# A HIGH DATA RATE TELEMETRY PROCESSING SYSTEM FOR THE HIGH SPEED TEST TRACK AT HOLLOMAN AFB


Troy E. Scoughton
Senior Systems Engineer
Physical Science Laboratory
New Mexico State University
Box 30002
Las Cruces, NM 88003-0002

Robert Danford
Vice President
Acroamatics
122 E. Gutierrez Street
Santa Barbara, CA 93101



## ABSTRACT

The system covered in this paper is the Telemetry Processing System (TPS) designed and installed for processing data acquired from high speed test sleds at Holloman AFB, NM. Because this facility operates as a test range, testing sleds from many different agencies for a variety of different purposes, prior knowledge is not always available concerning the instrumentation on the test sled to be used and therefore the type of data retrieval and processing required. The TPS must then be capable of acquiring and processing multiple data types including PAM and PDM, multiple FM streams (72 channels) and high speed PCM (4 channels) . Additionally, the requirement has been imposed for 3.2 Msample/sec analog-to-digital conversion capability for high resolution measurement of certain analog data (10 channels). When the above data are multiplexed with three time sources, eight channels of sled positional information and operated at maximum rate, the raw data exceed 15 Mbytes/sec. Depending on the scheme used to tag the samples, time stamp the data, and convert the data to engineering units, the processed data rate could have exceeded 100 Mbytes/sec and therefore the reasonable limit of existing telemetry processing technology.

The TPS requires not only the capability to acquire and record this very high rate data, but also the realtime display of selected measurements. Further, the acquired data must be readily available immediately after the test for quick look evaluation, and for data selection for archival storage. This paper will explore the design process that allows the system to meet these requirements using mostly off-the-shelf or only slightly modified equipment by making clever compromises and effective use of stream separation. The paper will explore the hardware and software considerations which were examined and the solutions implemented in the final design. Development and integration of this system are currently underway, with delivery scheduled for later this year.

## INTRODUCTION

The acquisition of telemetered data from multiple sources has classically been handled by tagging and time stamping that incoming data, then sorting it as required. Any realtime display was a matter of searching for and out-putting the tag or tags of interest. This is a clean and comfortable approach for most low speed applications but requires a considerable overhead that may exceed 500% (10 bytes of overhead for every 2 bytes of data) or more reasonability 300% (6 bytes of overhead for each byte of data).

As data rates increase to the present state-of-the-art telemetry systems, the approach of tagging and time stamping each piece of data can become staggering. The increased processing rates and storage required to accommodate the additional overhead are often enough to require a system much faster and more capable (expensive) than anticipated and will in extreme cases push the required performance beyond what is realistically available.

## THE IDENTIFICATION TAG

The identification tag is required when many sources of data are merged on either a common bus or common storage medium. Some method of tracking where the data originated is necessary.

Many systems incorporate a separate tag or I.D. bus but even so that tag must be processed somewhere and, if the data are stored, the tag too must be stored.

The number of possible tags in a system is dependent on many factors but of most significance is the number of unique data types to be tagged. Assuming the least reasonable size as a byte (8 bits) , a 1-byte tag could only represent 256 unique inputs, a fairly limited system in these days of a single PCM stream having thousands of measurements. The next reasonable division is the 16-bit tag, allowing 64 K measurements. This seems to be a fairly reasonable choice for most modern applications but will still impose limitations if every piece of incoming data is to be tagged (eg. , each unique word in a PCM map).

Based then on the above assumption of a 2-byte tag, the overhead will be 100% for most inputs, with the possible exception of an 8-bit input such as an 8-8-bit PCM word where the overhead will be 200%. Words smaller than 8 bits are uncommon and will not be considered for this discussion.

## THE TIME STAMP

If the incoming data streams require a tag for identification, they will likewise require time stamping for correlation (between streams). The time stamp used can vary from some form of delta timer to the more standard IRIG A & B standards. If the latter is used, the complete representation can require as many as 64 bits for each stamp. A more realistic time stamp for incoming data would be one that has been derived from the IRIG time stamp and compressed into 32 bits to reduce the percentage overhead. If, however, a higher resolution is required such as the 1-microsecond tick of IRIG G, more than the minimal 32 bits would be required to present enough time information (on the order of 44 bits or 6 bytes). Many systems would require this to be filled to 8 bytes to allow for transfers on an even (or odd) word boundary.

The overhead incurred then for time stamping could be as small as 200% using a compressed form of IRIG time and given 16-bit inputs or as high as 800% for an 8 bit input with the full 8-byte time word.

## TOTAL OVERHEAD

The total overhead then for a 100% tagged and time stamped telemetry system that requires a tag and time stamp on each input can run from 300% for a system with 16-bit inputs, 16-bit tags, and 32-bit time stamps to 1000% for a system with 8-bit words, 16-bit tags and 64-bit time stamps. So, for each byte of data recorded, as many as 10 bytes of overhead will be required to identify the source of the data and when the sample was taken.

Although excessive, this amount of overhead may be acceptable for systems where the input rate is low enough and the system has the excess processing capacity to allow the additional bandwidth required. For example, if the incoming data stream were to arrive at 10 Mbit/sec, with 12-bit words (a typical PCM stream) after processing required to convert these data to floating point values in standard units (ft. lbs., degrees, etc.), the required output bus bandwidth would be on the order of 3.3 M byte/sec for untagged data. Systems using a 16-bit tag on each word would increase the output bandwidth to 5 Mbyte/sec and the inclusion of a time stamp with each (32 bit) to 8.3 Mbyte/sec. A full IRIG time stamp would drive the output bandwidth to 11.67 Mbyte/sec. Now if the requirement were for two or three streams to be inputted simultaneously, the output bandwidth could exceed 35 Mbyte/sec, beyond the bandwidth of all but the most exotic disk systems. One other factor to be considered at this point is that with this amount of data on the disk (10.5 Gbyte in 5 minutes) retrieval also becomes a problem. Transfer times using Ethernet rates for the 10.5 Gbytes of data acquired in 5 minutes will exceed 3 hours. The time required for finding a particular piece of data will also be considerably more than necessary.

For systems operating at higher data rates, the possibility of tagging and time stamping each word input quickly becomes unreasonable and in extreme cases impossible given current technology. In any case the percentage of overhead will not change and in the case of this system could be higher due to a General Time Code (GTC) that was also required as a reference in addition to IRIG time resolved to 10s of microseconds. The total amount of overhead data will therefore be a function of the data rate.

## REDUCING THE AMOUNT OF STORED DATA

One traditional method of reducing the amount of data to the system is to take data samples only if the incoming data are significantly different from than the previous sample. In this way the amount of data taken on a channel that is not highly dynamic is greatly reduced. This can be a great savings for data that may only react during certain phases of an operation (eg., terminal guidance) or that are inactive during long periods when processing and recording every point would be a waste. This technique does have limitations and can be applied only to those systems where it is well understood that the incoming data will lend itself to this type of compression. Also, by using any form of data compression, the absolute time-ordered relationship between the input data stream and the recorded data is lost, thus making time stamping and ID tagging of every datum mandatory.

## REDUCING THE AMOUNT OF OVERHEAD

The question at this point in the discussion is why not reduce the amount of overhead? This is a simple concept but one whose implementation is not immediately obvious. There are many software manipulations that will allow the reduction of a certain amount of overhead, but the requirement still exists for the 2-D identification of the incoming data. Any system that uses a common bus for processing or output or a single disk for storage will require the incoming data be tagged. Reducing the number of tags required can only be accomplished by increasing the number of distinct data path and will be discussed.

One method of reducing the amount of overhead required that has already been referenced is to reduce of the size of the time stamp. After the initial time stamp the requirement to know the year, month, and day is no longer real. In fact, for systems operating for under an hour it may not be necessary to contain the hour. This will allow the reduction in size of the time word to less than ½ of its original size.

Reducing the amount of overhead by reducing the number of time stamps requires a more detailed look at the incoming data streams. If the data are synchronous and a definite timed pattern of occupance can be established such as for a PCM frame map, the requirement could quickly drop from each word stamped to each frame stamped. A time stamp on each frame is not often necessary and often a time stamp on every 100 frames will be acceptable. The only absolute requirement for a time stamp is one at the beginning of the run and one after each dropout.

Most issues concerning time in the telemetry business will draw comments that the absolute requirement is for the most accurate time stamp possible on each word inputted to the system. And, as with most issues of this type, the real question is if the user can afford the cost in increased processing and storage required (or if the present state of the art can provide such a system).

## PUTTING THEORY INTO PRACTICE, A TELEMETRY PROCESSING SYSTEM

When the input data rates are low, the decision of whether or not to implement one or more of the methods for reducing the amount of overhead remains an option; the choice of which, if any, are used can be left to the system designers. When the data rates approach the limits of current technology, the reduction of any unnecessary overhead is an absolute must. A system designed and built for the 6585th Test Group at Holloman AFB, NM, to upgrade existing capabilities for the high speed test track has input data rates that require such minimization of overhead.

The test track presents a most difficult problem for the system planners and designers in that there is no may to know what might be coming down the track next. Although each run is carefully planned, the telemetry system had to be ready for any IRIG signal that might need to be received and processed. These will include PCM, PAM, PDM, multiple channel FM, and multiple time sources, all at state-of-the-art rates. Possible expansions might include Mil-Std-1553 or other aircraft buses that could be connected with guidance, control, or ejection seats.

In Figure 1 the basic system input bandwidth requirements are shown. As can be seen in this diagram, the amount of data from different sources input to the system is such that, if confined to a single backplane, the total data rate could exceed 100 Mbyte/sec and therefore is what is possible given current technology. The rates given are not for a burst mode or average acquisition rate over a small time frame but are for sustained data input, throughout the duration of the test (< 5 min.). A close examination of current technology will show the above sustained rates far exceed the capabilities of existing and advertised systems. The reduction of overhead in this case is no longer an option. Some method was required of reducing the input data rate to a level that could be tolerated by reasonable technology.

The answer to the reduction of this unnecessary overhead is to keep the streams separated and time stamp the synchronous data as sparingly as possible. These techniques will reduce the required overhead from the overwhelming burden of several times the data rate to a minor amount that can be easily absorbed.

As can be seen in Figure 2, the design of the Telemetry Processing System (TPS) is such that the above considerations can easily be incorporated. By keeping each stream separated, the data rate to any one disk is small enough to allow standard ESDI disks to be used. This not only greatly simplifies the hardware design but also allows the use of more standard (less expensive, more reliable) parts.

In the case of the High Speed Analog-to-Digital converter, the output bandwidth is 6.4 Mbyte/sec and therefore beyond the bandwidth of an ESDI drive. The answer then is to fan the data to several drives so that the data rate can be sustained while eliminating the need for exotic parts.

Realtime display of the data is accomplished via a separate data path that is provided purely for that purpose. The data identified for realtime display are routed through that data path to the control processor where combination of the data into derived parameters and conversion of the data into engineering units can take place. The data are then transferred to a work station for realtime display.

Of major concern to the customer for this project was the capability of the system to quickly access data immediately following the test. This requirement would have been quite difficult using a single disk of disk system due to the manner in which the data are stored and excessively long search times required to sort through each tag. By storing each channel of data on its own disk, the process transforms into a time search on the disk (channel) of interest.

Other features incorporated into this system are the standard windowed display and setup features that are covered in considerable detail in another paper to be published this year. The entire system is then connected to a mainframe host where archival of the data and batch type processes can be performed as required by a wide number of users over standard networks.

## CONCLUSION

Although not always a realistic alternative, the reduction of overhead on the data acquired by any telemetry system is a goal that will give considerable rewards. When the incoming data can be allowed to remain separated into parallel paths, the requirement for tagging the data, a source for 100% to 200% of overhead on the incoming data, is greatly reduced. By further relying on the position of the data in the frame map or other similar structure, the need for tagging can be eliminated. Time stamping can also be reduced by using only that portion of the time stamp necessary for the particular system and only time stamping the data on as sparse an interval as is possible given a synchronous data input.

By combining all of the above techniques, the amount of incoming data that can be processed and recorded is greatly increased. Even systems of modest cost can be made to perform at rates some would consider beyond current technology.

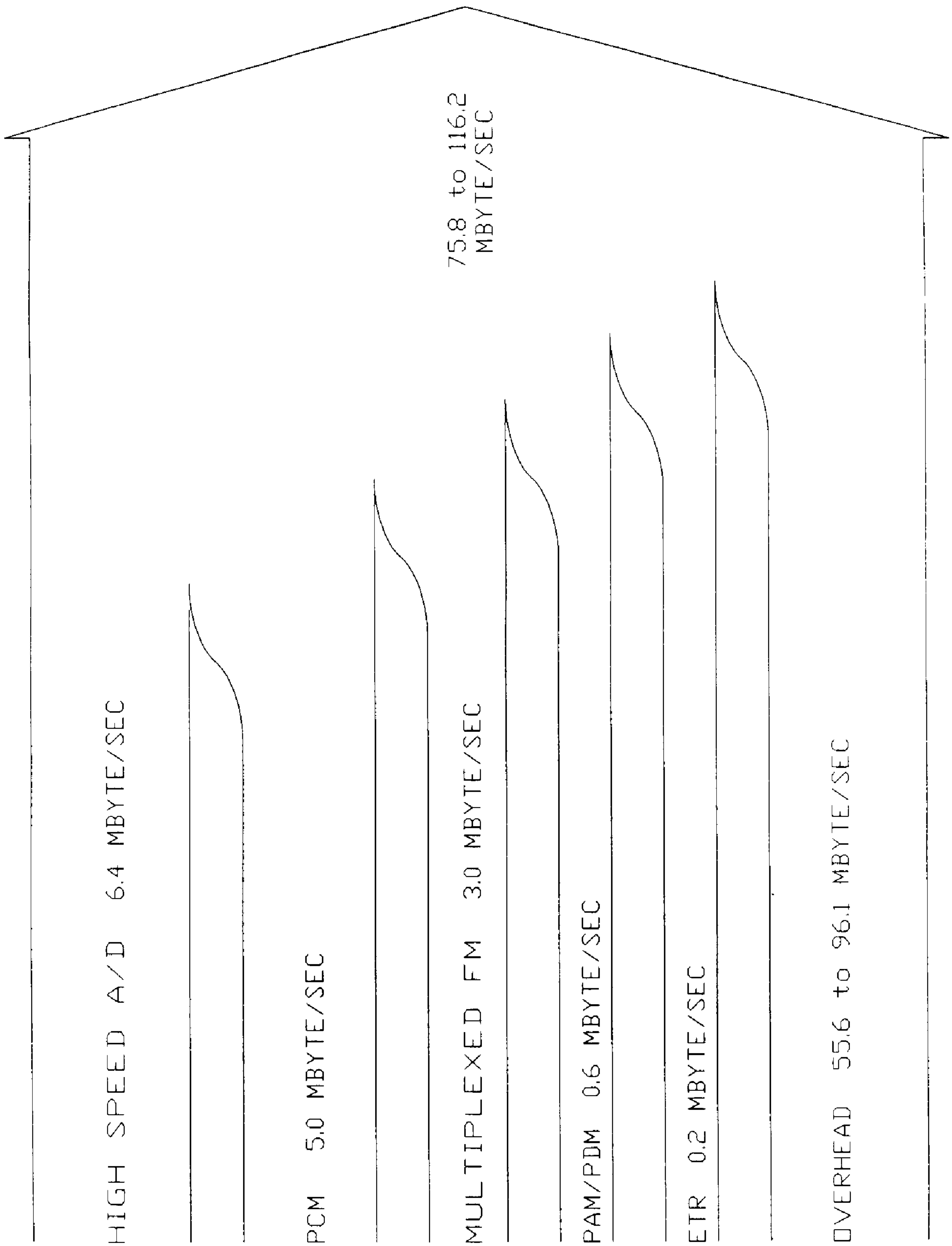


Figure 1. Input Data Rates

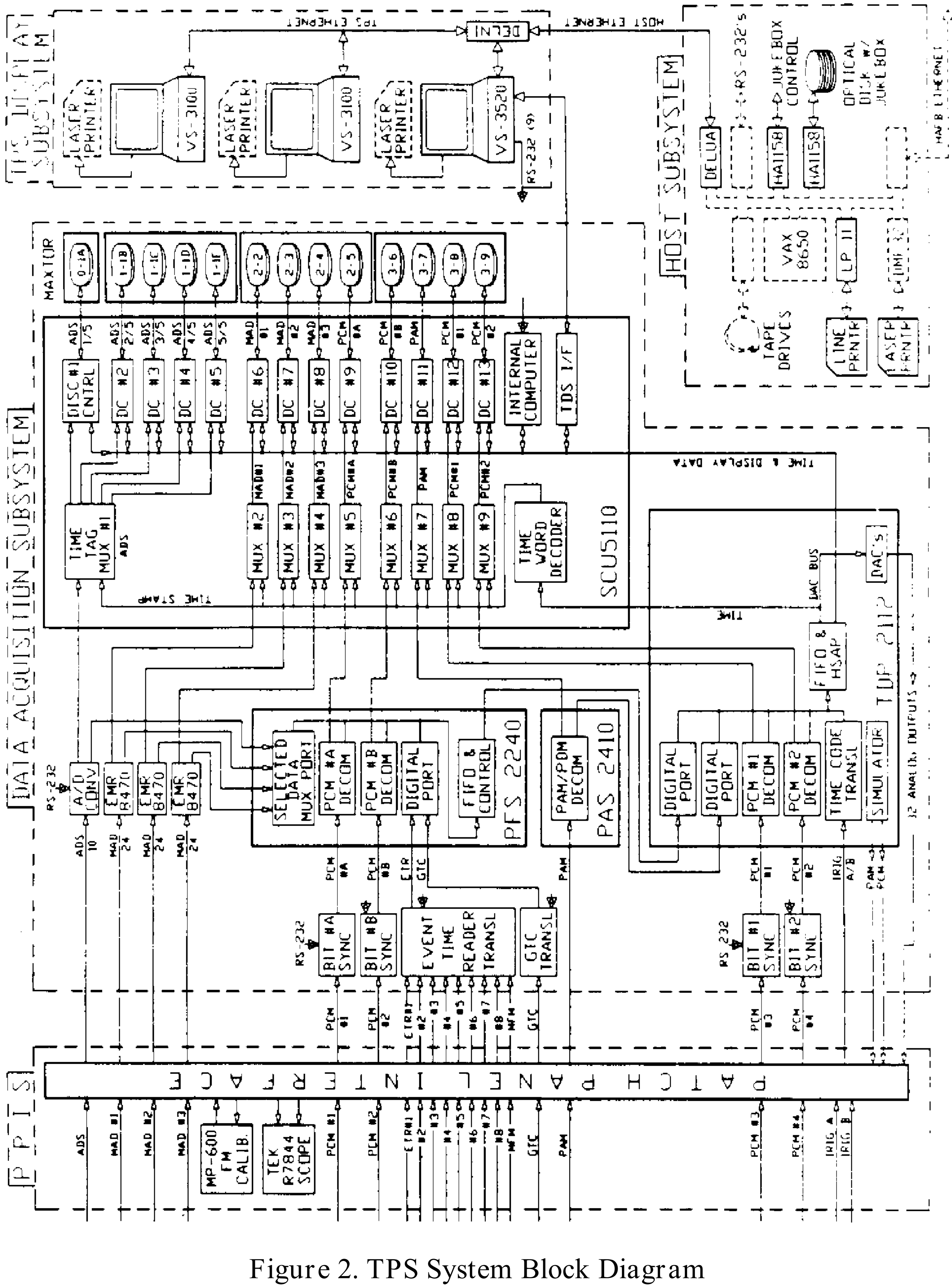


Figure 2. TPS System Block Diagram