BENEFITS OF USING
A PROGRAMMABLE ARCHITECTURE MULTIPROCESSOR
IN A REAL TIME TELEMETRY SYSTEM

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ABSTRACT

Designing and constructing a real time telemetry system for unique applications can involve considerable time to evaluate, choose, acquire, and interface the necessary elements. The use of a highly versatile single chassis telemetry acquisition system can reduce or obviate the need for external pre- or post-processors as well as the potentially difficult hardware and software interfacing. It also results in an easily upgradable and generally modifiable system from the development phase, through delivery, and on site by both the designer and user. The basis of the system described here is a parallel/serial multiprocessor whose architecture is programmable.

INTRODUCTION

A survey of the functions commonly performed by telemetry systems and other external requirements can be used to characterize the nature of the equipment which might serve the largest set of applications. These functions often conflict requiring compromises in equipment or capability. This is particularly true when new equipment is to be integrated into existing systems. When more of the total function can be integrated, physically and electronically, fewer compromises must be made, the system requires less time to manage and configure and new requirements, whether anticipated or not, are more easily accommodated.

The result of reviewing these functions has led to construction of a single chassis multiprocessor for both real time and other telemetry applications.

TELEMETRY FUNCTIONS

The functions may be represented in three broad categories which are usually executed in approximately serial order. The character of each, and its relationship to other functions in the system define implementation. The functions include input processing, intermediate processing and reprocessing, and destination processing.

Input Sources

The first category is concerned with the acquiring of information from a variety of sources of generally well defined form. The form may or may not require extensive processing to extract its intelligence. Sources commonly include direct analog data, digital data whose original source is PAM, digital PCM data whose original source may be analog, and other digital data sources. One source of data, time, requires special mention. Time often governs all processing of telemetry information. It may constitute a separate source or may be implicit in one of the other sources. In the latter instance it may be separated at an earlier stage thus effectively constituting a separate source with its own characteristics.

The PCM certainly requires the most complex initial processing and likely the highest bandwidth. Its processing is also the most difficult to specify in a sufficiently general fashion so that its programming is not intolerably burdensome. Two additional difficulties are variation of the overall PCM bandwidth and the variation of the rate of delivery of data from each original source in the stream. The latter has implications not only for the PCM decommutation but the processing of the PCM output as well. Other digital sources will require little initial processing.

The initial processing of analog data will consist mainly of amplification and filtering. Depending upon what use is to be made of this data further conversion to digital form may be required.

General Processing

The foregoing suggests the requirement for several input processors each designed to convert its incoming source to a common form. Once the data have been assigned some suitable common form it is ready to have analytical or form conversion procedures applied to it. This second category is then the general processing of data from the various sources. The nature of the transformations applied to the data clearly depends upon both what use is to be made with the information and what information is actually available in the source. It is not uncommon for portions of the incoming data to describe what is currently available. For example, PCM data often incorporates information about what data are being provided at the moment.

Although the decisions as to what procedures are to be applied to the data are normally made prior to beginning its acquisition an even more sophisticated system would allow analysis of certain of the data to define or modify what procedures are applied. This type of analysis implies the necessity for temporary storage of intermediate results.

Among the procedures which may be applied are filtering (including such processes as data compression), Fast Fourier Transform (FFT), scaling and data type conversion, and packing and unpacking of data from several channels within a source. It is also commonly desirable to apply more than one procedure to a given information channel, perhaps to ultimately present it in more than one form. This may be done immediately or may require delay until more information is available. This implies the necessity for temporary information storage. If the further processing is substantially different in character, or if the total procedure requires very different methods it may be desirable to pass information to a completely different type of processor.

In order to accommodate this range of processes and time constraints in a real time system it is necessary to have several processors each with the ability to handle certain types of procedures. General purpose processors as a rule will not be as fast as one with a more specific purpose. Also, the ability for these processors to operate in parallel will augment the volume of data which can be processed.

Output and Interface

The final dispersion of the data comprises the last category. Typically the data is formatted and recorded, processed or unprocessed, on temporary or permanent media. Video displays, strip chart recorders, various types of plotters, magnetic tape, and various magnetic disks are common. It may be desirable for some of these devices to be an integral part of the system. In addition, there may be a requirement to directly pass data to a large mainframe computer.

A REAL TIME TELEMETRY DATA PROCESSOR

The 2110 series Telemetry Data Processors (TDP) combines all of the above abilities into a single 7 inch high chassis, including its own power supply. A variety of configurations are available most of which are comprised of plug in PC card sets.

Unique data source identification is the central property around which the system is designed. As will become evident, it provides for complete specification of processing of the source data until its delivery to a destination.

Input Processors

PCM DECOMMUTATOR. The PCM decommutation computer consists of 5 to 8 cards with the capability to support mainframe plus 1 to 6 subframes. Up to two streams may be included. The computer has a unique instruction set oriented to the task of PCM decommutation with up to 8096 words of program memory. The processor can accommodate input bit rates up to 11 MHz. The mainframe sync may consist of up to 64 individually maskable bits. The mainframe processor also supports alternate complement sync, correlation and sync strategy thresholds, odd/even parity, msb/lsb, autopolarity, 3 bit sync window, and input source selection. Subframes sync includes recycle sync and ID sync in binary, bcd, count up, count down, and jam modes.

A unique feature is that the input data is treated as a serial bit stream allowing the stream to be broken into words 1 to 32 bits in length. When both clock and data are provided the data rate may vary from 0 to the maximum rate. Both TTL and differential inputs may be supported. The decommutated data is output as uniquely ID tagged data. ID’s are programmablely defined in the range 0 to 8095 with data words of 1 to 32 bits. ID’s may be reassigned under program control.

ANALOG SECTION. This input processor directly accepts up to 32 channels of analog data. Each ADC (up to 12 bits) is individually programmable for rates to 200 kHz and delivers its data with a unique ID.

TIME PROCESSOR. Although time may be a part of the PCM stream it may also be accepted separately. Both serial and parallel time are accepted and ID tagged for delivery. The time may be inserted into the data stream resolved to tenths of milliseconds.

DIGITAL PORTS. Digital input ports are provided which will deliver data with fixed ID tags in settable blocks or input already tagged data. The latter may be used to acquire multiple PCM streams decommutated in another chassis. Programmable Format Synchronizers (a variation of the TDP) using the PCM computer described above, supporting two PCM streams, each can be used for this purpose. Another common data source for the digital port is decommutated PAM data. A Programmable Analog Synchronizer is available for extracting PAM data and delivery of tagged data to the TDP digital port.

FEEDBACK PORT. This input does no processing but rather provides a data path for data partially processed by any downstream processor and information initiated by any processor other than one of the input processors.

Distribution Section

DISTRIBUTION PROCESSOR. All of the input processors and the Feedback Port present their tagged data to the distribution section. The function of this section is to accept the information and pass it to downstream processors. This is accomplished using a programmable memory. The program defines, by ID, what type of data is associated with the ID, what processor is to receive it, what procedure is to be performed upon the data, constants and pointers to intermediate data storage, and where the processed data is to be delivered. The memory may also provide temporary data storage. The memory is sufficient to accommodate all 8095 ID's.

This processor and existence of data paths between processors provide the flexibility of the machine. Since any tagged datum can be returned to distribution with a new ID (tag), the eventual output data stream can carry differently processed data with separated tags from the same input source. Consider the following example. Suppose that some word in a PCM stream, of arbitrary length, has meaning both as a word and as groups of bits within the word. The PCM decommutator could be programmed to extract the entire word and send it to the distribution with some tag. The word could then be passed to one of the general processors which might send it to the output stream with the same tag. At the same time the general processor could extract the relevant groups of bits and deliver them to the distribution with new tags for which other processing could be specified. This process could be inverted with the PCM decommutator breaking up the word into separately tagged words and the general processor used to reconstruct and retag desired groups. The choice would depend on the PCM input rate and what processing was required. Where very high input rates and extensive processing are involved, the multiprocessor structure and the reprocessing capability allows the machine to be configured to adjust the processing workload.

General Processors

The general processors perform the bulk of data analysis and formatting. They are generally programmable and accept their data from and under control of the distribution section. Results may delivered directly to destination (output) devices, directly to other processors, or back to the distribution section via the Feedback Port.

HIGH SPEED ARITHMETIC PROCESSOR. One or two of these programmable bit slice processors, each occupying three PC cards may be inserted in the chassis. The program consisted of 64 bit microcoded instruction with an instruction time of 180 nanoseconds. A subsequent version of this processor is expected to have local data memory and substantially faster execution time.

The program memory is divided into fusible ROM and RAM. The ROM may contain a standard set of 42 algorithms or specially developed algorithms. The RAM portion is available for the additional special algorithms which may be provided or may be developed by the user. Execution time is the same for both types of memory. This processor is commonly provided with an output formatting algorithm which may be made to replicate a format already in use. This facility is ideally suited when the TDP is being used to replace older equipment as it minimizes or eliminates the need to modify existing equipment. Also, since the formatting algorithm may reside in RAM, future changes are easily accommodated. Multiple formats can also be supported.

Because of the time input processor the output format can include time annotated, tagged data with tenth millisecond resolution. Also major time of day data can be inserted into the output stream at intervals. Data recorded in this form is appropriate for further processing and latter reconstruction on various plotting equipment.

FFT PROCESSOR. A Fast Fourier Transform (Butterfly) processor can also be provided which resides on a three PC card set. This processor is microprogrammable for any transform size from 2 to 2048. It normally is preprogrammed for 32 point self test operation and 1024 point normal operation.

MICROCOMPUTER. A sixteen bit microcomputer which provides the interface between the operator and the front panel controls and all other devices in the TDP. It is also provides the interface between a host system and the TDP and between the TDP and such upstream input devices as the Programmable Format Synchronizer or Programmable Analog Synchronizer. The microcomputer is given the ability to program and control all of the devices in the TDP. The latter is the basis for integral self test procedures. The tests are conducted by operator command from the front panel controls.

The microcomputer can also be used as a general processor. As such the processor is particularly suited to low rate applications such as final formatting and control of visual displays. All of the data paths available to the other general processors are also available to it. Hence, in addition to basic control and interface software, this device may contain substantial custom software. To fulfill these functions, the microcomputer is fitted with 128k bytes of RAM and EPROM.

Output and Interface

The TDP is designed to operate independently as a stand alone device or in an integrated system under the control of a host. The latter is most likely a computer which may control the setup of a complete ground station facility. Communication with a host can be implemented on a variety of standard interfaces or specially designed for unique existing facilities. Specifically, the digital output data stream may be directed on the digital output bus to any of 3 channels each of which supports 4 port addresses. The data stream may be under DMA control. The digital data may also be directed to a DAC bus whose address field may be unique or may address all DAC's simultaneously. The latter is principally for execution of calibration functions. In addition to the digital input ports, other communication is provided via the microcomputer. Implicitly supported are both parallel and serial interfaces for communication with such devices as a system host, micro-floppy, and terminals, and a parallel interface for both upstream and downstream devices under the control of the TDP. The channels may also be operated under DMA control.

PROGRAMMING

While it is possible to completely program all elements of the TDP from the front panel, in practice the complexity and size of the necessary programs to do all but the simplest data acquisition makes such a task impractical. Moreover it requires considerable knowledge of each of the processors and their interfaces. Even a sophisticated user would not care to occupy himself with this task which while complex is fixed and well defined. The burden is therefore placed upon a System Setup Compiler which is based upon a language natural to the way information is processed in the TDP.

The compiler is source device independent and can be communicated with over any type of interface supported by the TDP. It accepts ASCII text input which it converts to the required operational programs and optionally provides program listings and symbol tables. It also supports setup of upstream devices such as the Programmable Format Synchronizer and Programmable Analog Synchronizer. The most common interface for the compiler has been RS232 from both terminal and a host computer and micro-floppy disk (the TDP can include a floppy controller). In the latter case a binary image of the of the memories can be transferred to the disk creating a library of setup files.

All aspects of the TDP capabilities are within the control of the System Setup Compiler and hence the user. PCM decommutation, the data processing and data path (including output bus and device selection), and setup of upstream and downstream devices are all accessible. Programming of the data processing extends to devising and specifying algorithms for the High Speed Arithmetic Processor. The user is no longer limited to a preselected list of processes but may use his own talents to meet changing situations and requirements.

Where the acquisition tasks are few and not likely to change, their specification can be imaged in the microcomputer memory and loaded from the front panel. Setup may also be imaged in electrically alterable ROM's. This technique is used in one particular application noted below.

INTEGRATION OF THE TDP IN A PARTICULAR SYSTEM

As an example of the versatility of this processor, a brief description of its incorporation into a system with a unique application will be described. This system, the Bar Chart Monitor, was developed under contract to the NASA AMES research facility at Moffet Field. The application requires driving a real time display of various functions of the input data and passing data to DAC's for recording equipment. Figure 1 is a photograph of the system prior to installation showing the display during acquisition. Figure 2 is a block diagram of the system showing those data and control paths actually used in this implementation. This is effectively a selection of the architecture which will vary from system to system.

The input sources are 2 PCM streams and 64 analog channels. Each PCM had to accommodate variable word lengths at rates to 125 kilowords per second and a maximum bit rate of 2 Mbits per second. No subframes were required but supercommutation was included. Each PCM source also had a flag incorporated into the data which described whether or not the data was valid. Each frame was either entirely valid or invalid. Data in an invalid frame was to be rejected. The analog sources and DAC outputs are provided with programmable filter/amplifiers. The display is a color coded bar graph for functions of up to 50 sources. The bars can be individually programmed to change color at two preselected values to reflect critcal transitions. Each bar is labeled with a source color coded 3 digit number below the bar. Each source in the PCM streams and analog input had to be selectable for processing by five arithmetic functions, scaled, and presented to an arbitrarily selected position in the display at 2 possible update rates. All five functions were to be simultaneously selectable for any source. In addition, the programming of the analog filter/amplifiers and passing of PCM data to the DAC's was required.

An appropriate color graphics terminal and keyboard was selected and interfaced via the TDP's RS232 port and DMA. The filter/amplifiers and ADC's were housed in a separate chassis with integral power supply connected to the TDP by control and data busses. An 8096 word Electrically Alterable memory was included sufficient to retain 16 complete system setups.

Software for the microcomputer was generated to provide a menu driven setup programming environment including program storage and retrieval and setup error checking. Some menus provided status summaries of the setup. Where possible all parameters, including menu selection, were made selectable via single key strokes. The arithmetic functions involved a number of unique processes including calculation of the RMS value over a 10 second window. The major burden for the arithmetic processing and data rejection was given to the High Speed Arithmetic processor. It was designed to provide tabular data for each required function and source channel at 1/2 second intervals, the data being stored in the distribution memory. The microcomputer then read the tables at each 1/2 second boundary, executed the window processing, and formatted and transferred the results to the display.

SUMMARY

The diversity of functions necessary to convert telemetry input to useful output and the time constraints of a real time system lead immediately to consideration of a multiprocessor architecture. A multiprocessor not only permits parallel processing but allows each processor's design to be limited to a small set of similar functions. This generally reduces the complexity and increases the speed of each processor. Moreover the interfacing of what may have been several pieces of equipment is now implicit and need not considered by the system designer. In this particular machine the unique ability to effectively adjust the architecture to suit the processing workload leads to considerable versatility and power. The physical arrangement in a single chassis with an integral power supply results in a portable system suitable for range safety applications.

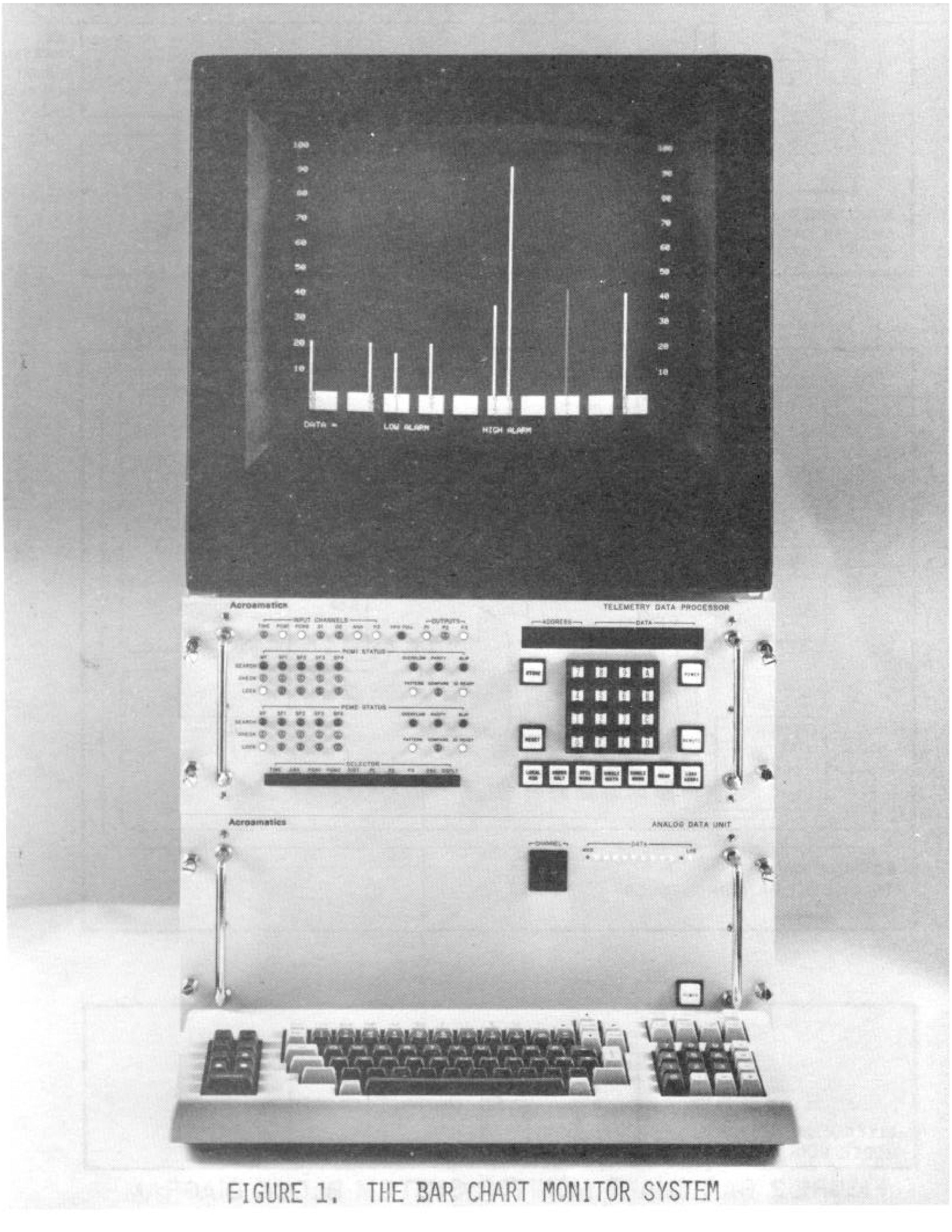

FIGURE 1. THE BAR CHART MONITOR SYSTEM

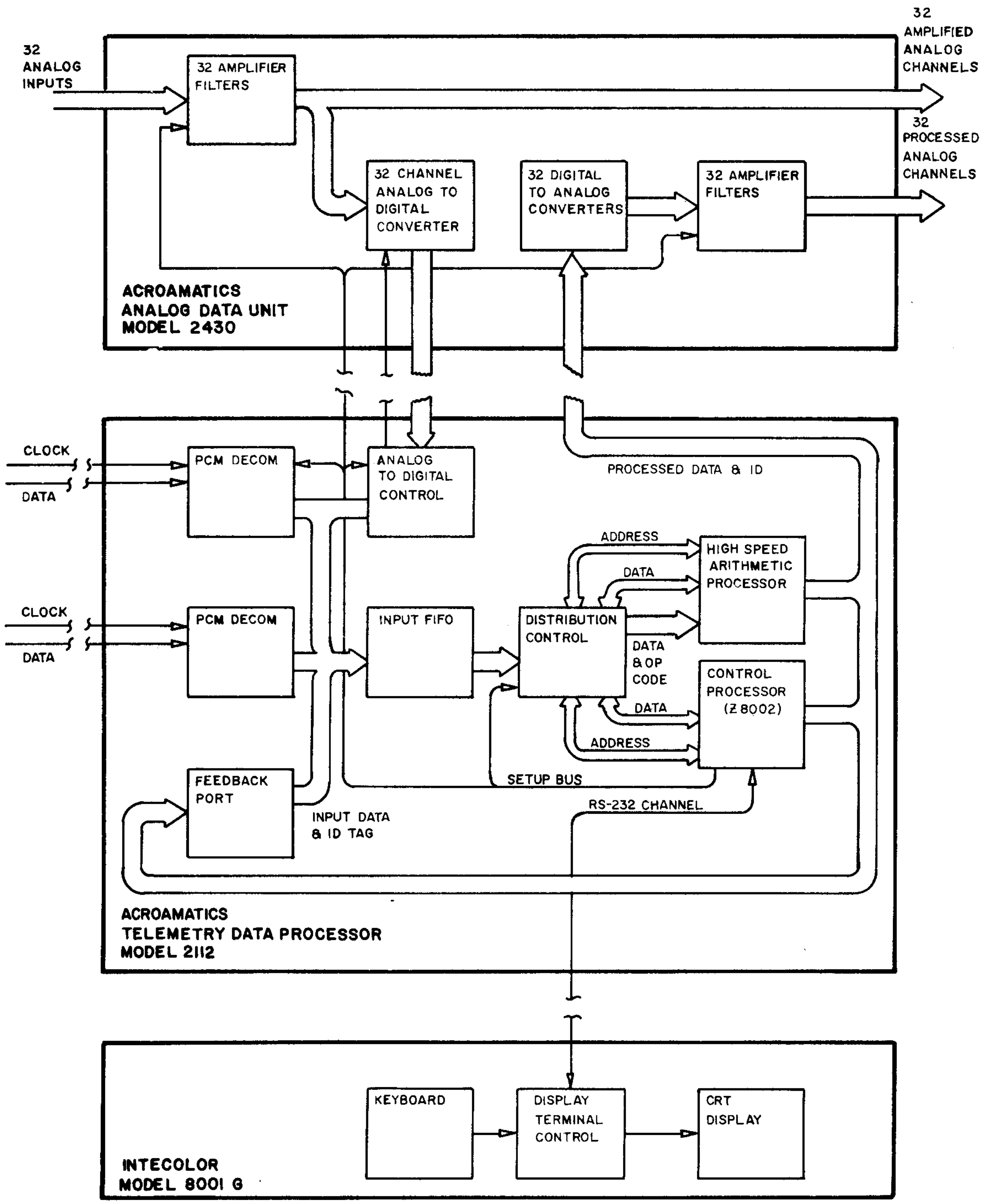

FIGURE 2 BAR CHART MONITOR SYSTEM BLOCK DIAGRAM