THE ROLE OF THE PC IN GROUND TELEMETRY DATA ANALYSIS

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ABSTRACT

The growth of personal computer use was explosive in the last decade. In the telemetry industry, however, the adaptation and utilization of a PC-based telemetry instrument for high-speed data processing and display did not come about until the Intel 80386™ or equivalent processors were widely used in the late 1980s. At this time, the power of these processors finally began to meet the requirement to display, store, and play back the high-speed data (such as 10 Mbps with an embedded asynchronous data stream) that is typical in telemetry applications. Many users are still hesitant to use PCS for their telemetry applications because of the real-time limitations of these instruments. This paper will examine the advantages and disadvantages of PC-based test equipment, the performance these instruments, and the future of PC-based telemetry instrumentation. This paper will also focus on Loral Instrumentation's d*STAR as an example of a PC-based telemetry system.

INTRODUCTION

In the 1970s, telemetry ground stations were composed of special-purpose equipment with discrete logic designs. These designs required racks of very expensive equipment. In the 1980s, with the advent of the microprocessor, these multiple racks of equipment were condensed into single chassis that contained multiple printed circuit boards that incorporated microprocessors, LSI chips, fast memory chips, discrete logic components, and bit slice processors.

Over the last few years, several telemetry companies have taken advantage of the advances in PC technology to design state-of-the-art integrated circuits on several PC AT™ boards that can be plugged into an IBM (or compatible) PC™. Although the PC-based systems are in some ways limited by the speed of the PC's processor, the PC's storage drive, and the AT bus, the systems provide a capable low-cost solution for a variety of telemetry applications.

ADVANTAGES OF A PC-BASED TELEMETRY SYSTEM

In parallel with the advances in telemetry instrumentation came great improvements in PC capabilities in the 1980s. Processing speed increased from 4.77 MHZ to 33 MHZ. Processor (CPU) design evolved from an 8-bit to a 32-bit architecture. The PC processors of today, such as the Intel 80286™, Intel 80386™, and their associated math coprocessors, offer sufficient processing power for many of the telemetry tasks previously handled by a telemetry front-end interfaced to a host computer. [1] For example, PCS can perform telemetry processing tasks such as engineering unit (EU) conversion and limit checking of sampled data for display purposes.

Also in the 1980s, the speed of PC memory doubled and cache designs eliminated the constraints of memory wait states. With the advent of the Intel 80286 processor in 1984[2], the designs of the PC I/O bus improved from the original 8-bit path to the 16-bit AT bus or "Industry Standard Architectural" (ISA) bus. In addition, hard disk speed increased to allow real-time data storage on the PC's internal hard disk at a rate greater than 2 Mbps.

The resolution and quality of PC graphics also improved over the last decade. PC-based telemetry workstations can take advantage of a PCS' video adapters and flexible software capabilities to provide high-quality color displays of telemetry data. The more advanced PC video adapters are the EGA (Enhanced Graphics Adapter) and VGA (Video Graphics Array). These adapters have on-board ROM that is mapped into the PC's memory space. With the EGA adapter, the IBM Enhanced Color Display is capable of a resolution of 640 by 350 with 16 colors. The VGA system is designed to display up to 262K colors.

In addition to the PC itself, the number and quality of PC peripherals have increased. This fact is important because all of the peripherals supported by the PC, including mass storage devices, communication networks, and host computers, become available to the telemetry user.

The flexibility of programming on the PC and the wide variety of commercially available data analysis packages make the PC a powerful display and analysis tool for the telemetry user. For example, data analysis packages such as DADiSP™ provide users with significant flexibility in analyzing and displaying data. DADiSP is a graphics-based worksheet that can display and manipulate 64 waveforms at once and can create a data reduction chain containing up to 65 windows of complex processing steps. DADiSP allows users to zoom, scroll, expand, compress, add grids, change scales, print, or edit waveforms.

There are other advantages to a PC-based telemetry system. For example, the disk operating system (DOS) handles file manipulation and other functions. In addition, the PC has many word processing software packages that can be used in conjunction with telemetry software. For example, graphics displays can be captured and imported directly into word processor documents for report generation. The flexibility and power of the PC, combined with its low cost, ensure that the PC will play an increasing role in telemetry instrumentation in the future. However, there are limitations in the PC that limit the application of current PC-based telemetry stations and create a challenge for system designers.

DISADVANTAGES OF A PC-BASED TELEMETRY SYSTEM

The major constraints of a PC-based telemetry system are limited processing power, the bandwidth of the AT bus, and the slow storage rate to the hard disk. These constraints limit the current applications of these instruments and call for innovative designs to circumvent or overcome the limitations.

The power of the current processors in the PC limits the ability of the PC-based telemetry system to do real-time limit checking and engineering unit conversions on every sample of each parameter at high data rates. Although current bit synchronizers and decommutators can handle data at rates of up to 10 Mbps, the processing of the PC's CPU is typically limited to the sampled data that is displayed. Special purpose processor boards which plug into the PC are necessary to overcome this limitation. Another approach is to use another real-time telemetry front-end to acquire the data and pass it to the PC for display, storage, and postanalysis. This approach does provide a viable solution for a number of applications, but the system is then burdened with the cost of the front-end in addition to the PC and any hardware and software required to interface the two elements.

Although 32-bit processing became available with the introduction of Intel's 80386 processor, most PCS still use the 16-bit Industry Standard Architecture (ISA) bus. This use significantly limits the performance of the PC. To solve this problem, a consortium of large PC-compatible manufacturers jointly developed a new high-performance, 32-bit Input/Output (I/O) bus called the Extended Industry Standard Architecture (EISA) bus. This bus is compatible with the ISA bus in all areas including physical specifications, DMA, and bus mastering, so that all ISA cards fit into EISA connectors. The EISA bus has superior data transfer rates, enhanced memory capability, improved DMA modes, and numerous other benefits. IBM also produces a 32-bit bus called the Micro Channel Architecture (MCA) bus. Telemetry PC cards of the future must take advantage of the higher data transfer rates of 32-bit or higher buses.

The storage of telemetry data to the internal hard disk is limited by the access time of the disk, the bandwidth of the AT bus, and other factors. Current designs have obtained real-time storage of telemetry data at rates of up to 2.5 Mbps. As PC technology advances in this area. the storage rate will become less of a bottleneck.

DATA STATION FOR ANALYSIS AND RETRIEVAL

An example of today's PC-based telemetry systems is Loral Instrumentation's d*STAR, for Data STation for Analysis and Retrieval. d*STAR is a PC-based personal ground telemetry workstation that includes a bit synchronizer, decommutator, simulator, time code translator, and analog outputs. The bit synchronizer and decommutator serve as a front-end for the PC workstation that is used for analysis and display. d*STAR's primary advantages are its high-performance front-end, quick-look capabilities, and postanalysis capabilities. In addition, d*STAR's software takes advantage of the flexibility of the PC, and utilizes pop-up windows, pull-down menus, and context-sensitive help screens.

The d*STAR bit synchronizer accepts data at rates of up to 15 Mbps. (This data rate exceeds that of the decommutator since the bit sync can be used in applications independently.) It reconstructs a serial PCM signal that has been degraded by noise or distortion and creates a coherent clock. A block diagram of the d*STAR bit sync is shown in Figure 1. The bit sync handles all IRIG codes and operates within 1.5 dB of the theoretical bit error rate. The bit sync utilizes a digital design, which eliminates the need to recalibrate since digital components do not drift. In addition, the bit synchronizer locks onto the signal 10 times faster than traditional analog bit syncs, typically within 10 data transitions.

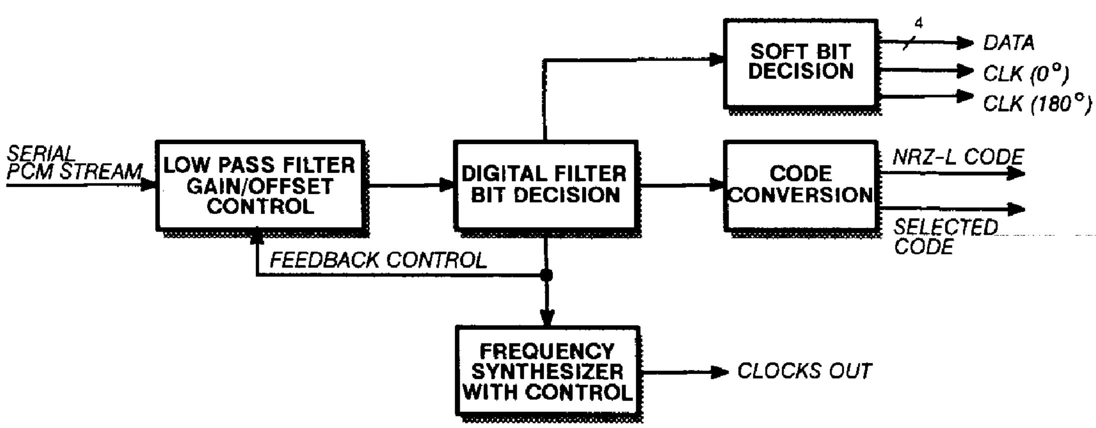


Figure 1. Bit Sync Block Diagram

The d*STAR decommutator operates at data rates of up to 10 Mbps and handles embedded asynchronous data streams, without requiring any additional hardware. The decom accommodates large formats of up to 32,000 words in the major frame, and complex frames with embedded and embedded subframes. The decom board also includes a simulator that exercises the primary modes of operation of the decom, assists in software/data base development, and is used for the system self-test.

The decom card synchronizes the serial data from the bit sync and stores the data into dual-port RAM that is shared by the PC. A block diagram of the decommutator/ simulator card is shown in Figure 2. The synchronization functions are performed by multiple bit correlators with corresponding PAL state machines. The data storage functions are determined by the primary control, embedded control, and address RAM. The control RAM determines the number of bits in each word in the frame and specifies the significance of each field's location (e.g., frame sync code, subframe ID, end of buffer, etc.). The address RAM determines where each field should be stored in the dual-port data RAM.

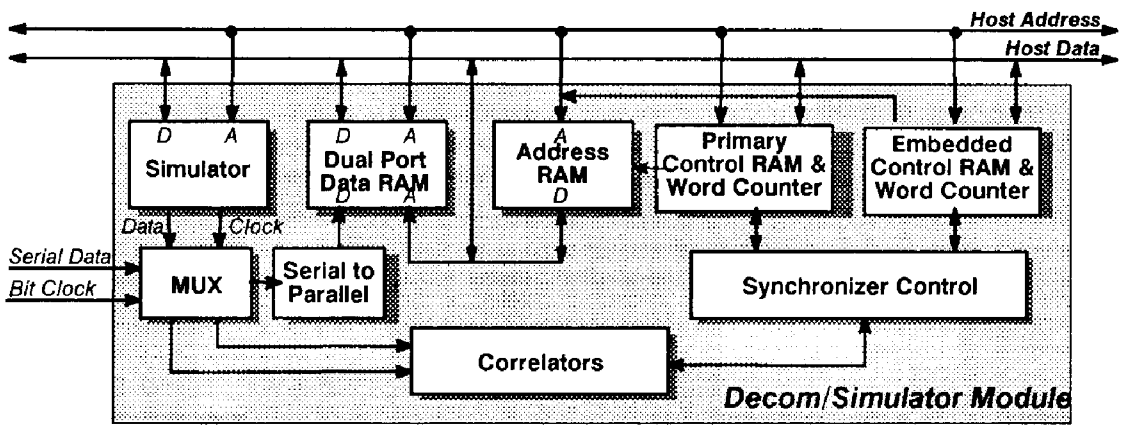
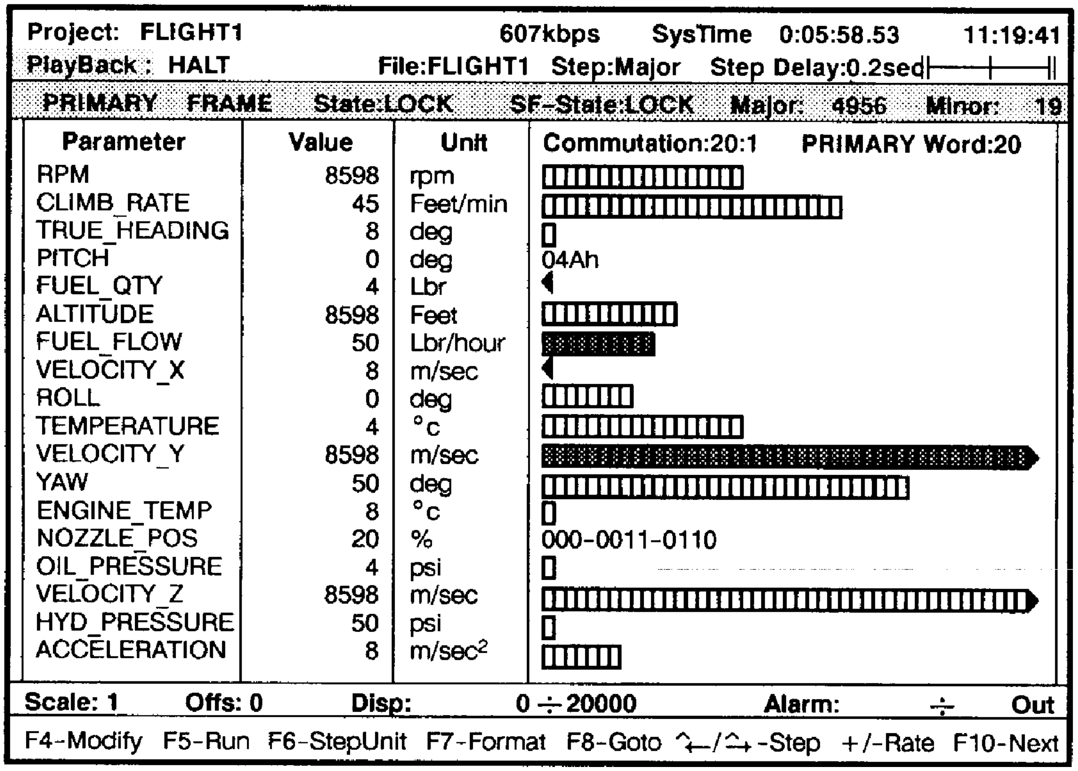


Figure 2. Decom/Simulator Module Block Diagram

One of the biggest advantages of a PC-based telemetry workstation is the ability to store the incoming data onto the PC's internal hard disk for later analysis. d*STAR stores all or selected parameters and the lock status at data rates of up to 2.5 Mbps. In addition, the PC supports the storage of data to an external hard drive for applications with requirements for extensive data storage.

d*STAR utilizes the EGA/VGA adapters of modern PCS to generate color bar charts and graphs for quick-look, in real time or during playback, of key parameters during a telemetry test. In d*STAR's numeric mode, a user can view parameters in engineering units, and create an additional color bar chart or a binary or hex display of the same data that highlights alarm conditions in red. The numeric mode display is shown in

Figure 3. The user can change the EU scaling, display range, and alarm limits on-the-fly. The update rate of the display is greater than 10 Hz and depends on the power of the PC.



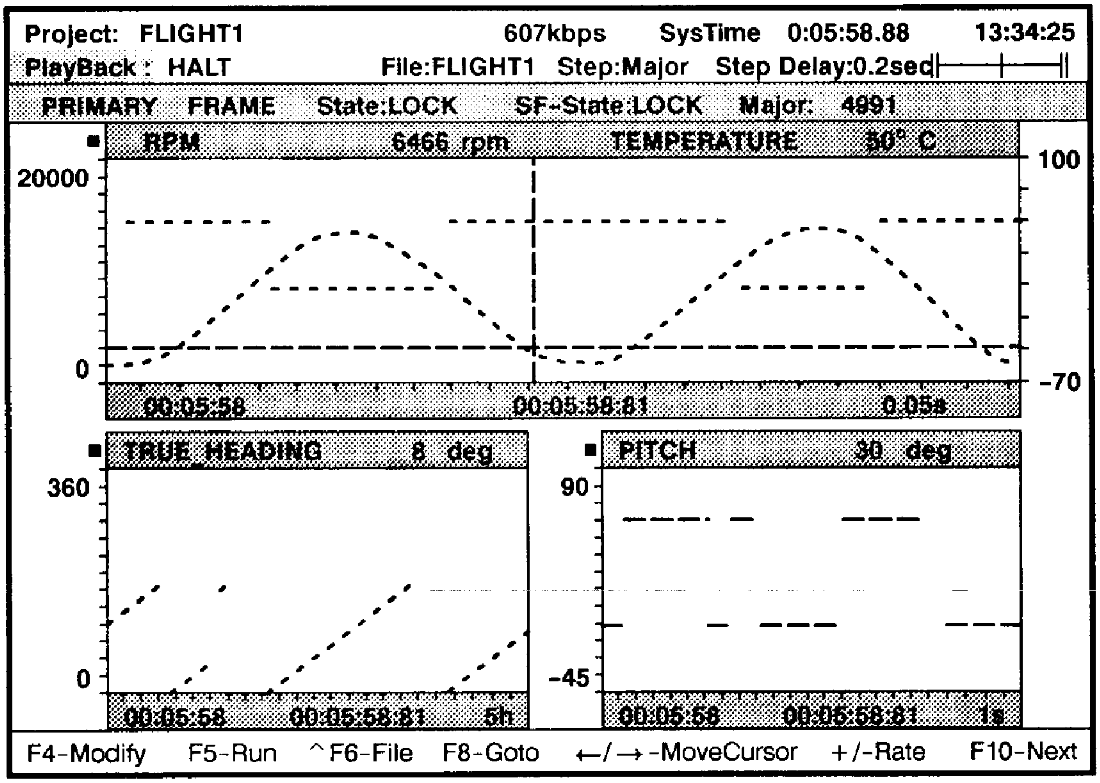
This numeric mode display page shows parameters in engineering units, color bars binary, and hex.

Figure 3. Numeric Mode

d*STAR uses the same displays to show both real-time and playback data, so a user does not have to define separately the scaling and display setup for each. While data is played back from the PC's internal hard disk, a user can control both the display rate and step size (in words, minor frames, or major frames) between successive values and can step forward or backward through the data, play the data back at the desired rate (and step size), or jump to a certain time, frame number, or marked position. During the test, upon the occurrence of an interesting event such as a parameter turning red, the user can mark positions in the data on the hard disk by pressing the F6 key. This flexibility in analyzing the data after the data is captured allows the user to evaluate quickly key events that may have occurred during a test.

In graphic mode, d*STAR's three levels of "zoom" allow a user simultaneously display up to four graphs, or fill the screen with just one graph. The graphic mode display is shown in Figure 4. Alarm limits are indicated by a color line on the graph;

the parameter's data points are plotted in red if the value is in the alarm range. One or two parameters can be plotted per graph. An additional graph can be stacked behind each graph so that a user can toggle between the two. The time scale of each graph can be changed easily from 0.01 seconds to five hours. In both real time and playback from disk, a user can "freeze" the graph to analyze the data in detail, using "cross-hairs" to travel across the graph to point at and display data values versus time.



In this display page, the graph with parameters RPM and Temperature has been expanded (zoomed) to half the screen and "cross-hairs" point to a specific value.

Figure 4. Graphic Mode

CONCLUSION

The future of PC-based telemetry systems will be even more exciting than the recent past. As PCS become increasingly powerful and workstations less expensive, the distinction between the two will begin to disappear. UNIX is already being installed in PCS for heavy-duty, multi-user environments.

Advances are already underway in PC processors, the PC I/O bus, and networking that will be utilized for the telemetry systems of the future. The Intel 80486™ processor is currently becoming common and will be closely followed by the 80586™. These faster processors will allow greater throughput of calculations such as engineering unit conversions and alarm checking. Telemetry cards will utilize improved buses, such as the Enhanced Industry Standard Architecture (EISA) bus or IBM's Micro Channel Architecture (MCA) bu to take advantage of the 32-bit data pathway and other capabilities. PC local area network (LAN) use is rapidly becoming widespread. The PC-based telemetry system of the future will share real-time data in transparent way so that users can be located in different areas of a large facility and use LANs or modems to access different data from the same data stream for later analysis.

As computer software and hardware evolve, it is clear that the importance of incorporating emerging standards is essential to avoiding rapid obsolescence. The future of evolving standards is uncertain, but it clear that successful players in the telemetry industry will increasingly utilize standard hardware platforms, such as the PC, and widely accepted software as a base for their designs.

REFERENCES

1. Nelson, Wade and Shurtleff, Diana, "Bridging the Gap Between Telemetry and the PC," Proceedings of the International Telemetry Conference, Volume XXIV, 1988.

2. Mueller, Scott, "Upgrading and Repairing PCS," Que Corporation, 1988.