback signals to be modified and cater for the appropriate level of response of soft or firm damping. This automatic action is primarily for stable flight from a gyroscopic reference. Additionally, the processor allows signals to be introduced from other equipment.

Higher quality autopilots are three channel systems which provide signals for the roll , pitch and yaw axes. The roll and yaw channels are electronically linked to coordinate rudder and aileron responses.



A THREE AXES AUTO PILOT SYSTEM

HANDOVER/TAKEOVER

All pilots are familiar with manual aircraft controls which affect the aircraft control surface by either push/pull rods or cables. When an autopilot is fitted, it must have a means of moving the control surface. Most small aircraft use electro-magnetic clutches and electric servo motors for this purpose.

During pre-flight checks, the autopilot is turned ON and tested. It is not permitted to be ENGAGED to fly the aircraft unless aviation regulations and manufacturers conditions are met. The autopilot is therefore not usually engaged below 1000 ft AGL.

Before engagement, the clutches are in their uncoupled state. While there is no signal to the servo motor at this stage, if it turned, it could not drive a cable or push rod as the clutch is uncoupled. When engaged, the clutches couple and basic flight stabilization (inner loop) is active, and the aircraft will return to straight and level, but will not maintain heading or altitude. To control heading and altitude appropriate outer loop control inputs must now be connected to the autopilot via the mode selector.

It is important to trim the aircraft before engaging the autopilot. Should the system fail or you disengage to an out of trim condition, the aircraft may make an unintended manoeuvre.

Quick Disengagement

The pilot retains responsibility for the aircraft when the autopilot is flying. The pilot must be able to overpower the autopilot manually, should immediate corrections be necessary. Additionally, the pilot can disengage at the control panel and a quick disconnect button is mounted on the control handle to allow the pilot to take over at short notice. Where an aircraft is fitted with an electric powered trim system, activation of the electric trim, disengages the autopilot.

When disengaging the autopilot, the controls should be held firmly,to avoid unintended manoeuvres.

Torque Limiting

Torque-limiting devices are fitted between servo motor and control surface to protect against excess structural loads due to rapid control movement or servo motor runaway. These devices take the form of spring-loaded couplings which slip, or disengage altogether, when pre-set torque loads are exceed.

SYSTEM COUPLING

Manoeuvre control and system coupling make available some very useful autopilot modes. After autopilot engagement, these modes are selected by push button switches.

Auto pilot modes

HDG
NAV
APPR
REV
GS
ALT
LOC

Rotary turn selectors and pitch trim selectors are usually available for manual adjustments.

Systems coupling allows the pilot to select and hold a heading. An error signal is generated at the HSI if there is any difference between the aircraft heading and the heading bug. This error signal is sent to the roll axis of the autopilot which commands the aircraft to turn until the error signal is minimised. Similarly, a selected navigation input from a VOR radial, will generate an error signal if the aircraft is not on the selected radial. When the heading (HDG) and navigation (NAV) signals conflict, the HDG is given priority until the navigation requirements can met, at which point the autopilot will intercept and turn onto the navigation selection.

The approach (APPR) button causes the autopilot to capture the localizer beam or to make the approach on other lateral navigation inputs such as VOR or RNAV. The reverse (REV) selection allows back course information to be used for an approach from the opposite direction. The glideslope (GS) button allows capture and descent profile on the glideslope beam.

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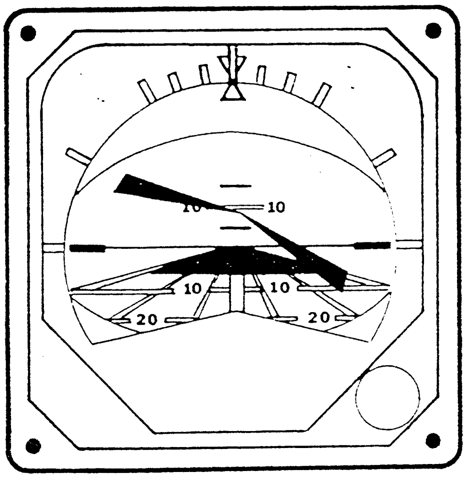
Altitude hold (ALT) consists of a sensitive altitude capsule that provides an electronic signal output. When ALT hold is not engaged, this signal is kept at a null by a chase motor system. When ALT hold is engaged, a climb or descent will now generate a corresponding error signal to the pitch channel and the elevator movement will then cause the aircraft to regain its original altitude.

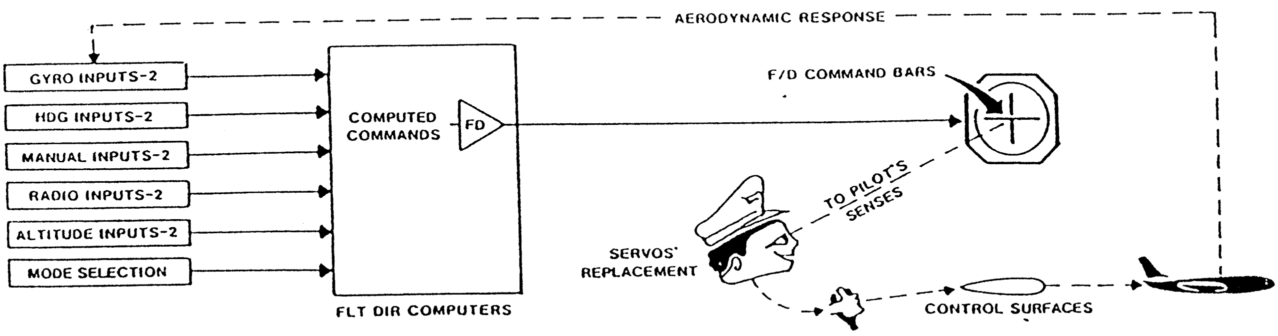
THE FLIGHT DIRECTOR

Most small aircraft do not have a flight director. When they do, it is usually a fairly simple device which allows selections similar to the autopilot modes, but transfers this information to special command bars on the attitude indicator. In this situation, the pilot must manually fly the flight director commands to achieve the result of the selected mode. For example if, on the ILS, the aircraft was slightly low and to the left, the command indication would be to fly UP and turn RIGHT.

Should the selection be available, the autopilot can be coupled to the flight director and the autopilot will fly the flight director's commands.

The flight director accepts the same flight data input as the autopilot and processes this information in the same form so that it has similar modes to the autopilot. However, the flight director cannot physically fly the aircraft but will provide its commands to either the pilot or autopilot.





FLIGHT DIRECTOR COMMAND BARS

AUTOMATIC FLIGHT IN LARGE AIRCRAFT

A small aircraft will at best have one autopilot and some may have a flight director. These devices enable very limited but very useful automatic flight functions. Autoflight in large aircraft is far more advanced and uses many inputs from other aircraft systems and sensors, and provides accurate and precise aircraft control. The autopilot and flight director systems share so much information and hardware that they are often considered one system but remain as separate functions or modes within that system. Autoflight typically incorporates the:

- Auto pilot / Flight director
- Autoland
- Autothrottle
- Pitch trim, and
- Yaw damper

To appreciate modern systems, extracts from both Boeing and Airbus systems are presented in this chapter. The operating environment and governing regulations for these aircraft manufacturers are the same, but the methods of operation and terminology used, varies.

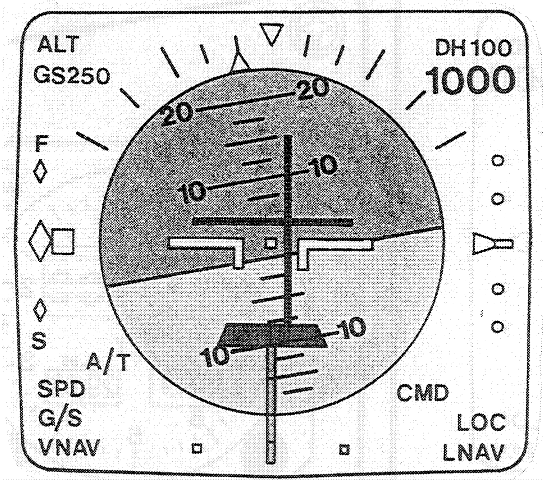
AUTOPILOT FLIGHT DIRECTOR SYSTEM

The AFDS is a triple system and in Boeing aircraft, consists of three individual Flight Control Computers and a single Mode Control Panel. The mode control panel provides coordinated control of autopilot, flight director, altitude alert and autothrottle functions.

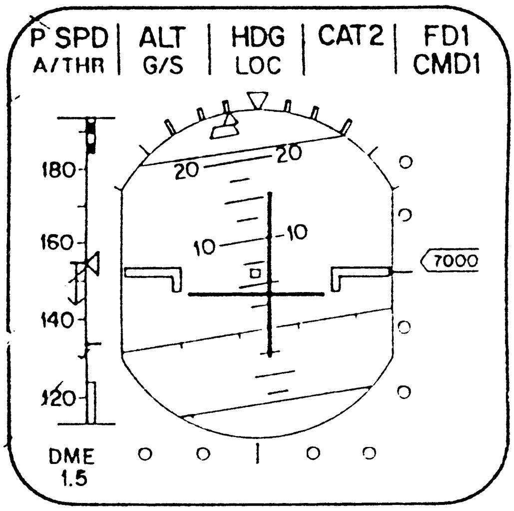
Boeing use three flight control computers, identified as left, centre and right, to send control signals to their respective autopilot control servos which operate the flight controls through the three separate hydraulic systems. These three flight control computers are powered from separate electrical sources Only one autopilot controls the ailerons and elevator during a flight with the rudder being controlled by the yaw damper. During an AUTOLAND approach, all three autopilots engage automatically and the rudder is now controlled by the autopilots. Nose wheel steering is also engaged during rollout from an automatic landing. Airbus aircraft achieve similar functions using two flight control computers.

In general, all modes can be disengaged by selecting another related mode. The exception is APP mode after LOC and GS capture. In this situation, APP mode can only be disengaged by disengaging the autopilot and turning both flight directors OFF, or engaging GA. VNAV, LNAV, LOC and APP modes, when selected, can only be deselected by pushing the mode switch a second time.

AFDS modes and failures are annunciated on the EFIS screens. It appears on the bottom of the screen if it was manufactured by the Collins Electronic Company or across the top of the screen, if made by Honeywell.



COLLINS



HONEYWELL

DATA INPUT

These outer loop data inputs, which are relevant to the aircraft's required flight profile, are "coupled" to the AFDS to achieve conditions of **hold**, **lock,** or **capture**. For example, a system maintaining automatic flight at a pre-selected altitude would be said to be operating in height-lock or altitude hold mode. "Capture" refers to the interception of radio beams from ground-located aids such as ILS or VOR. Interception of, and locking to the ILS Glideslope is known as **Glideslope Capture** and subsequently, **Glidepath Hold** in a system coupled to the ILS receiver.

Typical outer loop data inputs are as follows:

Air Data or Manometric Data: Air data inputs are required directly for the vertical navigation (VNAV) modes which apply control about the aircraft's pitch axis:

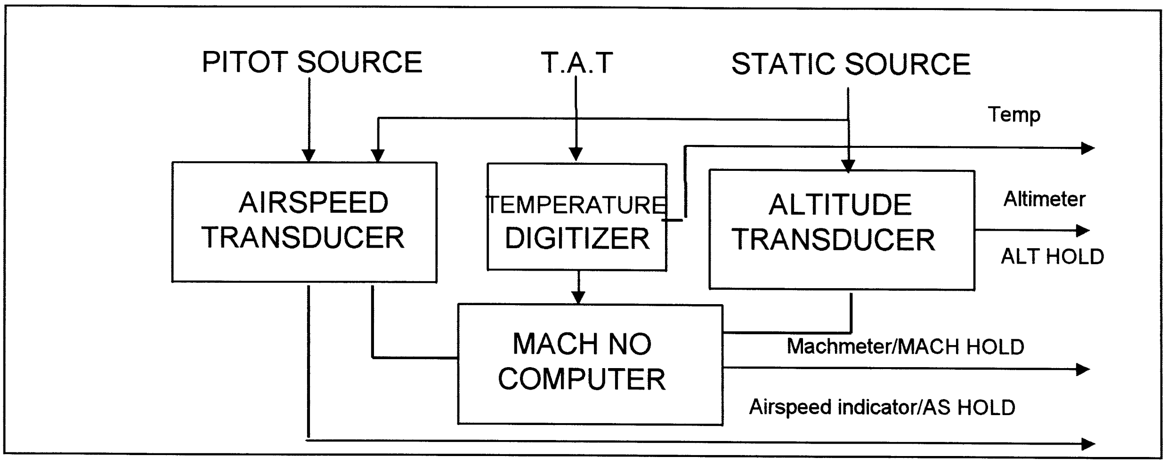
Altitude hold — A static pressure sensing unit applies a biasing signal to the pitch control inner loop to maintain a constant pressure altitude.

Airspeed hold — Dynamic pressure is sensed and a biasing signal is applied to the pitch control inner loop to maintain constant dynamic pressure (IAS).

Mach hold — At high altitude cruise, airspeed hold is usually replaced by Mach hold. By integrating the outputs of the altitude and airspeed hold, a Mach signal output can be generated, and used to bias the control loop. In present generation aircraft, the signal may also be fed to the auto throttle system. The combination of signals to produce a Mach hold output is accomplished by a central air data computer (CADC).

Vertical Speed Hold During the climb-out, a constant rate of climb is normally required, and this can be maintained automatically by the CADC. A reference vertical speed is inserted by the pilot, and the CADC compares rate of change of altitude from the static pressure sensing with the rate of change of altitude demanded by the pilot, biasing the pitch control loop as necessary, to maintain a constant rate of change.

AIR DATA COMPUTER



Vertical speed hold and altitude hold are selected from the same source. This is usually a thumb- wheel, with a centre detent **altitude hold** position, rotated down for a climb and up for a descent. The system can be further sophisticated to provide such features as pitch hold, pitch trim and vertical navigation.

Heading Hold. Heading hold implies maintenance of flight on a selected heading, which involves turning the aircraft. This is achieved through the ailerons, so heading hold relates to the roll control loop.

Instrument Landing System (ILS) The aircraft ILS receiver outputs indicator information to the ADI (PFD) for the localiser, to fly either left or right, and for the glideslope, to fly either up or down.

When the ILS receiver is coupled to the autopilot, the localiser signal is applied to the roll channel of the autopilot in conjunction with the runway magnetic heading input from heading hold. The combined effect will automatically adjust the horizontal flight path to intercept the extended centre-line. Once established on the localiser beam, the glideslope can be intercepted and captured, and the glideslope signals applied to the autopilot pitch channel to maintain the necessary pitch attitude.

VOR The VOR receiver outputs may also be coupled to the autopilot roll channel. In association with steering commands and heading data this will automatically control the flight path in relation to fixed locations on the ground. To avoid the errors which would occur within the VOR's cone of confusion, an automatic cut-off is activated on entering the cone. Whilst in the cone, the roll control channel responds only to heading input data.

INS Coupling. The INS or IRS, can be coupled to the autopilot pitch, roll and steering control channels. The autopilot will then maintain the INS computed track through sequential waypoints.

A combination of all these data inputs, will result in automatic control of the aircraft's planned flight path, in both azimuth and elevation, from take-off to touch down. Most automatic flight control systems also provide the pilot with the ability to manoeuvre the aircraft in pitch and roll, without the need to disengage the autopilot.

This may be in the form of pitch and turn controls on the automatic flight system control panel, or it may be by means of control wheel steering (CWS). In the latter system, applying normal manoeuvring forces to the control wheel, achieves the same result. Once the control wheel is released, the automatic control system holds the aircraft at the desired attitude. An alternative system, known as touch control steering (TCS), employs a thumb switch on the control yoke. When activated, the autopilot is disengaged whilst the pilot flies the aircraft to the desired attitude. Once the switch is released, the autopilot re-engages to hold the desired attitude.

Servo motors operate the primary, and in some cases the secondary flying controls, in those aircraft not fitted with hydraulic power-operated controls. When connected in series with the manual control system, they move the flying control surface without moving the pilot's controls. Parallel-connected servo motors move both the pilot's control and the control surfaces.

AUTOMATIC LANDING SYSTEM

Automatic landing (AUTOLAND) is a subsystem of the AFDS. An automatic flight control system incorporating autoland facilities must embody safety features that ensure that:

a) There is sufficiently rapid response to prevent deviation from the flight path in the event of disturbances such as windshear or turbulence, and that,

b) Control system failures must be passive and indicated. These are failures which do not cause an immediate deviation from the flight path.

Autoland is discussed in depth in **Chapter 5**.

AUTOMATIC THROTTLE SYSTEM

The autothrottle is a full time system which provides automatic thrust control from start of takeoff through the climb, cruise, descent, approach and go-around or landing.

Autothrottle operation is controlled through mode and speed selection from the AFDS mode control panel. When in vertical navigation mode, the flight management computer selects autothrottle modes and targets thrust values.

The autothrottle can be overridden manually at anytime, or disconnected by using either autothrottle disconnect switch.

Thrust Management Computer

The thrust management computer exercises primary control of the autothrottle system. It operates the autothrottle in response to manual mode requests from the pilots or to automatic mode requests from the flight management computer. Manual autothrottle mode requests are made from the mode control panel. The Thrust Mode Select Panel provides for the selection of reference thrust.

The basic thrust management computer functions are to:

1. Calculate thrust limits and thrust settings or follow the FMC thrust settings.
2. Generate fast slow indications for display on the PFD.
3. Detect and transmit autothrottle failures.
4. Adjust flight idle with engine anti-ice operation.
5. Actuate the thrust levers through the servo motor and clutches.

Auto Throttle Modes

Once armed, the autothrottle can be engaged in one of the following modes. Each ADI displays the engaged mode.

1. **EPR/N1:** autothrottle controlling to the selected EPR/N1 reference thrust.
2. **SPD:** autothrottle controlling thrust to maintain the speed selected in the Speed Window or, if VNAV mode engaged, the speed as programmed by the flight management computer.
3. **FL CH:** autothrottle controlling to a maximum of the selected mode reference thrust during climb, and to a minimum N1 during descent.
4. **GA:** autothrottle controlling to a maximum of the go-around reference thrust with adjustment, as necessary, to maintain a climb rate of 2000 fpm with GA displayed as the pitch mode. If both flight directors and the autopilot are off, the autothrottle controls to the GA reference thrust subject to flap and VMO limit speeds.
5. **IDLE:** autothrottle is reducing or has reduced thrust to flight idle. It may engage in a VNAV descent. It will engage when FLARE is engaged.
6. **THR HOLD:** The current thrust setting is maintained.

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YAW DAMPER

This system provides the following three functions:

- Dutch roll damping, which is armed for operation by the PIC prior to a flight and is therefore able to operate, as required, during the whole phase of flight. This function is activated if the IRS detects a yaw rate.
- Turn coordination is armed if no autopilot is engaged. This function is activated if a roll control wheel deflection is detected above a predetermined threshold.
- Auto pilot assistance in case of an engine failure. This function is activated if the IRS detects a lateral acceleration which is above a predetermined threshold when autopilot is engaged.

PITCH TRIM

This system provides the following three functions:

- Manual trim function, which is electrically operated by means of pitch trim control switches mounted on the control wheels. These are usually a two position rocker switches. This trim function provides pitch stabilisation about the lateral axis which, of course, eliminates the load on the control column. This function is available both on the ground and in flight when the autopilot is not in CMD.

- Autotrim function, which provides automatic pitch stabilisation about the lateral axis, thus eliminating the load on the control column. It is armed at autopilot engagement (ie, A/P in CMD mode) and operates automatically without any requirement to manually operate the rocker switches on the CWS. It also prevents the possibility of abrupt and maybe rapid pitch manoeuvres at autopilot disengagement.

- Angle of attack trim or the Alpha Trim function is to counter any nose down tendency, known as **Mach Tuck**, at high Mach numbers. It operates when the speed brakes are not extended and independantly of the autopilot (ie, it operates even when no autopilot is engaged). It also counters excessive angles of attack (ie, greater than 19°) at low speeds. The trim signals are computed from the signals supplied by angle of attack sensors.

AUTO PILOT CHANNELS AND MODES

All large aircraft autopilots use rate gyroscope inputs from the IRS as their attitude, stabilization references. Most use two channel autopilots in pitch and roll with the third channel in yaw, only activated in the final stages of autoland for decrabbing and rollout or to assist in case of an engine failure to balance the engine asymmetric effects. For most of the flight, the yaw damper system will very efficiently remove any adverse yaw tendency. Most of the autopilot modes have been described, but to note each mode against its autopilot channel makes understanding these complex systems easier.

PITCH CHANNEL	ROLL CHANNEL
Pitch Attitude Hold	Roll Attitude Hold
Turbulence	Turbulence
Vertical Speed Hold	Heading Hold
Glide Path Engaged (captured)	Heading Select
Airspeed Hold (IAS or Mach)	Turn Knob
Altitude Hold	VOR Captured + On Course
Pre-selected Altitude Captured	LOC Captured + On Course
Control Wheel Steering	INS Captured + On Course
Auto Land	L Nav
V Nav	Control Wheel Steering
Flight level change	Auto Land

Engine Indicating and Crew Alerting System (EICAS)

EICAS primarily displays engine indications and provides a centrally located crew alerting system for abnormal situations. EICAS is a Boeing designator, but Airbus use a slightly different concept with their Electronic Central Aircraft Monitoring system known as ECAM. EICAS and ECAM are not part of the FMS. These systems are discussed later in this book.

Electronic Flight Instrument Systems (EFIS)

EFIS is part of the FMS and displays information on two, approximately 5 inch square screens for each pilot. One screen corresponds to the Attitude Director Indicator (ADI), and the other to the Horizontal Situation Indicator (HSI). The computer-generated displays convey far more navigation information than is possible with the conventional electro-mechanical flight director system. EFIS is discussed also discussed later in this book.

Chapter 5

AUTOMATIC LANDING SYSTEMS

Automatic landing (AUTOLAND) is a subsystem of the Auto Pilot Flight Director System. An automatic flight control system incorporating autoland facilities must embody safety features that ensure that:

a) There is sufficiently rapid response to prevent deviation from the flight path in the event of disturbances such as windshear or turbulence, and that,

b) Control system failures must be passive, monitored and indicated. These are failures which do not cause an immediate deviation from the flight path.

Consequently, to meet the requirements of a safe approach and landing, an autoland system must:

a) not deviate from the flight path as the result of a malfunction.

b) have sufficient control authority for accurate maintenance of the flight path.

c) incorporate warning of passive failure.

d) not prevent completion of the intended manoeuvre, following a failure.

These criteria are met by the adoption of the system redundancy concept, whereby duplication or triplication of autopilot system or channels, ensures that a single failure within a system, has an insignificant effect on overall performance during an automated approach and landing.

There is a large element of risk associated with allowing an aircraft to land itself. As the preceding criteria indicate, very high quality developed systems are needed to minimize this risk. The ideal pilot skills required to land a heavy aircraft must be translated to the automatic flight control systems. The ground facilities must also be of a very high standard to qualify for autoland, allowing the aircraft to make the final approach inside very small tolerances.

Performance Requirements

The list of items needs to be addressed by any design of an autoland system. The aircraft must:-

- touch down inside the recognised touch down zone.
- reduce to threshold speed during finals.
- reduce engine power and flare, consistent with weight.
- reduce vertical speed to 2 ft per second just prior to touchdown.
- decrab prior to touch down should the approach be made in a crosswind.
- have a high tolerance to turbulence, gusts and windshear.

To develop a complete understanding of this type of system, a number of important terms must be considered. Please study the “Glossary of Terms” which form the last pages of this chapter.

AUTOPILOTS - NORMAL OPERATION

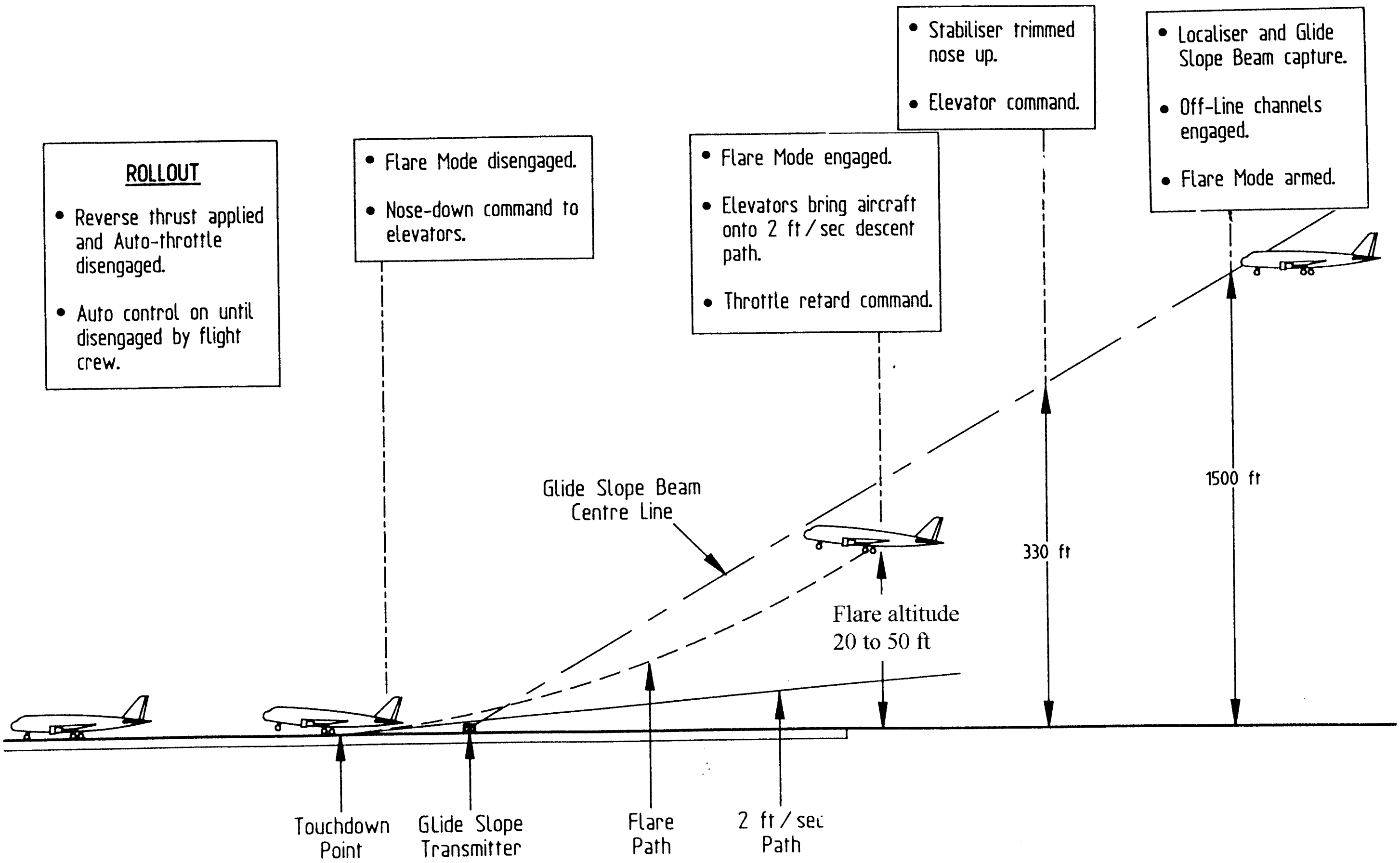
There may be two, three or four autopilots on a large aircraft. While all these systems are selected on, only one can be 'engaged' to actively fly the aircraft at any time (except during AUTOLAND). The remaining autopilots are following (synchronised) and are therefore ready should the pilot wish to change autopilots. Engaging a different autopilot, disengages the active system. The autopilot system is not available for take-off, however the flight director is. An autopilot can be engaged at fairly low level after take-off at 300 - 500 ft provided certain conditions are met.

During climb, cruise and descent the autopilot is designed to use only its pitch and roll channels. The yaw damper is normally on. During descent, selecting the approach mode (APPR) arms the Autoland and the required sub-systems.

AUTOLAND PROFILE

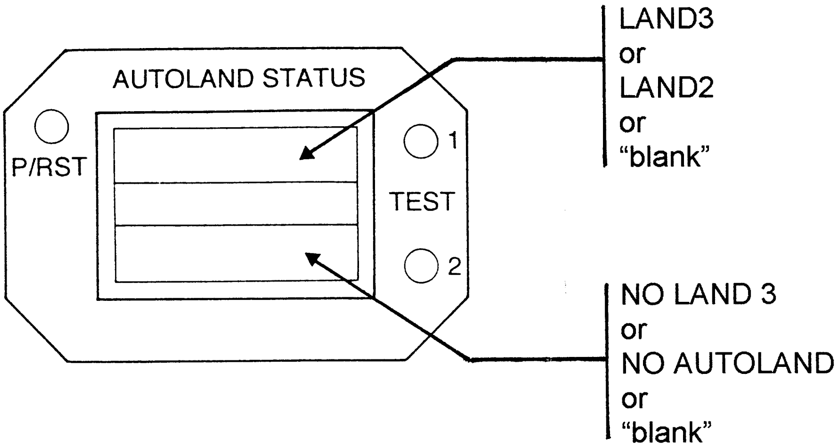
With the ILS localiser and glide slope modes armed, the radio altimeter becomes effective and inputs radio altitude from about 3000 ft.

Approaching 1500 ft RA with Localiser and Glideslope beams captured, the remaining two autopilots engage. This is the start of the AUTOLAND sequence which is further signaled as the Autoland Status Annunciator indicates LAND 3. The aircraft is now being controlled by three autopilots. As the AUTOLAND sequence begins, the Autoland 'flare' submode is armed. This next diagram provides a good general picture of an autoland. Note; Flare mode engaged for a B747 is 50 ft RA and for a B767 is 23 ft RA.



THE AUTOLAND SEQUENCE

Autoland Status



AUTOLAND ANNUCIATOR

Monitoring of the autopilot systems is indicated by the autoland status system when the electrical system is powered. A fault which limits the autopilot system is shown as NO LAND 3 or NO AUTOLND on the autoland annunciator. Should the limiting fault clear prior to the selection of APP mode, the autoland status annunciator will blank when APP mode is selected. Faults that do not require immediate crew action are annunciated after touchdown.

With a LAND 3 indication, the level of redundancy of the autopilot system is such that the occurrence of any single fault would not prevent the autopilot system from making an automatic landing. This is known as fail operational. With a LAND 2 indication, the level of redundancy is such that any single fault does not cause a significant deviation from the flight path, which would be fail passive.

Autothrottle during Autoland

The autothrottle is a full time system which provides automatic thrust control from start of takeoff through the climb, cruise, descent, approach and go-around or landing.

Autothrottle operation is controlled through mode and speed selection from the AFDS mode control panel. When in vertical navigation mode, the flight management computer selects autothrottle modes and targets thrust values.

The autothrottle can be overridden manually at anytime, or disconnected by using either autothrottle disconnect switch. That is AUTOLAND can be flown with or without autothrottle.

Flare (Submode of AUTOLAND)

The FLARE submode is a multi-autopilot mode designed as part of the AUTOLAND sequence. It is not intended for single autopilot, or flight director only operation and:

- FLARE is armed when LAND 3/LAND 2 is annunciated on the Autoland Annuciator
- FLARE engages at approximately 45 feet RA and the autopilots start the landing flare manoeuvre.
- The FLARE engaged annunciation replaces G/S captured annunciation on the PFD.

During flare manoeuvre the following also occurs:-

- Below 50 feet RA, the autothrottle starts retarding thrust to idle and the autothrottle annunciation changes from SPD to IDLE
- If yaw exists because of a crosswind, the runway align submode levels the wings when the rollout mode is engaged.
- Approaching touchdown the autopilots cause a gentle pitch down to lower the nosewheel to the runway.
- FLARE annunciation disappears at touchdown

Rollout (Submode of AUTOLAND)

ROLLOUT is a multi-autopilot approach submode and provides runway centreline rollout guidance and:

- ROLLOUT is armed when LAND 3/LAND 2 is annunciated.
- Approaching touchdown ROLLOUT engages
- ROLLOUT replaces the LOC captured annunciation
- Localiser centreline is maintained by autopilot control of rudder and nose wheel steering
- Rollout guidance continues to a full stop or until autopilots are disengaged

During rollout the following also occurs relative to the autothrottle:-

- IDLE mode remains engaged until autothrottle is disengaged
- Reversing thrust disengages autothrottle
- Activation of reverse thrust is a pilot manual control

Go-around (GA)

A fully automatic go-around is normally performed with multi-autopilot operation from autoland, but a single autopilot or a flight director only go-around can also be made. With GA mode engaged, the AFDS controls pitch and roll while the autothrottle increases and controls thrust to establish a 2000 fpm climb without exceeding the maximum GA reference thrust which is programmed into the thrust management computer (TMC).

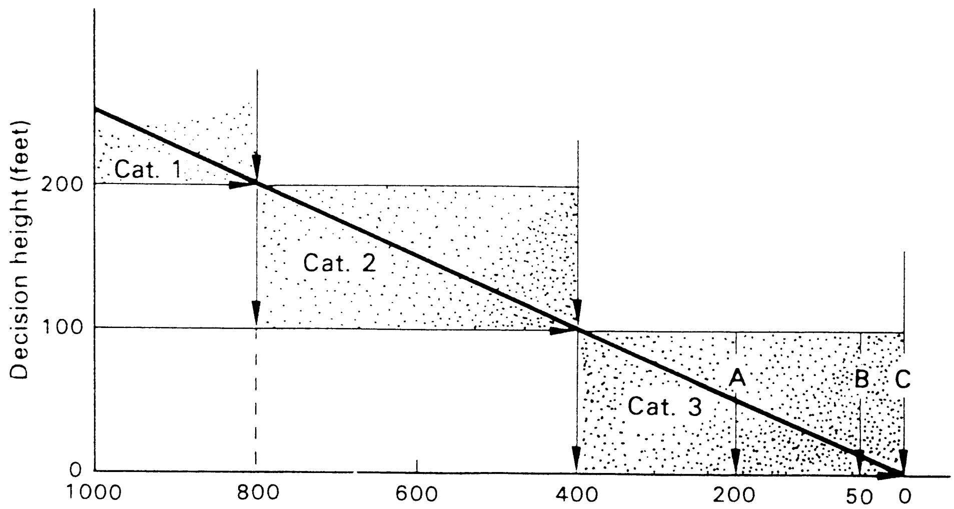
The Go-around mode is armed when the flaps are down or glide slope is captured. Arming is not annunciated. GA remains armed until 2 seconds after 5 feet RA. Pushing either GA switch on the thrust levers during this period of the approach engages the GA mode. The mode will remain engaged even though the airplane touches down in executing the go-around. The GA switches are interlocked with the thrust reversers to prevent GA mode engagement during reverse thrust operation.

During GA mode operation:

- Autothrottle increases thrust for go-around
- AFDS increases pitch to hold existing or establish selected speed, whichever is higher, as thrust increases
- When 2000 fpm climb established, autothrottle controls the thrust to maintain climb rate
- If flap setting is 20° or less, a thrust mode other than GA can be selected from the thrust management selector panel
- At selected altitude, AFDS pitch mode changes to ALT HOLD and autothrottle mode changes to SPD with thrust decreasing to maintain selected speed
- GA remains engaged in the roll mode until another roll mode is selected
- Landing gear and wing flaps must be operated manually

GLOSSARY OF TERMS - AUTOLAND

AUTOLAND CATEGORIES - ICAO



Category 1:	Operation down to minima of 200 ft decision height and runway visual range of 800 m with a high probability of approach success.
Category 2:	Operation down to minima below 200 ft decision height and runway visual range of 800 m, and to as low as 100 ft decision height and runway visual range of 400 m with a high probability of approach success.
Category 3A:	Operation down to and along the surface of the runway, with external visual reference during the final phase of the landing down to runway visual range minima of 200 m.
Category 3B:	Operation to and along the surface of the runway and taxiways with visibility sufficient only for visual taxiing comparable to runway visual range value in the order of 50 m.
Category 3C:	Operation to and along the surface of the runway and taxiways without external visual reference.

Comparison Monitored - This term is used for a system which operates on data which results from a comparison of two or more similar systems.

Decision height - This is the wheel height above the runway elevation by which a go-round must initiated by the pilot unless adequate visual reference has been established. It is also the position on the approach path where the aircraft has been visually assessed as satisfactory to safely continue the approach or landing.

Dual-dual - This term is used by some manufacturers to define a twin fail-operational system having twin passive monitoring system. It is not necessarily the same as a duplex system, because the control systems may not be active simultaneously. Should a monitor detect a failure in its associated system, the second system with its monitor automatically takes over.

Duplex System - Two complete systems or channels which are interconnected, and which together provide continuous control, forms a Duplex System. It is normally a fail-passive system. However if comparison monitoring is provided, a duplex system can provide fail-operational capability. This is not the same as duplicate-monitored or duplicate-redundancy.

Duplicate-Monitored - This term is used for a system comprising two systems in parallel and with separate power supplies. The components of both are designed to be either self-monitoring or to have their outputs checked by parallel comparator circuits. Only one system is engaged at any particular time, the other system being in a follow-up mode, and thereby serving as an active standby. In the event of a fault being shown up by the self-monitors or comparators of either of the systems, control is automatically changed over to the standby system.

Equaliser - An Equaliser is a device which adjusts the performance of the sub-systems in multiplex systems to remove differences between sub-system outputs that may arise other than as a result of fault conditions.

Fail-Operational - Fail-Operational describes a system in which one failure (sometimes more) can occur, but leaves the overall system still operating, without resulting in degradation of performance beyond the limits required for automatic landing and roll-out. This type of system can be referred to a Fail Active.

Fail-Passive - Fail Passive is a term used to describe the ability of a system to withstand a failure without endangering passenger safety, and without producing excessive deviations from the flight path. Also known as Fail Soft.

LAND 3 - This is an Autoland status condition, indicating that three autopilot systems are functioning. Three autopilots provide a 'fail operational' system, should a fault at this stage cause one system to disengage the condition will change to LAND 2. The autoland should be continued.

LAND 2 - An Autoland status condition, indicating two autopilot systems are functioning. Two autopilots provide a 'fail passive' system, but if one autopilot fails the pilot must land manually or go around.

Monitoring - Monitoring defines the process of making comparisons either between two or more control signals or between a control signal in a reference datum. The monitoring process can also act as a limiting function, it may be set up to cause a system to disconnect whenever the error signal exceeds a prescribed limit.

Multiplex - Multiplex is applied to a system comprising two or more independent simplex systems. In the event of a failure of a system, the remaining systems are capable of performing the controlling function. The number of systems involved is qualified by the terms duplex, triplex and quadruplex.

No Autoland - An Autoland status condition that is displayed if autoland has been armed but the conditions have not been met or maintained.

Runway Visual Range (RVR) - Runway Visual Range is an instrumentally derived value that represents the range at which high-intensity lights can be seen in the direction of landing along the runway. Its readings are transmitted to the air traffic controller who will inform the pilot of the current visibility conditions.

Simplex - The term 'simplex' is usually used to define a single automatic control system. Although various elements of the system may be duplicated, a single failure anywhere in the system will result in complete unserviceability of the automatic control system. This is a non redundant system.

Triplex - A Triplex system is a fail-operational system with dual redundancy. It consists of three complete systems or channels which are interconnected and which together provide continuous control. In the event of failure of one of the systems or channels, that system is automatically disengaged. Control is therefore continued in duplex as a fail passive system. In the event of a further fault in either of the two remaining systems or channels, the faulty channel will be disconnected, leaving the one remaining channel to hold the aircraft in a trimmed and safe attitude. This satisfies the safety requirement that failures must not cause any deviation from the flight path and ensures that the pilot can safely and smoothly resume control of the aircraft.

Chapter 6

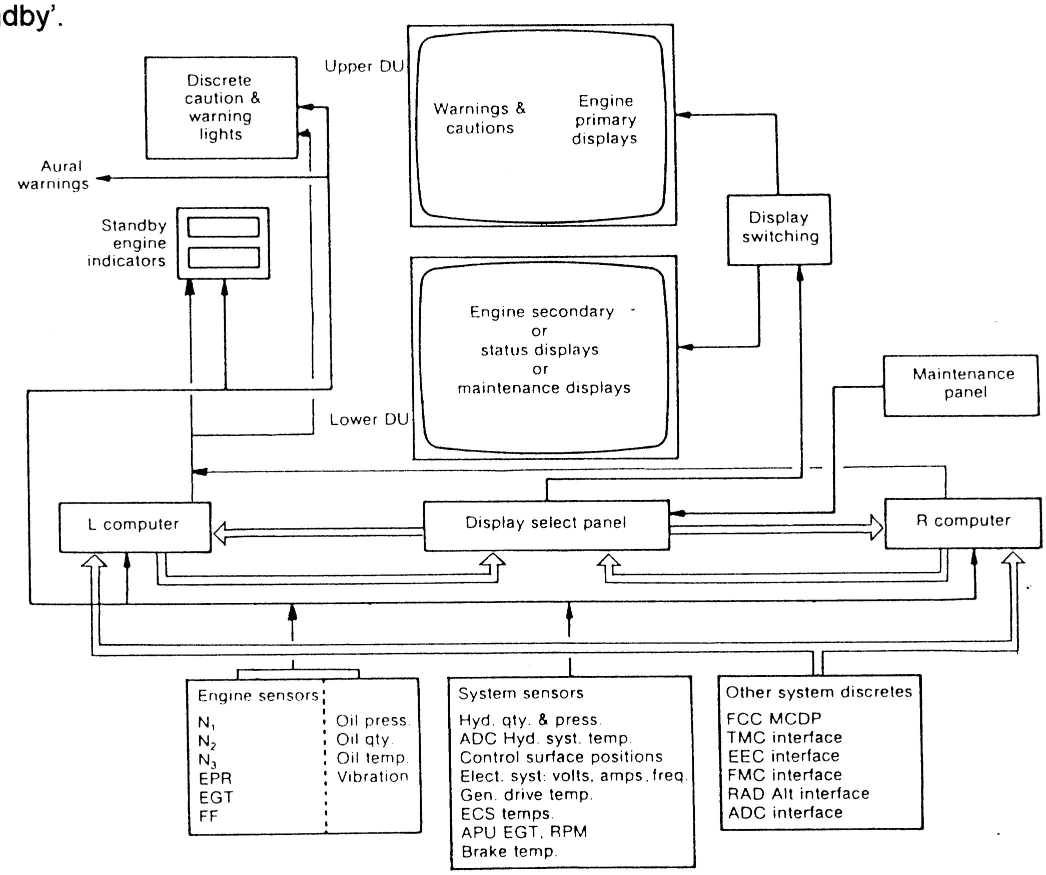
ENGINE AND AIRFRAME SYSTEMS MONITORING

On modern heavy aircraft, electronic screens display engine indications and provide a centrally located crew alerting system for abnormal situations. Typically, two computers receive inputs from engine and systems sensors and continuously monitor each other. The computers display the received information on two screens. These screens may be Cathode Ray Tubes (CRT) or Liquid Crystal Displays (LCD). In normal operation, one of the screens displays primary engine information and the other will display pictorial or secondary information such as pressures and temperatures. In the event of an abnormal situation, such as an unusual vibration amplitude, the secondary display is automatically called up and an appropriate symbol appears in a colour appropriate to the urgency of the situation. The secondary display can be alternatively used to display the status of various aircraft systems by selecting Status Display.

There are two main electronic monitoring systems in use. Boeing aircraft use the Engine Indicating and Crew Alerting System (EICAS). Airbus aircraft use Electronic Central Aircraft Monitoring (ECAM). The philosophy of operation of these systems is very different.

EICAS

This system comprises two display units, a control panel, and two computers supplied with analog and digital signals from engine and system sensors. The computers are designated 'Left' and 'Right', and only one is in control at a time; the other is on 'standby'.

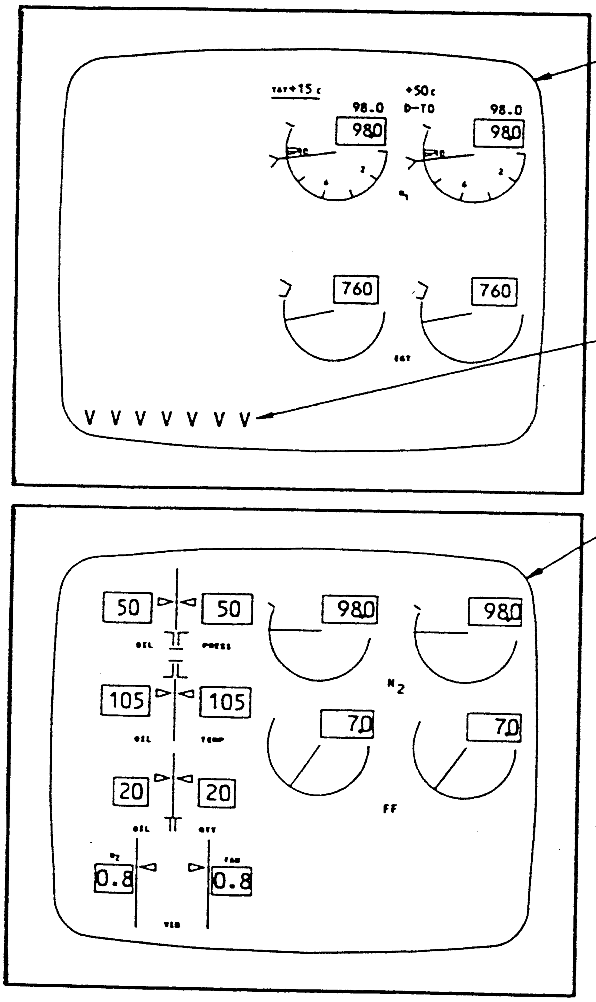


EICAS: FUNCTIONAL DIAGRAM

Operating in conjunction with the system, are discrete caution and warning lights, standby engine indicators and a remotely-located panel for selecting maintenance displays. The EICAS provides the flight crew with primary engine parameters and with secondary engine parameters and advisory, caution and warning alert messages as required.

EICAS SCREENS

The upper unit displays the primary engine parameters, N_1 speed, EGT, and warning and caution messages. This unit may also display EPR depending on the type of engines installed. The lower unit displays secondary engine parameters, N_2 speed, fuel flow, oil quantity, pressure and temperature, and engine vibration. Airframe systems such as flight control surface positions, hydraulic system, APU information, can also be displayed. A row of 'V's shown on the upper screen indicates secondary information is being displayed on the lower unit.



EICAS: ENGINE DATA DISPLAYS

Seven colours are produced by these screens and they are used as follows:

White: All scales, normal operating range of pointers, digital readouts.

Red: Warning messages, maximum operating limit marks on scales, and digital readouts.

Green: Thrust mode readout and selected EPR/N_1 speed marks or target cursors.

Blue: Testing of system only.

Yellow: Caution and advisory messages, caution limit marks on scales, digital readouts.

Magenta: During in-flight engine starting, and for cross-bleed messages.

Cyan: Names of all parameters being measured (N_1 oil pressure, TAT, etc.) and status marks or cues.

EICAS MODES

EICAS is designed to categorize displays and alerts according to function and usage, and for this purpose there are three modes of displaying information:-

(i) operational,
(ii) status, and
(iii) maintenance.

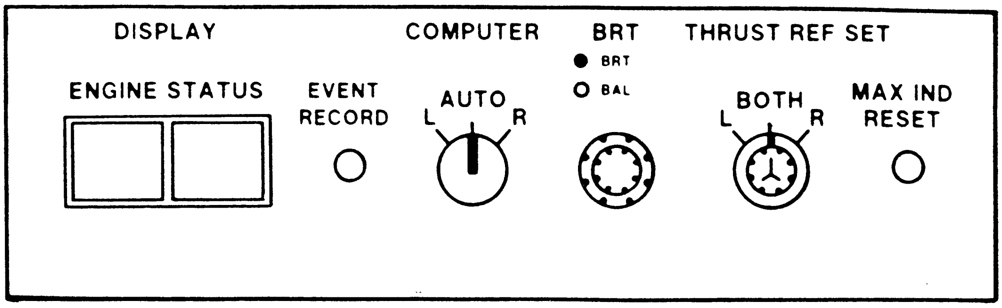
Only the operation and status modes are available to the pilot.

Operational Mode

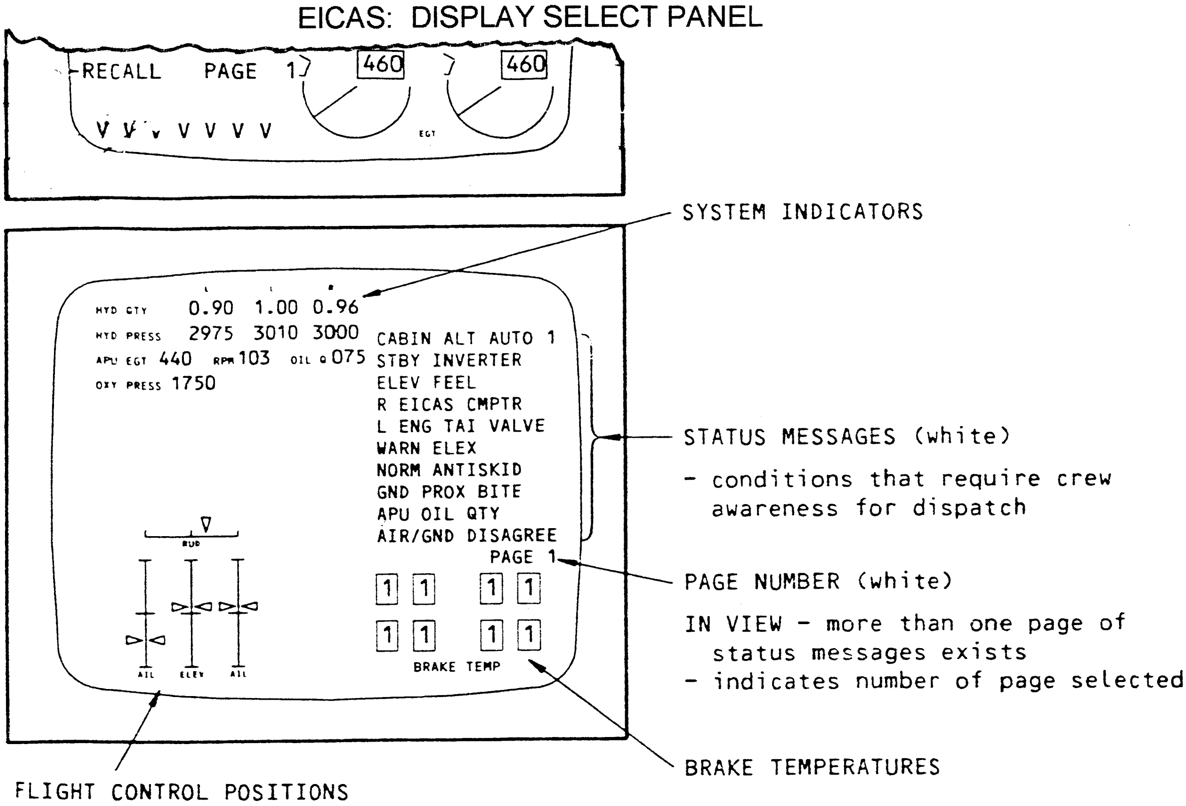
This mode displays the engine operating information and any alerts required to be actioned by the crew in flight. Normally only the upper screen presents information; the lower one remains blank until required.

Status Mode

When selected, this mode displays data to determine the dispatch readiness of an aircraft, and is closely associated with details contained in an aircraft's Minimum Equipment List. The display shows positions of the flight control surfaces in the form of pointers registered against vertical scales, selected sub-system parameters, and equipment status messages on the lower display unit. Selection is normally done on the ground either as part of pre-flight checks of dispatch items, or prior to shut-down of electrical power to aid the flight crew in making entries in the aircraft's Technical Log.



EICAS: DISPLAY SELECT PANEL



STATUS MODE DISPLAY

EICAS DISPLAY SELECT PANEL

The lower screen is controlled from the Display Select Panel. Secondary engine information can be displayed or cleared.

System Status pages can be selected and alerts that are generated above a maximum indicated, level can be reset when that parameter is back within limits. The thrust reference switch allows display selection of either N_1 or EPR for the engines.

ALERTS

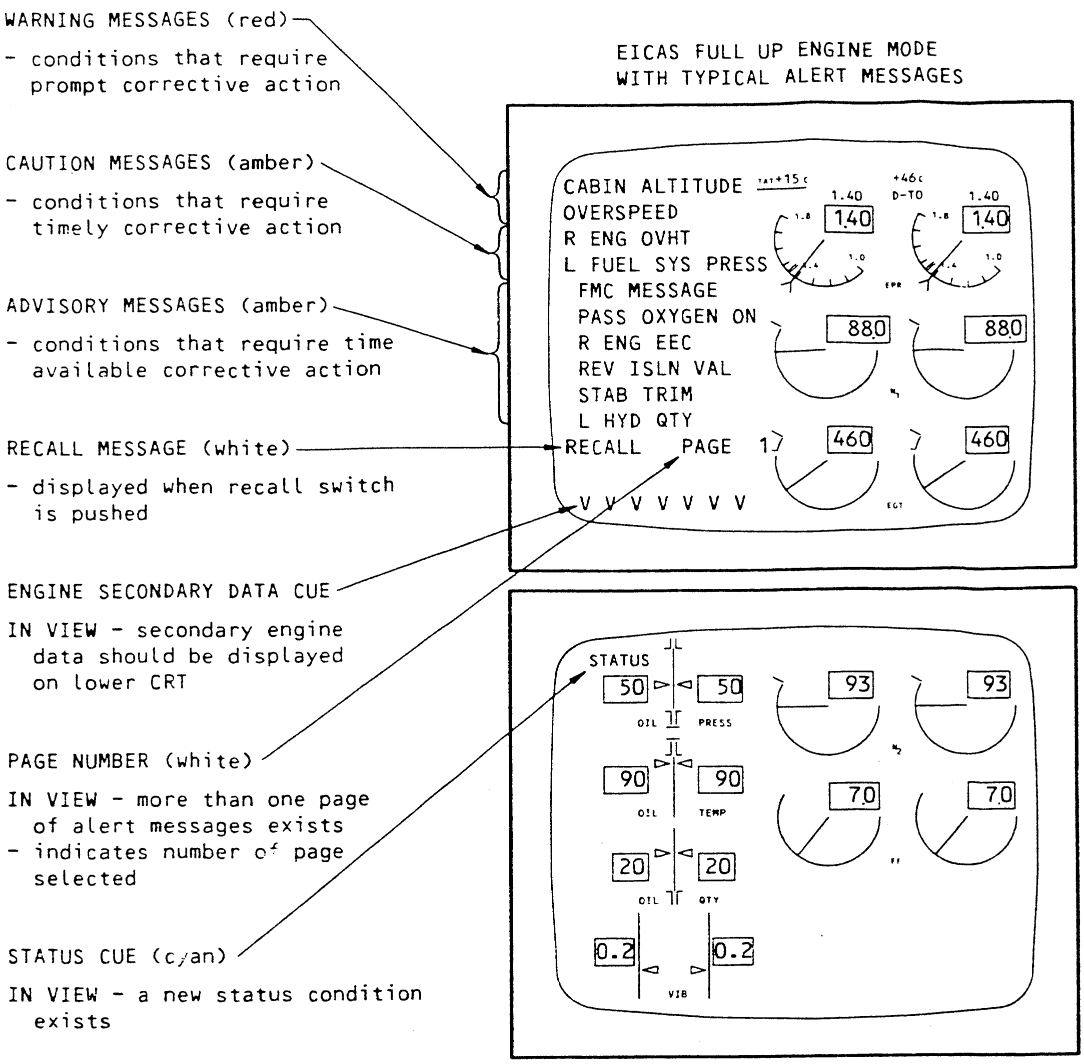
This system continuously monitors about 400 parameters from engine and airframe systems. Should a malfunction occur, alert messages are generated and displayed on the upper screen.

The alerts are displayed according to a predetermined priority system in the form of warnings, cautions and advisories. To distinguish between cautions and advisories, advisories are spaced slightly to the right.

Warning requiring immediate corrective action. They are displayed in red. Master warning lights are also illuminated and aural warnings from a central warning system are given.

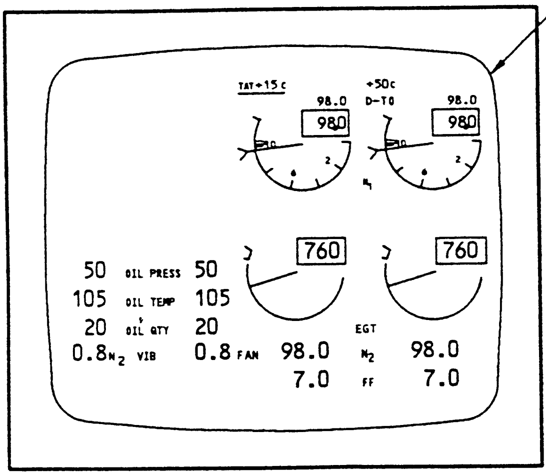
Cautions requiring immediate crew awareness and possible action. They are displayed in amber, and also by message caution lights. An aural tone is also repeated twice.

Advisories requiring crew awareness. Also displayed in amber. No caution lights or aural tones are associated with this level.



ALERT MESSAGE LEVELS

EICAS COMPACTED MODE

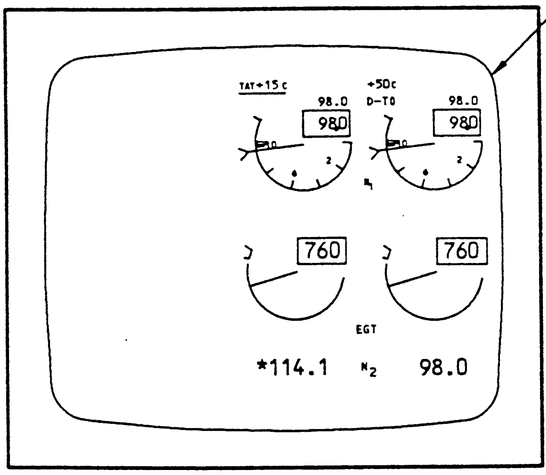


COMPACTED ENGINE INDICATIONS

N1
EGT
N2
FF
OIL PRESS
OIL TEMP
OIL QTY
VIB
- displayed when full up engine display selected when one CRT has failed
- displayed when maintenance page selected on the ground

TOP SCREEN - COMPACT MODE

EICAS PARTIAL COMPACTED MODE (TYPICAL)



PARTIAL COMPACTED ENGINE INDICATIONS

N1
EGT
- displayed continuously on the active CRT

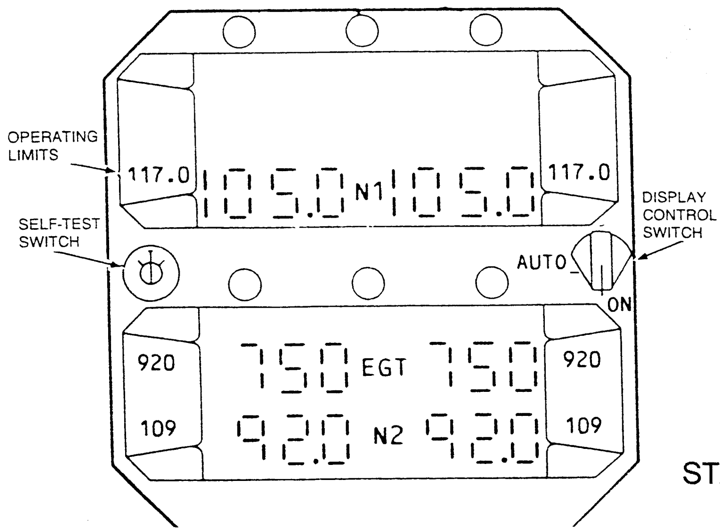
N2
OIL PRESS
OIL TEMP
OIL QTY
- displayed if Amber Band or Red Line Limit is reached or exceeded
- a secondary engine exceedance exists and then status is selected
- a secondary engine exceedance exists when one CRT has failed

*Displayed due to overspeed

TOP SCREEN - PARTICAL COMPACT MODE

STANDBY ENGINE INDICATIONS

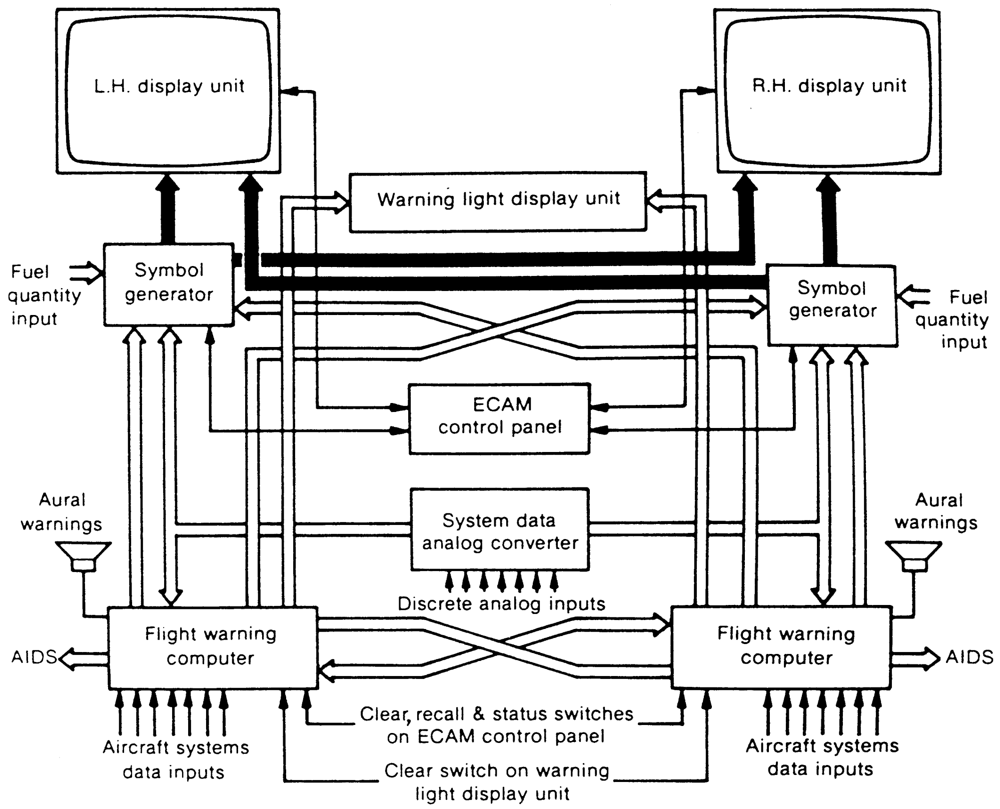
Should total loss of EICAS displays occur engine information such as N_1 and N_2 speeds and EGT; are displayed on an LCD, known as the Standby Engine Indication. Operating limit values are also displayed on this LCD.



STANDBY ENGINE INDICATOR

ECAM

Developed for AIRBUS ECAM deals with that information essential only to the primary systems of the aircraft. This information displayed in check-list and pictorial format. Engine operating parameters are displayed on conventional instruments.



ECAM SYSTEM FUNCTIONAL DIAGRAM

DISPLAY SCREENS

Two screens are mounted side-by-side; the left-hand unit is dedicated to information on the status of systems, warnings and corrective action in a sequenced check-list format, while the right-hand unit is dedicated to information in pictorial format.

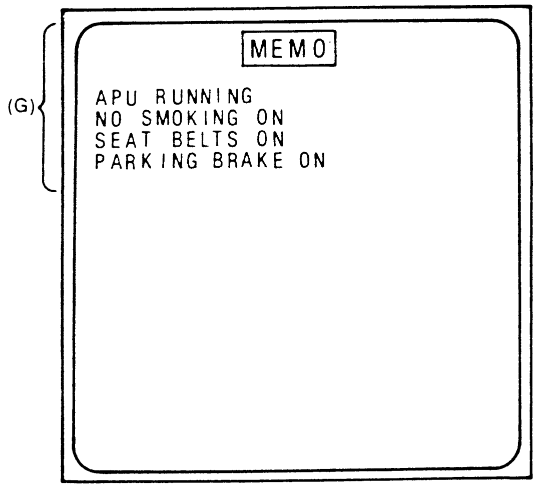
DISPLAY MODES

The ECAM uses four display modes, three of these are automatically selected, these are:-

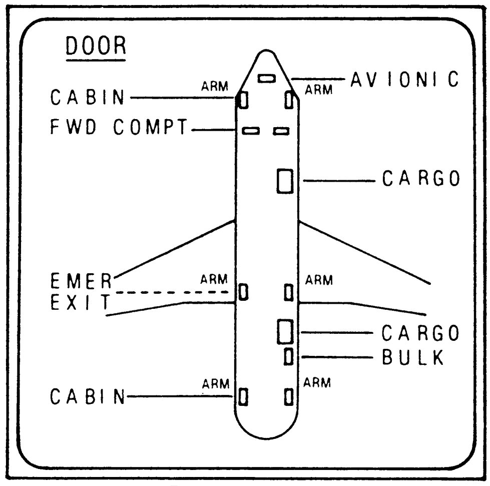
- flight phase mode,
- advisory mode, and
- failure mode.

The fourth mode is manual, which permits the selection of any of 12 of the aircraft's systems diagrams for routine checking. Manual mode also allows the selection of status messages if no warnings are displayed.

The flight phase mode is used for normal operation and displays the pre-flight, take-off, climb, cruise, descent, approach, or after landing. Sample pre-flight screens are shown below. The left screen displays an advisory memo, and the right screen displays a diagram of the aircraft's fuselage, doors, and arming of the escape slides deployment system.



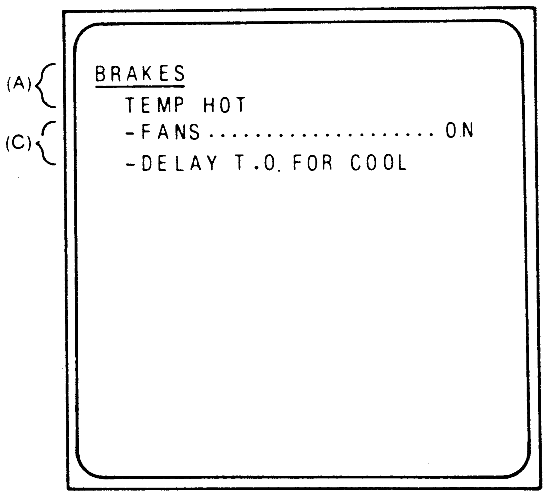
L.H. display unit



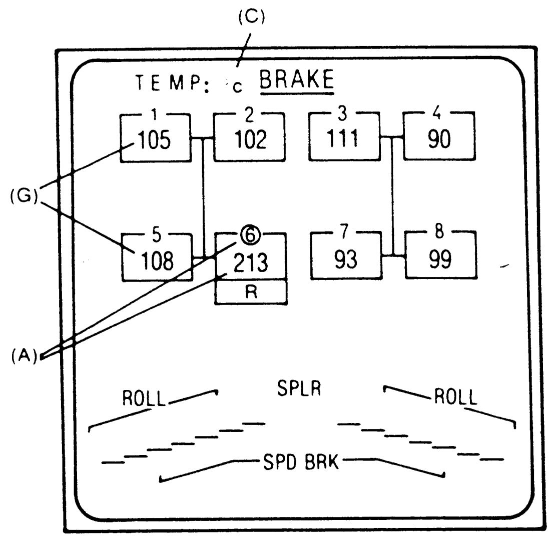
R.H. display unit

PRE-FLIGHT PHASE-RELATED MODE DISPLAY

The failure-related mode takes precedence over the other two automatic modes an the manual mode.



L.H. Display unit

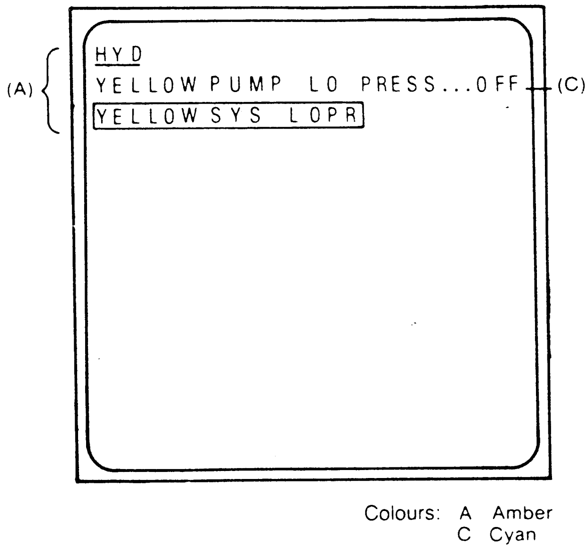


R.H. Display unit

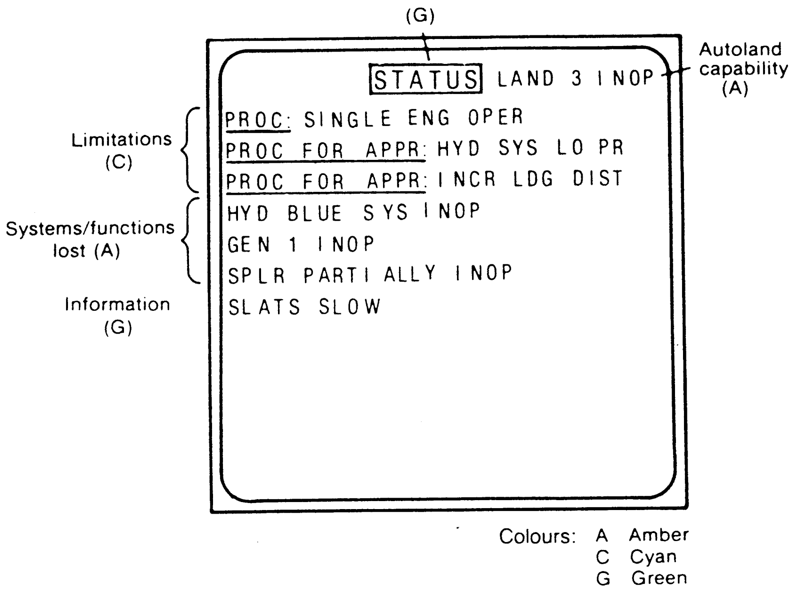
FAILURE-RELATED MODE DISPLAY

Colours: A Amber
C Cyan
G Green
Remainder of display white

Samples of some of the ECAM screens follow.



DISPLAY OF FAILURE AFFECTING A SUB-SYSTEM



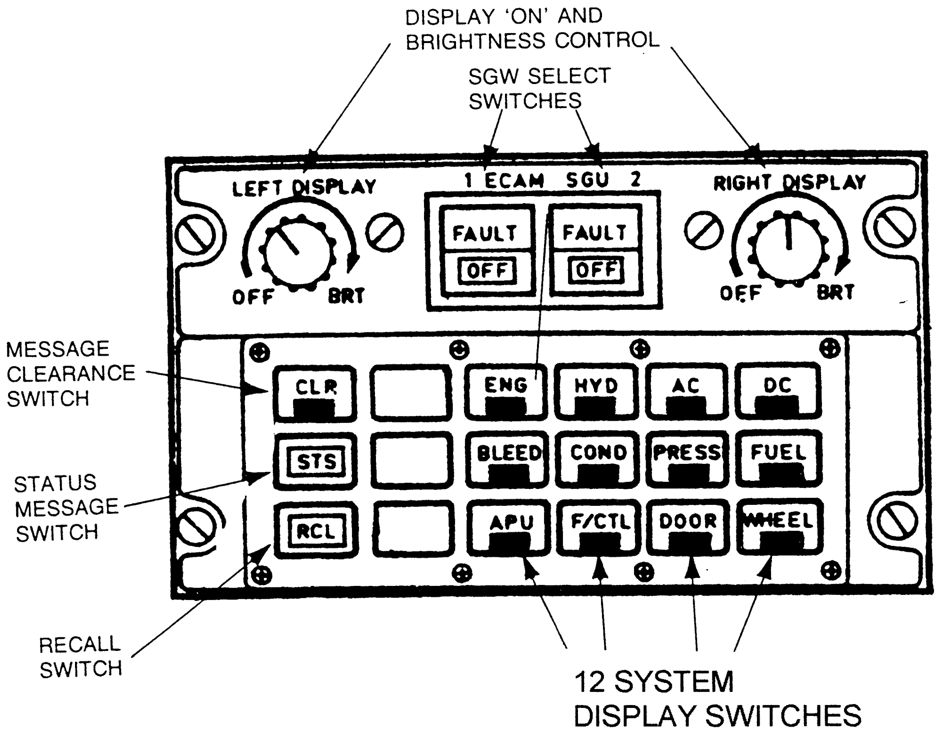
EXAMPLE OF STATUS DISPLAY

PILOTS ECAM CONTROL PANEL

The layout of this panel is shown in the following diagram; all switches, with the exception of those for display control, are of the push-button, illuminated caption type.

SGU Selector Switches - Control the symbol generator units, and the lights are off in normal operation of the system.

System Display Switches - Permit individual selection of diagrams corresponding to each of 12 systems, these illuminate white when pressed. The display is automatically cleared when a warning or advisory message occurs.



ECAM CONTROL PANEL

CLR Switch - Light illuminated white when a warning or status message is displayed on the left screen. Clears messages when pressed.

STS Switch - Allows manual selection of an aircraft status message is suppressed if a warning occurs.

RCL Switch - Enables previously cleared warning messages to be recalled provided the failure conditions still exist.

POWER ON SELF TEST

A power-on test routine is also carried out for correct operation of the symbol generator units. During this test the screens remain blank.

Chapter 7

ELECTRONIC FLIGHT INFORMATION SYSTEMS

Electronic data displays, using cathode ray tubes (CRT) or liquid crystal displays (LCD) are described as " the glass cockpit". These revolutionary forms of display are a logical step in the development of modern aircraft with their complex systems of interconnected digital computers. As aircraft systems have become more automatic and the available information more diverse, there has been an increasing need to bring together into easy-to-read displays that information which is most important to the pilot in a given phase of flight or situation.

The data displayed may concern navigation or aircraft systems. The former is displayed by the Electronic Flight Instrument System (EFIS) and the latter by the Engine Indication and Crew Alerting System (EICAS). This chapter contains information about EFIS. The major aircraft manufacturers BOEING and AIRBUS have adopted different EFIS terminology. These notes are not intended to be type-specific but for consistency a choice has been made to use primarily Boeing terminology.

Flight Management System

It is not possible to describe EFIS without describing the aircraft's FMS (Flight Management System) of which EFIS is a sub-system. FMS has been described as a "pilot-interactive navigational computing and display systems designed to assist in flying an aircraft with maximum economy and safety to a previously planned route defined both laterally and vertically".

The sub-systems that allow FMS to fulfill these functions are as follows:

1) **Inertial Reference System**
   This sub-system provides navigation, attitude and heading data.

2) **Flight Management Computer System**
   This sub-system contains the navigation and performance data bases which facilitate route selection. It includes Control Display Units and the Flight Management Computer

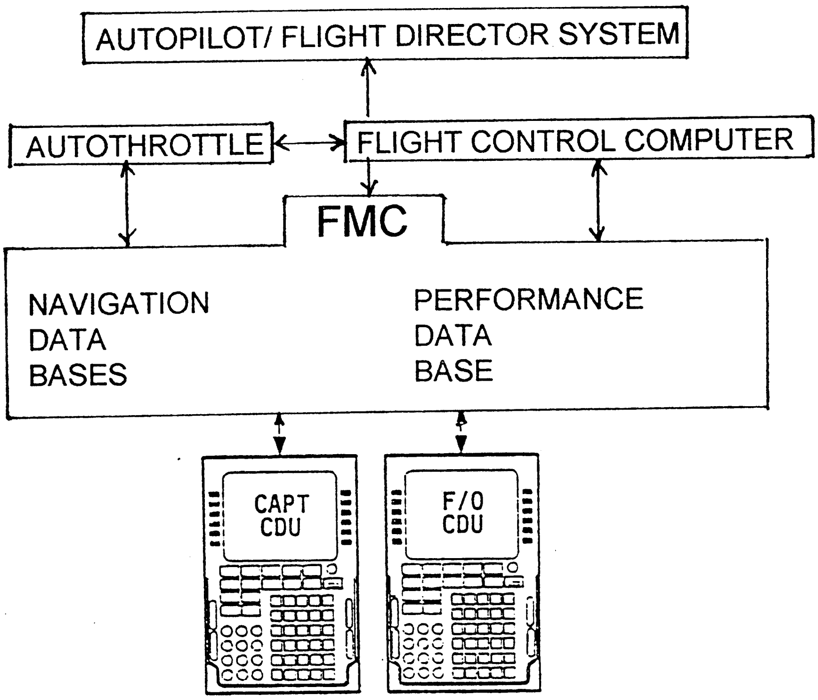
3) **Digital Flight Control System**
   This sub-system allows selection of normal flight director and autopilot modes and commands. It also translates FMC commands into control surface movements.

4) **Autothrottle**
   This sub-system allows engine thrust to adjust under control of the Flight Management Computer System or Digital Flight Control System.

5) **Electronic Flight Instrument System**
   This sub-system displays, along with normal flight parameters such as airspeed and altitude, the flight management computer system route relative to aircraft position and the Digital Flight Control System Mode annunciations. This chapter will allow study of the EFIS displays.

FMS - Data Input/Output

The term FMS implies the concept of joining independent components into one integrated system which provides continuous automatic navigation, guidance and performance management. The Flight Management Computer (FMC) is the heart of the system, performing navigational and performance computations and providing control and guidance commands. The data bank of the FMC contains navigational information, such as the position of waypoints, and performance data, such as thrust limits, as found in the performance and flight planning sections of the aircraft's flight manual. In effect, the FMC serves as an electronic flight bag. Crew communication with the FMC is achieved through the Control Display Units (CDUs). The crew can enter flight plan routes and performance parameters into the FMC via the CDUs and then monitor the computations on the CDUs.
The FMS achieves savings in both time and fuel by optimising the management of performance and navigation.

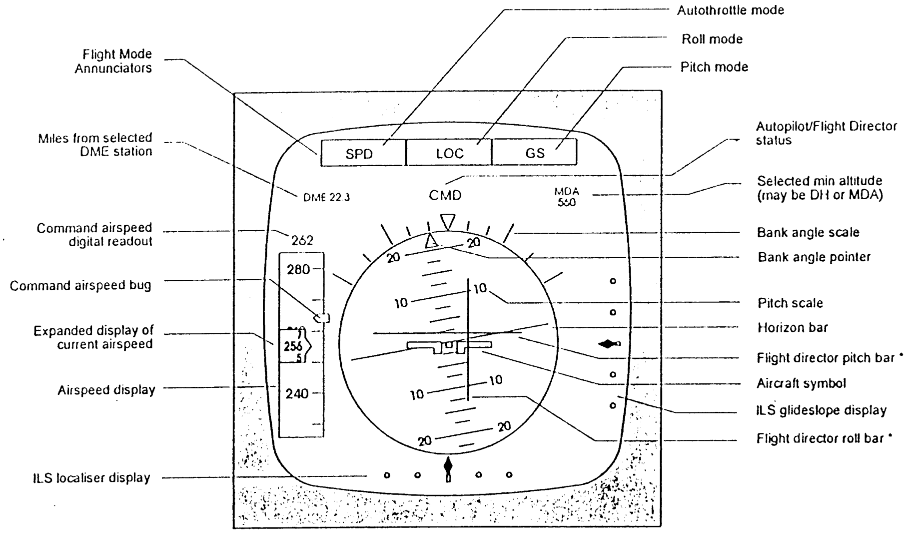


Area Navigation Systems

Area Navigation (RNAV) systems can be used in conjunction with a FMC so allowing the aircraft to be flown along routes between pre-stored waypoints. A typical system is operated with the VHF Nav Radios selected to AUTO so that the FMC automatically tunes stations having DME capability (DME or VOR/DME). The FMC has stored knowledge of the frequencies and exact location of the nav. aids and these are selected to obtain the best available signals for updating the RNAV/FMC position. With AUTO tuning, each radio is normally tuned to a separate DME but a single radio can be made to cycle between two DMEs. The lowest priority is the use of both VOR and DME from a single station. The best accuracy is achieved with AUTO DME-DME because the FMC selects stations based on best geometry. VOR is less accurate than DME and some systems do not use VOR beyond a range of 25 nm. RNAV normally provides accurate navigation data but consideration must be given to the possibility of propagation anomalies and other abnormalities which may be undetected because of AUTO tuning. RNAV is also used to update IRS positions.

Flight Directors

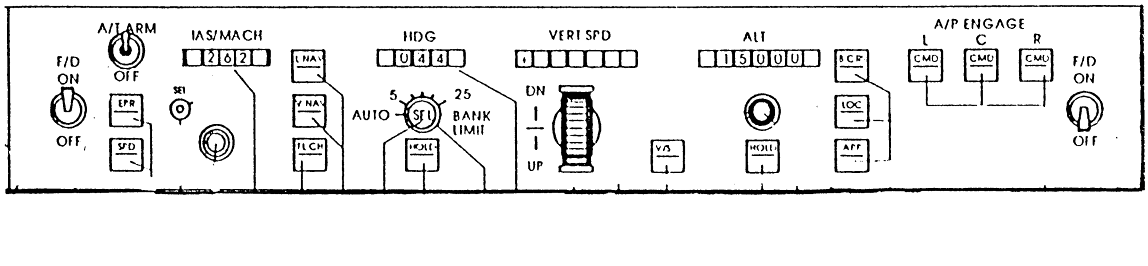
The Electronic Attitude Director Indicator, described in the following pages, is an example of the type of display associated with Flight Director systems. The display of pitch and roll attitude is integrated with radio nav. systems, such as VOR and ILS. It can also display command bars which, according to the pilot's selections on the Mode Control Panel, provide the commands required to manoeuvre the aircraft in pitch and roll. The command bars may appear as cross pointers (as in the diagram below) or as V shaped bars, towards which the aircraft is manoeuvred.



ATTITUDE DIRECTOR INDICATOR

Along the top of the display are mode annunciators showing the Mode Control Panel selected commands which may be directed to the autopilot and/or to the command bars. The Mode Control Panel, illustrated below, allows the selection of thrust, pitch and roll commands so that the aircraft will fly the required manoeuvre. Some examples of the selections are as follows:

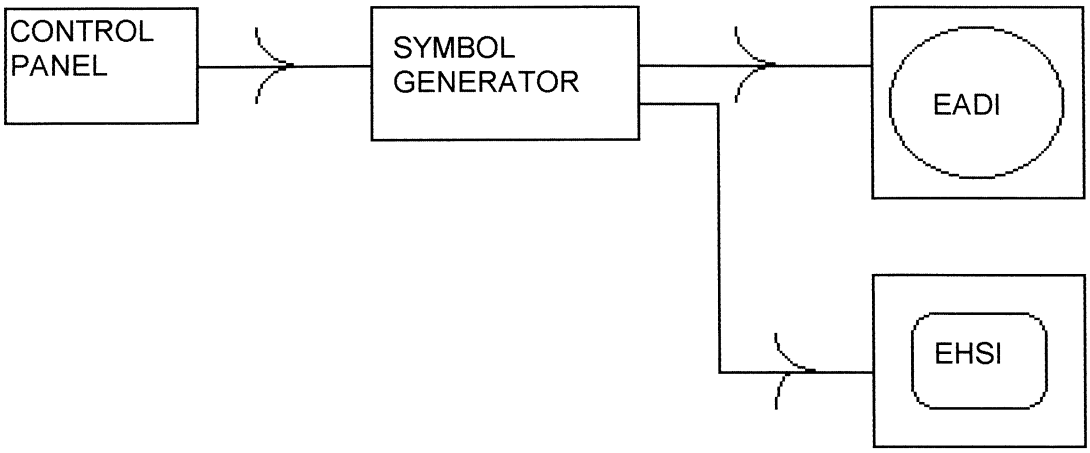
SPEED	The aircraft will capture and maintain the selected speed using auto-throttle.
LVL CHG	The aircraft will climb or descend at the selected airspeed.
V NAV	Pitch commands are controlled by the FMC.
L NAV	Roll commands are controlled by the FMC.
V/S	The aircraft will climb or descend at the selected vertical speed.
HDG SEL	Roll commands will enable the selected heading to be captured and maintained.

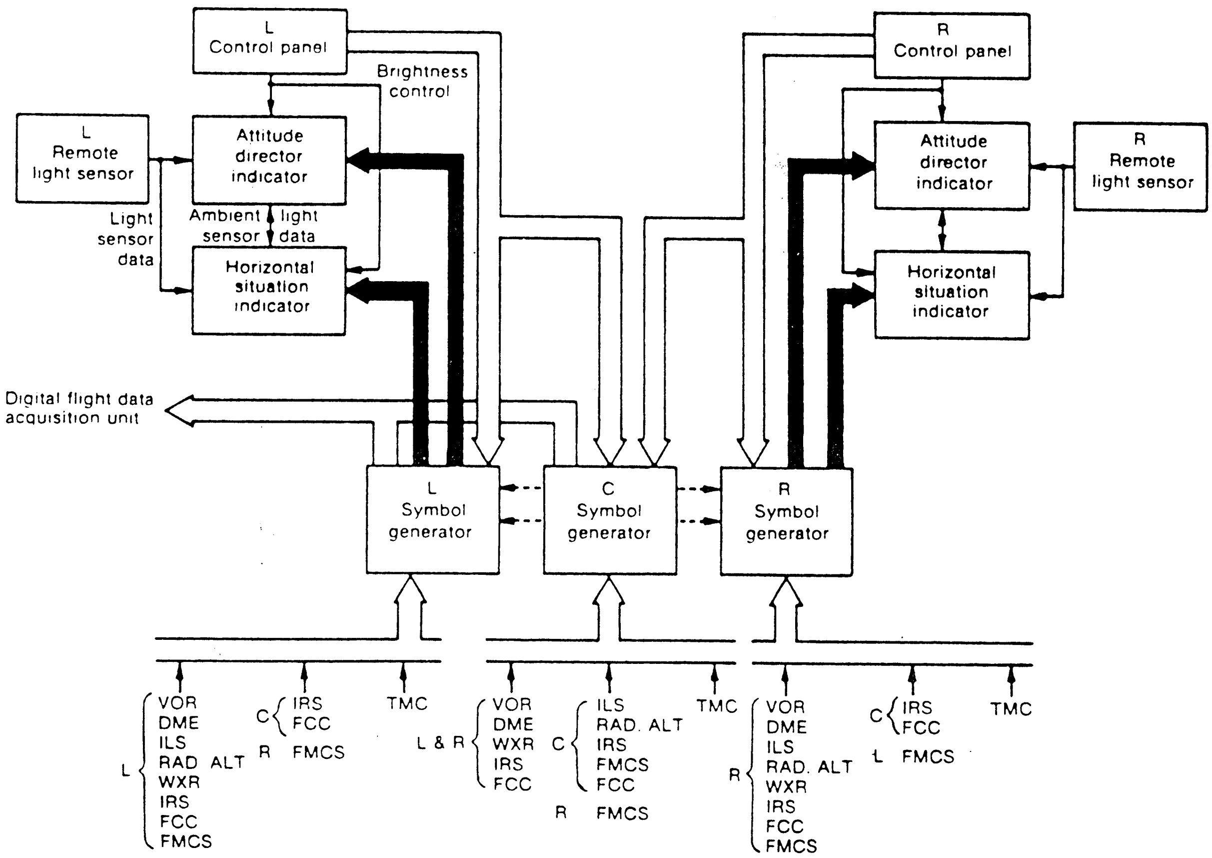


MODE CONTROL PANEL

EFIS Components

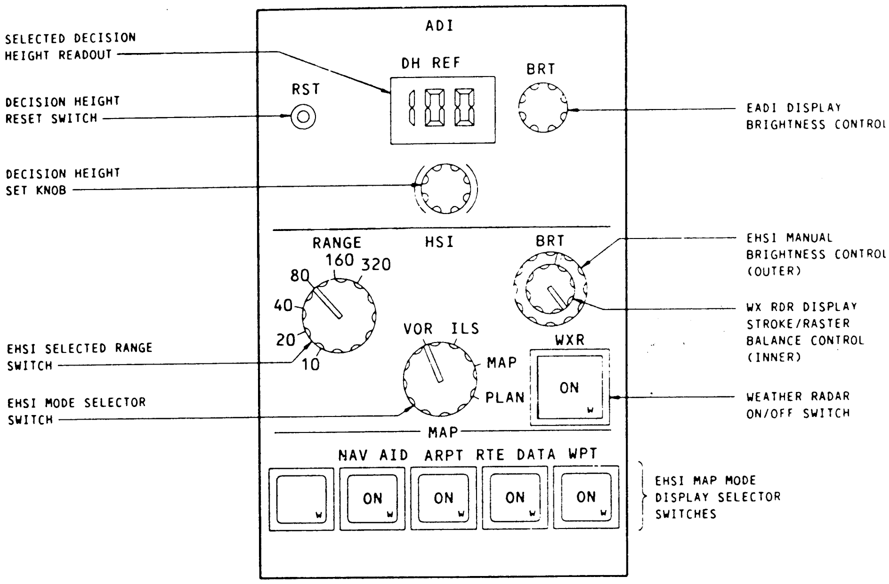
Each EFIS consists of Control Panels, Symbol Generators, Electronic Attitude Director Indicators (EADI), Electronic Horizontal Situation Indicators (EHSI) and ambient light sensing units.





EFIS SIGNAL INTERFACING

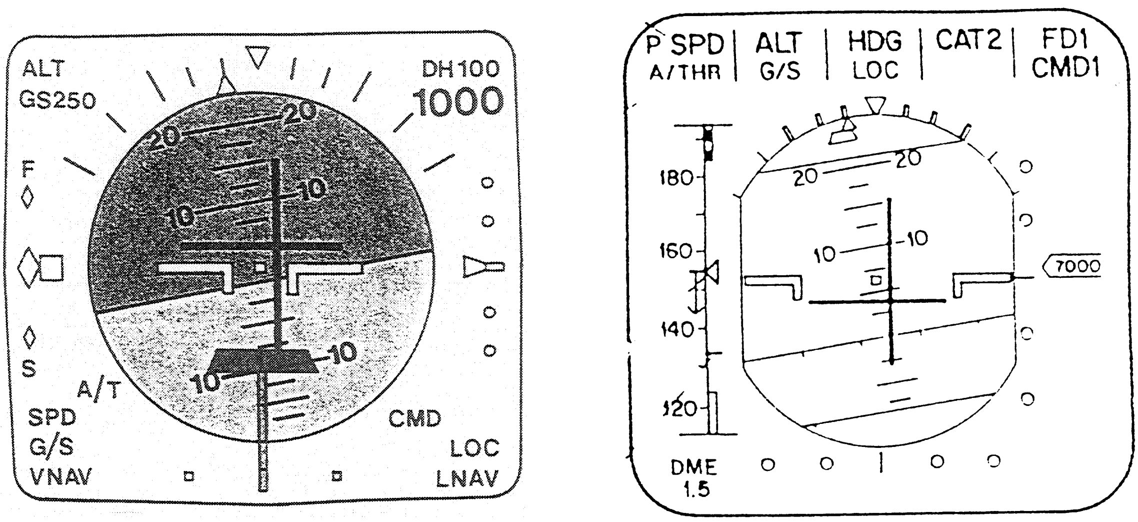
The CONTROL PANELS allow the Captain and First Officer separately to make selections affecting their own EFIS displays. These selections include EHSI display mode and range, EADI decision heights, EHSI weather radar and other EHSI options.



EFIS CONTROL PANEL

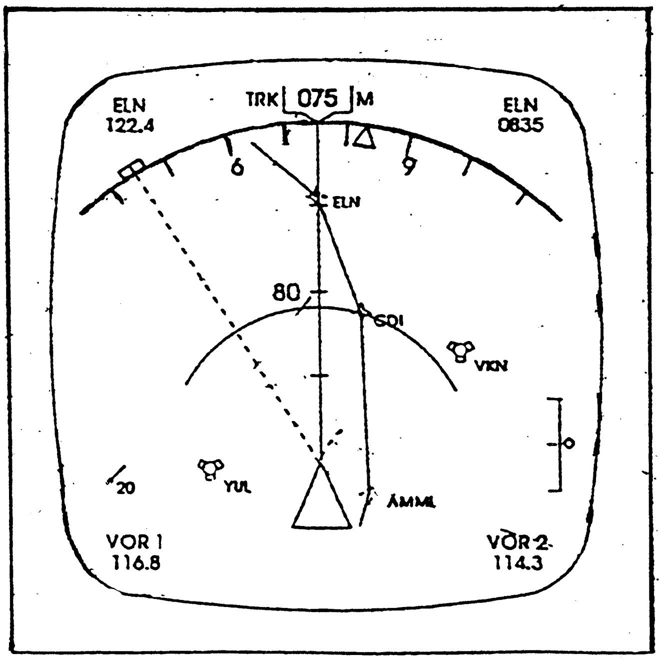
The SYMBOL GENERATORS receive inputs from various aircraft systems including VOR, DME, ILS LOC, ADF, SWC (Stall Warning Computer), ADC (Air Data Computer), RADIO ALT, ILS G/S, FCC(Flight Control Computer) and IRS. These inputs are then converted into the format required for display on the EADI and EHSI screens.

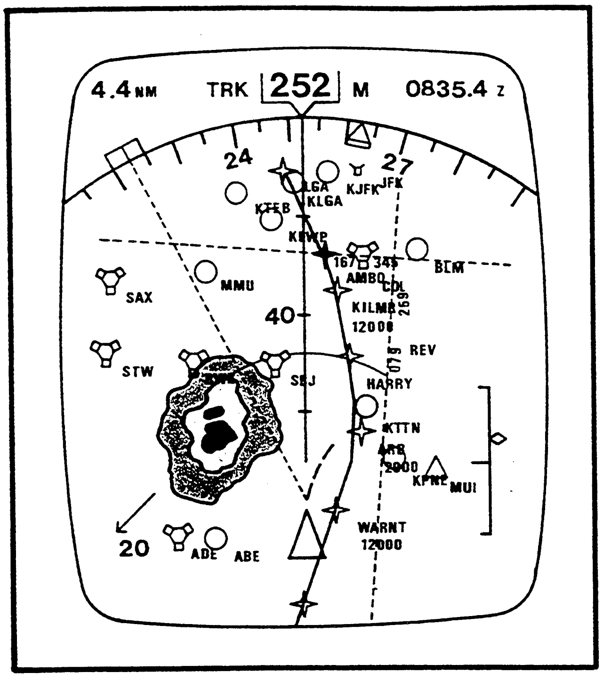
The ELECTRONIC ATTITUDE DIRECTOR INDICATOR (EADI) presents conventional displays for pitch and roll attitude, flight director commands and ILS deviations. It also displays autopilot mode annunciations, airspeeds (current CAS and minimum and maximum reference speeds), pitch limits, Mach No, ground speed, decision height and radar altitude.



EADI (PFD)

The ELECTRONIC HORIZONTAL SITUATION INDICATOR (EHSI) presents conventional HSI navigation data, which is left-right deviation from a defined lateral flight path, in VOR/ILS and NAV modes. The EHSI is also capable in the MAP modes of displaying aircraft position in relation to FMS defined tracks between waypoints. The PLAN mode allows the FMS flight plan to be reviewed on a plan view map, orientated to true north.





EHSI (ND)

The AMBIENT LIGHT SENSING UNITS **automatically** adjust display intensity to maintain a constant brightness relative to changing ambient conditions.

The Advantages of EFIS

EFIS has several advantages when compared with conventional mechanical instruments:

1) **INTEGRATION**. EFIS displays information from a variety of sources and in a format that facilitates the pilot's task of monitoring and co-ordinating the flight situation. The EADI combines attitude information, as displayed by an Artificial Horizon, with information from radio aids and other external sources. The EHSI can combine IRS/RNAV derived position with FMS route data and can also display information from various radio aids, for example VOR, ILS and DME

2) **FLEXIBILITY**. Information can be displayed on more than one CRT or transferred from one CRT to another as required. Furthermore, the information displayed can be whatever is important to the current phase of flight. By displaying only the relevant information, scanning workload is reduced.

3) **IMPROVED PRESENTATION**. The use of colour CRTs allows almost total freedom in the choice of form of presentation. Information is displayed in alphanumeric form or as symbols, which may flash or change colour if they are of special significance.

Colours used, are generally as follows:

COLOUR	TYPE OF INFORMATION
Green	Present situation information of low priority including source of data eg. VOR or ILS with frequency.
White	Present status situation and scales, for example, mode annunciators, distance to waypoint, present heading.
Magenta (dark pink)	Command information, pointers, active waypoints, selected heading bug, bearing to active waypoint.
Cyan (blue)	Non-active and background information, for example, off-route waypoints and nav-aids which are not in use.
Red	Warnings
Yellow	Cautions, alerts, faults and flags
Black	Blank areas, off condition

Note that CRTs may be replaced by full-colour LCDs (liquid crystal displays) with claimed advantages of lighter weight, fewer parts and higher resolution. Their disadvantage is that they provide a narrower field of vision.

4) **RELIABILITY.** A further advantage of EFIS compared with mechanical instruments is reliability. The CRT effectively has no moving parts.

5) **REDUNDANCY.** System failures are accommodated either by driving left and right hand displays from a common source or by bringing in an alternative source. For example, a symbol generator failure would be overcome on a B737-400 by driving both left and right CRTs from a common symbol generator whereas on a B747-400, the spare symbol generator would be brought on line.

Note that in the unlikely event of total EFIS failure, the pilots can revert to the standby instruments of airspeed indicator, altimeter and artificial horizon.

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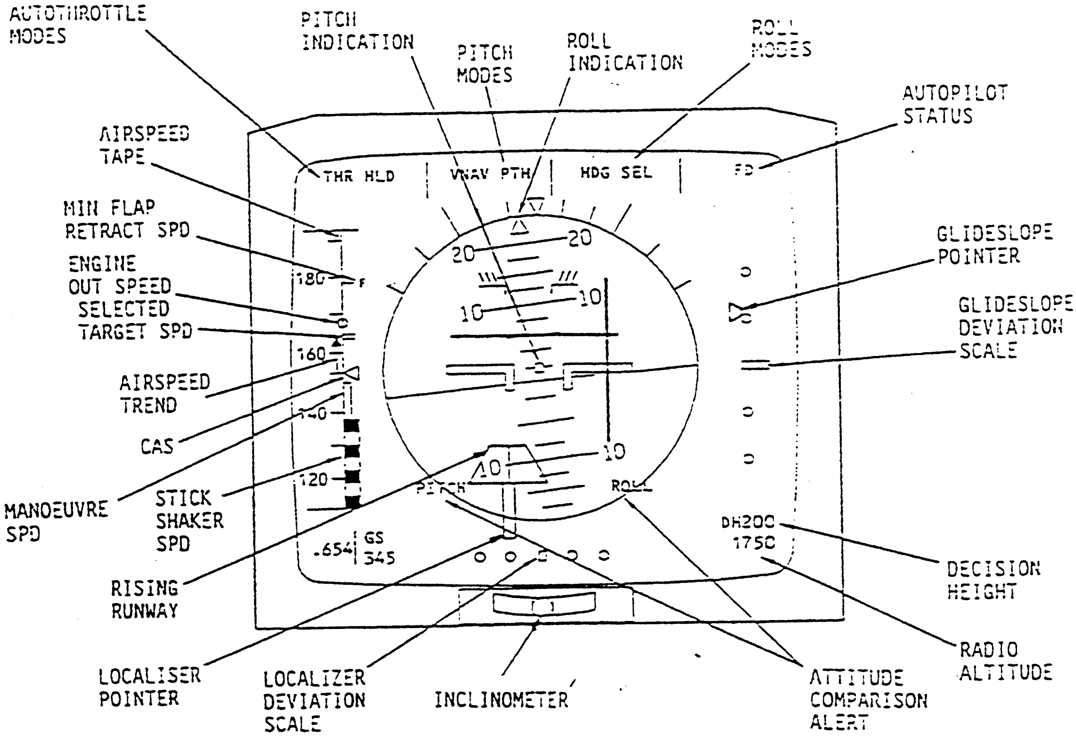
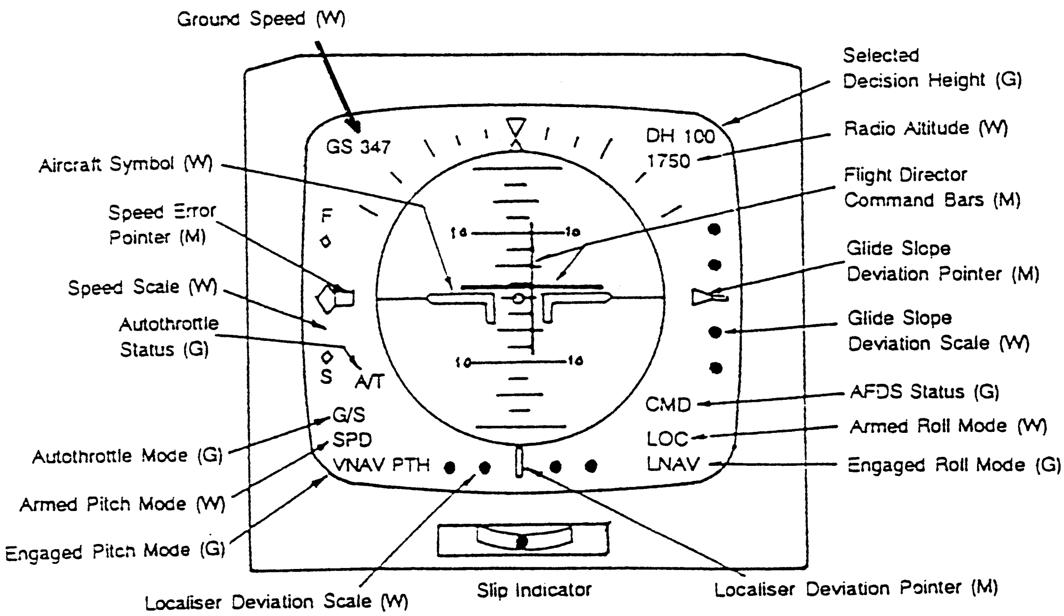
EADI Displays

The EADI may be referred to as the Primary Flight Display(PFD) as it shows basic information: airspeed, altitude, attitude and flight director commands.





The following are some of the features of the EADI:-

- ATTITUDE DISPLAY In modern airline aircraft, altitude data is provided by the Inertial Reference Systems (IRS). Pitch and roll altitude is valid through 360^{O} and is seen by viewing the aircraft symbol against a background, the upper half of which is blue and the lower half brown.

- MODE ANNUNCIATIONS. Autoflight mode annunciations for autothrottle, pitch and roll are displayed at the top or lower left and right,depending on the manufacturer.

- FLIGHT DIRECTOR COMMANDS are displayed in pitch and roll either by two pointers or by command bars which form a shallow inverted V. The command bars move up and down to command a change in pitch attitude and rotate clockwise and anti-clockwise to command a change of bank attitude. As EFIS displays are produced electronically, it is possible to readily change the form of the flight director display from separate pointers to V command bars.

- GLIDESLOPE and LOCALIZER DEVIATION DISPLAYS are shown in conventional positions with a RISING RUNWAY symbol at the top of the Localiser Deviation pointer. It displays the aircraft's close proximity to the ground as the aircraft descends through the last 200 feet of radio altitude. The glideslope deviations scale may change from white to amber (alert) if there is an excessive deviation from the glideslope.

- PITCH/ROLL COMPARATOR. If there is a difference of more than 3° between the Captain's and First Officer's pitch or roll display, the words PITCH or ROLL in amber will appear on both EADIs.

- RADIO ALTITUDE and DECISION HEIGHT. Radio altitude is displayed when height is less than 2500 feet agl. It is compared with the decision height that has been set and when this height is reached, a DH ALERT occurs.

- MACH NUMBER is obtained from the AIR DATA COMPUTER.

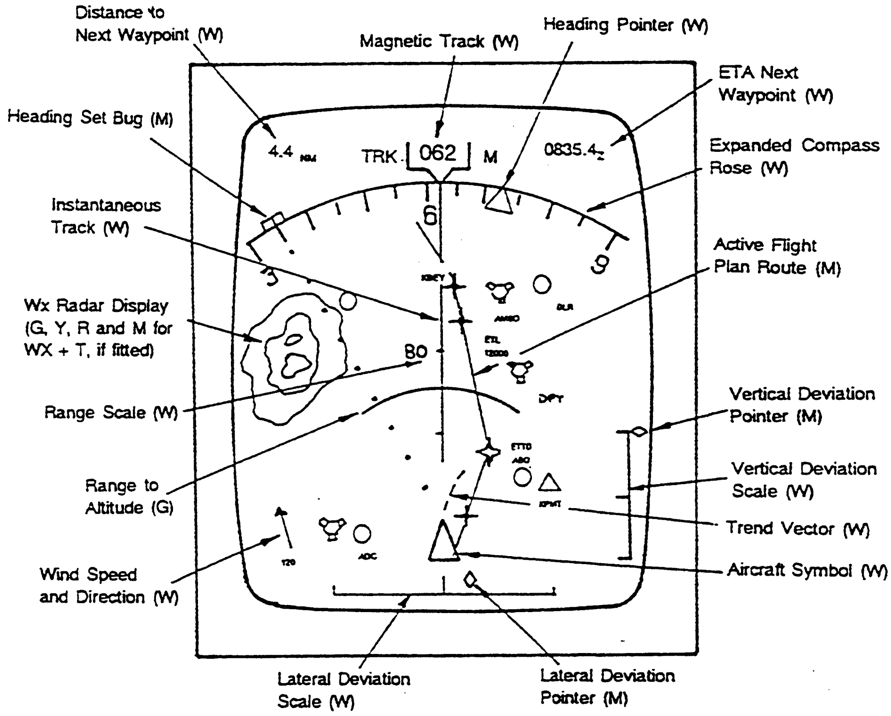
- GROUNDSPEED is obtained from the INERTIAL REFERENCE SYSTEM via the FLIGHT MANAGEMENT COMPUTER

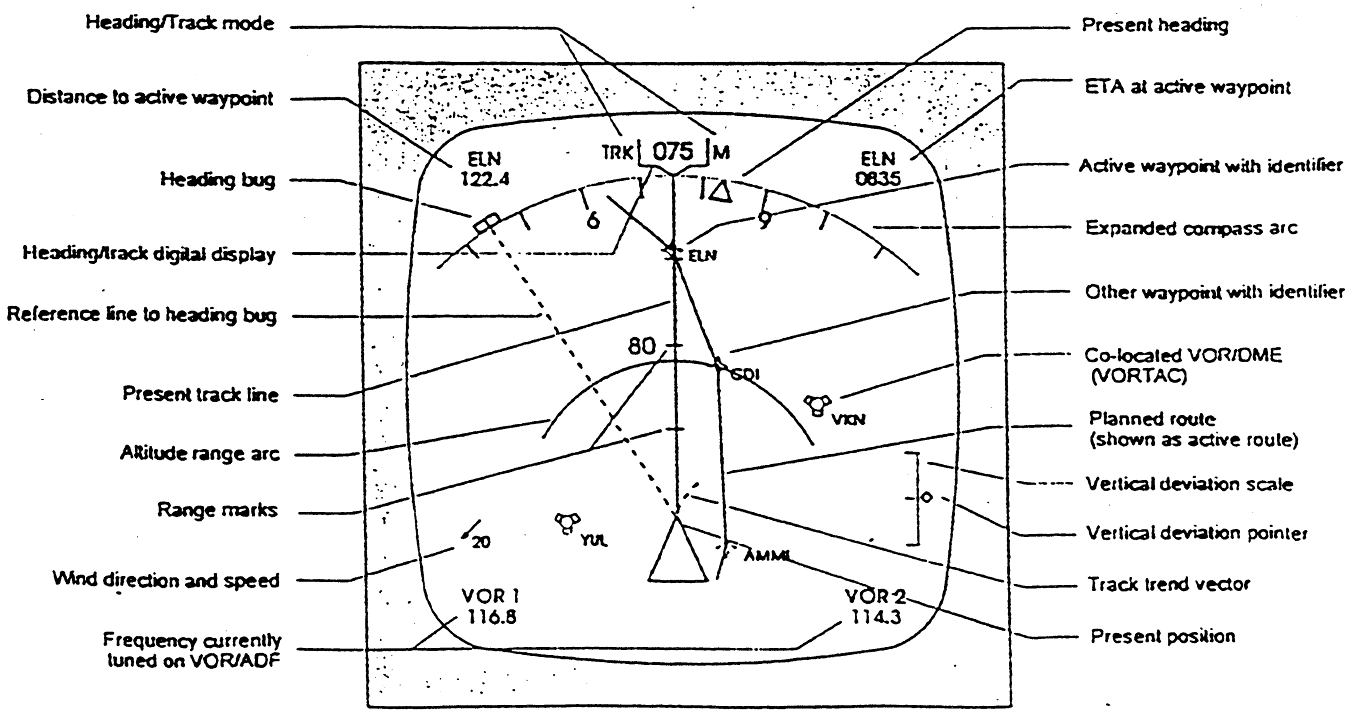
- AIRSPEED TAPE DISPLAY consists of a graduated scale which moves relative to a fixed reference pointer. Various reference speeds related to aircraft performance are displayed on the speed tape. A trend arrow points to the speed that the aircraft will achieve in the next 10 seconds.

- INCLINOMETER The state of balance of a turn is displayed by a conventional "ball-in-tube" slip indicator.

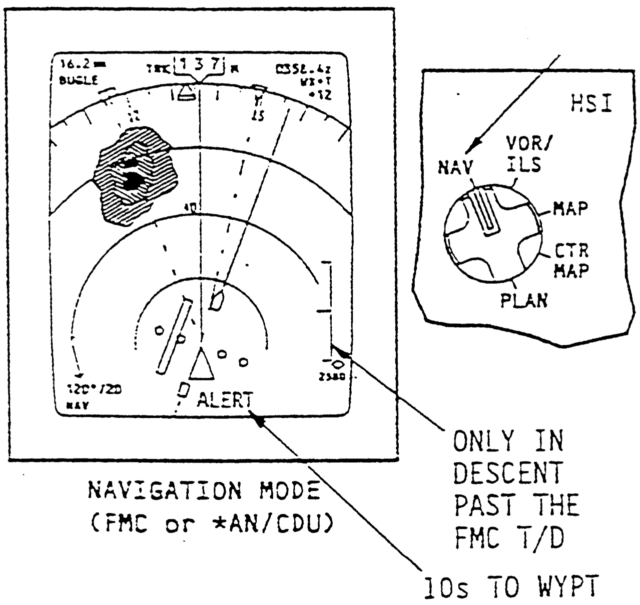
EHSI Displays

As described earlier, the EHSI uses a conventional fly left/fly right display in VOR/ ILS and NAV modes and shows aircraft position relative to planned tracks in the MAP modes. Depending on the mode, weather radar will also be displayed if selected, as well as airports and navigation aids. The following pages show the EHSI as it would appear when the various modes are selected. Note the HSI MODE SELECTOR selects the type of data and symbol displayed on the EHSI.

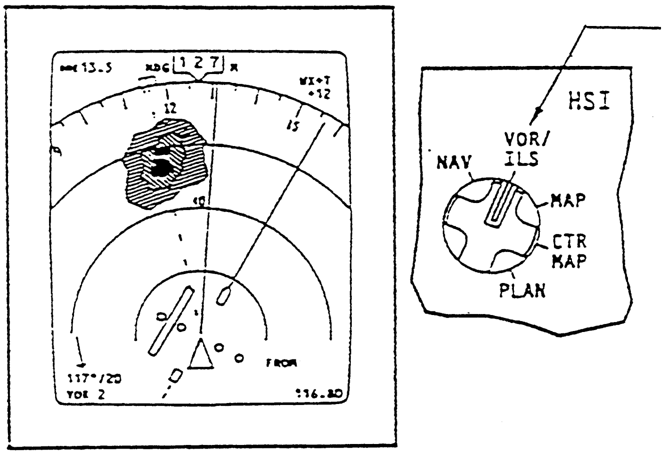




EHSI (ND)

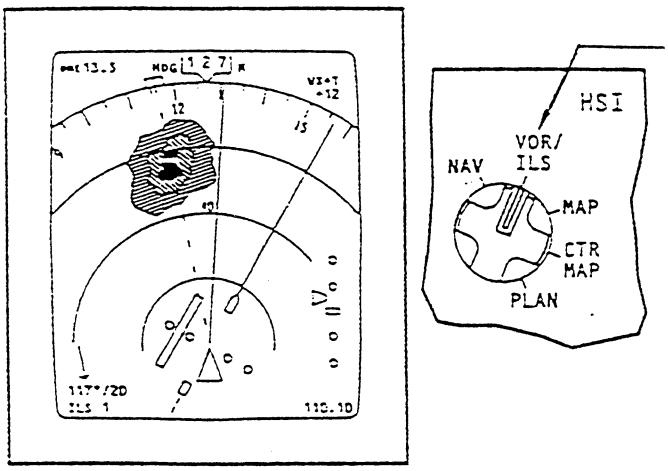


NAV- Displays lateral and vertical navigation guidance information similar to conventional HSI but oriented to airplane track. The FMC is the primary source of the guidance data.
Weather Radar returns are displayed when the WXR Switch is ON.



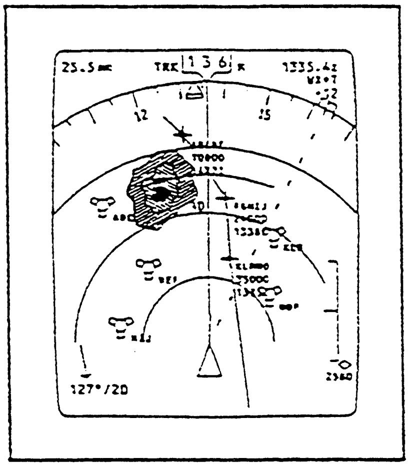
VOR MODE

VOR/ILS- With a VOR frequency selected, The EHSI displays VOR navigation data oriented to the airplane heading.
- Displays the source of navigation data as VOR 1 or VOR 2 in the lower left corner of the EHSI.
- Displays TO/FROM annunciation and the navigation source frequency in the lower right corner of the EHSI.
- Weather Radar returns are displayed when the WXR Switch is ON.

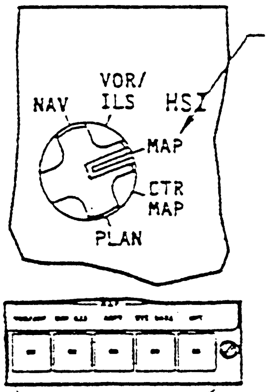


ILS MODE

VOR/ILS- With and ILS LOC frequency selected, the EHSI displays ILS navigation data oriented to the airplane heading.
- Displays the source of navigation data as ILS 1 or ILS 2 in the lower right corner of the EHSI.
- Displays the navigation source frequency in the lower right corner of the EHSI.
- Weather Radar returns are displayed when the WXR Switch is ON.



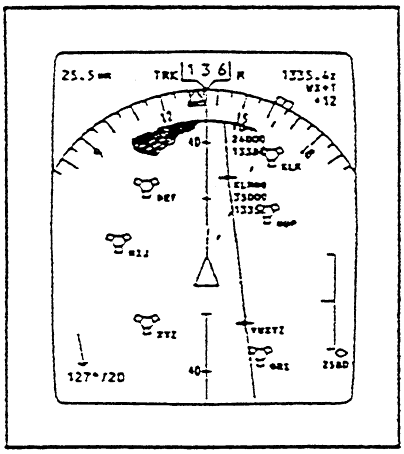
MAP MODE



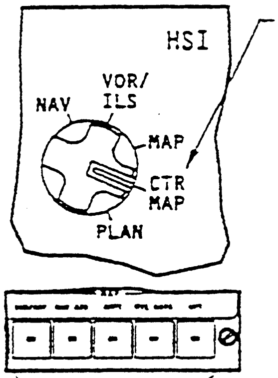
MAP background options are enabled.

MAP- Displays plan view of flight progress by means of a fixed aircraft symbol superimposed on a moving map background. The basic map background data includes origin/destination airports, flight plan route, and display of navaids in use. Optional background data includes off-route navigation aids, airports and named waypoints; tuned VOR/ADF relative bearing or radials; and flight plan route waypoint ETAs and altitude constraints.

- Weather Radar returns are displayed when the WXR Switch is ON.

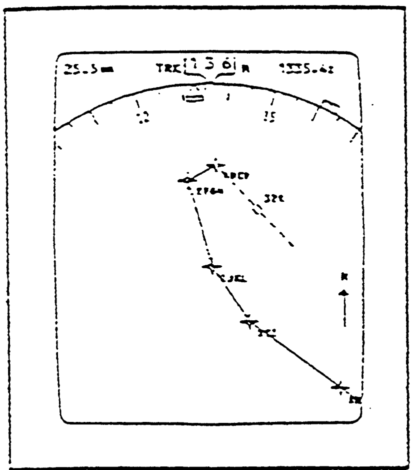


CENTER MAP MODE

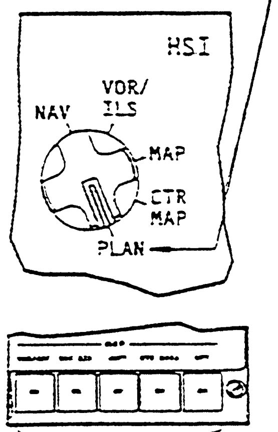


MAP background options are enabled.

CTR MAP - Displays the same data and symbols as the MAP mode, but the Airplane Symbol is placed in the centre of the map area so that MAP information behind the airplane is displayed.



PLAN MODE



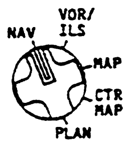
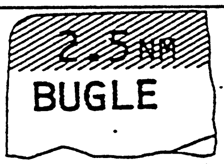
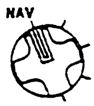
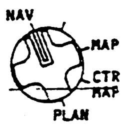
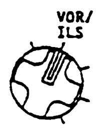
MAP background options are enabled, except VOR/ADF.

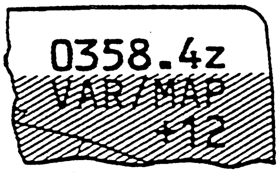
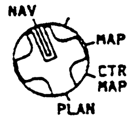
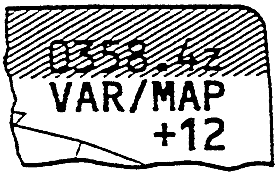
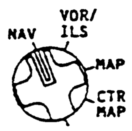
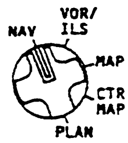
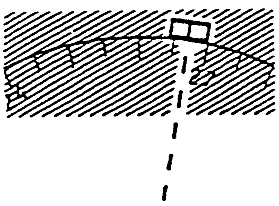
PLAN - The PLAN mode is a map display which may be used to view an FMC flight plan route, either in total for a short route, or waypoint-by-waypoint for a longer route. The display is oriented to True North.

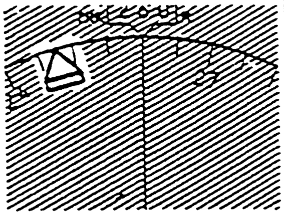
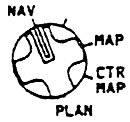
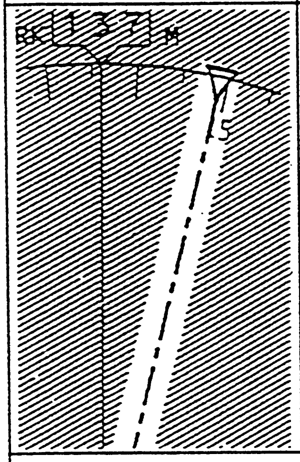
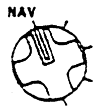
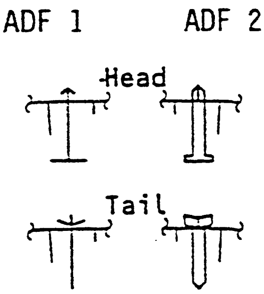
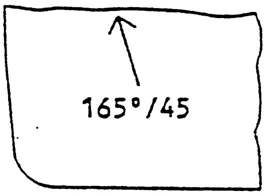
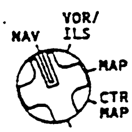
EHSI SYMBOLOGY

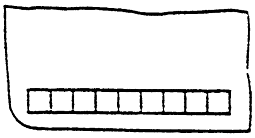
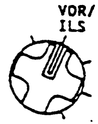
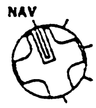
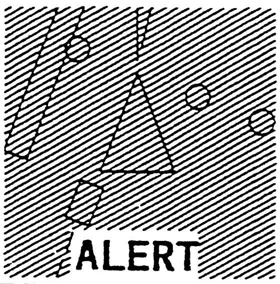
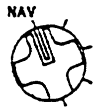
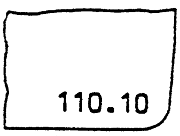
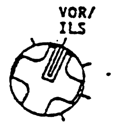
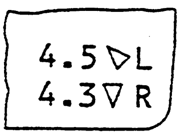
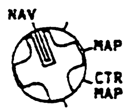
The following symbols may be displayed on each HSI depending on EFIS Control Panel selections. General colour presentation is as follows :-

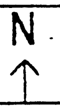
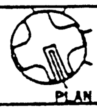
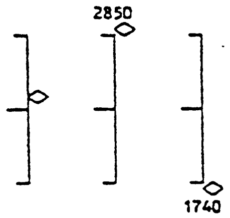
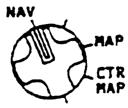
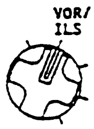
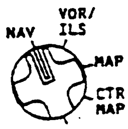
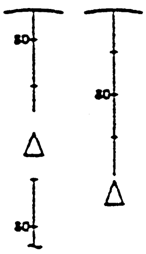
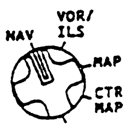
GREEN (G)	- indicates active or selected mode and/or dynamic conditions.
WHITE (W)	- indicates present status situation and scales
MAGENTA (M) (pink)	- indicates command information, pointers, symbols, and fly-to conditions, weather radar turbulence
CYAN (C) (blue)	- indicates non-active and background information
RED (R)	- indicates warning
YELLOW (Y)	- indicates cautionary information, faults, flags
BLACK (B)	- indicates blank areas, off condition

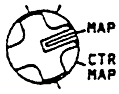
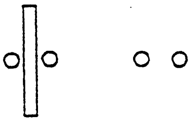
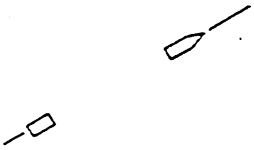
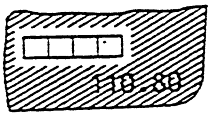
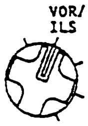
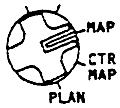
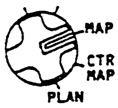
SYMBOL(S)	DATE NAME/(COLOUR)	APPLICABLE MODE(S)	REMARKS
200NM OR DME 124	DISTANCE DISPLAY (W)		Distance to next navigation waypoint (NM) or tuned navaid (DME) is displayed. (When displayed distance is less than 100 miles, tenths are displayed).
	ACTIVE WAYPOINT NAME (M)		Displays the name of the active waypoint.
TRK 062 M TRK 062 TRU	HDG (G) - Displayed data is referenced to A/P HEADING TRK (G) - Displayed data is referenced to A/P TRACK. └╯┘ (W) - TRACK/HDG index pointer. 062 (W) - Numeric value of HDG or TRK.	TRK (track-up) 	Indicates number under index pointer is the current track.
HDG 062 M HDG 062 TRU	M (G) - Indicates display is oriented to MAGNETIC North TRU (G) BOX (W) - Indicates display is oriented to TRUE North.	HDG (heading-up) 	Indicates number under index pointer is the current heading.

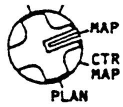
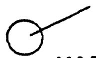
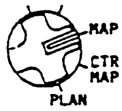
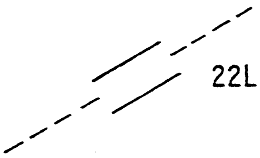
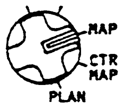
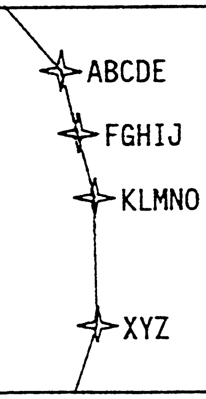
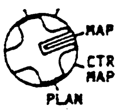
SYMBOL(S)	DATE NAME/(COLOUR)	APPLICABLE MODE(S)	REMARKS
	ETA DISPLAY (W)		Indicates FMC or AN/CDU computed ETA for the active waypoint.
	WEATHER RADAR ANNUNCIATION GAIN (G)/MODE (G) TILT (G)		GAIN - VAR indicates gain control on weather radar control panel is not in the CAL (calibrated) detent. MODES: MAP - Weather radar is operating in map mode. WX - Weather radar is operating in weather mode. WX+T- Weather radar is operating in weather mode with turbulence detection enabled. TEST- Weather radar is in test mode and test pattern is displayed. TILT- Indicates antenna tilt.
	Expanded Compass Arc (W)		The heading/track compass arc can rotate through a full 360°. In the NAV, VOR/ILS, MAP, and PLAN modes, an arc of approximately 70° is displayed An arc of approximately 120° is displayed when the CTR MAP mode is selected.
	Selected Heading Bug (M) and Reference Line (M)		Indicates the heading selected on the MCP. A dashed line extends from the marker line to the airplane symbol (except for Plan mode) for ease in tracking the marker when it is out of view.

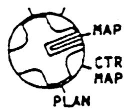
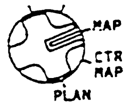
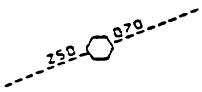
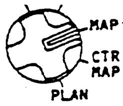
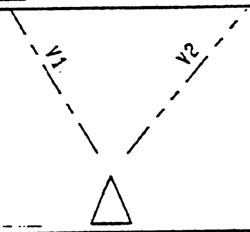
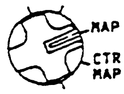
SYMBOL(S)	DATE NAME/(COLOUR)	APPLICABLE MODE(S)	REMARKS
	Heading Pointer (W)		Indicates airplane heading when selected mode has track-up orientation. Drift angle can be determined by observing the difference between current heading and current track.
	WAYPOINT BEARING POINTER (M)		Displays relative bearing to active waypoint.
	ADF BEARING POINTERS (G)		Indicates relative bearing to tuned ADF station as received from the respective ADF radio.
	DIRECTION ARROW (W) WIND DIRECTION/SPEED (W)		Indicates wind direction and wind speed in knots with respect to the map display orientation (TRK or HDG) and compass reference (MAG or TRU). Direction arrow rotates through 360°. Displayed if wind magnitude is greater than 6 knots and blanked if wind magnitude becomes less than 4 knots.

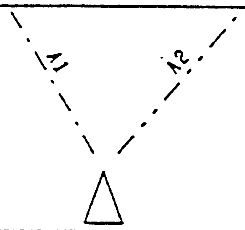
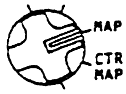
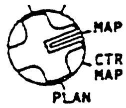
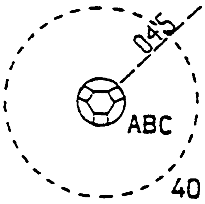
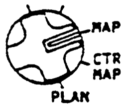
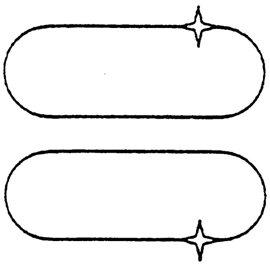
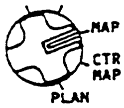
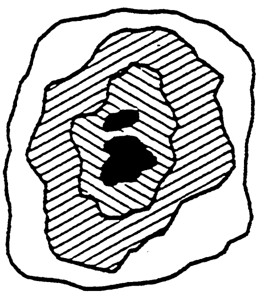
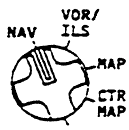
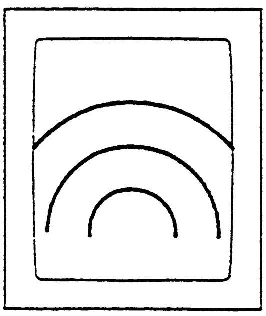
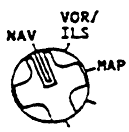
SYMBOL(S)	DATE NAME/(COLOUR)	APPLICABLE MODE(S)	REMARKS
VOR 1 or VOR 2 ILS 1 or ILS 2  **NAV** **ALT NAV L** **ALT NAV R**	RADIO NAV DATA SOURCE (G)	 	Indicates the source of the displayed navigation data. Data source is a function of: VOR/ILS mode - tuned frequency (VOR or LOC) and position of VHF NAV transfer switch. NAV mode - position of Captain's or F/O's NAV switch on light shield.
	COURSE CHANGE ALERT ANNUNCIATION (A)		Displayed 10 seconds prior to course change or 10 seconds prior to sequencing a waypoint if no course change is required. Removed as A/P begins roll to new course or when waypoint is sequenced.
	VOR/ILS FREQUENCY DISPLAY (G)		Displays frequency of manually tuned navaid. The word "AUTO" is displayed in place of the frequency if the VHF NAV radio is in the auto tune mode.
	POSITION DIFFERENCE DISPLAY (W)		ALPHA Characters - Indicate which IRS the displayed difference is associated with. ARROWS - Rotate thru 360^{o} to indicate relative bearing to the respective IRS position. NUMERICS - Indicate the distance in NM between the selected NAV data source (FMC, ANS L or ANS R) and the right IRS and left IRS positions respectively. Display is enabled when the position difference exceeds predetermined limits as detected by the FMC or by the Symbol Generator.

SYMBOL(S)	DATE NAME/(COLOUR)	APPLICABLE MODE(S)	REMARKS
	TRUE NORTH POINTER (G)		Indicates map background is oriented to true north.
	VERTICAL POINTER (M) DEVIATION SCALE (W) NUMERIC DISPLAY (W)		Displayed only during descent. Displays vertical deviation from FMC descent profile. Scale range is ± 400 feet deviation. Numeric value is displayed when pointer moves beyond the scale limits. Pointer represents path. Center of scale represents airplane position.
	GLIDESLOPE DEVIATION POINTER (M) AND DEVIATION SCALE (W)		Displays glideslope deviation. Scale appears when LOC frequency is tuned. Pointer appears when signal is usable. The pointer is not displayed when track and the front course on the MCP differ by more than 90° (Back course).
	AIRPLANE SYMBOL (W)		Represents the airplane. In MAP modes, present position is indicated by the apex of the triangle.
	CURVED TREND VECTOR (W)		Displays prediction of airplane's ground track. The furtherest end point of each vector segment represents the airplane's predicted position after a period of 30, 60 and 90 seconds respectively. The selected range determines number of segments displayed. Range > 20 NM ..... 3 segments Range = 20 NM ..... 2 segments Range = 10 NM ..... 1 segment
	PRESENT TRACK LINE (W) AND RANGE SCALE (W)		Displays present ground track based on airplane heading and wind. The displayed range numeric value(s) is (are) one-half the actual selected range. With heading-up orientation (VOR/ILS mode), the track line will be rotated left or right at an angle

SYMBOL(S)	DATE NAME/(COLOUR)	APPLICABLE MODE(S)	REMARKS
	ALTITUDE RANGE ARC (G)		The intersection of the arc with the track line is the predicted point where the MCP altitude will be reached. The prediction is based on present ground speed and airplane vertical speed.
	LATERAL DEVIATION INDICATOR BAR (M) AND DEVIATION SCALE (W)		Displays ILS, VOR or NAV (FMC or AN/CDU) course deviation. ILS 1 dot = 1^{o} VOR 1 dot = 5^{o} NAV 1 dot = 2 NM
	SELECTED COURSE POINTER (W) and LINE (M)		Points to selected course as set by the respective MCP course selector in VOR/ILS. It represents Desired Track in NAV.
TO FROM 	TO/FROM ANNUNCIATION (W)		Operative in VOR mode only. Indicates whether or not the selected course, if intercepted directly, and tracked, would take the aircraft TO or FROM the station.
(Standard WPT)  AMBOY (Conditional WPT) 	FLIGHT PLAN WAYPOINT: ACTIVE (M) DOWNPATH (W)		Active - Represents the flight plan waypoint the airplane is currently navigating to. Downpath - Represents a waypoint in an Active or Modified flight plan route. Data with parenthesis for conditional waypoints indicates type of conditional waypoint (altitude, "VECTORS" "INTC", etc.).
 ABCDE	OFF-ROUTE WAYPOINT (C)		When the WPT switch is ON, FMC data base waypoints are displayed. Displayed only for HSI ranges of 10, 20 or 40 NM.

SYMBOL(S)	DATE NAME/(COLOUR)	APPLICABLE MODE(S)	REMARKS
 KXYZ	AIRPORT (C)		ARPT switch - OFF Only origin and destination airports are displayed. ARPT switch - ON All FMC data base airports within the MAP area are displayed.
 KABC 22L	AIRPORT IDENTIFIER AND RUNWAY (W)		Available when the EHSI display range is 80, 160, or 320 NM. Displayed if the airport has been selected as the origin or destination airport with a specific runway selected.
 22L	AIRPORT AND RUNWAY (W)		Available when the EHSI display range is 10, 20 or 40 NM. Displayed if the airport has been selected as the origin or destination airport with a specific runway selected. Runway symbol is scaled to represent the length of the selected runway. The dashed center lines extend outward 14.2 nm from the runway threshold.
	INACTIVE ROUTE (C) ACTIVE ROUTE (M) ACTIVE ROUTE MODIFICATION (W)		An active route is displayed with continuous lines between waypoints. An active route modification is displayed with short dashes between waypoints When a modification is executed, the short dashes are replaced with the continuous lines. Inactive routes are displayed with long dashes between waypoints.
 ABCDE 12000 0835Z	ROUTE DATA (M, W)		When the RTE DATA switch is ON, altitude constraints and ETA's for route waypoints will be displayed.

SYMBOL(S)	DATE NAME/(COLOUR)	APPLICABLE MODE(S)	REMARKS
○ T/C ○ S/C ○ T/D ○ E/D ○	VERTICAL PROFILE POINTS (G) IDENTIFIERS (G)		Represents an FMC computed vertical profile point in the active flight plan as T/C (top-of-climb), T/D (top-of-descent), S/C (step climb), and E/D (end of descent). A deceleration segment point has no identifier.
	VOR (C, G) DME/TACAN (C, G) VORTAC (C, G)		NAV AID switch - OFF Tuned navaids (excluding NDB's) are displayed in green. NAV AID switch - ON All appropriate navaids contained in the FMC data base and within the MAP area are displayed when the range is 10, 20 or 40 nm. Only high altitude navaids are displayed when selected range is 80, 160 or 320 NM. Nav aids not being used are displayed in cyan (blue).
	MANUALLY TUNED VOR RADIALS (G)		When a VOR navaid is manually tuned, the associated MCP selected course and its reciprocal are displayed.
	VOR BEARING RADIALS (G)		The VOR/ADF switch on the EFIS Control Panel must be ON and a valid VOR signal must be received. Displays relative bearing to the tuned VOR station(s)

SYMBOL(S)	DATE NAME/(COLOUR)	APPLICABLE MODE(S)	REMARKS
	ADF BEARING RADIALS (G)		The VOR/ADF switch on the EFIS Control Panel must be ON and a valid ADF signal must be received. Displays relative bearing to the tuned ADF station(s).
	SELECTED FIX CIRCLE (G) FIX SYMBOL AND IDENTIFIER (C or G)		Depicts the selected reference point as entered on the FMC/CDU FIX INFO page. Can appear with other special map symbols (e.g. VOR, VORTAC, airport or waypoint, etc.) if stored in the FMC data base.
	SELECTED FIX RADIAL (G) SELECTED FIX DISTANCE CIRCLE (G)		A fix reference radial is displayed for each downtrack bearing entered on the FMC/CDU FIX INFO page. A distance reference circle is displayed for each distance entered on the FMC/CDU FIX INFO page.
	HOLDING PATTERN ACTIVE (M) MODIFICATION (W) INACTIVE (C)		Appears as a fixed size holding pattern if selected range is greater than 80 NM. A scaled representation of the holding pattern is displayed when the selected range is 80 NM or less <u>and</u> the airplane is within 3 min. of the holding fix.
	WEATHER RADAR RETURNS (G, Y, R, M) RANGE ARCS (W)		When either WXR switch is selected to the ON position, multicoloured weather radar returns are displayed. The most intense precipitation areas are displayed in red; less intensities, yellow and lowest intensities, green. Areas of turbulence associated with precipitation are displayed in magenta.
	RANGE ARCS (W)		Range arcs are displayed in the expanded rose VOR/ILS and NAV modes when the Weather Radar Switch is ON. Range arcs are displayed in the MAP mode with or without the WXR Switch ON.

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Chapter 8

SAMPLE QUESTIONS -

SEMICONDUCTORS, LOGIC, AUTOFLIGHT, EFIS

1 Name the two common semiconductor elements:-

a) Lead and Nickel
b) Cadmium and Carbon
c) Silicon and Germanium

2 What is the name of the process of adding specific impurities to pure semiconductor material to create its unique properties?

a) flashing
b) doping
c) electrolysis

3 Semiconductor material which has an excess of electrons is called:

a) F.A.T.
b) P type material
c) N type material

4 The term 'solid state' is often applied to semiconductors because they:-

a) have no moving parts
b) are made of solid matter, not liquid or gas
c) can't be damaged if dropped

5 The two general uses of semiconductors are:-

a) electronic switches and system computers
b) relays and magnetic amplifiers
c) amplifiers and electronic switches

6 Why is gold used on connectors inside modern computers?

a) Gold increases the value of the computer making it more attractive to the top end of the market.
b) Gold doesn't oxidize and therefore offers very little resistance to the small currents used in digital computers.
c) As connectors must all sit horizontal gold is used to balance them.

7 Logic circuits can be made to function by using:-

a) manually operated switches
b) relays
c) transistors
d) all of the above

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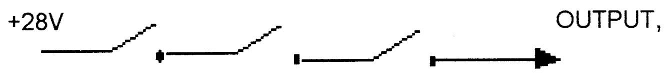
8. The three 'primary' logic gates are:

   a) AND, OR, NOT
   b) NAND, NOR, XOR
   c) NOT, NAND, NOR
   d) GOLDEN, WEST, WATER

9. Decode the following binary word to a decimal number; 1000:-

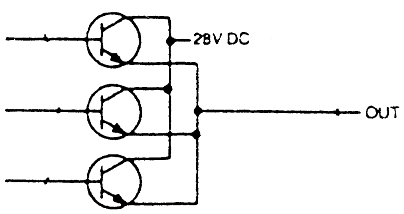
   a) 4
   b) 8
   c) 16
   d) 32

10. If switches were placed in series like this circuit it would represent:



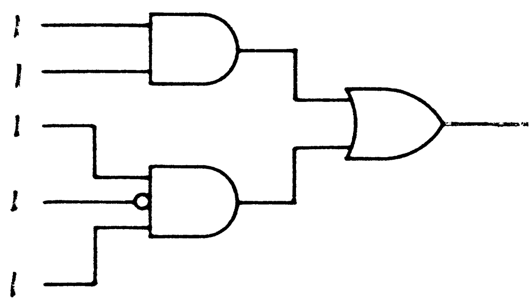
   a) a NOR gate
   b) an AND gate
   c) a NAND gate

11. If transistors were connected in the 'common emitter' configuration as in the circuit below, this would represent:-



   a) an OR gate
   b) an AND gate
   c) a NAND gate

12. In the logic diagram below the last symbol is an (1) __________ gate and the output is (2) __________.



   a) (1) XOR (2) 0
   b) (1) OR (2) 1
   c) (1) AND (2) 0
   d) (1) OR (2) 0

13 The sine wave represents:-

a) an analog signal
b) a digital signal
c) a hybrid signal

14 When compared to a digital computer, analog computers:-

a) are much faster because they directly represent a parameter.
b) can be very useful but can usually do only one task.
c) are old technology and are of no further use.

15 When compared to an analog computer, digital computers:-

a) cost much more than analog computers.
b) are cheaper, lighter and have the flexibility of being software driven.
c) are always stand alone devices which don't need analog inputs or outputs.

16 On modern light aircraft the attitude reference for the auto pilot is usually the:-

a) central Air Data Computer.
b) laser strap down gyros of the IRS.
c) the vertical gyro in the attitude indicator.

17 In an auto pilot the stabilization process is a function of:

a) the control wheel steering system.
b) the inner loop.
c) auto trim.

18 A vertical gyroscope provides?

a) rate of change information in azimuth.
b) stable pitch and roll attitude information.
c) pitch and turn signals.

19 An inner loop control system is one in which:

a) a deviation produces an error signal, producing corrective action proportional to the magnitude of the deviation.
b) all three axes of movement in flight are sensed and the appropriate actuator is selected.
c) only roll control can be achieved.

20 What flight controls can the localizer input to?

a) Aileron and elevator.
b) Rudder and elevator.
c) Aileron.

21 The flight director output:-

a) is amplified and sent directly to the flight control computer.
b) can be sent to the ADI (PFD) and pilot flies the aircraft.
c) is only ever used to monitor auto pilot actions.

22 A fail passive system is one which:

a) embodies sufficient redundancy to ensure safe operation in the event of partial system failure.
b) will not produce excessive deviation from the intended flight path in the event of partial system failure.
c) prevents completion of an intended manoeuvre in the event of system failure.

23 An auto pilot component has failed below decision height during an autoland sequence, with a fail operational system. Do you:-

a) abort the landing immediately?
b) continue and complete a normal autoland?
c) take control and complete a manual landing?

24 Airspeed hold in an automatic flight system:-

a) applies a dynamic pressure-based signal to the pitch loop.
b) applies a dynamic pressure-based signal to the roll loop.
c) applies a static pressure-based signal to the pitch loop.

25 The CADC requires three inputs, these are:-

a) airspeed, groundspeed and heading
b) TAS and Mach Number and altitude
c) pitot pressure, static pressure and true air temperature

26 The display brightness control on the EFIS displays:-

a) is manually adjusted only.
b) is unnecessary.
c) is usually automatic.

27 On an EFIS equipped aircraft the altitude arc intersection across the planned track on the MAP display indicates?

a) a point where the target altitude will be attained at the present rate of climb or descent.
b) a prediction of the path over the ground to be followed for the next 30, 60 and 90 seconds.
c) the resent historical flight path.

28 What is displayed on the PFD?

a) ADF information.
b) VOR radial.
c) ILS deviation.

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29 What are the main modes of the EHSI (ND)?

a) RANGE, VOR, ADF, TRK.
b) MAP, PLAN, VOR/ILS, NAV.
c) AUTO, WXR, EHSI, LOC.

30 From what equipment is the track trend vector derived for the EHSI?

a) ADC.
b) FMS.
c) SWC.

Chapter 9

SAMPLE PAPER 1

ELECTRICS AND AUTOFLIGHT

The following sample exam paper is similar in format to that produced by the UK CAA International Division and you should anticipate having to answer the 40 questions in 40 minutes.

1. What is the electrolyte in a lead acid battery?

   (a) dilute sulphuric acid
   (b) hydrochloric acid diluted with distilled water
   (c) lead compound in liquid acidic suspension

2. Where is a TRU used?

   (a) to provide a suitable AC from a DC BUS BAR
   (b) between an AC supply and a DC BUS BAR
   (c) to convert 115VAC 400HZ to 26VAC 400HZ

3. What does an Ammeter measure?

   (a) EMF in volts
   (b) current in Amps
   (c) frequency in Hertz.

4. In the cockpit, how can you check the charge state of battery?

   (a) by the use an hydrometer
   (b) by checking the voltmeter in the “off-load” condition
   (c) by switching on a reasonable load and checking that the voltmeter indicates the rated voltage.

5. Is it satisfactory to have two unparalleled generators that are not in phase?

   (a) no, as a phase incomparability will cause a malfunction
   (b) yes, because the BTBs will protect the circuits
   (c) yes, provided they supply separate systems

6. When load shedding takes place,

   (a) voltage reduces at the bus bar
   (b) field current increases
   (c) current at the bus bar reduces

7. If one phase of a 3 phase AC motor circuit opens, the

   (a) motor will stop immediately
   (b) motor will continue to run at a lower RPM, producing less power
   (c) motor will slow down and stop

8. What does 'open circuiting' do?

   (a) will isolate the power from the component
   (b) will increase the power to the component
   (c) will simply switch that component ON

9. One purpose of bonding, is to?

   (a) connect one electrical component to another
   (b) create a low resistance path for the discharge of static electricity
   (c) ensure all the bus bars are of the same potential

10. A pilot excitor is :

   (a) a small separate D.C. coil used to excite the main A.C. generator.
   (b) a generator excitor coil operated by an impulse mechanism.
   (c) any object of arousal that appeals to a pilot's random impulses.

11. Power Factor is defined as :-

   (a) the sum of true and reactive power.
   (b) the ratio between true power and apparent power.
   (c) the ratio between inductive and capacitive power reactance .

12. The line voltage of a three-phase star-connected AC. is :-

   (a) less than phase voltage.
   (b) greater than phase voltage.
   (c) equal to phase voltage.

13. The output frequency of an AC generator is governed by :-

   (a) controlling the strength of the magnetic field.
   (b) changing the number of windings in the field coils.
   (c) controlling the RPM of the armature.

14. The purpose of a CSD is:-

(a) to allow the generator to run at a constant frequency with changing engine RPM,
(b) to provide the engine with a constant load,
(c) to assist the voltage regulation function.

15. Heaters and electrical de-icing systems can be supplied by frequency wild AC supplies, after voltage regulation because:-

(a) resistance is not affected by frequency,
(b) these circuits contain reactive components,
(c) this method saves a lot of DC.

16. A static inverter is a :-

(a) solid state device which converts DC to AC.
(b) rotary device which is fixed to the airframe and cannot be moved.
(c) is simply a DC motor turning an alternator.

17. Two 24 volt 20 AH batteries connected in parallel will provide :-

(a) 48 v 10 AH
(b) 24 v 40 AH.
(c) 12 v 80 AH

18. Fuses and circuit breakers are placed :-

(a) in parallel with its component,
(b) in series with its component,.
(c) in either series or parallel with its component.

19. The field excitation current for AC. generators is :-

(a) DC. and may be varied to control output voltage.
(b) AC. and therefore cannot be varied to control output voltage.
(c) AC. and may be varied to control output voltage.

20. On an aircraft fitted with an earth return electrical system:-

(a) static electricity is discharged through the tyres on landing
(b) one lead from the battery and each component is connected to the metal airframe.
(c) capacitive devices may suffer from over-voltage

21. Semiconductors are sometimes called:

a) one way valves
b) inverters
c) solid state devices

22. Computers using binary code are known as:

a) analogue Computers
b) digital Computers
c) linear Computers

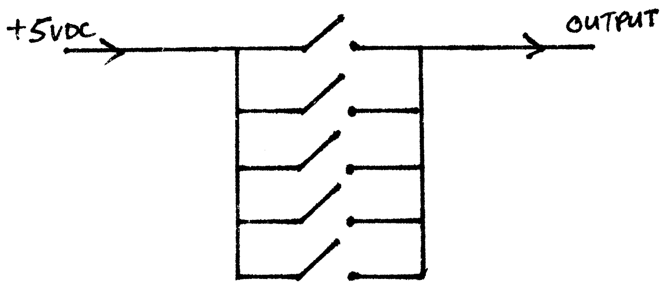
23. In logic circuits, semi conductors are used as:

a) power amplifiers
b) current storage devices
c) electronically controlled switches

24. Convert binary code 10001 to a decimal number.

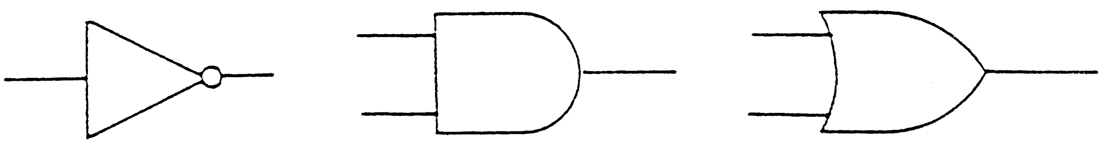
a) 11
b) 17
c) 31

25. What logic gate does the following diagram represent?



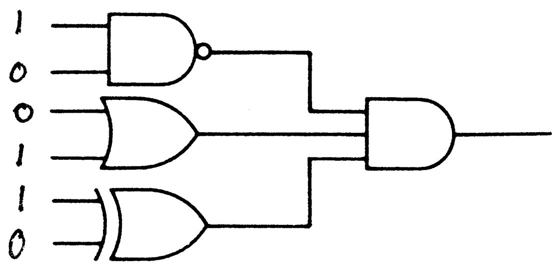
a) OR gate
b) NAND gate
c) AND gate

26. The correct descriptions of the logic symbols shown in order are:



a)	AND	NOT	OR
b)	NOT	NAND	NOR
c)	NOT	AND	OR

27. Using the inputs as indicated, what is the output of the following diagram?



a) 0
b) 1
c) 2
d) 3

28. In order to switch off the lamp in the diagram below, the inputs must be:

a) A = 1, B = 0
b) A = 1, B = 1
c) A = 0, B = 0

29. The NAND Function is achieved with the use of:

a) a NOT Gate and an OR Gate
b) a reversed AND Gate
c) a NOT Gate and AND Gate
d) an AND Gate and an OR Gate

30. On a small aircraft, auto pilot pitch and roll signals are supplied from:

a) the auto pilots' own gyros
b) pick offs from the aircraft Flight Attitude Indicator
c) the turn and balance instrument

31. The pitch trim thumb wheel is operative only when:

a) the auto pilot is engaged.
b) heading mode only is engaged.
c) altitude hold is engaged.
d) the electric trim is off.

32. When disengaging the auto pilot the:

    a) vacuum system must be at least 4.2" Hg
    b) hydraulic pumps should be turned off
    c) aircraft controls should be held firmly

33. The main purpose of an auto pilot is to:

    a) provide a smooth flight at all times
    b) respond to radio communications
    c) relieve pilot workload
    d) provide full automatic takeoff and landing capability

34. When altitude hold is engaged, the aircraft:

    a) will maintain the pitch attitude at time of engagement
    b) heading mode must be engaged first
    c) will sense pressure changes and maintain the pressure altitude selected
    d) pitch gyro must be engaged

35. When using the Flight Director the pilot should:

    a) constantly trim the aircraft
    b) either engage the auto pilot or fly the FD commands
    c) relax and increase his lookout for other aircraft
    d) ensure the auto pilot is disengaged

36. In a large aircraft if the aircraft is off the ILS track, what signals does it use to regain track?

    a) VOR and LOC only
    b) Localizer only
    c) VOR only

37. The colour code for a cautionary message on an EFIS display is:

    a) red
    b) amber
    c) magenta

38. On the EHSI, in what modes is RADAR available?

    a) MAP, PLAN, ILS
    b) PLAN, ILS, VOR
    c) ILS, VOR, MAP

39. AUTOLAND always requires:

    a) three autopilots to function
    b) two automatic systems which continuously compare ILS deviation and RA data
    c) altitude hold to be engaged

40. Go-around (GA) may be initiated by:

a) switching the autopilot off
b) pressing the GA button on one of the throttle levers
c) selecting FD only

SAMPLE PAPER 2

ELECTRICS AND AUTOFLIGHT

The following sample exam paper is similar in format to that exam produced by the UK CAA International Division and you should anticipate having to answer the 40 questions in 40 minutes. A final tip - study hard and be nice to your mum!

1. What is one way to check the charge of a battery?

   (a) check the voltmeter in the "off-load" condition
   (b) compare on load and off load voltage
   (c) use the ammeter indicator before start

2. In a star connected three phase generator :

   (a) phase voltage is less than line voltage
   (b) line current is greater than phase current
   (c) phase voltage is greater than line voltage

3. What happens when a fuse wire blows?

   (a) the increased current flow is likely to cause a fire
   (b) a circuit breaker should also break the circuit
   (c) the fuse wire melts and separates

4. When should a circuit breaker be reset?

   (a) immediately it is noticed to have popped
   (b) after the fault has been corrected
   (c) only when the aircraft is safely on the ground

5. When can AC voltage from frequency wild generators be parallel?

   (a) never
   (b) only when heaters are connected
   (c) always

6. What could be the effect if frequency decreases in an inductive circuit?

   (a) the circuit impedance would increase
   (b) no obvious change would occur unless the voltage changes
   (c) the components may overheat

7. How is voltage from an AC generator increased to its regulated value ?

   (a) by increasing the speed of rotation (RPM)
   (b) by increasing the magnetic field strength in the generator
   (c) by decreasing the load on the bus bar

8. With a NICAD battery, after start you notice a large positive charge rate;

   (a) this is normal provided this first charge is not prolonged
   (b) this is dangerous, the system must be shut down immediately
   (c) the engine must be stopped

9. Static inverters may be used to supply :

   (a) emergency constant frequency A.C.
   (b) emergency constant frequency D.C.
   (c) emergency frequency wild A.C.

10. Three Phase induction motors are used :

   (a) to provide small amounts of power to operate clocks
   (b) to operate devices requiring large amounts of power
   (c) only as inverters

11. Power Factor in a circuit with an imbalance of inductance and capacitance is :-

   (a) greater than unity. (> 1).
   (b) unity (= one).
   (c) less than unity (< 1).

12. The output voltage of an AC generator is usually controlled by :-

   (a) controlling the strength of the magnetic field..
   (b) changing the number of windings in the field coils.
   (c) controlling the RPM of the armature.

13. The armature of a brushless generator contains :-

   (a) the output windings.
   (b) the rotating field and diodes.
   (c) either sliprings or a commutator.

14. Malfunction of a CSD requires :-

(a) automatic electrical disconnection of the generator drive,
(b) manual disconnection by operation of the generator drive,
(c) the generator drive shaft to shear.

15. The opposing potential in AC circuits (and changing DC circuits) is known as :-

(a) PD.
(b) Forward EMF.
(c) Back EMF.

16. Frequency wild alternators :-

(a) are often connected in parallel.
(b) can be connected in either series or parallel.
(c) are never paralleled.

17. The capacity of a battery is determined by :-

(a) the area of its plates,
(b) the applied load,
(c) its discharge rate.

18. A type of AC motor whose running speed is directly related to the frequency of the supply voltage is a :-

(a) universal type.
(b) squirrel cage type.
(c) synchronous type.

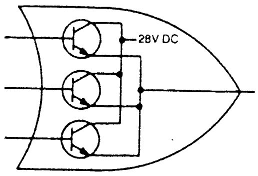
19. If the inductive reactance decreases due to under-frequency in an AC. supply:-

(a) inductive devices may overheat.
(b) AC. motors may over speed.
(c) capacitive devices may suffer from over-voltage.

20. Press to test lights are used:-

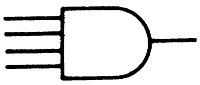
(a) to indicate to the pilot that the circuit has power,
(b) to indicate to the pilot that the circuit has no power,
(c) to indicate to the pilot that the circuit has malfunctioned.

21 What logic gate does the 'common emitter circuit' diagram below represent?



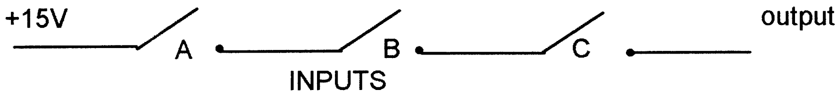
a) AND gate
b) OR gate
c) NOR gate

22. What type of logic gate does the following symbol represent?



a) AND gate
b) OR gate
c) NOR gate

23. A set of switches in series as depicted below represents what type of logic?



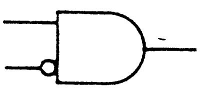
a) AND gate
b) OR gate
c) NOR gate

24. Convert binary code 10011 to a decimal number:

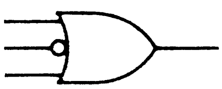
a) 33
b) 19
c) 11

25. Select the diagram that represents an EX-OR gate:

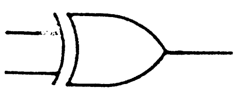
a)



b)



c)



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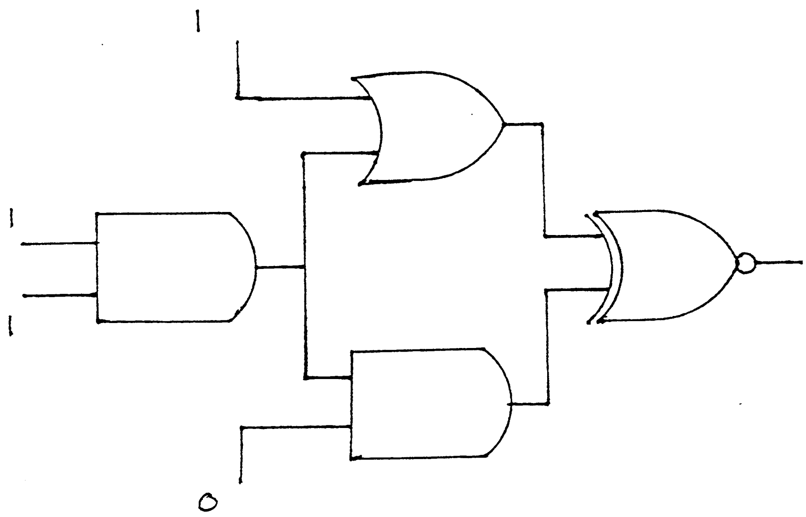
26. The output of the following diagram using the inputs as indicated is:



a) 0
b) 1
c) 2

27. In small aircraft what type of gyroscope is used to determine the aircraft attitude?

a) a rate gyro
b) a lazer gyro
c) a vertical gyro

28. The basic autopilot in a small aircraft receives its pitch and roll signals form:

a) the turn indicator
b) the artificial horizon
c) the HSI

29. The 'quick disengage' switch for the autopilot is normally on the:

a) control handle
b) throttle
c) ADC

30. When compared to analog computers, digital computers are:

a) heavier, cheaper, software activated but cannot share information easily
b) slower, more accurate and present information in a much nicer format
c) lighter, cheaper and can easily transmit and share data

31. Autopilots on large aircraft receive attitude information from rate gyroscopes which are part of the:

    a) CADC
    b) PFD
    c) IRS

32. From where does the autopilot LOC capture mode receive its input?

    a) LOC only
    b) LOC and course error signals
    c) LOC and heading signals

33. In the HDG SELECT mode, bank limit signals are input to?

    a) roll attitude gyro outputs
    b) reset heading output signals
    c) control the position indicators signals

34. What is 'course washout'?

    a) autopilot correcting for x-wind on finals
    b) the autopilot making a smooth transition to the localiser before capture
    c) autopilot heading error signals increasing

35. What autopilot modes function in the pitch channel?

    a) VNAV, ALT, AUTOTRIM, AUTOTHROTTLE
    b) LNAV, HDG, LOC, AUTOLAND
    c) YAW DAMPER, ROLL TRIM.

36. If the EADI is receiving invalid information, what are the indications?

    a) a white flashing screen with a red display
    b) a blank screen
    c) an amber flag, no display and a blank screen

37. What is the more sensitive mode, for an approach for landing?

    a) ADF
    b) VOR
    c) ILS

38. What planes of an aircraft in flight does 'dutch roll' affect?

    a) YAW and PITCH
    b) PITCH and ROLL
    c) ROLL and YAW

39. How is the expanded compass rose selected on the EHSI?

    a) by pressing the expand/normal switch on the EHSI
    b) by adjusting the scale selection on the EHSI control panel
    c) by selecting the expanded mode of the required display

40. At take-off which of the following equipment or modes will be operating?

    a) AUTOLAND
    b) FLIGHT DIRECTOR
    c) AUTOPILOT

ANSWERS

Chapter 8
Sample Questions

1C	21B
2B	22B
3C	23B
4B	24A
5C	25C
6B	26C
7D	27A
8A	28C
9B	29B
10B	30B
11A	
12B	
13A	
14B	
15B	
16C	
17B	
18B	
19A	
20B	

Chapter 9
Sample Paper 1

1A	21C
2B	22B
3B	23C
4C	24B
5C	25A
6C	26C
7B	27B
8A	28C
9B	29C
10A	30B
11B	31D
12B	32C
13C	33C
14A	34C
15A	35B
16A	36B
17B	37B
18B	38C
19A	39B
20B	40B

Chapter 9
Sample Paper 2

1B	21B
2A	22A
3C	23A
4B	24B
5A	25C
6C	26A
7B	27C
8A	28B
9A	29A
10B	30C
11C	31C
12A	32C
13B	33A
14B	34B
15C	35A
16C	36C
17C	37C
18C	38C
19A	39C
20A	40B