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DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

AERONAUTICAL RESEARCH LABORATORY

MELBOURNE, VICTORIA

Technical Report 21

AN IBM PC BASED ARINC INTERFACE

by

M. IOB

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AN IBM PC BASED ARINC INTERFACE

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SUMMARY

A general purpose ARINC (Aeronautical Radio, INC) serial interface has been developed for use with an IBM PC or compatible computer. The interface consist of a PC card and software to selectively read, log, time tag and process data read from the ARINC bus. The PC card uses an XT slot and the data is written onto floppy disk or hard disk. The data logging and post-processing software has been configured for ARINC 419/561 but can be readily reconfigured to other ARINC formats. ARINC 419/561 are low speed standards dealing with systems operating at 11 ± 3.5 kilobits per second. The interface and PC software could readily be adapted to handle much higher speed ARINC and non-ARINC formats.

DSTO AUSTRALIA

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1.0 INTRODUCTION

A general purpose ARINC (Aeronautical Radio, INC) serial interface has been developed for use with an IBM PC[1] or compatible computer. ARINC 419/561 (see references 1 and 2) uses a 32 bit data word containing an 8 bit address or label. The ARINC data stream consists of packets of these data words. The interface consists of a PC card and software to selectively read, log, time tag and process data read from the ARINC bus. The PC card uses an XT[1] slot and the data is written onto floppy disk or hard disk. The data logging and post-processing software has been configured for ARINC 419/561 but can be readily reconfigured to other ARINC formats. ARINC 419/561 are low speed standards dealing with systems operating at 11 ± 3.5 kilobits per second. The interface and PC software could readily be adapted to handle much higher speed ARINC and non-ARINC formats (upto 100 kilobits per second).

The interface and the PC software provide the following broad capabilities. The data logging software allows the user to select data to be logged and the rate for data logging. This information is passed to the interface which proceeds to gather data, time tag it and transmit it to the PC for logging. In addition the interface processes events, PC generated and external. The post-processing software can be used to view data and output it in a form suitable for plotting or further analysis.

The following document describes the interface in greater detail. Section 2.0 gives some background to the development of the interface. Section 3.0 describes the PC card hardware and controlling software in some detail. Finally section 4.0 gives some details on the capabilities and operation of the data logging and post-processing software written for the PC.

2.0 DEVELOPMENTAL BACKGROUND

The original requirement for the interface resulted from ARL's involvement in an RAAF trial to evaluate the integration of a Global Positioning System (GPS) set with a Litton LTN-72 Inertial Navigation System (INS) in a P-3C aircraft. ARL was responsible for logging data from the LTN-72 while DSTO Surveillance Research Laboratory (SRL) was tasked with logging data from the GPS.

The first ARINC interface was designed and built by Engineering Facilities Division at ARL with assistance from Air Operations Division. It was separate from the PC and communicated with it by way of a Mondotronic[2] Digital Parallel I/O Board (PIO-6U). The board used an XT slot in the PC. In this way the software communicated with the interface and logged data that was collected by the interface.

This interface was taken to the then Department of Aviation Flying Unit's facilities at Essendon Airport and connected to an LTN-72 on a test bench. It performed successfully under these conditions and the decision was made to build the PC board version of the interface. The design of this second interface was completed in Air Operations Division. Due to delays outside the control of ARL in obtaining a GPS set, the RAAF trial was eventually cancelled and consequently neither interface has been tested in flight.

3.0 PC CARD

The design of the PC ARINC interface is an extension of the first interface design produced by Engineering Facilities Division. It has been enhanced by the use of Altera Corporation EPM5128 Erasable Programmable Logic Devices (EPLDs). The board can be used with either one or two of these EPLDs. If two EPLDs are used then two ARINC lines can be monitored. The EPLDs perform three major functions. These are to assemble the serial data into parallel form, allow the interface CPU to communicate to the PC and perform onboard interrupt control.

Design of the board was completed in Air Operations Division with design layout drawings produced by Engineering Facilities drawing office. Logic design for the EPLDs was carried

1. IBM PC and IBM XT are the registered trademarks of IBM Corporation.
2. Mondotronic PTY. LTD. Victoria, Australia..

out using Altera Corporation MaxPlus software on an IBM compatible 80286 PC. The hardware is configurable to accommodate both ARINC 561 and 419 standards. Figure 1 depicts a typical test setup for the interface card.

3.1 Interface Hardware Description

The PC interface board consists of two sections. One section interfaces with an ARINC 419/561 system while the other interfaces with the standard 8 bit PC bus. It is identical in lenght to an AT card and has the option to be cut in half and the two halves mounted together to fit in a half slot such as those found in lap-top PCs. At the end of the card is a 37 pin male D connector used to connect to one or two ARINC systems. ARINC data and system control lines are interfaced to the board via opto-couplers providing a high degree of isolation.

The main components on the board consist of the Hitachi 6303 central processing unit (CPU), RAM, a First In First Out (FIFO) memory chip, an EPROM and the EPLDs. Under the ARINC 419/561 standards, an ARINC data word is 32 bits in length. The EPLDs perform the task of collecting ARINC serial data and passing it through a 32 bit shift register to a 32 bit latch. The 6303 is then interrupted and it stores the 32 bits (one byte at a time) in an input FIFO (implemented in RAM). The background task of the 6303 is to process data in the input FIFO and place it in the output FIFO (i.e. FIFO chip) for collection by the PC. The use of this FIFO chip permits considerably faster data transfer from interface to PC. In addition to the output FIFO there is further buffering is available on the interface (up to 100K bytes).

3.2 Interface Firmware Description

The firmware (i.e. controlling software) resides in the EPROM on the board. The background task of the program is to gather and process incoming ARINC data for output to the PC as shown by figure 2. All ARINC data is time stamped as it is processed. This is achieved via a two byte counter in RAM which is incremented via an IRQ (interrupt request) line derived from a timer on the CPU chip, every millisecond (see figure 3). Incoming ARINC data is gathered under interrupt control (see figure 4a) as is the transmission of processed ARINC data to the PC (see figure 4b).

Time base synchronization may be required when multiple data logging systems are being used and it is necessary to synchronize data collection. The interface outputs time synchronization (SYNC) pulse counts, viz PPS (Pulse Per Second) and PPM (Pulse Per Minute), which are time stamped. These SYNC pulses can be generated internally or externally. External PPS and PPM pulses are input to the interface via the opto-isolated control lines and the interface keeps a count of them (see figure 4b). The internal time synchronization counts are generated from a counter which is incremented every 25 ms from an IRQ line (see figure 3). This counter is never reset and provides an absolute clock. The selection of the source is automatic. On power-up the source is internal. If an external pulse arrives it is used for SYNC data and with reversion to the internal source occuring if the external source is interrupted.

The firmware must also process events, whether PC generated or external. External events are input to the interface via a control line and the interface maintains a count of these events (see figure 4b). PC generated events are sent to the interface with an event count. The program time stamps these event counts (2 bytes in length) and outputs them to the PC. It is necessary to pass these events to the interface for time stamping as there is always an unknown volume of data waiting to be passed to the PC. The PC event must be time stamped and placed in the data stream after any data that has already been placed in the output FIFO.

The final function of the controlling program is as a system monitor for the interface. It enables some interaction with the program itself for software maintenance purposes and for performance measurement. Commands can be issued and the responses monitored via the RS232 port on the interface as shown in figures 1, 2 and 4c.

Figure 5 shows the format of output sent to the PC by the controlling program. ARINC data is preceded by a uppercase ASCII "L" character followed by the two byte time stamp (in milliseconds). External PPS and PPM data are preceded by uppercase "S" and "M" characters respectively followed by the time stamp. For internally generated synchronization data lowercase "s" and "m" characters are used. External events are preceded by an uppercase "E" and a time stamp. PC events are preceded by an uppercase "P" and a time stamp.

The interface will also accept input from the PC. An example of this is the PC generated event which occurs when an uppercase "P" is sent to the interface. The PC also re-initialises the interface for data collection by sending the hexadecimal character "7F" followed by a sequence of bytes describing the new setup. In addition if the PC sends the uppercase "S" character to the interface it responds by only outputting PPS and PPM synchronization data. Finally the character "A" commands the 6303 to setup the interface for a desired standard and speed (determined by the byte following the character "A").

4.0 PC SOFTWARE

The software written for the PC based interface evolved from the software produced for the early interface. It has been written using Borland Turbo Pascal to run on IBM PCs or compatibles from the DOS* operating system. It essentially consists of two programs; one is used to log data coming from the interface (called AR_IFACE.EXE) while the other is for post-processing the data off-line (called AR_POST.EXE).

The data logging software was written for low speed serial standards such as ARINC 561 and 419. The ability of the software to cope with higher speed standards (upto 100 kilobits per second) will be affected by the speed of the processor in the PC and the rate the user wishes to log data. When high data logging rates are required the use of floppy disks as the storage medium will be impractical necessitating the use of hard disk for storage. Generally if a sufficiently fast PC is used, logging data from high speed serial standards should not present a problem.

4.1 Structure and Capabilities of the Data Logging Software

The software has been written to log data that are transmitted according to ARINC standards such as 419, 561 and other similar ARINC standards. As mentioned previously it is currently configured for ARINC 419, however only minor changes in the data decoding routines would be required to reconfigure the software to another standard. Data are stored on floppy disk rather than hard disk because it was deemed to be a more robust storage device for use in high vibration environments such as aircraft. Nevertheless the software could be readily reconfigured to use a hard disk. The program can be broadly considered in two parts; the initialization section and the runtime section. Initialization of the program also consists of a number of stages as detailed below.

The first step in the initialization is for time base synchronization. The software uses the "S" command described in section 3.2 to instruct the interface to send synchronization data. The PPS and PPM data received are used to compute a total pulse count. This count is displayed on the synchronization screen and can be modified by the user to facilitate synchronization with another system displaying a similar count. The modified count is kept by the software and stored with logged data. If this facility is not required by the user it can be ignored. The program proceeds to prompt the user to insert a formatted floppy disk on which data is to be stored.

In the last stage of initialization a series of menus and prompts permit the user to select the data to be logged and the rate at which it will be logged. This section uses the characteristic of these ARINC standards where all data must possess an 8 bit code or label. The software reads these codes from an ASCII data file called LABELS.DAT. A sample LABELS.DAT file is shown in figure 6. By modifying the LABELS.DAT file the software can be configured to log any ARINC data using the interface. The software sends the setup selected

* PC DOS is a registered trademark of IBM Corporation.
MS DOS is a registered trademark of Microsoft Corporation.

by the user to the interface (i.e. using the "7F" command described in section 3.2) which then proceeds to log data in the prescribed manner.

For each label in the LABELS.DAT file other information must also be provided. This information is required to decode the logged data. The labels are entered in the data file in octal as this is how they are often referenced in the ARINC standards. Following the labels is a three character string which describes the nature of the data. The data can be binary (BIN), binary coded decimal (BCD), status information (STA), degrees-minutes-seconds (DMS) or a packed word (PCK). For binary and DMS data two more items of information are required. First is the value of the most significant bit followed by the number of bits in the data. Finally a title describing the nature of the data is required. Only 14 characters of the title are used by the software and the rest are ignored. The data must be entered in the format shown in figure 6.

Once the data to be logged have been selected from the menus, the program will enter the runtime section. Here the user is presented with a screen that displays data being logged. It is updated once every 4 seconds so that the user can monitor data being logged.

All data collected are stored on floppy disk in their "raw" state (i.e as bytes) and the operator must change floppy disk as required. The program monitors free space on the floppy disk and when it fills, the user is prompted to insert an empty formatted floppy disk. The computer also beeps to warn the user that a floppy disk change is required. The user has a limited time to change the floppy disk as the software continues to store data in an internal buffer. If the operator is too slow in changing a disk, the buffer will overflow and data will be lost. An indicator of the buffer's state is provided on the runtime screen. Typically, on an 8 MHz PC AT with all ARINC data being recorded (at 11 ± 3.5 kilobits per second), the buffer will fill in approximately 30 seconds. The user should aim to change the disk in 15 seconds or less; a task which is readily achievable if the operator is alert. This is obviously a worst case since in an operational situation it would not normally be necessary to record all ARINC data.

The occurrence of an event can also be recorded by the software. An event can be one of two types; internal or external. An internal event is generated when the user presses the "p" key at the runtime stage. A message is sent to the interface (i.e. using the "P" command of section 3.2) containing the event count kept by the PC software. The interface time stamps the event and places it in the logged data stream. An external event is generated when the event pulse capability of the interface is in use. The interface counts these events and time stamps them for logging. Consequently each event is logged as a number (starting at 1) and the user can keep a separate record of the nature of these events.

Data that are logged onto floppy disk are stored in one large file. The filename takes the form ARINC_n.DAT where n is the run number and ranges from 0 to 99. When the software starts up the run number is zeroed and it is incremented after every data logging run. Consequently data are stored on floppy disk according to the run number.

4.2 Structure and Capabilities of the Data Post-Processing Software

The post-processing software has been written to process the files generated by the data logging software. It uses the same data decoding routines used by the data logging software to convert raw data to a usable and readable form. Using the program, data can be viewed or plot files generated for use with a plotting program of the user's choice.

When the program starts up the first screen presents the user with a number of options. The first two options allow the user to select a file to be processed (i.e. according to run number) and to set the time base (i.e. either external or internal). If the operator attempts to view data or generate a plot file without having selected a file he will be prompted to do so. If the operator does not select a time base, internal is used by default. To move from one option to another or to exit the program, the user is prompted to return to the main screen.

On the data viewing screen the user is presented with considerable information. Each line is one data point or data word from the ARINC data stream. It is presented in columns each with a title identifying its contents. The first column displays the title string of the label. When data are logged by the interface they are time stamped and this is displayed in the second column. The total time (in seconds) from the start of the run is displayed in the third column. The label number in octal and hexadecimal are shown in the following two columns. In the next column decoded data are displayed followed by the hexadecimal representation of this data. Finally the last column shows the raw data word (in hexadecimal) that is logged by the interface. This is 4 bytes in length and contains the label (i.e. 3 bytes of data and one byte for the label).

Finally the program can also be used to generate a plot file for plotting of data with generally available plotting programs. Two alternatives are offered for plot file generation. The first option is to convert all data for plotting. Otherwise the user must nominate a time interval (referenced to the time base of the data) which specifies the frequency of data conversion for plotting. At each time interval the program will convert the first occurence of each label it finds in the logged data. It continues searching the logged data until it has converted one data point for each label. Plot files are written to the user's current directory on the hard disk of the PC. The ARINC data plot file created will have a name of the form ARINC_n.PLT where as with the other file names, n is the run number. Similarly events, both external and internal, are written to a file called EVENTS_n.DAT. All events, regardless of the conversion time interval, will be written to this file.

4.3 Operating the Software

The software (i.e both programs) is operated from the DOS command line. This is done by entering the name of the program (AR_IFACE or AR_POST). Once the program is running, the various screens and menus guide the operator in using the program. The next two sections describe the operation of both programs in more detail.

4.3.1 Operating the Data Logging Software

The data logging program can be run from any appropriate medium. With data being logged onto floppy disk the user should keep a plentiful supply of formatted floppy disks at the ready especially when high data logging rates are selected. Once the program is running, various menus and screens instruct and query the user at each step. Figure 7 shows a flow chart which decribes how the program functions from startup.

As we can see from figure 7, the program proceeds through the time synchronization screen and floppy disk insertion screen to the main screen. If the user chooses to record all data at this screen then the program proceeds to the check screen. If all is satisfactory then the program proceeds to log data. Alternatively the operator can choose not to record all data and the software proceeds to the label selection screen. At this screen the user must choose those labels which are to be logged. A list of labels is presented and the arrow keys are used to move through the list while the space bar is used to select and deselect a label. Once the label selection process is complete the user presses the carriage return key to move on. At this point the user is prompted to specify if all occurences of the selected labels are to be logged. If so then the program proceeds to the check screen and, if all is satifactory, data logging can begin.

If the user chooses not to record all occurences of the selected labels, data will be logged in blocks at regular intervals. To specify the block the user must select the starting label. The program returns to the label list from which the user selects the starting label. The arrow keys are used to move through the list and a carriage return selects the label. The program then proceeds to prompt the user for the time interval between logging of data blocks. Finally the user is prompted for the total number of labels in this block. This actually specifies the number of labels in the data stream, after the starting label, which are checked by the interface. If the label is one of the selected labels it is logged; otherwise it is ignored.

Generally the ARINC data stream consists of a block of labels which repeats continuously. Labels that only appear once in a block should be selected as starting labels. In this way, data logging will begin at the same point in the data stream for each data block that is logged. Once the block size has been defined by the user the program proceeds to the check screen. If the operator confirms the selection the program proceeds to the data logging stage.

As is shown in figure 7 the user can restart the initialization process or exit the program at any time. Pressing the escape key (<ESC>) from any of the screens will cause the program to return to the main ARINC data selection screen. The user can also press the "Q" key from any screen to exit the program and return to the DOS command line.

At the data logging stage the runtime screen is displayed. The user can monitor data as they are logged and change floppy disks as required. As discussed in section 4.1, this must be done quickly to prevent any loss of data. If data is lost during a floppy disk change over the user is promptly informed. Data collection can be terminated at any time with either a reset or a quit command. With a reset the software will return to the menus where another data collection run can be started. This is done by typing the reset key ("R" key) from the runtime screen. Pressing the quit key ("Q" key) will cause the program to exit to DOS.

4.3.2 Operating the Post-Processing Software

Once the post-processing program is running the user is presented with a screen displaying five options numbered 0 to 4. Option 0 is the exit to DOS option. Option 1 allows the user to enter the run number of the file to be processed. This file name is then displayed on the main screen and as well as on the data viewing screen. Next if the user wishes to change the time base, option 2 shold be selected. On this screen the user can toggle between internal and external time base to select one of them. The user should first select option 1 followed by option 2 if necessary. The operator can then proceed to view the data using option 3 or generate a plot file with option 4.

For data viewing the user can scroll up and down through the file in various ways. Line by line scrolling is done using the up arrow and down arrow keys or page by page using the page up and page down keys. The user can also go directly to the top or bottom of the file using the control/page up and control/page down key combinations respectively. When the operator wants to move on to the next floppy disk in a run, or a previous one, pressing the escape key causes the program to prompt for the floppy disk. When a floppy disk is inserted, viewing can continue. Data viewing can be terminated by pressing the "Q" (quit) key. Viewing data from a different run requires the user to quit to the main screen and select another file.

As mentioned in section 4.2, the user can choose to convert all data or specify a frequency of data conversion. The user should consider the rate at which data was logged when generating a plot file. For instance, if all ARINC data were logged then choosing to convert all data for plotting may generate a very large plot file.

On completion of data processing activities the user returns to the main screen and may exit to the DOS command line.

5.0 CONCLUSION

An ARINC serial interface for an IBM PC or compatible has been designed and built at ARL. This design has been configured for ARINC 419/561 standards. The use of Erasable Programmable Logic Devices in the design, which as the name suggests are programmable, allows adaptation of the interface to other ARINC standards and many other serial data standards. As has already been mentioned, the card could be readily adapted to high speed serial standards of the order of 100 kilobits per second.

Software exists, for the PC, to log and process data collected by the ARINC interface. While the software is configured for ARINC 419, it is readily reconfigurable to ARINC 561. Minimal software changes would be required to adapt the software to other ARINC standards which may be accessible with the interface. Its use with high speed ARINC standards may require it to be hosted on a relatively fast PC. More significant software modifications would probably be required before it could be used to log non-ARINC serial standards.

ACKNOWLEDGEMENTS

The author wishes to recognize the contributions of all those involved in the development of the ARINC interface. Thanks are due to Dr R. B. Miller for the original concept. Design and development of the original interface was completed by Reg Worl of Engineering Facilities. Peter Futschik implemented further improvements to the original interface and completed design and development of the PC interface while Stefan Walter conducted the testing of the PC interface.

REFERENCES

1. 'Air Transport Inertial Navigation System - INS ARINC Characteristic No. 561-11,' Aeronautical Radio, Inc., Annapolis, Maryland, 17 January, 1975.

2. 'Digital Data System Compendium ARINC Specification No. 419', Aeronautical Radio, Inc., Annapolis, Maryland, 15 February, 1973.

FIGURES

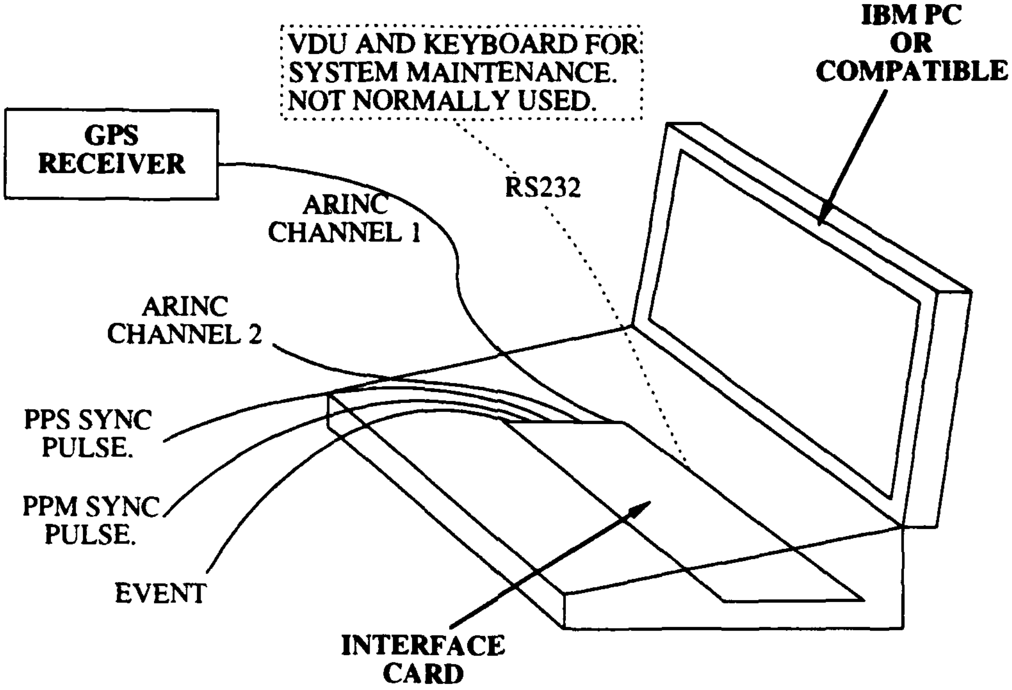


Figure 1. A typical test setup for the ARINC interface.

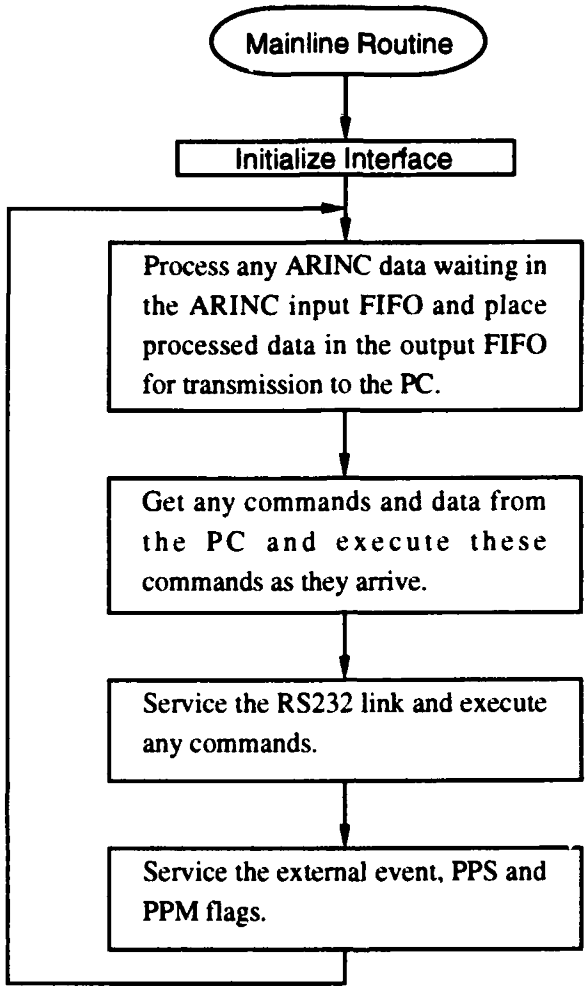
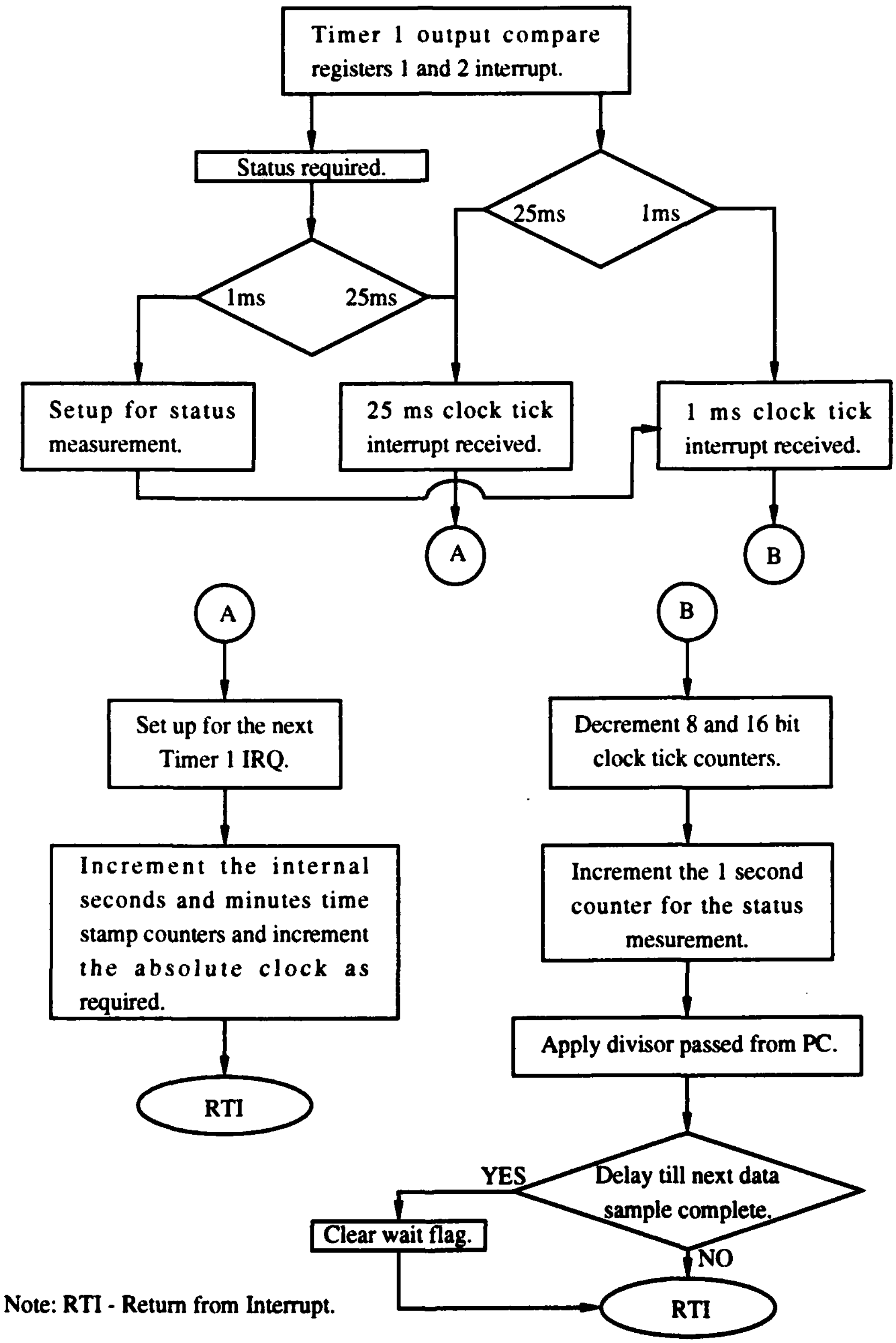


Figure 2. Main routine of the interface firmware.



Note: RTI - Return from Interrupt.

Figure 3. Timer interrupt routines.

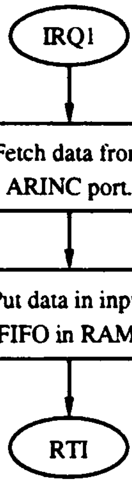


Figure 4a. Incoming ARINC data interrupt routine.

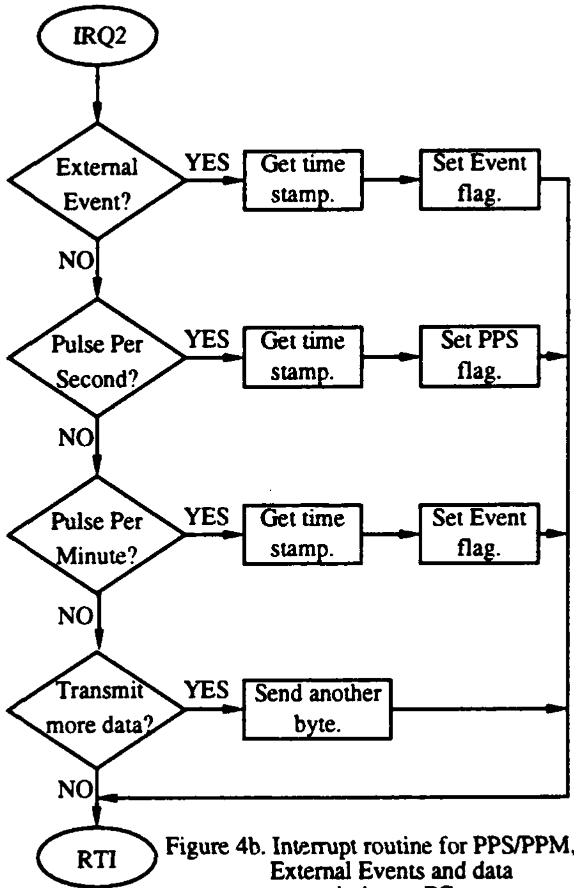
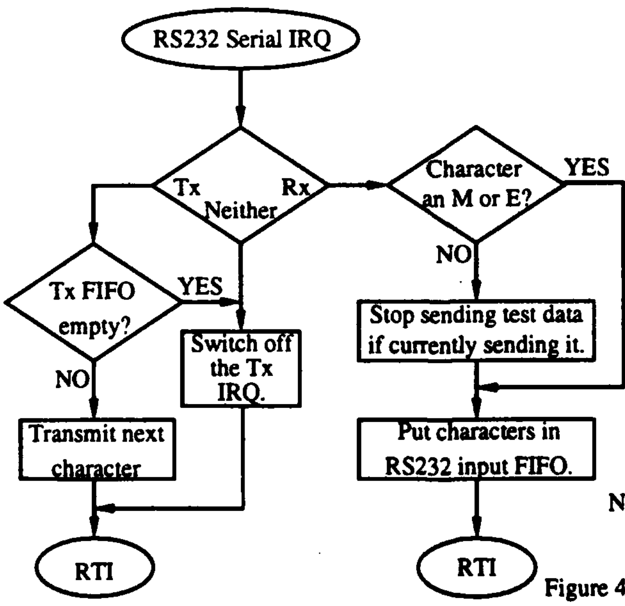


Figure 4b. Interrupt routine for PPS/PPM, External Events and data transmission to PC.



Note: Typing the character "?" will print a list of commands to the vdu.

Figure 4c. Serial line interrupt routine.

ARINC data

"L"	Time LSB	Time MSB	Label	Data LSB	Data	Data MSB

PPS (external source)

"S"	Time LSB	Time MSB	Seconds Count LSB	Seconds Count MSB

PPS (internal source)

"s"	Time LSB	Time MSB	Seconds Count LSB	Seconds Count MSB

PPM (external source)

"M"	Time LSB	Time MSB	Minutes Count LSB	Minutes Count MSB

PPM (internal source)

"m"	Time LSB	Time MSB	Minutes Count LSB	Minutes Count MSB

EVENT (external source)

"E"	Time LSB	Time MSB	Event Count LSB	Event Count MSB

PC Event (from PC)

"P"	Time LSB	Time MSB	Event Count LSB	Event Count MSB

Note: (1) Each rectangle represents a byte.
(2) LSB - Least Significant Byte, MSB - Most Significant Byte.

Figure 5. Formats of output to PC.

```
014 BIN 90.0 12 TRUE HEADING
066 BIN 1638.35   15 NTH VELOCITY
067 BIN 1638.35   15 EAST VELOCITY
010 DMS 90.0 21 LATITUDE
011 DMS 90.0 21 LONGITUDE
013 BIN 90.0 12 TRACK
012 BIN 1638.35   15 GRND SPEED
007 STA STATUS
020 BIN 90.0 12 PITCH
017 BIN 90.0 12 ROLL
314 BIN 90.0 12 PLAT HEADING
132 PCK WPT COUNTER
133 BIN 90.0 21 WPT DATA
074 PCK WPT X_FILL
030 BIN 90.0 12 MAG HEADING
031 PCK TO/FROM, XTK
377 BCD SPARE
```

Figure 6. Sample LABELS.DAT file.

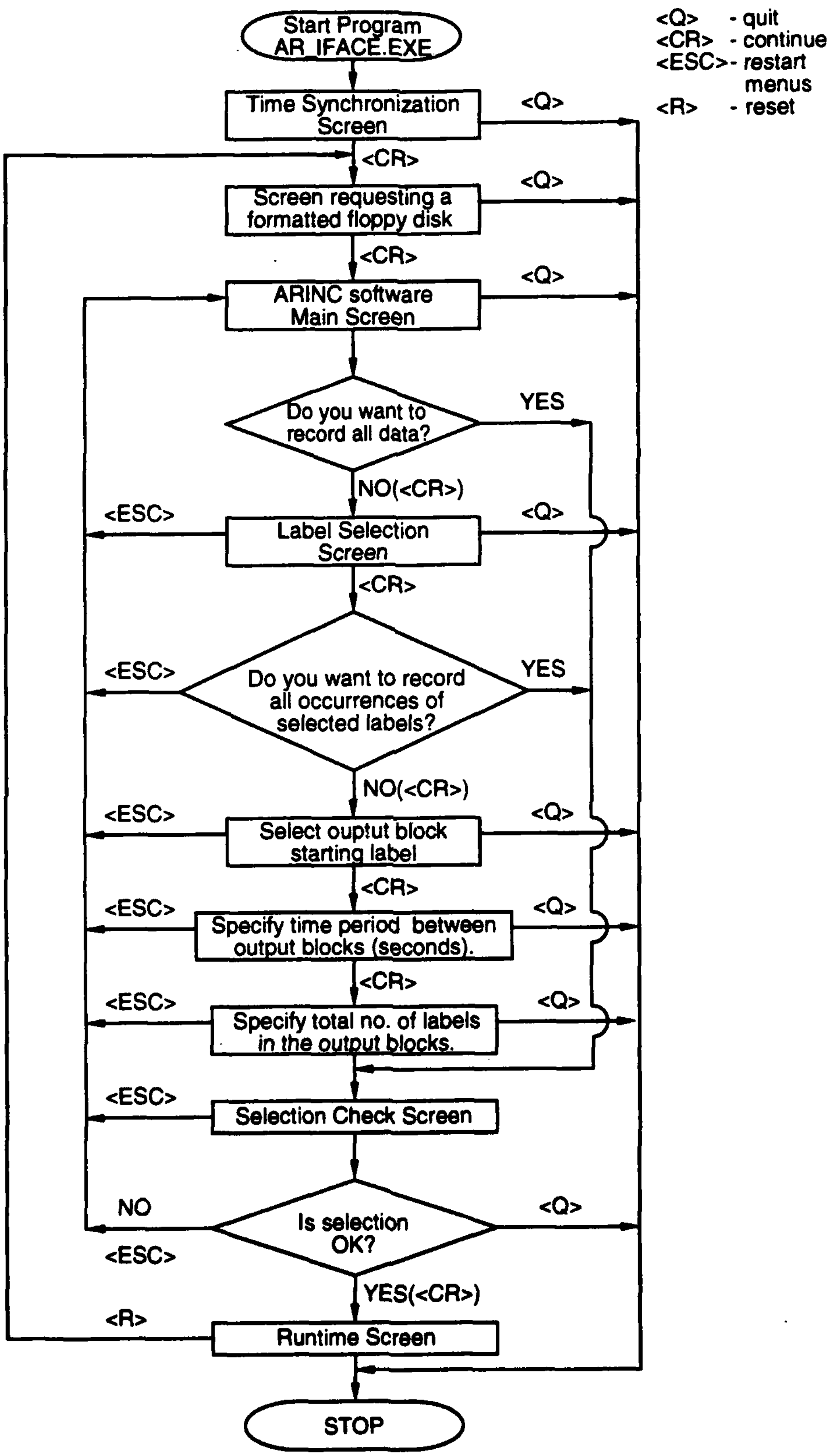


Figure 7. PC data logging software operation flow chart.

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A general purpose ARINC (Aeronautical Radio, INC) serial interface has been developed for use with an IBM PC or compatible computer. The interface consist of a PC card and software to selectively read, log, time tag and process data read from the ARINC bus. The PC card uses an XT slot and the data is written onto floppy disk or hard disk. The data logging and post-processing software has been configured for ARINC 419/561 but can be readily reconfigured to other ARINC formats. ARINC 419/561 are low speed standards dealing with systems operating at 11 ± 3.5 kilobits per second. The interface and PC software could readily be adapted to handle much higher speed ARINC and non-ARINC formats.

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