APPLICATION OF A DIGITAL COMPUTER TO REAL TIME TELEMETRY SYSTEMS

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Introduction The majority of the real-time telemetry decommutation systems currently in use fall into one of three categories. Each of these have advantages and disadvantages.

The first approach is illustrated in Figure Aa. For a PCM, PAM, or PDM input, the approach consists of a primary (bit) synchronizer (signal conditioner), a frame synchronizer, and a stored-program decommutator. A stored-program decommutator may use either a core memory or a patchboard for the program storage. The stored-program decommutator may be programmed by means of switches, patchboards or, more recently, core memories. This concept was introduced when most of the data outputs were recorded on strip-chart recorders. It has the advantage of being reasonably simple, flexible, and fast. Today, when most of the data output is put in a digital format for further processing by some computer, it has the disadvantage of not being able to directly generate output tape in a gapped-computer format.

The second approach, illustrated in Figure Ab, is to replace the stored program decommutator with a general purpose computer, This approach usually sacrifices some of the speed of the special purpose decommutator but increases the flexibility and application of the total station. With this approach, it is possible to produce completely reduced data as an output. Two obvious drawbacks to this second approach are the large investment of money and the overall complexity of the hardware and programming system. A third operational drawback to this approach is the difficulty of determining where the trouble lies if the reduced data output is unintelligible.

The third approach, Figure Ac, is identical to the second approach except for the addition of a stored-program decommutator in front of the general purpose computer. This provides the ability to reduce a few channels of data for quick-look purposes without tying up the large computer. However, it costs even more money than the other two approaches.

The purpose of this paper is to explore a fourth approach which appears to solve some of the problems of the other three approaches. The solution is to use a medium size telemetry processor to perform secondary (group) synchronizong strategy, decommutation, and limited reduction functions without requiring the large investment necessary for a large general purpose computer.

The Beckman 8420 Telemetry System is used as an example. The functions performed by the “heart” of the system, the 420 Telemetry Processor is covered in detail.

General The system to be discussed in this paper was designed to take advantage of the power and flexibility of the modern digital computer --in this case, the Beckman Model 420 Telemetry Processor. In its fully expanded form, this system has the capability of decommutating and processing PCM, PAM, PDM, and FM type data.

The hardware and the Processor programs are organized in a modular fashion, so that it is possible to delete any portions not required for a particular system requirement or to easily expand a basic system at some later time.

The main advantage realized in using a high speed computer, as the central portion of a system of this type, is that the system operation isunder the control of the computer program. By doing this, changes in system organization to accommodate different formats, processes, rates, sync codes, and word length, can be accomplished by changing the programming logic rather than having to change the system hardware wiring.

System Organization The system is organized to operate in one of six different input modes of operation. These are as follows: ,

1. PCM. -The system accepts a PCM-bit stream (1 to 1,000,000 per second), converts the data to a word-serial stream (4, to 12 bits per word), determines frame and subframe syncs, and performs a decommutation operation. The data is then normally recorded on a computer-format digital tape.
2. PAM. -The system accepts an analog PAM signal (10 to 100, 000 channels per second), determines pulse and frame sync, digitizes each channel (II bits plus sign), and decommutates the input. Normally, the data is then recorde on output tape.
3. PDM. -Same as PAM except that the input is PDM.
4. FM. -The incoming data is normally in a frequency multiplexed form. It is demodulated, through discriminators, and commutated to a single ADC --for conversion to a digital format (Up to 40, 000 conversion per second). The digitized data is then entered into the processor for decommutation and recording on output tapes.
5. Merge (PAM and FM). -PAM and FM data is converted to a digital format and merged on a single output tape. The conversion of the FM data to a digital format is controlled by timing derived from the input PAM signal.
6. Merge (PDM and FM). -Same as above except for the incoming data being PDM.

The above six modes define the types of data inputs. While in any of these modes, or while data is being played back from previously generated computer tapes, a number of processing operations can be performed. These include:

1. Edit. -Incoming data is inhibited, on a selective basis, from entering the Telemetry Processor.
2. Sort. -Data is automatically sorted, on a per channel basis, and routed to several areas of the processor memory.
3. Data Compression. -Selected channels are checked against limits, static or dynamic, and the system output is controlled.
4. Quick-Look. -Selected channels are stripped out for display on decimal displays, analog recorders, or printer.
5. Arithmetic Operations. -The arithmetic capability of the Telemetry Processor is used to perform operations such as scale and offset, linearizing, etc.

Hardware Organization The general hardware organization of the system is shown in Figure B. A specific Configuration consists of a Telemetry Processor (Model 420) and only those peripheral subsystems necessary to perform those functions required of a system configuration.

The 420 Telemetry Processor operates like a standard computer. It consists of a central processor section, an I/O section, and a core memory. The memory can be of any size from 4096 words to 32,768 words. It can be furnished with any number from one to eight input/output channels and one to eight interrupts.

The PCM Subsystem consists of a primary (bit) synchronizer and a secondary (group) synchronizer. The input to this system is a serial bit stream. At the interface between the subsystem and the Telemetry Processor, the data has been converted to a word-serial format. If the PCM input has a fixed word length, this is- established during the system setup. If the format is such that the word length varies from word to word, a list containing the word length definition is stored in the Telemetry

Processor memory, and a list word is extracted for each PCM input word. This list word controls the shift register in the secondary synchronizer and determines the word length going into the Telemetry Processor.

The FM Subsystem consists of high-level commutators and an analogto-digital converter. The commutators accept analog voltages from the Discriminator Subsystem and time multiplexes these into a single analogto-digital converter. The output of the digital converter, in a word-serial format, is then transferred into the Telemetry Processor. To provide flexibility in the sequence of digitizing the discriminator outputs, a list containing the commutator addresses is stored in the Telemetry Processor. For every conversion of the FM input a list word is extracted that determines which discriminator output is to be sampled. By doing this, it is possible to establish any pattern of commutation, super-commutation, and subcommutation required for various frequency contents of the incoming FM data.

The PAM/PDM Subsystem basically contains a PAM synchronizer and digitizer. In the PDM mode, a PDM-to-PAM converter is included to convert the incoming PDM data to PAM data. This subsystem accepts the incoming telemetry data in a channel-serial format, determines frame sync, and controls the conversion of the incoming data to a lZ-bit digital word, The word-serial stream from the ADC is then transferred into the Telemetry Processor.

The Time Subsystem receives a serial-time code, either from the Analog Tape Subsystem or in real time, and converts it to a parallel time code for entry into the Telemetry Processor. The function of searching the time code, contained on the input tape, to determine processing start and stop times is performed in the Telemetry Processor. During this period, when the input tape is being searched for the start time, the processor is relatively unloaded and, therefore, is available for sophisticated tape search routines. These routines include such things as predicting when a start time will occur and switching the analog tape from high-speed search to normal playback speed, thus eliminating the reversing operation encountered in normal tape search approaches.

The Simulator Subsystem consists of a stored program simulator which can be loaded and controlled from the Telemetry Processor. This simulator has the capability of simulating PCM, PAM, PDM, and analog inputs.

The Analog Tape Subsystem consists of an analog tape transport that can be set up and controlled from the Telemetry Processor.

Contained in the Discriminator Subsystems, are manual or rernotecontrolled discriminators which can be patched, by means of the video patch bay, for different input requirements.

The digital tape transports, for recording computer formatted data, are contained in the Output Tape Subsystem. In most applications, only a single tape transport is required. However, it is possible to store programs and tables on these output tapes (which function in the same fashion as normal computer peripheral tapes). In this case, more than one tape transport is required.

The Quick-Look Output Subsystem contains the necessary interface and conversion equipment to provide quick-look data during reduction. This subsystem normally contains a digital display, several digital-to-analog converters for driving strip chart recorders or oscillographs, and, in some cases, a tape printer for checkout and quick-look purposes.

The system set up and control, as derived from the 8421 Processor program, is accomplished by means of the Set Up and Control Subsystem. All mode “set ups” and remote control registers are contained in this subsystem.

Since the Telemetry Processor operates similar to a normal digital computer, it is possible to attach other computer peripheral equipment to the telemetry system. Quite often, it is desirable to be able to load set up and operation programs by means of Punched cards from a standard card reader. Other peripheral equipments available include high-speed line printers, card punches, and barg raph displays.

Program Organization The power and flexibility of a telemetry system incorporating a processor is available because of the ability to change the system by rewriting system programs. It is not enough to just put a digital computer into the system to realize all of this flexibility. The programming organization and philosophy must be considered at the initial inception of the system concept; something that is too often ignored until the hardware organization is complete.

In the system described in this paper, the programming design was accomplished in parallel with the hardware design. Functions that are performed once per telemetry frame, or less often, are implemented in software, and those functions which have to be performed more often are accomplished in hardware. For example, with a, PGM input, the bit synchronization and frame synchronization correlation are accomplished in the PCM Subsystem. The strategy for determining whether the system is frame synchronized with the incoming data is implemented in the Telemetry Processor program. Since this is done only once per frame, it is possible to incorporate very sophisticated frame synchronization strategy without using an excessive amount of the Telemetry Processor’s available capacity. This PCM secondary sync strategy is discussed late r.

The overall program organization is shown in Figure C. It is modular designed with each module under control of a Telemetry Executive program, (TELEX). With this approach, it is possible to delete routines not required in a particular operating mode. The routines called upon by TELEX are divided into three categories: on-line (critical timing); on-line (non-critical timing): and off-line operations.

The executive routine (TELEX) performs the function of determining whether a particular function is to be performed and when. It is comprised of simple routing instructions.

On-line routines involving critical timing include those required for processing of PCM, PAM, PDM, FM, and time inputs. The routine necessary for controlling the output of data to magnetic tapes and quick-look devices is also included. A typical on-line processor is the PCM Processor. This includes frame and subframe sync strategy control, decommutation, and the ability to define and call up routines to be performed on the data. These routines might include data compression, formatting of data for output to displays, and formatting of the data for recording on output tapes.

The on-line routines involving non-critical timing include the Set Up and Evaluate routine (SEAL), the Tape Search, Processor, and the Process Summary.

SEAL controls the set up of hdrdware subsystems and evaluates the resulting configuration for correctness. In the case where some of the subsystem functions are manually set up, SEAL controls the recording of these settings.

The Tape Search Processor controls the searching of the input data for a predetermined start time of the processing operation. The selection of the input tape speed is under control of this processor, After a particular period of input data processing, the process summary generates an end-of-process tabulation of such parameters as suspect-of -bad-frames, number of frames processed, areas of signal dropout, etc.

To aid the system user in setting up the programs for his particular process, a series of off-line programs have been developed. A major program in this group is FORGE. FORGE is a problem-oriented assembler that accepts input statements describing the data format and the specific processing operations to be performed. These are automatically translated into an operating program for TELEX. This function is comparable to the use of an assembler to permit symbolic rather than binary machine language programming of the general purpose digital computer.

The Executive Loader (EXEL) is also included in the off-line group of programs. EXEL loads FORGE program tapes and other parameters into the operating program, during the set up for a particular processing operation.

The Telemetry Simulator Translator (TEST) generates programs for the stored program simulator. This simulator is used to rapidly checkout the operational condition of the telemetry system and is also used during troubleshooting operations.

The final package in the off-line programs is the processor and System diagnostics (SYSTEST). SYSTEST is a maintenance and troubleshooting aid which allows a rapid determination of the portion of the system that is not operating correctly.

System Capability Because of the flexibility that is inherent in a system built around a digital computer, it is difficult to fully specify the total capability of the system. Therefore, this paper will define several applications that have been analyzed to illustrate typical capabilities.

The first problem, sorting PCM data, is presented in detail to show the method of system operation, and the method required to analyze the system loading. The other three applications are presented in summary form.

APPLICATION NUMBER ONE ON-LINE SORT OF PCM DATA

General This application is basically an on-line sort of PCM data recorded on an analog magnetic tape recorder. The sort is to be performed at an input word rate of 25,600 eight-bit words per second. Data is to be sorted into eight output buffer areas, each buffer area connected to a digital magnetic tape for recording the data in a gapped format.

While the data is being sorted, other functions to be performed include: tape search, data editing, quick-look, data compression, and merging of time and fixed data. Figure I illustrates the overall data flow.

Inputs The inputs consist of PCM data recorded on an analog tape and a time code recorded on the same tape. The format of the PCM data is illustrated in Figure 2. It consists of one major frame consisting of 50 minor frames. The major frame repeats once every second and contains 25,600 eight-bit words. Each minor frame consists of 512 eight-bit words and repeats once each 20 milliseconds.

The time word consists of a standard IRIG format with 27 bits per time word. The time words have a resolution of 1 millisecond.

Outputs The primary output consists of up to eight magnetic tapes each containing gapped, computer-formatted digital data. Each tape contains data with record lengths of from 1000 to 2000 characters. The output tapes contain data that has been sorted into up to eight groups. The data may have been sorted by sample rate, transducer type, subsystem, or any other programmed function. Figure 3 illustrates the output tape format.

Other outputs consist of a single channel display which may be operator controlled to display any of the incoming data channels and eight Digital-to-Analog Converters for recording selected channels of data on strip chart recorders.

System Configuration Required The system configuration used is shown in Figure 4. The controlling portion is the Telemetry Processor. Peripheral equipments to the processor consist of a PCM bit and frame Synchronizer, a Time-Code Translator, a DAG and Display Subsystem, .eight Digital Tape Transports, and one Analog Tape Transport.

The Telemetry Processor required for this configuration has four standard I/O channels, one direct memory access channel, four interrupts, and 16,384 words of memory.

The PCM Subsystem consists of a Bit Synchronizer and Frame Synchronizer.

The Time-Code Translator accepts the serial-time code from the analog tape transport and converts it to a parallel-time code for transfer to the 4ZO. The translator has the capability of representing time-of-year in milliseconds as an output.

The DAG and Display Subsystem consists of a DAC and Display Interface, one 3-digit BCD digital display, and eight digital-to-analog converters.

The eight Digital Tape Transports record output data at 800 bpi or at a character rate of 120,000 characters per second (60,000 data words per second.)

The Analog Tape Transport is capable of being remotely controlled from the processor. This includes the capability of remotely selecting the speeds.

Approach-General Figure 5 illustrates the sort operation. A list containing externally specified buffer (ESB) addresses is stored in the processor memory. This list is synchronized with the incoming telemetry minor frames. As each PCM word is transferred into the processor , memory, an associated ESB address is extracted from the list and is used to specify a set of buffer control words. Eight sets of these words are in memory and control the storage of incoming data in the eight output buffer areas.

As each output buffer area is filled, (individual area lengths are independent of the other output areas), the output tape associated with that particular buffer area is started. For simplicity of organization, each output tape record contains a multiple of words contained in the minor frames and is started only at the conclusion of a minor frame.

The functions of inputting PCM data through a normal I/O channel, outputting the ESB address list through the direct memory access channel, and outputting data to the magnetic tape transports consume 57.2% of the memory time on an average basis. The remaining 42.8% of machine time is available to perform the other functions of edit, time merge, quick-look output, sync maintenance, and data compression.

Editing of the input data consists of deleting words from the incoming PCM data. This is accomplished with an op-code contained in the ESB address list. As each list word is extracted to be used in controlling the routing of input PCM words, it is inspected for the edit op-code. If this op-code exists, that word transfer to the processor is inhibited. In this manner, an on-line editing function is accomplished an only those data words required for further processing are entered into the processor memory.

The Time Merge consists of placing a time word from the incoming time code with each output record. This time word can be programmed to represent the first word in the output record or alternately can be programmed to represent the last time word in the output record.

The Quick-Look Output consists of stripping one channel of data and presenting it to the system operator in a decimal format. In addition, eight channels are stripped out for conversion to an analog voltage for driving strip chart recorders.

Sync Maintenance consists of looking at the minor frame sync once per minor frame, and determining if the PCM Subsystem is still synchronized. In the cases where synchronization is lost, a flag is inserted in the header of all records being assembled for recording on the output tapes. Each record is then filled out with zeros and recorded on the output tapes. When synchronization is re-attained, a flag is inserted in all of the record headers, signifying that this is the first record after re-synchronization, and the normal process continues. By this, the processor guarantees that all records on the output tapes are of the same length.

Sync Maintenance also includes the maintenance of the major frame sync. This is accomplished by the processor program once per minor frame. At that time, the sync word is examined, and it is determined whether the major frame is still in sync. If it is out of sync, appropriate flags are inserted in the output records, and a similar process to the above sync loss process is repeated.

The types of data compression include:

1. High/low limit check, with data flagging for data exceeding limits.
2. High/low limit check, with only those data exceeding limits being recorded.
3. Resettable limit check, I with only those data reaching the limits being recorded.

Figure 6 illustrates this latter form of data compression. Limits are set up around a reference point established by the data value at to. If a given period of time, in this case represented by t_0 to t_1, is exceeded, the time and data are recorded, the reference is reestablished, and a new set of limits are calculated. If the data reaches either the high- or low-limit prior to the expiration of the pre-determined period of time, this data and time are recorded, and the limits are re-established. This approach allows the maintenance of a data reference, where the data is varying slowly, and more frequent recording of data is needed during transient periods.

Approach-Programming The operation of the System is under control of programs stored in the Telemetry Processor. The basic controlling program is the telemetry executive program (TELEX) illustrated in Figure 7.

The first two functions performed under control of TELEX are off-line functions and are not time critical. These consist of the set up and evaluation (SEAL) of the total system and the start-up routines which initialize all input-output channels and connect appropriate peripheral devices.

The next function called up by the TELEX is that of tape search. This program searches the input analog tape at a high speed until a start time, set in by the operator during set up, is reached. At that time, the tape speed is changed to normal playback speed. During set up the operator has the ability to enter as many sets of start and stop times as he wishes. When the data defined by the first set of start/stop times is processed, the next set is used until all sets have been utilized.

After the tape search, TELEX waits for the next minor frame interrupt. At this time, the minor frame routine is entered. This routine is illustrated in Figures 8 through 14.

After the last frame (determined by the stop time) has been processed, TELEX then goes to the stop processor. The stop processor determines why the process was ended and generates a process summary for the operator. This summary may include suchthings as bit-error rates, suspect or bad frames, number of frames processed, areas of signal dropout, etc. The stop processor also controls the operating during the period when sync has been lost.

After the stop processor has completed its operation, TELEX then determines if there is a new set of stop/start times for further processing. If so, TELEX branches back to the tape search routine and repeats the above process. If not, the processing operation is stopped.

System Loading Analysis -Timing

1. **PCM Input** The PCM input word rate is 25,600 words per second. Each word takes 9.6 microseconds. The percent of available time used for PCM input is:

   9. 6 x 10^{-6} sec/word x 25,600 words/sec 0.24486 sec/sec 24.5

2. **Time Input** One complete time word (two computer words) are entered every minor frame or once per, 20 milliseconds. This is 100 words per second.

Required capacity:

9.6×10^{-6} sec/word x 100 words/sec = 0.00096 sec/sec ≅ 0.1%

3. **List Output** One list word (containing ESB address) is associated with every PCM input word. Each list word (through DMA) takes 3.2 microseconds.

Required capacity:

3.2×10^{-6} sec/word x 25,600 words/sec = 0.08192 sec/sec ≅ 8.2%

4. **Magnetic Tape Output** The total output rate is approximately 52,000 char/sec, or 26,000 words per second since there are two characters per word.

Required capacity:

9.6×10^{-6} sec/word x 26,000 words/sec = 0.2496 sec/sec ≅ 25%

5. **Quick-Look Output** In the worst case, one digital display and eight DAG are updated every 20 milliseconds. This is a word rate of 450 words/sec.

Required capacity:
9.6×10^{-6} sec /word x 450 words /sec 0.004325 sec /sec ≅ 0.4%

6. **Processor Operations** (Performed once every 20 milliseconds)

a) Time Processor. -This routine causes a set of time words to be entered and checks against pre-set stop time.

Required capacity worst case :

$$\frac{63.8 \times 10^{-6} \text{ sec/frame}}{20 \times 10^{-3} \text{ sec/frame}} = 0.00319 \text{ sec/sec} \cong 0.3\%$$

b) Sync Maintenance. -This routine determines if the minor frame and major frame are still in sync.

Required capacity :

$$\frac{390.4 \times 10^{-6} \text{ sec/frame}}{20 \times 10^{-3} \text{ sec/frame}} = 0.01952 \text{ sec/sec} \cong 2.0\%$$

c) Output Control. -This routine starts the output tapes if required during a minor frame interrupt routine. Worst case is starting two outputs per frame.

Required capacity:

$$\frac{80 \times 10^{-6} \text{ sec/frame}}{20 \times 10^{-3} \text{ sec/frame}} = 0.004 \text{ sec/sec} \cong 0.4\%$$

d) List Update. -The list contents (ESB address) vary from minor frame to minor frame due to subcommutation. In this problem, the average number of ESB addresses that must be updated, is limited to 50 per minor frame.

Required capability :

$$\frac{1091.2 \times 10^{-6} \text{ sec/frame}}{20 \times 10^{-3} \text{ sec/frame}} = 0.05456 \text{ sec/sec} \cong 5.5\%$$

e) Data Compression. -In most tests the data being checked . against limits falls within the limits. This requires 72. 0 microseconds per check. When the data falls outside limits, it takes 183. 6 microseconds to re -establish limits and prepare data for output. A reasonable average time is 83 microseconds per-channel-per-frame. For two channels per frame the required capacity is:

$$\frac{166 \times 10^{-6} \text{ sec/frame}}{20 \times 10^{-3} \text{ sec/frame}} = 0.0083 \text{ sec/sec} \cong 0.8\%$$

f) Quick-Look Processor. -Every minor frame it is possible to process one channel for digital display (binary-to-BCD) and eight channels for the DAC outputs.

Required capacity :

$$\frac{402.4 \times 10^{-6} \text{ sec/frame}}{20 \times 10^{-3} \text{ sec/frame}} = 0.02012 \text{ sec/sec} \cong 2.0\%$$

Summary of Timing Analysis The total loading is tabulated below:

	Operation	Percent Time
1.	PCM Input	24. 5
2.	Time Input	0. 1
3.	List Output	8. 2
4.	Tape Output	25. 0
5.	Q. L. Output	0. 4
6. a)	Time Processor	0. 3
6. b)	Sync Maintenance	2. 0
6. c)	Output Control	0. 4
6. d)	List Update	5. 5
6. e)	Data Compression	0. 8
6. f)	Quick-Look Processor	2. 0
	TOTAL	69. 2%

This leaves 30% of the processing time available for other on-line functions.

System Loading Analysis -Memory Requirements

1. **Output Buffers** Each output tape requires a double buffer area so that data can be unloaded from one area while being loaded into the other area. The average buffer length is 400 words (800 tape characters).

   Required memory:

   8 tapes x 2 x 400 words = 6400 words.

2. **List** The list is twice the length of a minor frame.

   Required memory:

   2 x 512 = 1024 words.

3. **List Update** The memory required to update the list is (64+words/ frame updated) x 50 frames.

   Required memory:

   114 x 50 = 5700 words.

4. **Program** It is estimated that the program plus associated registers are contained in 1000 words of memory.

Summary of Memory Requirements

	Operation	Memory Required
1.	Output Buffers	6, 400
2.	List	1, 024
3.	List Update	5, 700
4.	Program	1, 000
	TOTAL	14, 124

APPLICATION NUMBER TWO PAM (PDM) CONVERSION

General This application requires the conversion of PAM (or PDM) data to a digital format and stripping 500/c of the input channels for recording on a computer tape. At the same time, time and fixed data are merged with the data and two channels are displayed on a decimal display. Figure 1 5 illustrates the part of the 8420 used for this application.

Inputs

1. PAM (or PDM)	40, 000 chans/sec. 100 channels per frame.
2. Time Code	IRIG A, B, or G entered once per frame.
3. Fixed Inputs	Entered before process starts.

Outputs

1. Tape	Computer-format tape containing 50 chan per input frame (See Figure 16)
2. Displays	Two, three-digit decimal displays (Updated once per second)

Timing Summary

Operation	Percent
PAM (PDM) Input (50% edit)	19.2
Time Input	1.6
Edit List Output	12.8
Tape Output	20.8
Time Processor	5.6
PAM Processor	4.8
Output Processor	2.6
Quick Look Processor and Output	0.3
Total Time Required	67.7

APPLICATION NUMBER THREE FM CONVERSION

General The input consists of forty channels of FM data, each of which is sampled and digitized 1000 times per second. This defines a throughput rate of 40,000 words per second. The data is to be put on computer tape in a gapped format with time and fixed data. Two channels are stripped out, converted to BCD, and displayed. Tape search and control are also performed. Figure 17 illustrates the part of the 8420 used for this application.

Inputs

1. FM Data	40, 000 samples/second
2. Time Code	IRIG A, B, or C. (Entered every other millisecond)
3. Fixed Data	Entered prior to processing

Outputs

1. Tape	Gapped computer format (See Figure 18)
2. Displays	Two, three-digit decimal displays (Updated once per second)

Timing Analysis Summary

Operation	Percent
Data Input	12.8
Commutator address	12.8
Time Input	2.0
Tape Output	40.4
FM Processor	2.6
Time Processor	7.0
Output Processor	2.2
Quick-Look Processor and Output	0.1
Total Time Required	79.9

APPLICATION NUMBER FOUR MERGE FM AND PDM

General The input data consists of 7200 channels per second of PDM data and 28, 800 samples per second of FM data. This is merged into a single output tape with time And fixed data. Two channels are stripped for display on a decimal display. Figure 19 illustrates the part of the 8420 used for this application.

Inputs

1. PDM	7200 Channels per second 45 Channels per frame
2. FM	28, 800 Channels per second
3. Time	IRG A, B, or C (Entered once per PDM frame)

4. Fixed Data Entered prior to processing

Outputs

1. Tape	Gapped Computer format (See Figure 20)
2. Displays	Two, three-digit decimal displays (Updated once per second)

Timing Summary

Operation	Percent
PDM Input	6.9
FM Input	9.2
Time Input	0.6
Commutator Address	9.2
Tape Output	34.6
PDM Processor	3.1
FM Processor	2.7
Time Processor	2.3
Output Processor	1.1
Quick-Look Processor and Output	0.1
Total Time Required	69.8%

Conclusion The use of a medium size digital computer for telemetry systems offers a good balance between capacity And investment. Data rates up to about 40,000 words per second can easily be accommodated. Data rates up to 100,000 words per second can be handled under certain conditions. These rates are fast enough to handle most of the requirements now and for the next several years.

In addition, the system is extremely flexible for known requirements and is easily modified to meet future requirements.

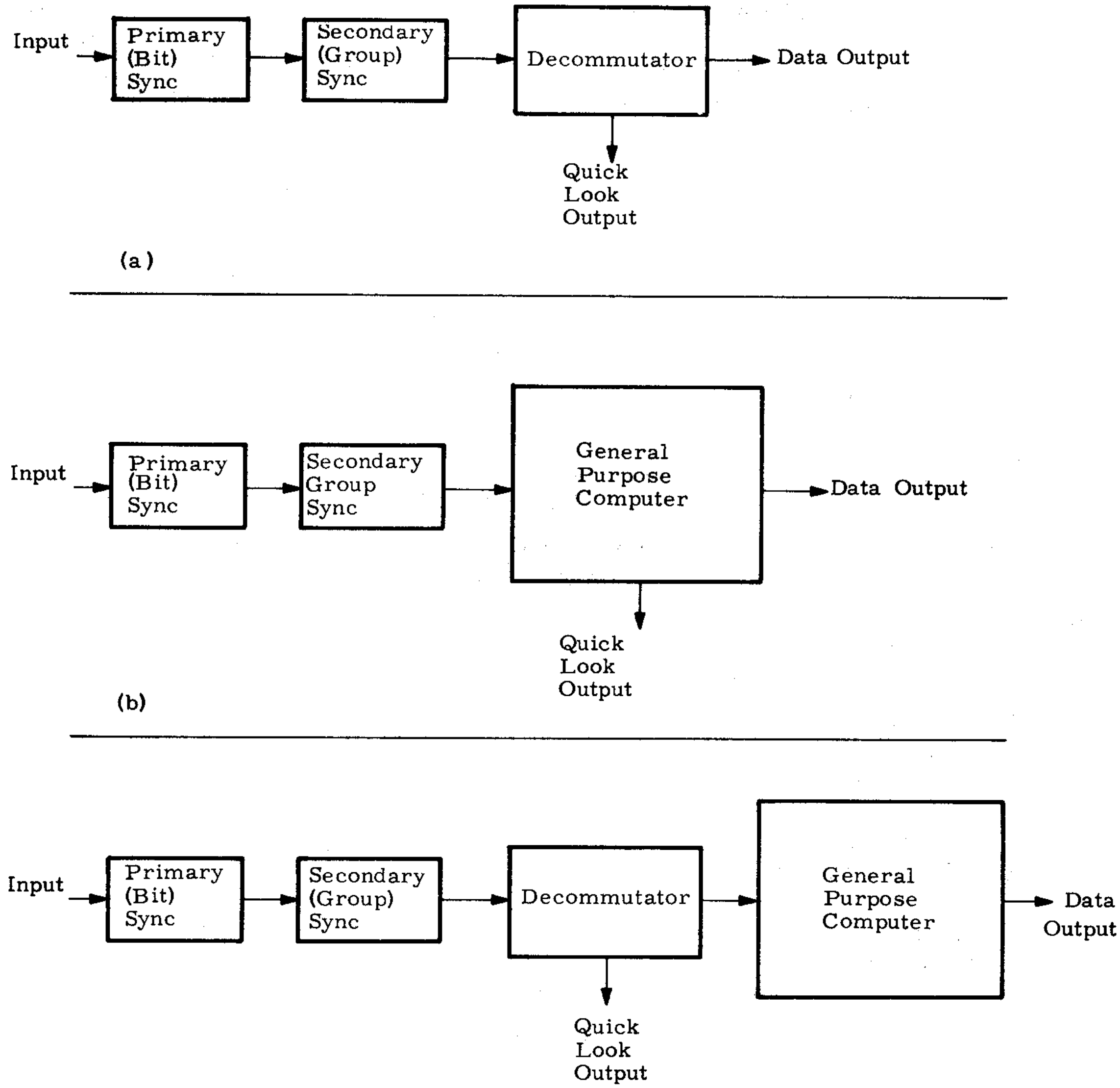


Figure A. Telemetry Station Approaches

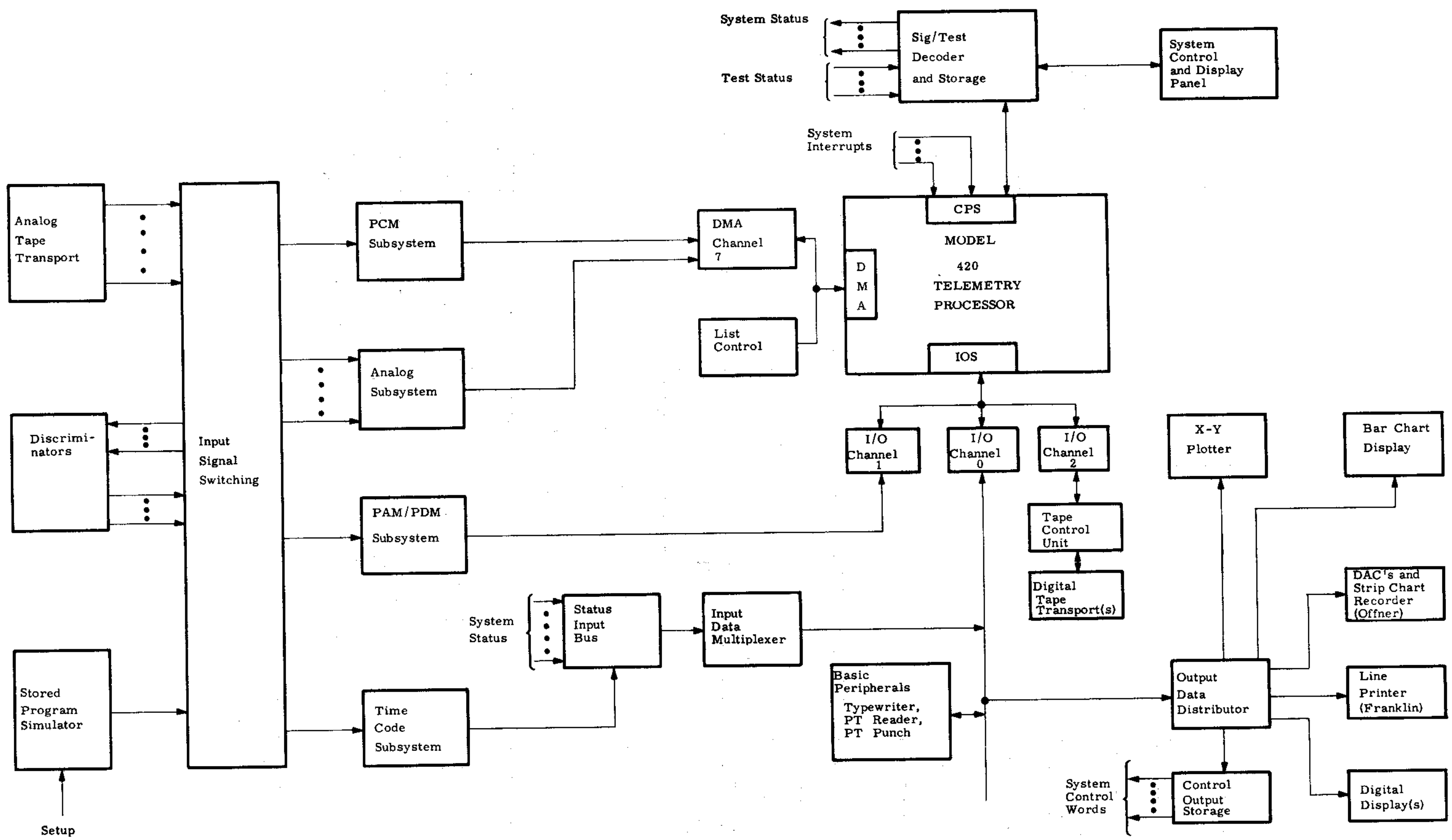


Figure B. Fully Expanded 8420

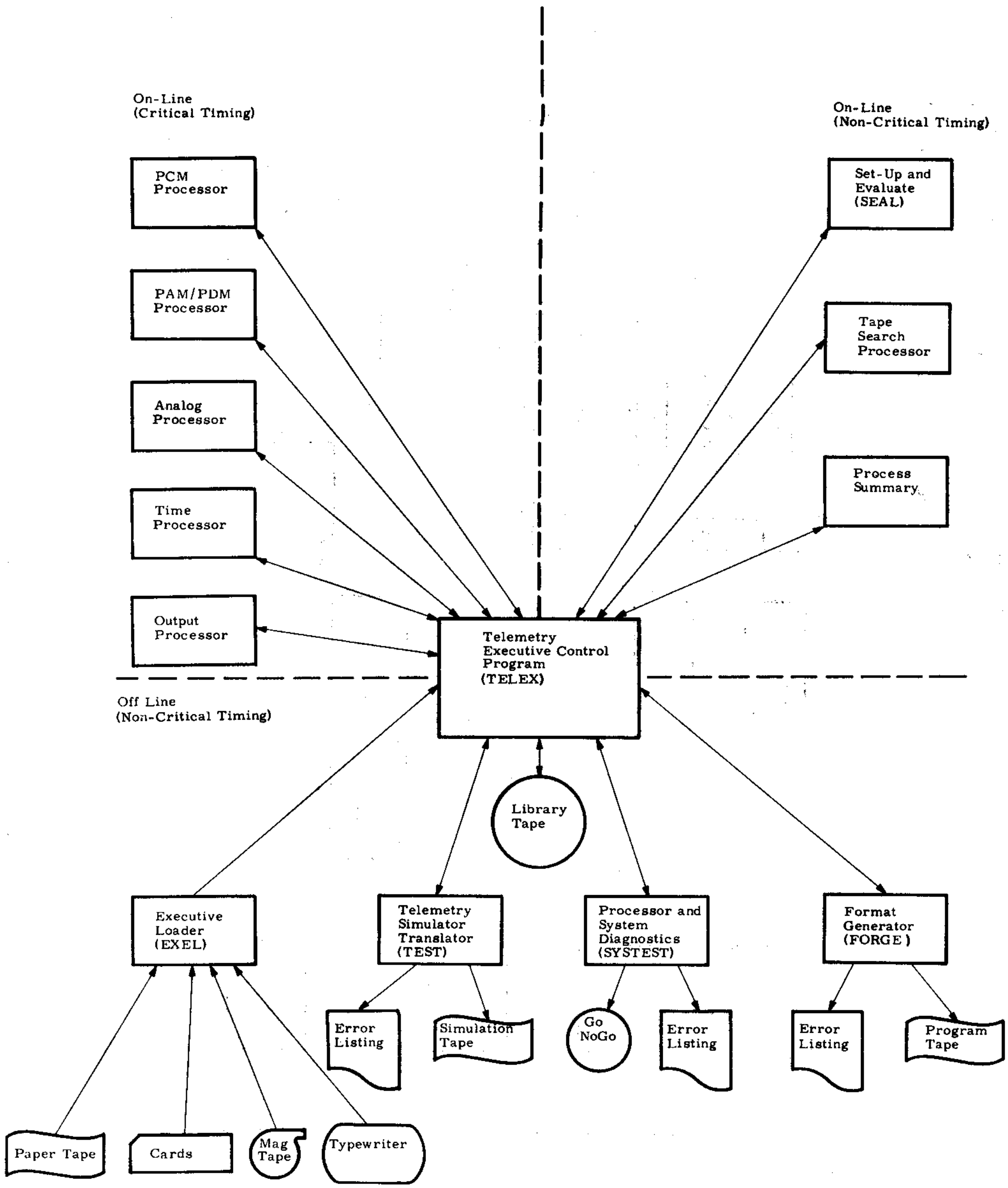


Figure C Programming Organization

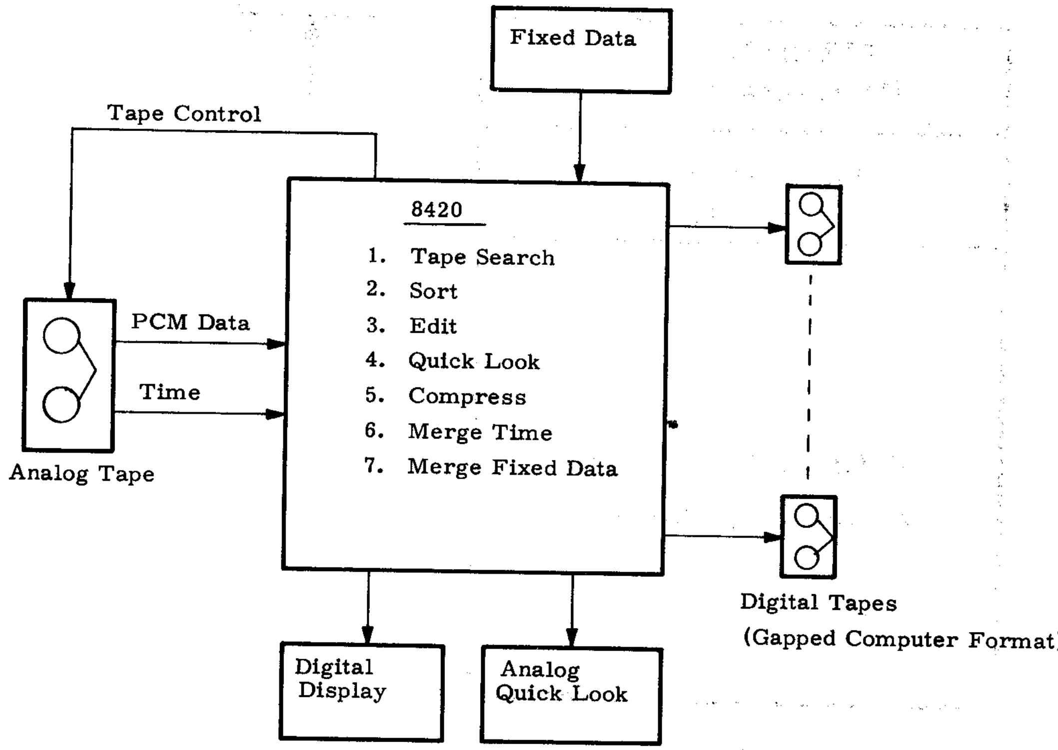
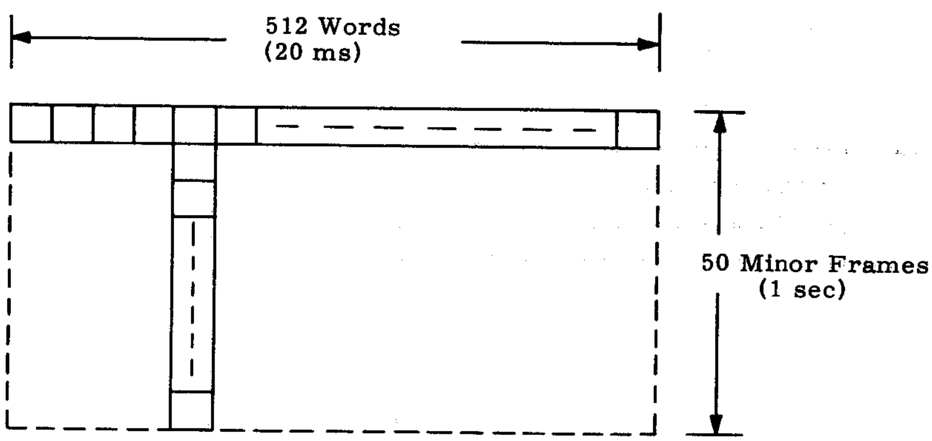


Figure 1. Overall Data Flow



DATA CHARACTERISTICS

Format	-	PCM
Bit Rate	-	204.8 KBS
Word Size	-	8 Bits
Word Rate	-	25.6 KWS
Minor Frame	-	512 Words
Major Frame	-	50 Minor Frame

Figure 2. Input Data Characteristics

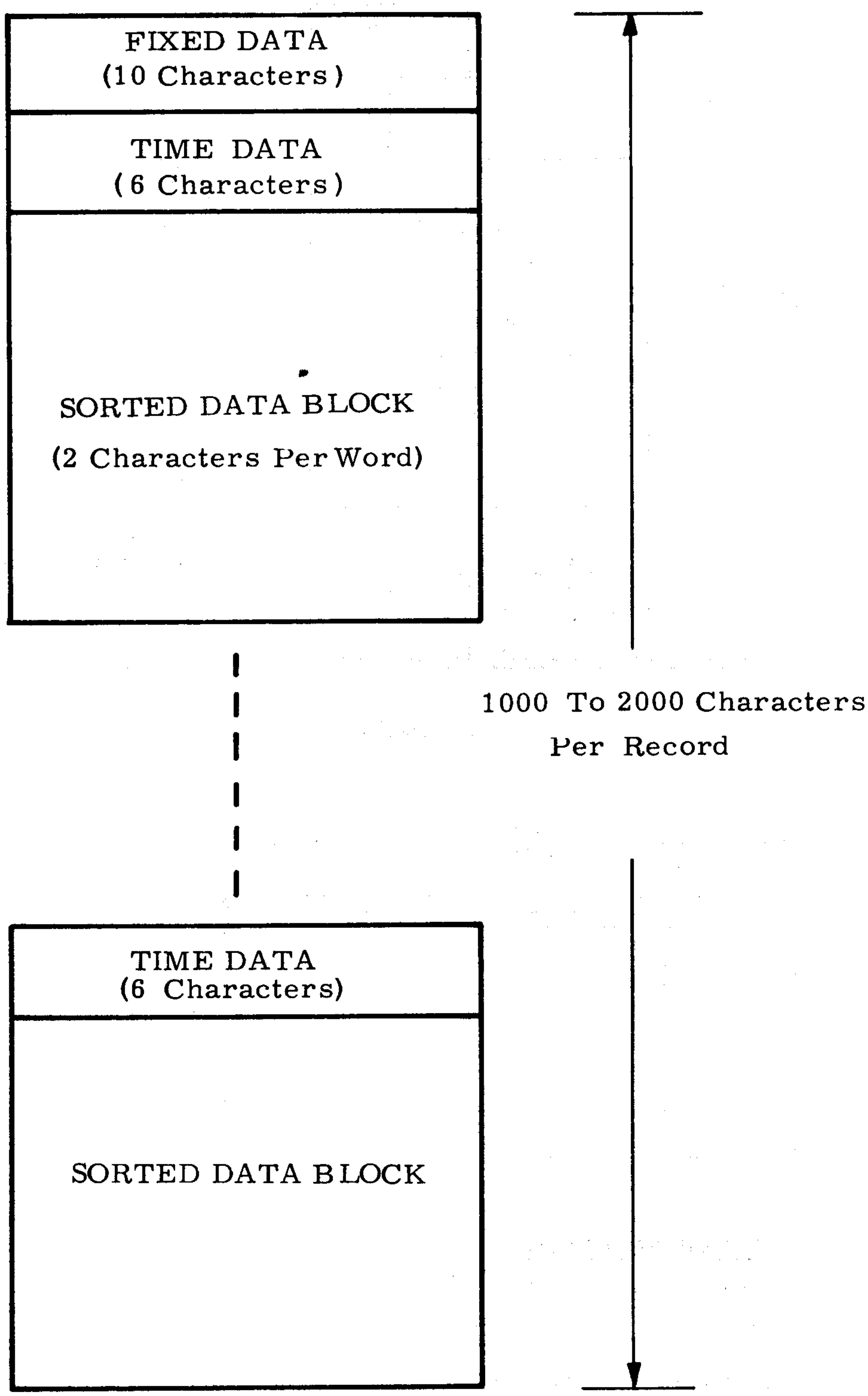


Figure 3. Output Record Format

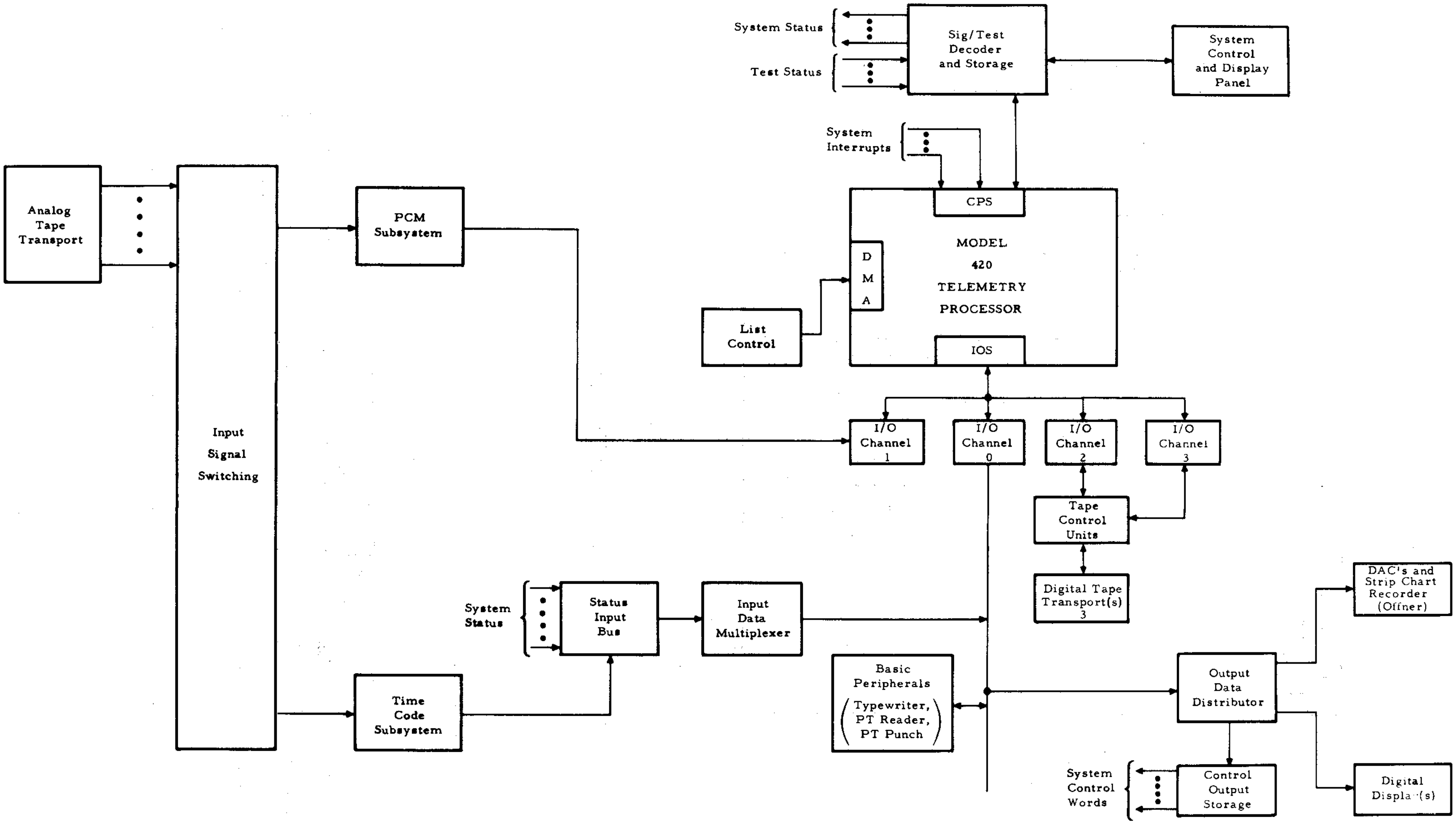


Figure 4. Model 8420 Configuration for Application Number One (On-Line Sort of PCM)

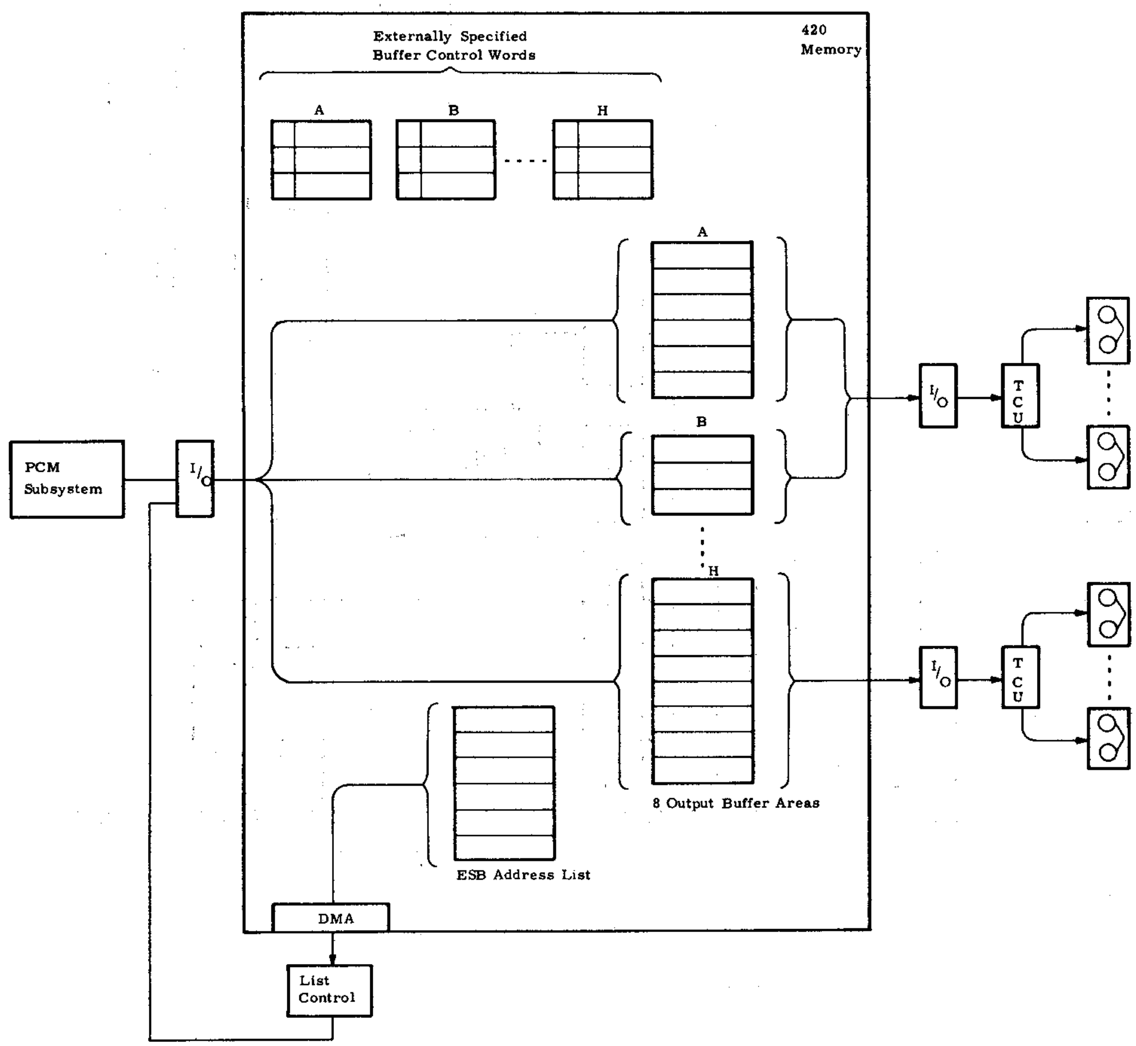


Figure 5. Online Sort

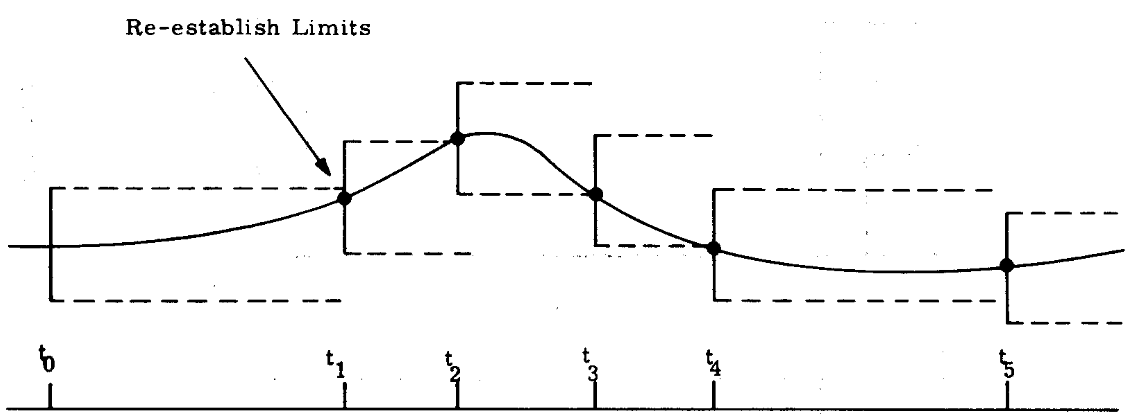


Figure 6. Data Compression

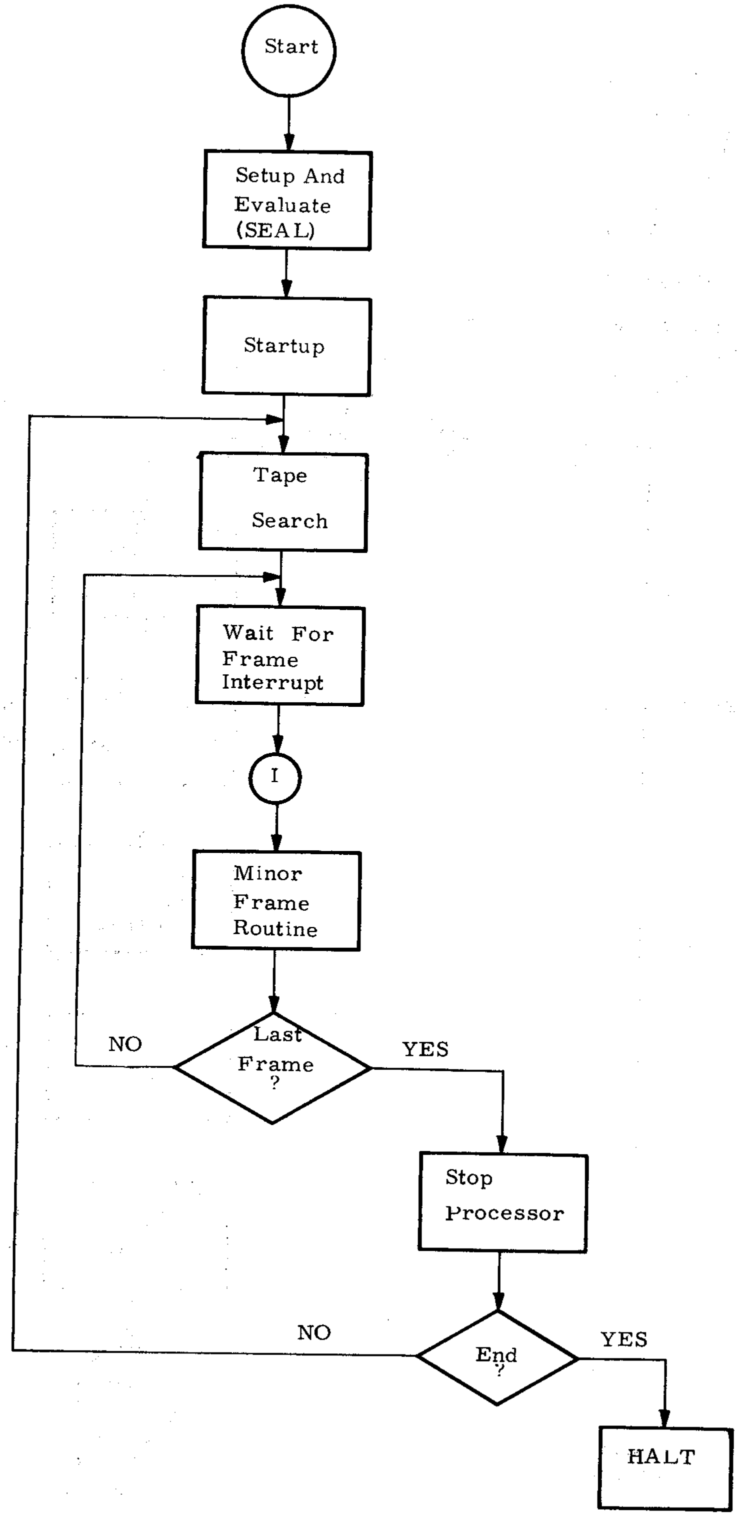


Figure 7. Executive Program (TELEX)

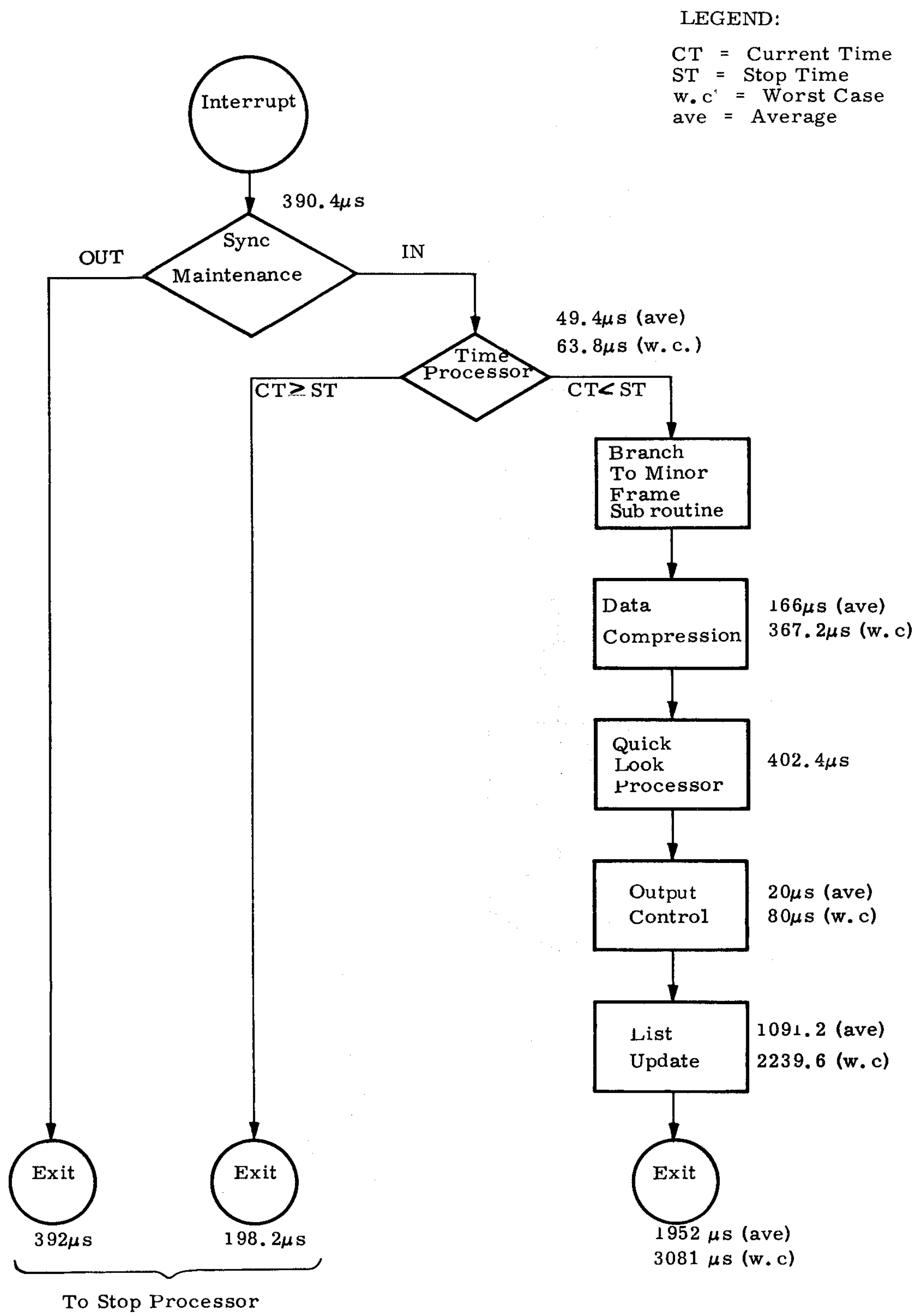


Figure 8. Minor Frame Routine

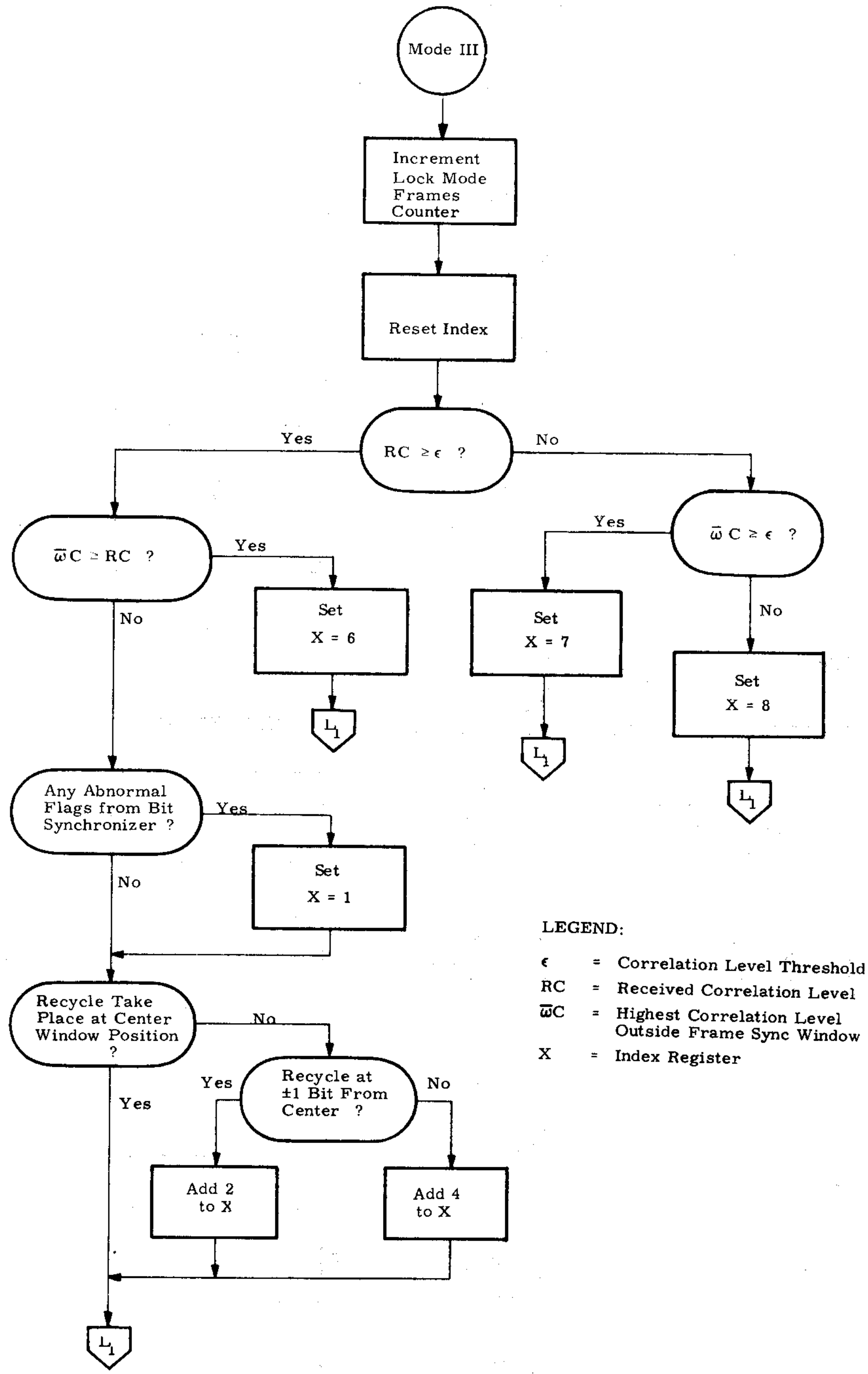


Figure 9. Sync Maintenance (1 of 4)

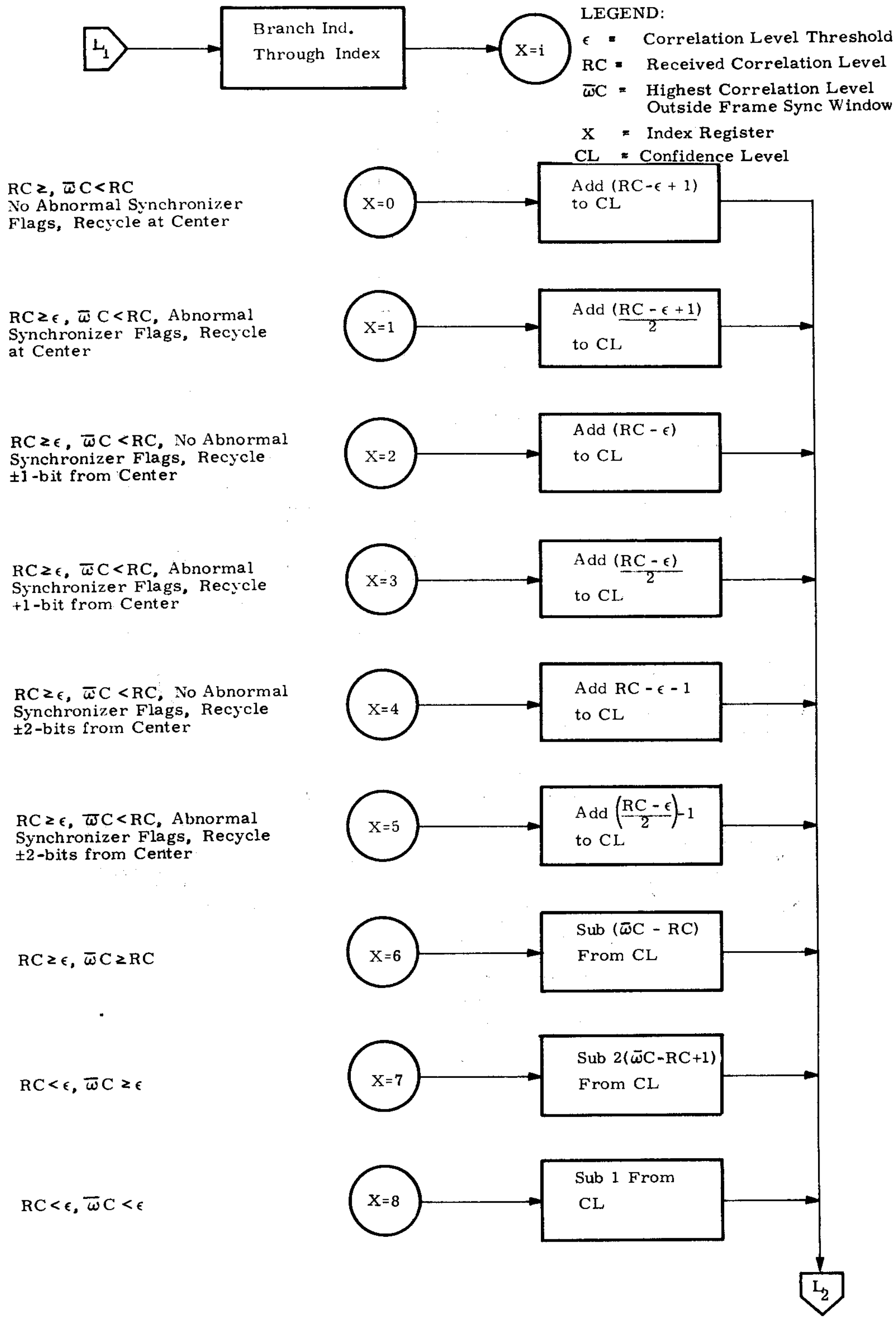


Figure 9. Sync Maintenance (2 of 4)

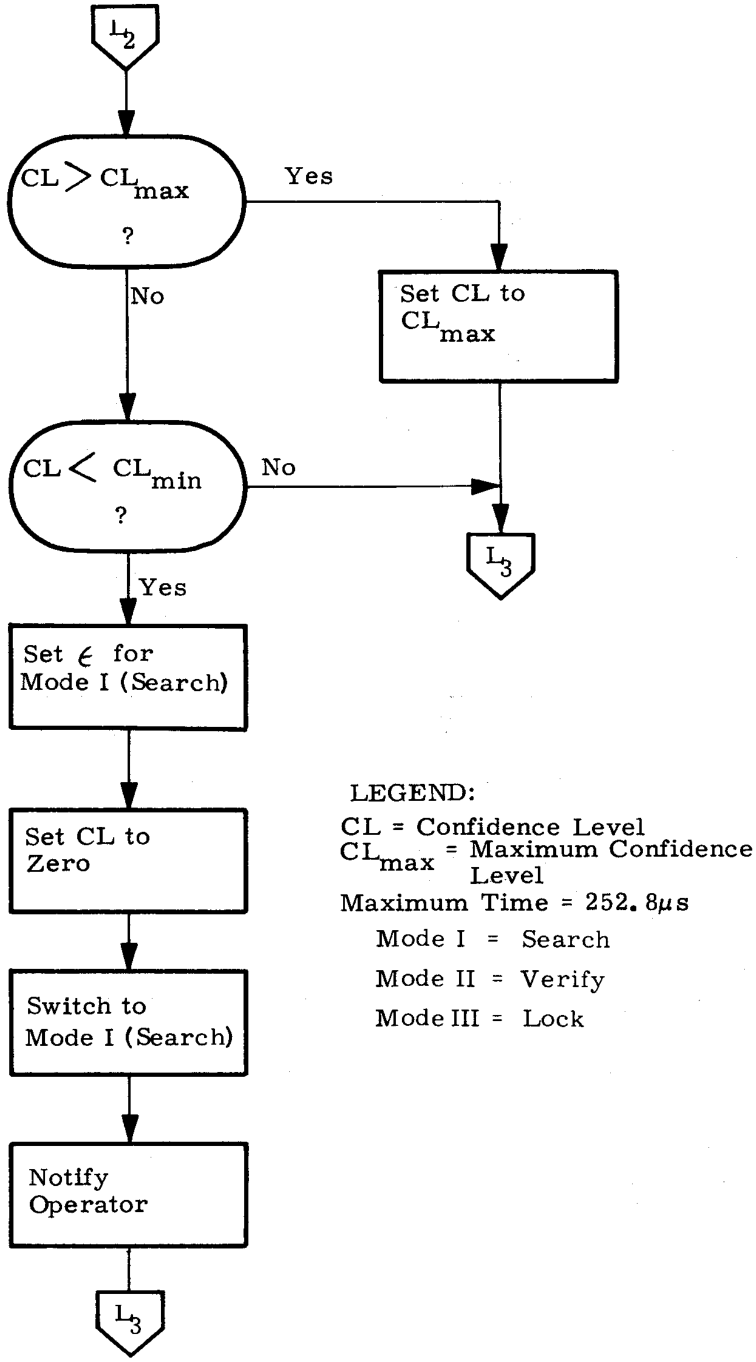


Figure 9. Sync Maintenance (3 of 4)

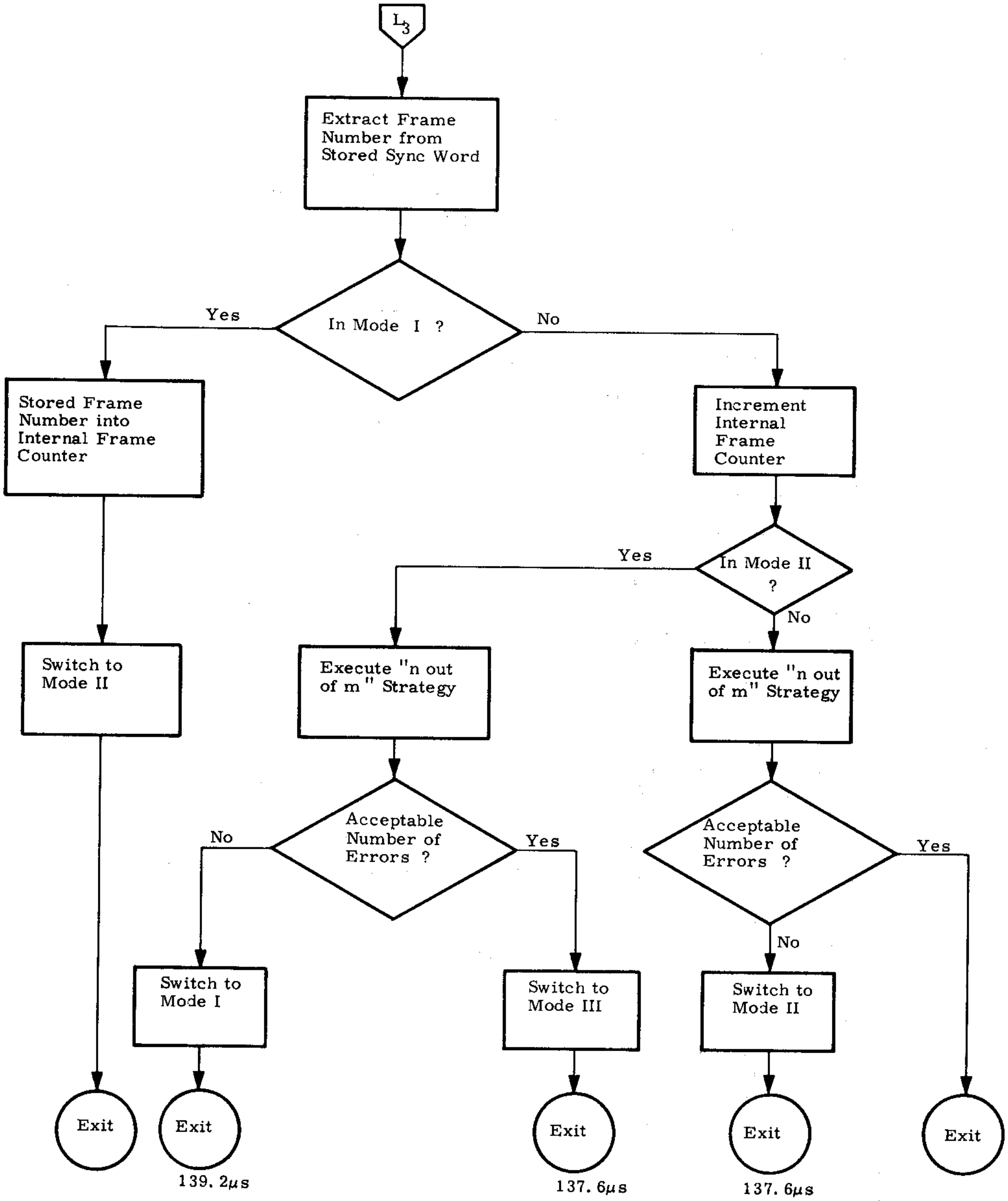


Figure 9. Sync Maintenance (4 of 4)

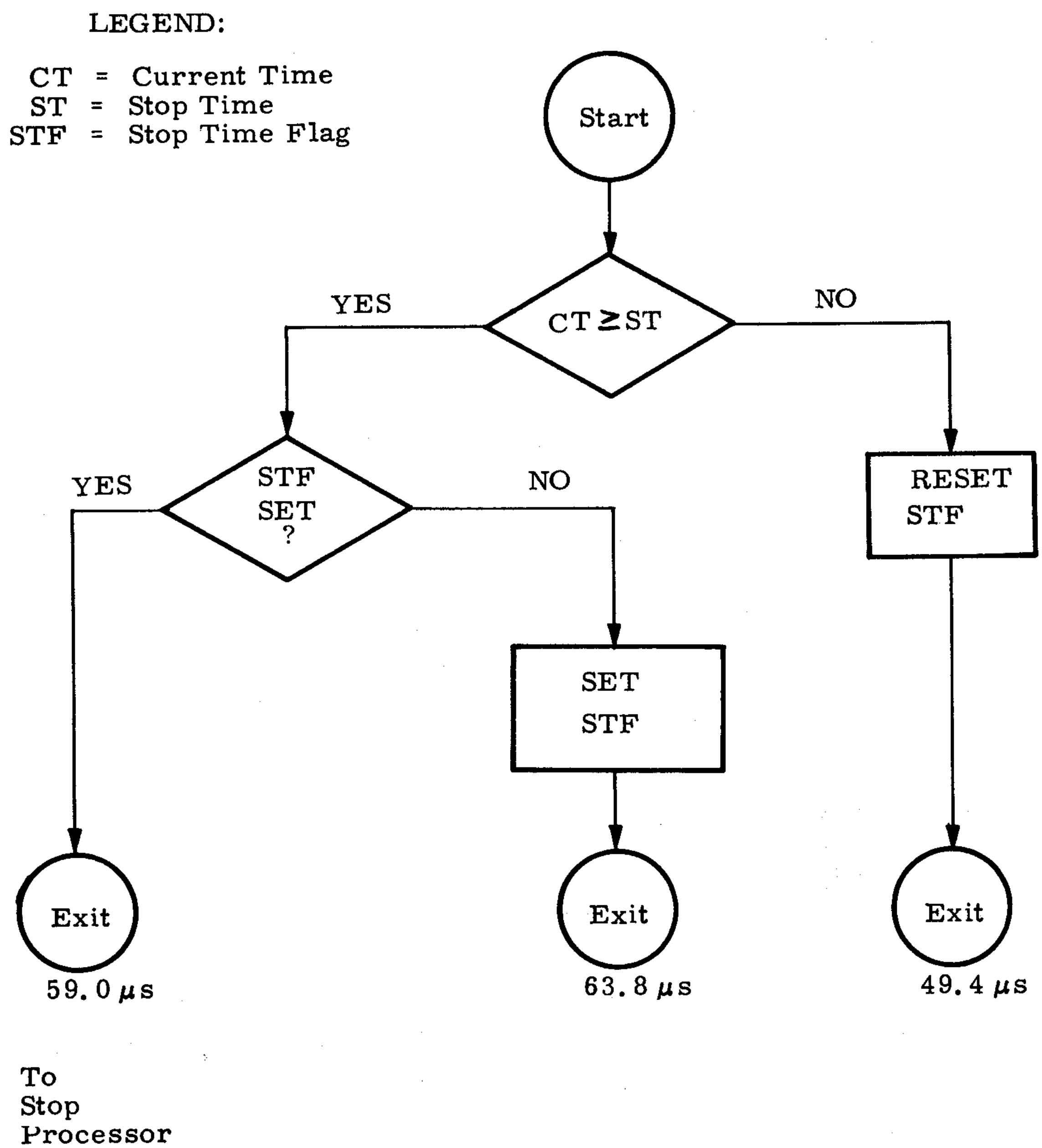


Figure 10. Time Processor

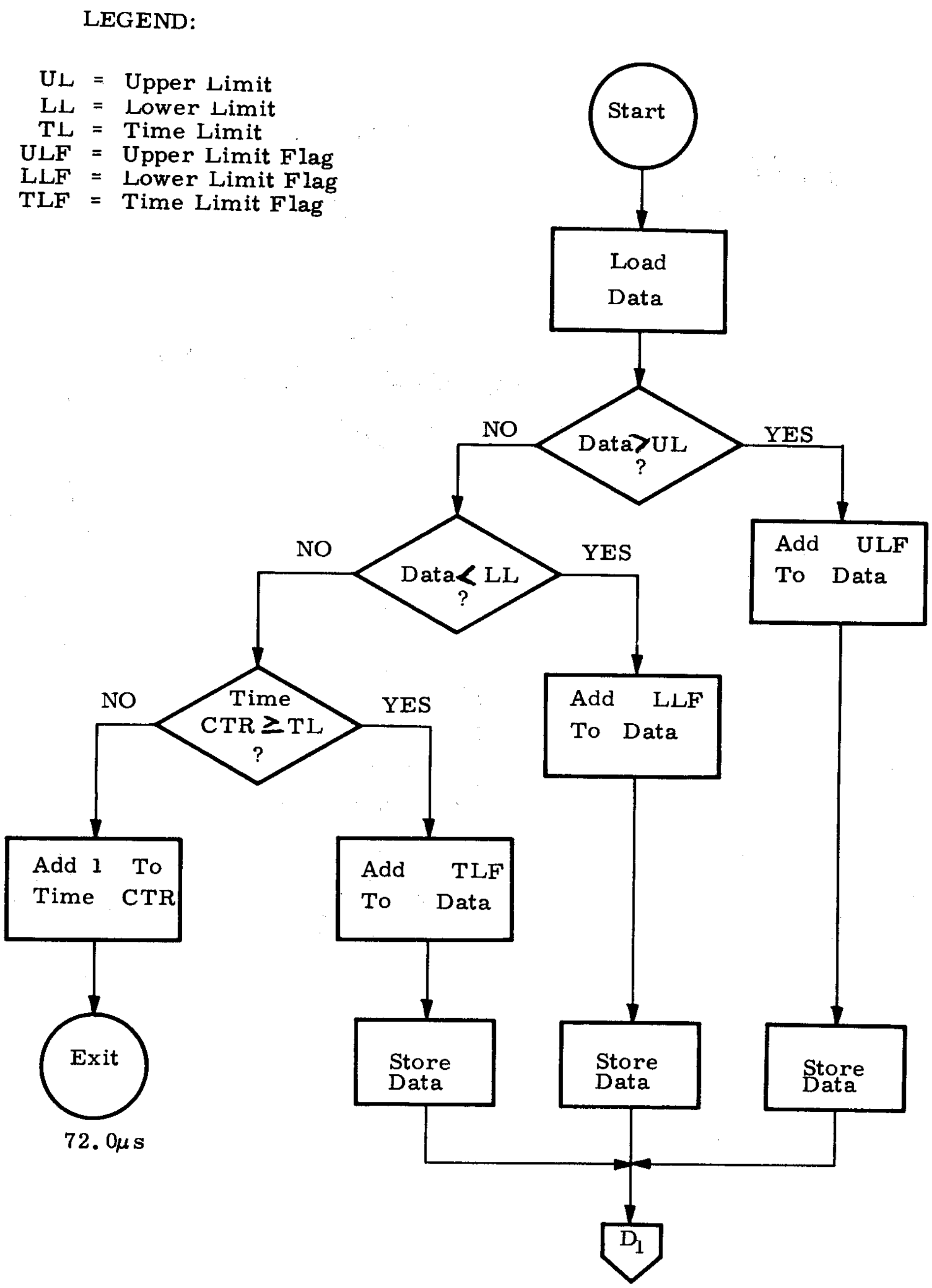


Figure 11. Data Compression (Resettable Limits) (1 of 2)

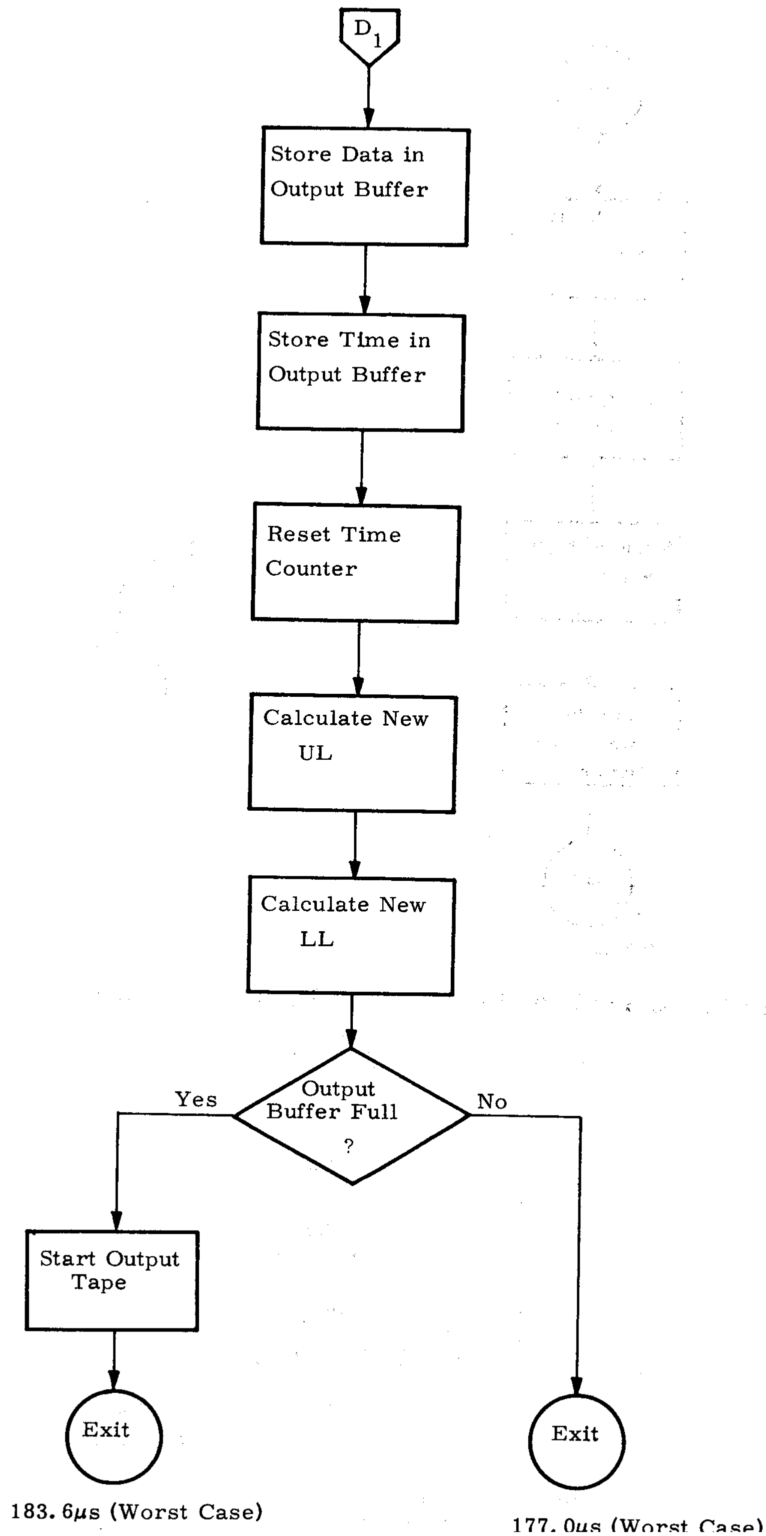


Figure 11. Data Compression (Resettable Limits) (2 of 2)

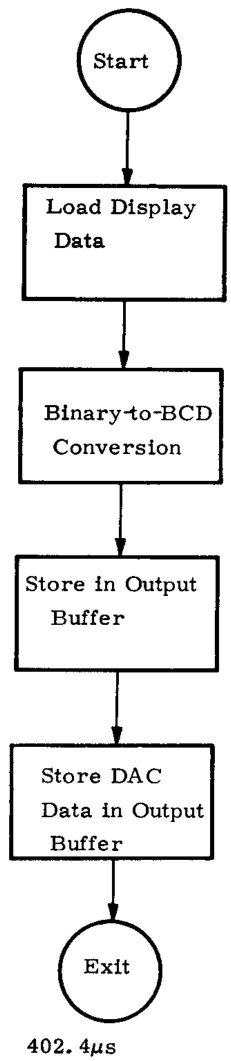


Figure 12. Quick Look Processor

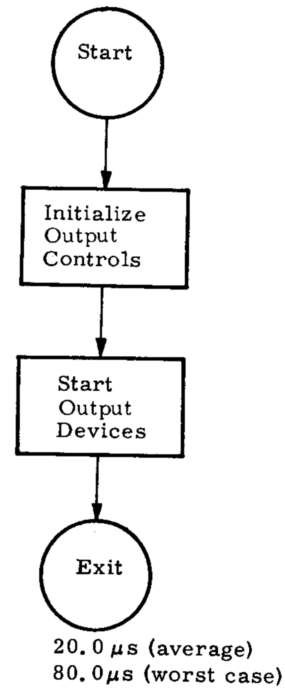


Figure 13. Output Control (Typical)

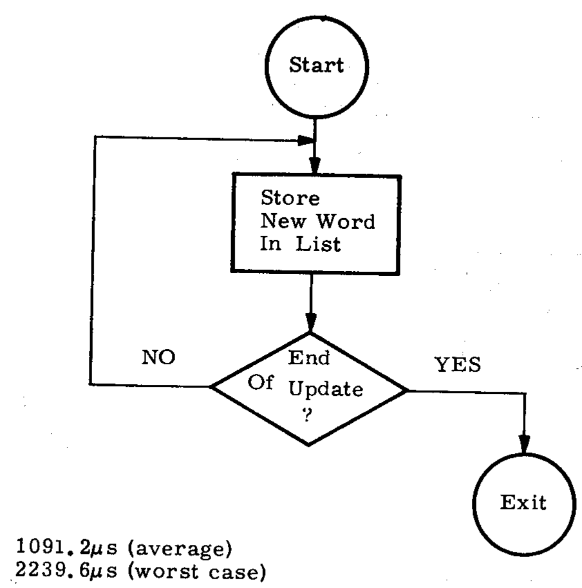


Figure 14. List Update

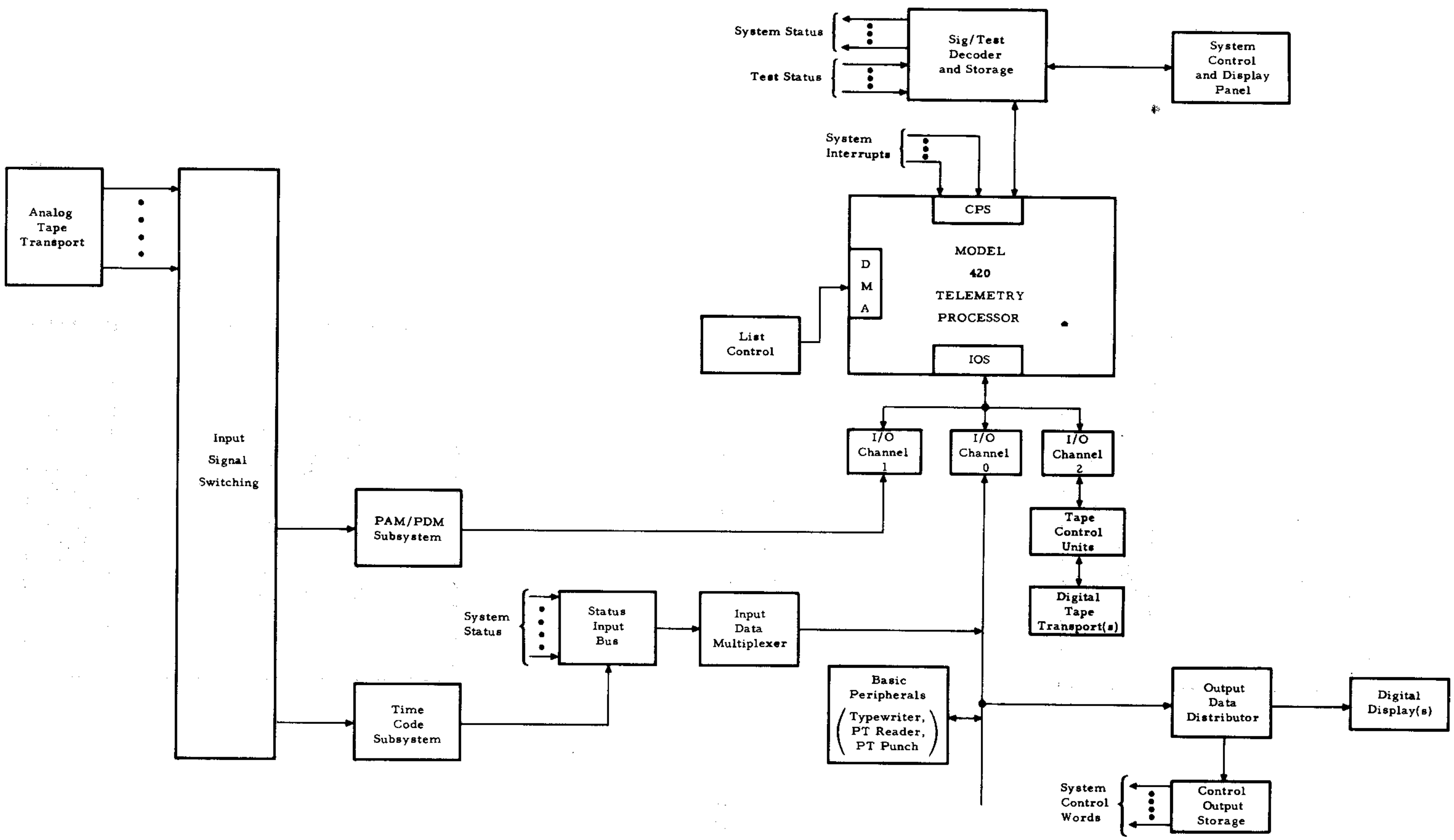


Figure 15. Model 8420 Configuration for Application Number Two (PAM/PDM Conversion)

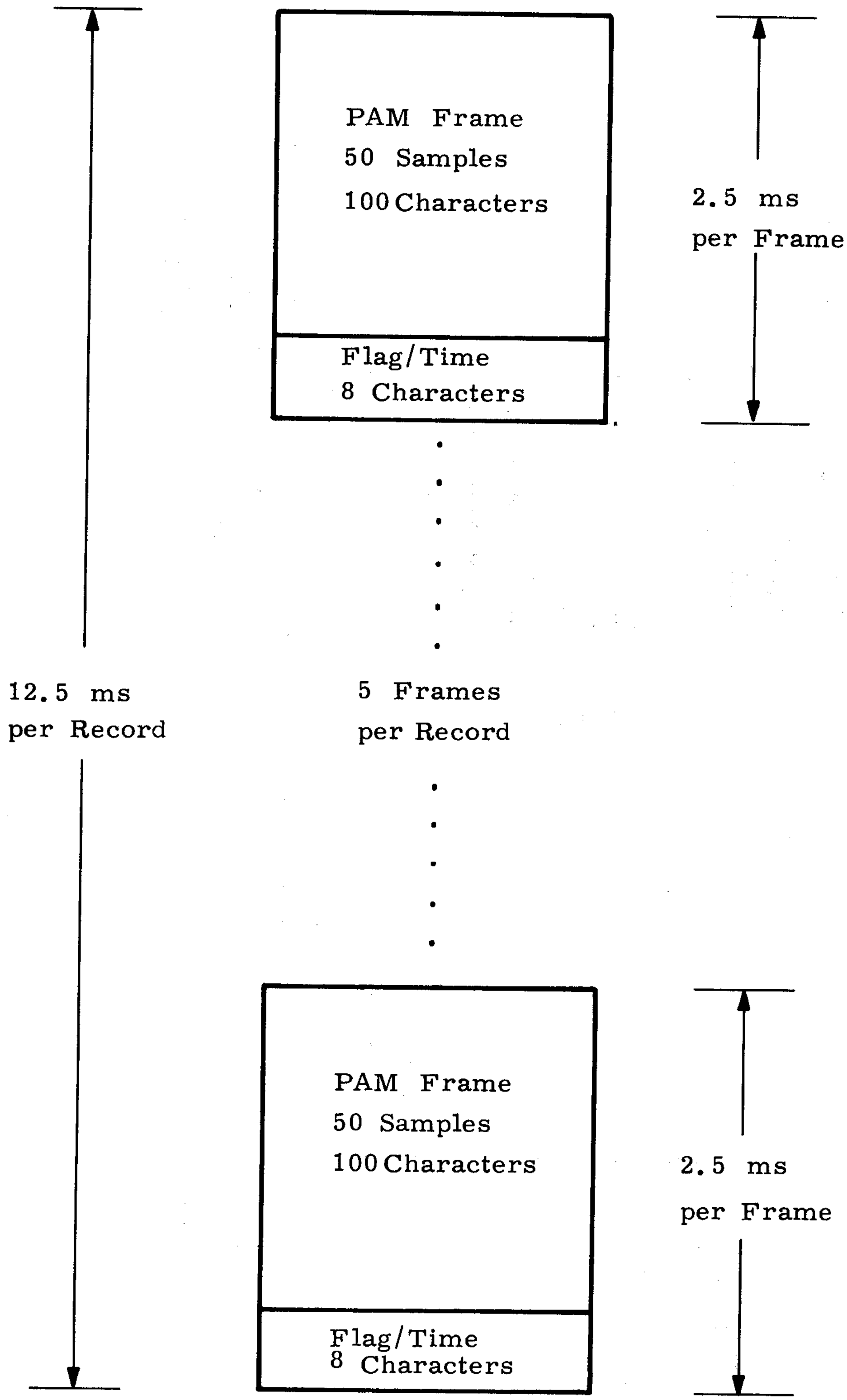


Figure 16. Output Record Format
Example 2

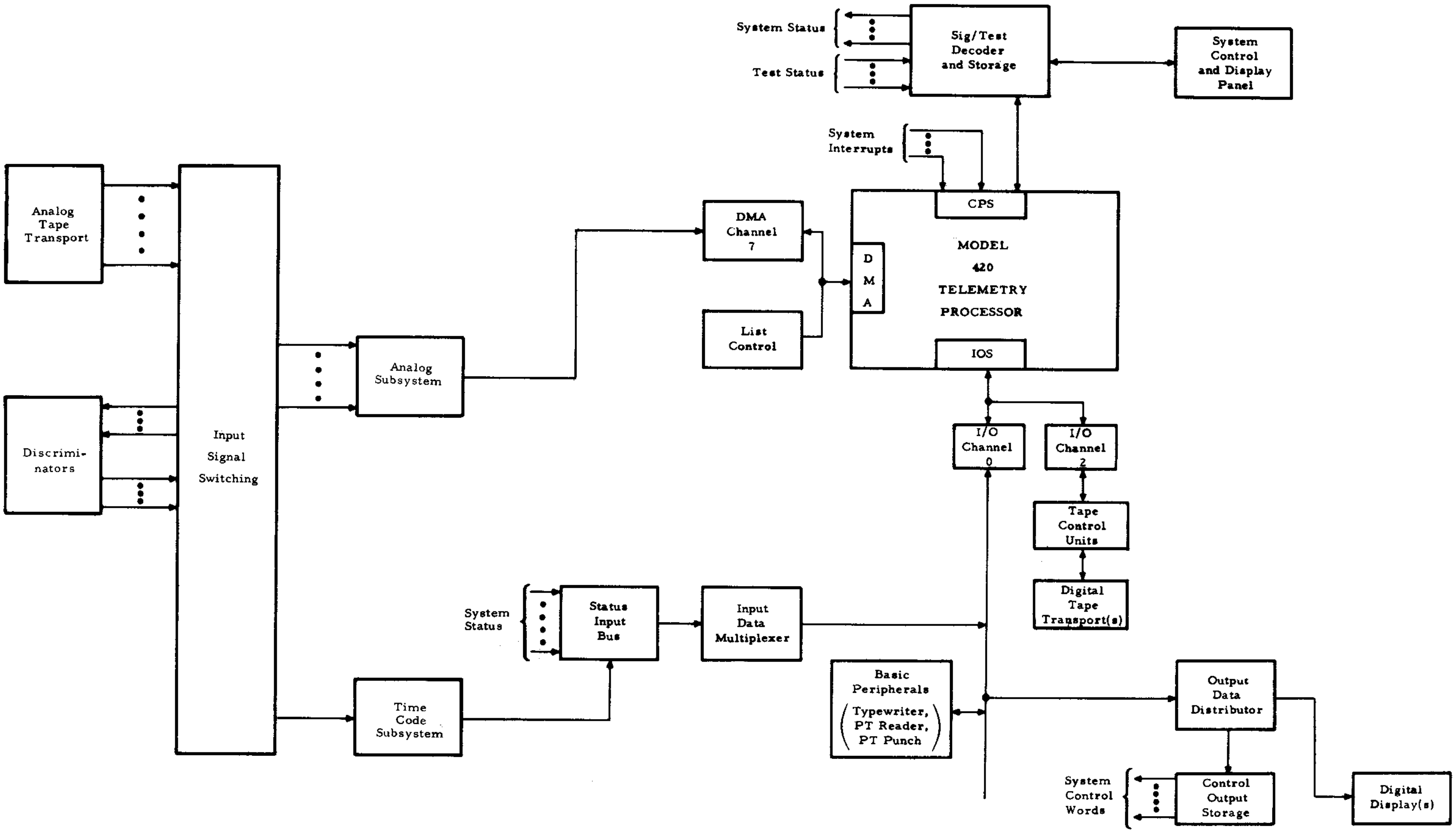


Figure 17. Model 8420 Configuration for Application Number Three (FM Conversion)

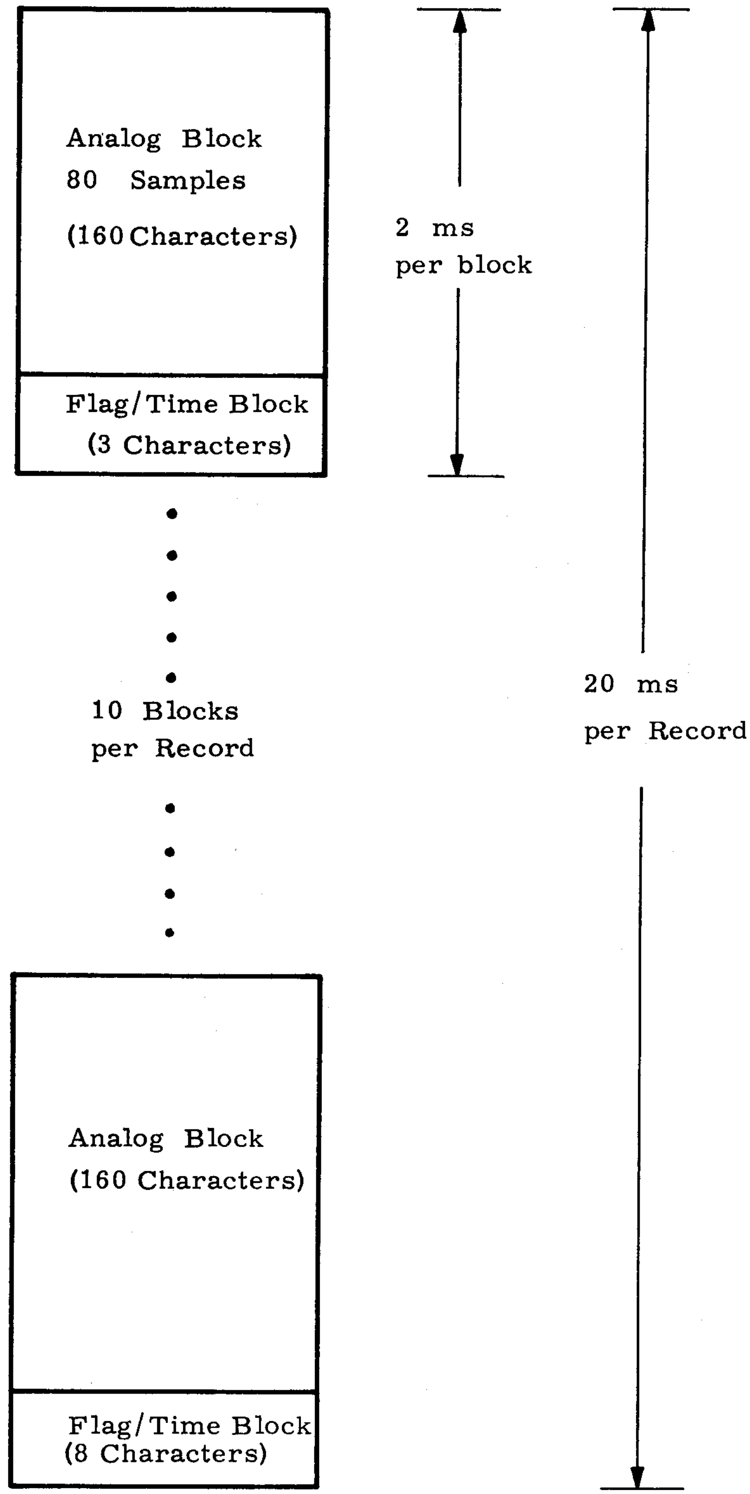


Figure 18. Output Record Format for Example 3

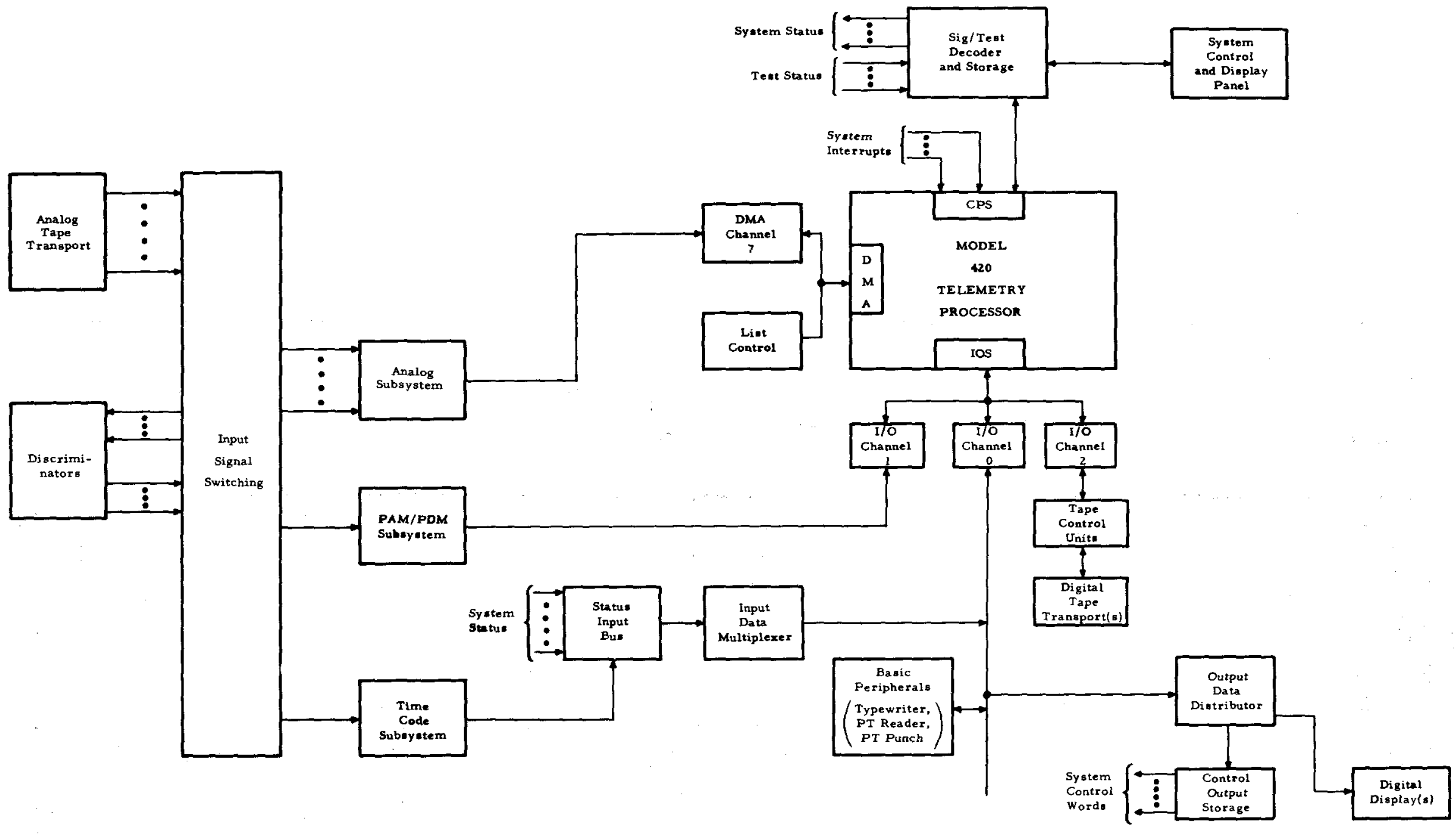


Figure 19. Model 8420 Configuration for Application Number Four (Merge FM and PDM)

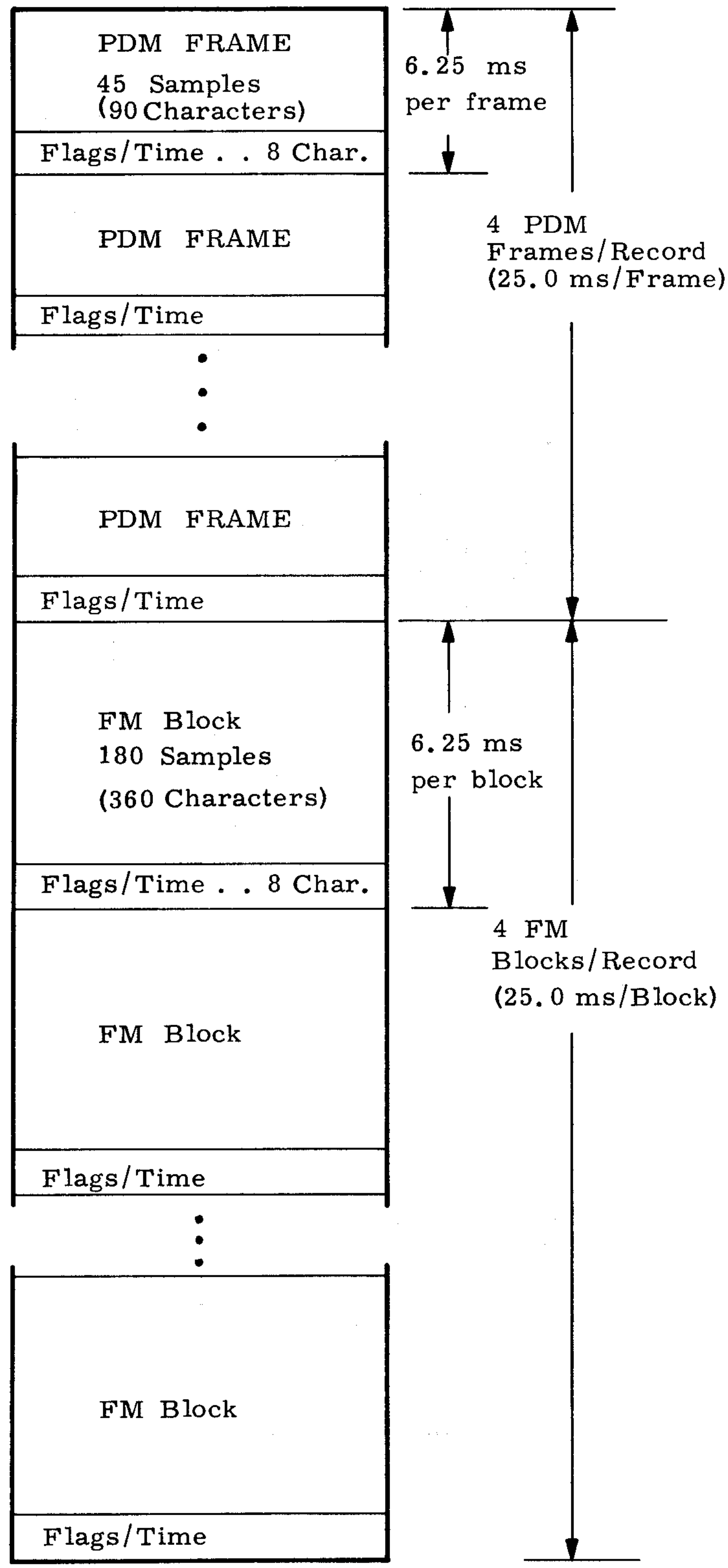


Figure 20. Example 4. Output Tape Format, PDM/FM Merge Mode