FIBEROPTIC AIR DATA SYSTEM

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Abstract

The state-of-the-art in most aircraft is to acquire the static and differential pressures and convert to Altitude and Airspeed using an analog meter. In most sophisticated military aircraft the information is fed to a digital computer and displayed on a CRT screen. In some experimental aircraft digital display of some parameters (not necessarily altitude and airspeed) is done using Liquid Crystal Displays (LCD) as Light Emitting Diodes (LED) are not visible in bright light or sunlight.

The Fiberoptic (F.O) Air Data System described is initially meant for acquiring two parameters of airdata, viz. Altitude and Airspeed as an experimental exercise on the LCRA (Light Canard Research Aircraft) at the National Aeronautical Laboratory. Expansion to an 8 channel system is very easy. With minor modifications the number of channels may be increased to 16 or more.

The data obtained is processed at the rear cockpit in the analog domain, converted to the BCD format every second, then to the serial format and manchester encoded. This signal then drives a fiberoptic transmitter which emits in the IR region (820 nm) of the electromagnetic spectrum. The F.O. transmitter is coupled to a F.O receiver through a F.O. cable at the front cockpit panel and the signal is converted back to the parallel BCD format in the electrical domain. This is then processed to drive a 4 1/2 digit (LCD). The system is calibrated using a standard altimeter and airspeed indicator.

Introduction

Fiberoptic links for data transmission have been used on some experimental aircraft.(1),(2) A F.O. air data system for acquiring airspeed and altitude and digitally displaying the same at the cockpit panel was developed on an experimental basis for testing on the LCRA (Fig.1).

The static and differential pressures measured using transducers are converted to altitude and airspeed in engineering units (ft and Mph) in the analog domain at the rear cockpit of the LCRA and then converted to PCM (Pulse code Modulated) digital data in the BCD (Binary Coded Decimal) format to drive a F.O. transmitter which is an LED emitting light in the near IR region.(3)

This light is coupled to a F.O. step index multimode cable and transmitted to a F.O. receiver - a PIN photo-diode - which converts the data back to the electrical BCD format at the front cockpit. The data is then seperated into altitude and airspeed and displayed at the cockpit panel using 4 1/2 digit LCD's. LED displays cannot be used as they are invisible when the ambient light is bright.

While the system is used for displaying only two parameters, by simple modifications it can be used for 15 or more parameters.

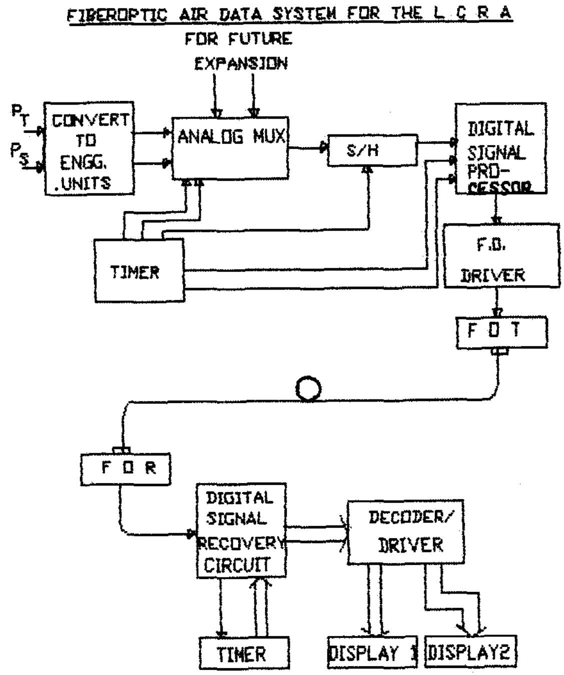

FIG. 1

Principle

The relation between the actual static pressure transducer output (o/p) 'x' and the altitude 'y' in feet is given by the linear equation

$$y = a x + b \qquad (1)$$

where 'a' and 'b' are constants.

These constants 'a' and 'b' were determined by subjecting the transducer and a standard altimeter to various pressures (below normal pressure to simulate various altitudes) and substituting in eqn.(1).

Similarly the differential pressure transducer and a standard airspeed meter were subjected to various diffferential pressures and the curve was found to fit the equation

$$q = \sqrt{c\ (p - 2.5)} \qquad (2)$$

where q = airspeed in mph
p = pressure o/p from transducer
c = constant.

When the outputs of the two transducers are fed to two analog circuits, they give outputs which are numerically equivalent to altitude and airspeed respectively. These are coded digitally at the rear cockpit, optically transmitted to the front cockpit and after further decoding are displayed at the panel. The maximum displayed value is 19999 ft for altitude and 199.99 mph for airspeed. Since the optical transmission is done in the digital domain a '1' in the data triggers the F.O. transmitter LED to emit light and a '0' no light. At the F.O. receiver, PIN photo diode, when light is received a '1' is output and '0' when no light is received.

Details

Before processing, the signals from the sensors are preamplified to required levels using Operational amplifiers (opamps).

For obtaining the Airspeed from the corresponding sensor, an offset of -2.5 V was given at the input and the gain of the amplifier was set at 'c' (eqn. 2). The square root of the output of this amplifier was obtained using a square root circuit and buffered before giving as an input to the analog multiplexer (mux) operating in the TDM (Time Division Multiplexer) mode.

Similarly the altitude sensor output is amplified using an opamp set to a gain of 'a' with an offset of 'b' at the output, as in eqn.1. This is also given as a second i/p to the analog mux.

The F.O. transmitter block diagram is shown in fig.2. A square wave oscillator with the frequency adjusted to suit the system requirements was wired to operate the time to give various control inputs to the analog mux, the ADC, sample (4)
Hold circuit and the manchester encoder.

The analog mux is controlled such that each channel is opened for about 1.25 secs (the time allowed in the system for the pilot to view the display without strain). The system is set for 4 channels (though 8 channels are possible with the chip used), out of which two are for altitude and airspeed, one is for frame sync code and one is a dummy.

The output of the analog mux is sampled and held once every channel time slot by a S/H (Sample Hold) circuit and converted to a BCD format using a 4 1/2 digit analog to digital converter (ADC). These 4 1/2 digits are avail-able in a parallel format and so a parallel to serial converter provides a serial stream of bits in the non-return-to-zero (NRZ) format. In order to retrieve the information without error at the receiving end, synchronized clock pulses are used to manchester encode the data so that it is in the return-to-zero (RZ) serial stream of bits.

Each channel now is a 20 bit stream starting (5)
with a '0' to avoid frame sync ambiguity. The frame sync itself is selected to have a code of 01111111111111111111 (as this code can never occur anywhere in the data channels) and is alloted the first channel time slot.

The signal in the electrical domain is buffered to drive an LED, emitting light at a wavelength of 820 nm in the near IR region. This light is coupled to a step index multimode F.O. cable which in turn is coupled to a PIN photo-diode at the front cockpit. This is the F.O. Receiver (Fig.3). The photo-diode faithfully reproduces the '0's and '1's from the optical to the electrical domain. A manchester decoder then seperates the clock pulses and NRZ data. As the clock pulses are synchronized with the data pulses - a timer operated from the recovered clock pulses provides all the control pulses needed for serial to parallel conversion, frame sync recognition and data enable for LCD.

The data in the NRZ format is converted to the parallel format and the frame sync recognizer gives a an output pulse for resetting a counter in the timer, which provides the data enable waveform to make the data available to the LCD at the appropriate altitude and airspeed time slots. In order to operate the LCD another pulse generator provides pulses at 60 Hz rate which need not be synchronized with the received clock pulses.

In the present system, as there is only a limited panel space available altitude and airspeed are displayed alternately using only one 4 1/2 digit LCD. During airspeed display a decimal point is energised so that the maximum value displayed is 199.99 mph which will make the pilot recognise it as the airspeed.

F.O. TRANSMITTER BLOCK DIAGRAM

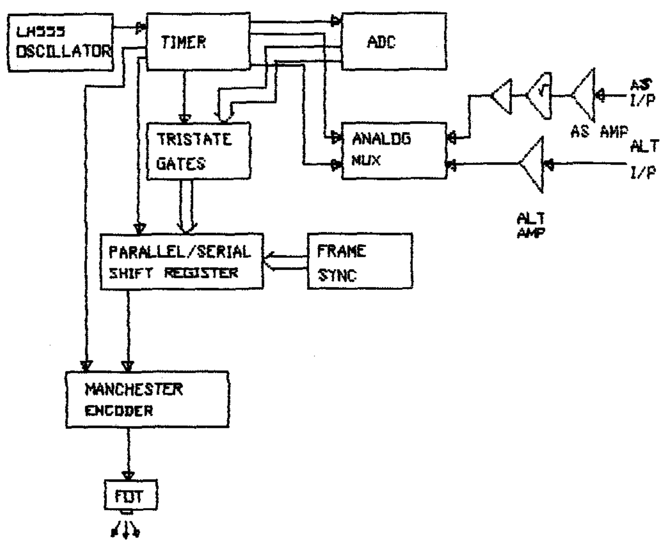

FIG. 2

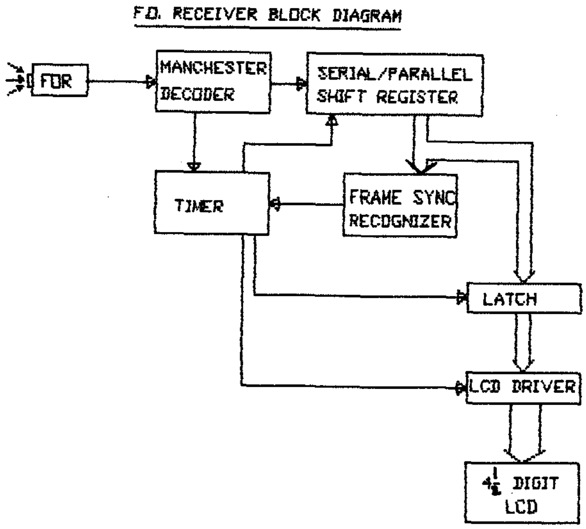

FIG. 3

Conclusion

It is claimed that since fiberoptics is used for transmission of data, the data received will always be identical with the data transmitted i.e. F.O. is not affected by EMI or RFI and so the integrity of the data is maintained (6). Secondly an optical fiber is much lighter than copper and there is no danger of short circuit as in the case of the latter. Hence laying the fiber in the aircraft is much simpler. Also the total power from the battery is much less than would be needed if copper wires are used for transmission.

References

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(4) Mrs. L.C.Manoharan, "Modem for Manchester - Data modulation/demodulation", NAL PDSE 8804, Feb. 1988.

(5) Mrs. L.C.Manoharan, "Frame Sync. ambiguity in simple fiberoptic telemetry", Int. Jou. of Electronics, 1980, Vol.49, No. 2, pp 167 -174.

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