THE INSTRUMENTATION DATA RECORDER IN AN AUTOMATIC MODE TO RECORD AND REPRODUCE DIGITAL DATA

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Abstract

The conventional IRIG Instrumentation Tape Recorder has two major disadvantages when used to record and reproduce digital data.

Firstly it has a limited number of discrete tape speeds, and secondly the operator has to calculate and then set the tape speed to give the appropriate packing density or clock rate.

The use of microprocessors has made it possible to take the majority of these calculations, and also the setting up of the recorder, out of the users hands. Also the tape speeds available are virtually continuous over the range 17/8 ips to 120 ips.

There are other facilities available and this paper describes the operation and facilities of an instrumentation recorder which is almost totally automatic.

1.0 Introduction

Instrumentation Data Recorders commonly conform to IRIG standards i.e. tape speeds are related in a binary sequence usually in the range from 17/8 ips to 240 ips although some are optimised for several ranges lower. Usually digital signals require the higher ranges and techniques of spreading the signal over many tracks enables data rates of up to hundreds of megabits per second to be recorded, and reproduced on a virtually standard recorder.

The amount of data to be recorded is usually very large and therefore it is essential to utilise the tape as efficiently as possible i.e. the maximum packing density must be used irrespective of the incoming data rate. If data has to be recorded which originates from several sources at different rates or the rate changes in the middle of a recording, unless the operator is aware of the new data rates and does the arithmetic and resets the tape speed each time, the tape will either be inefficiently used or worse, the packing density may be above the working range and the record will exhibit a high error rate on reproduction.

Another common problem is on reproduce where bit-syncs are used to separate the clock and data. A local clock in the bit sync circuit has to be set to the expected frequency and a phase-locked-loop can then operate to lock this clock to the data. The data rate range of 10 kb/s to 4.5 Mb/s per track implies some means of presetting the clock (provided the expected rates are known) or an auto-ranging bit sync design is needed which needs no pre knowledge.

The THORN-EMI tape recorder 9000HD is a version of the conventional IRIG model with extra facilities which deal with the difficulties mentioned above and also provides some extra facilities on FM and DR.

2.0 Configuration of Recorder

Fig 1 shows the layout of the recorder within a 6 ft rack. The major changes are:

1. A new control unit with microprocessor control, giving either automatic computation of tape speed or manual with memory of settings and a key lock to prevent unauthorised changes and to recall previous settings.

   The tape speeds available are virtually continuously variable 3 3/4 - 120 ips or the fixed IRIG speeds 7 1/2, 15 ips etc may be selected.

2. To achieve maximum packing density with a good error rate, the recorder and reproduce channels must have a good phase characteristic as well as the expected frequency response and good signal/noise ratio. Also since the recorder is designed to work with continuously variable tape speeds the equalisation cannot be the usual IRIG configuration which is only optimised at the standard speeds.

   The tape path is standard, as are the heads with a resolution of 2 MHz (DR) at 120 ips and a life in excess of 3000 hours.

3.0 Digital Electronics

The digital electronics are housed in another 6 foot rack. The inputs may be serial up to 144 Mb/s ECL, or parallel, up to 4.5 Mb/s TTL. The formatter spreads the data over as many tracks (up to 32) as is needed, at a maximum of 4.5 Mb/s/track to give the necessary throughput rate.

The following operations are performed on each individual data track.

a) The continuous input data is divided into groups of 476 bits, while retaining the relationship between tracks to enable the orginal input serial stream to be reconstructed on reproduce or to maintain the input skew on parallel streams.

b) The 476 bit group is speeded up so that a gap of 34 bits is created between each group.

c) The 476 bit group is divided by a poly nomial which produces a 16 bit remainder which is put into the gap. This is used for error detection.

d) The remainder of the gap is fitted with a block marker to identify uniquely the start of a block.

A further action performed is to generate a parity track from the parallel data streams. A maximum of eight data tracks produce a parity track. This track is treated in exactly the same way as a data track. This is for error correction. So far the data is in NRZ-L form but this is not a good code for recording and so it is converted into 3PM before being passed to the recorder.

On replay, data from the tape is first equalised in the recorder and then passed (still in 3PM code) to the digital processing rack.

Firstly clock and data are separated in the auto ranging bit sync and NRZ-L data is then processed for error detection and correction, deskewing, and finally parallel to serial conversion.

The user does not see the block marker or the error detection information. The system is transparent.

4.0 <u>Recording</u>

When the recorder is placed in an automatic mode the operator has to define the packing density.

This is an operator decision which is mainly determined by error rate requirements.

The use of 3PM code enables higher packing densities than NRZ or Miller, but depending on the requirements, the normal user figure of 40 kbpi may have to be degraded.

The reasons for restricting the packing density may be:

1. Poor quality tape.

2. Tape interchange between machines.

3. Up or down shifting e.g. record at 120 ips reproduce at 15 ips or vice versa.

Constant packing density gives the most efficient use of tape but there may be a requirement of the recording time, due for example to the time a satellite is within sight of an earth station which may mean that best error rate has to be compromised.

The computation done by the control unit in the auto mode is a simple one:

1. Measure frequency of incoming data clock.

2. With the packing density given, calculate the tape speed.

3. Set recorder to run at that speed.

4. Set equalisers to match the calculated speed to enable downstream monitoring of recorded data.

5. Continuously monitor the input clock rate to follow any changes.

There is no need for the operator to make a note of the packing density or tape speed for replay purposes.

Where several tracks are used the format must be noted so that they system can be reset to that configuration, but data rates and packing densities are contained in the data on the tape.

5.0 <u>Reproduction</u>

The crucial item in the replay chain is the auto ranging bit synchroniser which uses the block marker to provide information to set up the bit sync oscillator frequency to nearly the required one. A description of the waveform will be necessary.

3PM coding takes the NRZ input in groups of 3 bits and using a look-up table, recodes it into six bits and records the information as flux changes in six bit cells. The combinations chosen only allow transitions further apart than 3 code bit cells i.e.

1 1/2 data bit periods. NRZ can have transitions 1 data bit period apart. This factor is the one which enables higher data packing densities than other codes.

For the block marker we use another feature of 3PM. The maximum time between transitions is 6 data bit periods. Therefore a unique block marker can be obtained by inserting an interval which never occurs in the data. We use 7 1/2 data bits set in an 18 bit window.

The choice of 18 bits enables easy stuffing arithmetic. Data is speeded up by 510/476 = 15/14.

In a train of data from the tape, an interval longer than all the others occurs every 510 bits and that interval is 7 1/2 bits long.

The auto bit sync module employs a microprocessor to firstly measure the time between transitions and remember the longest in a given time interval.

Secondly, the local oscillator is set to give 7 1/2 bits (15 2 x clock periods) in that time interval.

Thirdly, check that one of these markers occurs every 510 bits. If that is so then we can move on to the normal phase locked loop operation.

The design of that is easier since the pull-in range is determined by the micro as just described and the time constant of the loop can be optimised to match the characteristic of the recorder, and not be a compromise as is normally the case.

The measurement and setting of the coarse adjustment of the oscillator frequency continues during normal operation and so allows ± 10% variation of the rate from the tape and stay in lock. A bigger variation than this may mean the digital control will not cope and a change of range is necessary, depending on where the operation is within a given range.

Thus a tape played at any speed (within the operating range) will be decoded with no operator intervention whatsoever.

The data rate will depend, in the manual mode, on the tape speed and packing density, but an automatic mode is also available. This is known as ‘data on demand’. The tape is loaded and a clock applied. The recorder will fill a memory from the tape and each external demand clock pulse will read out one data byte or serial bit. The recorder keeps the memory half full. Since this is a large reel instrumentation recorder and the information is not written with inter block gaps, it is not possible to work on a start-stop basis but the system will lock up to any clock which has a relatively constant (± 5%) frequency.

This also relies on the auto-bit sync operation to lock-on. An initialisation routine, microporcessor controlled, sets the tape speed to provide nearly the required data rate and a servo using the difference from the memory being half full is then used for fine control of tape speed.

Firstly the tape recorder is set to 120 ips and when the bit syncs lock, the data rate is measured.

Secondly, the measured rate and the required rate are compared and the control unit resets the recorder to a new speed which will provide nearly the required data rate.

Finally the memory is filled from tape and when it is half full, the servo loop is closed and data is read out.

This mode is not only automatic, the data that comes out is synchronous with the demand clock and of course has no flutter.

6.0 Typical Application

This equipment has lots of different applications, but for the recording of downlinks from satellites its automatic features have enabled one set of equipment to record and replay the data from several satellites with no adjustment to suit the data rates.

For example:

ERS-1	Real time SAR at 105 Mb/s
JERS-1	Real time SAR at 60 Mb/s
JERS-1	Playback SAR at 60 Mb/s
RADARSAT	Real time SAR at 100 Mb/s
RADARSAT	Playback SAR at 100 Mb/s

With replay at almost any rate.

Another feature which is essential for the record/reproduce of these downlinks is the facility to record or reproduce in reverse. The equalisation is automatically selected for reverse when the transport is in the reverse mode, and the block markers and error correction also work in reverse. Again no user controls require adjustment.

7.0 Summary

The equipment described requires the minimum of user interaction to change the record or reproduce requirements for another application. The effect of data rate change is totally handled automatically, as is reverse operation.

The change from one channel to several asynchrous channels probably requires more user interaction than any other but provided the total data rate requirement does not increase this is only a minor internal cabling adjustment and resetting of two DIL switches.

FIG.1.

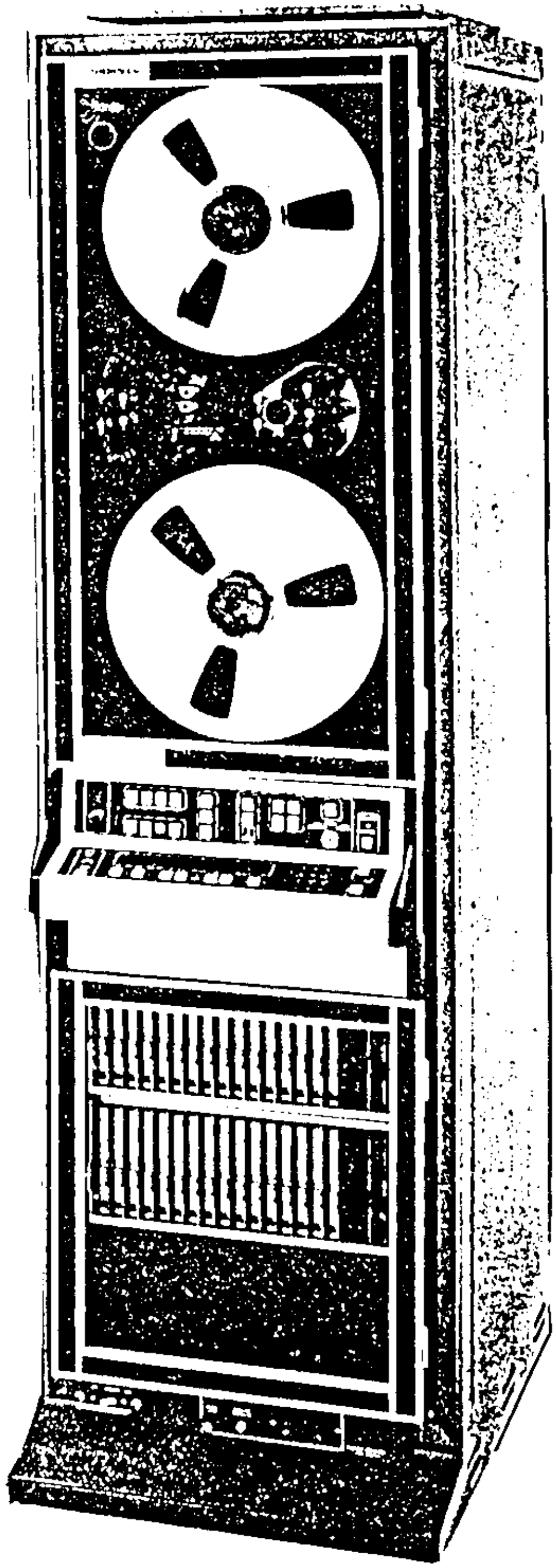
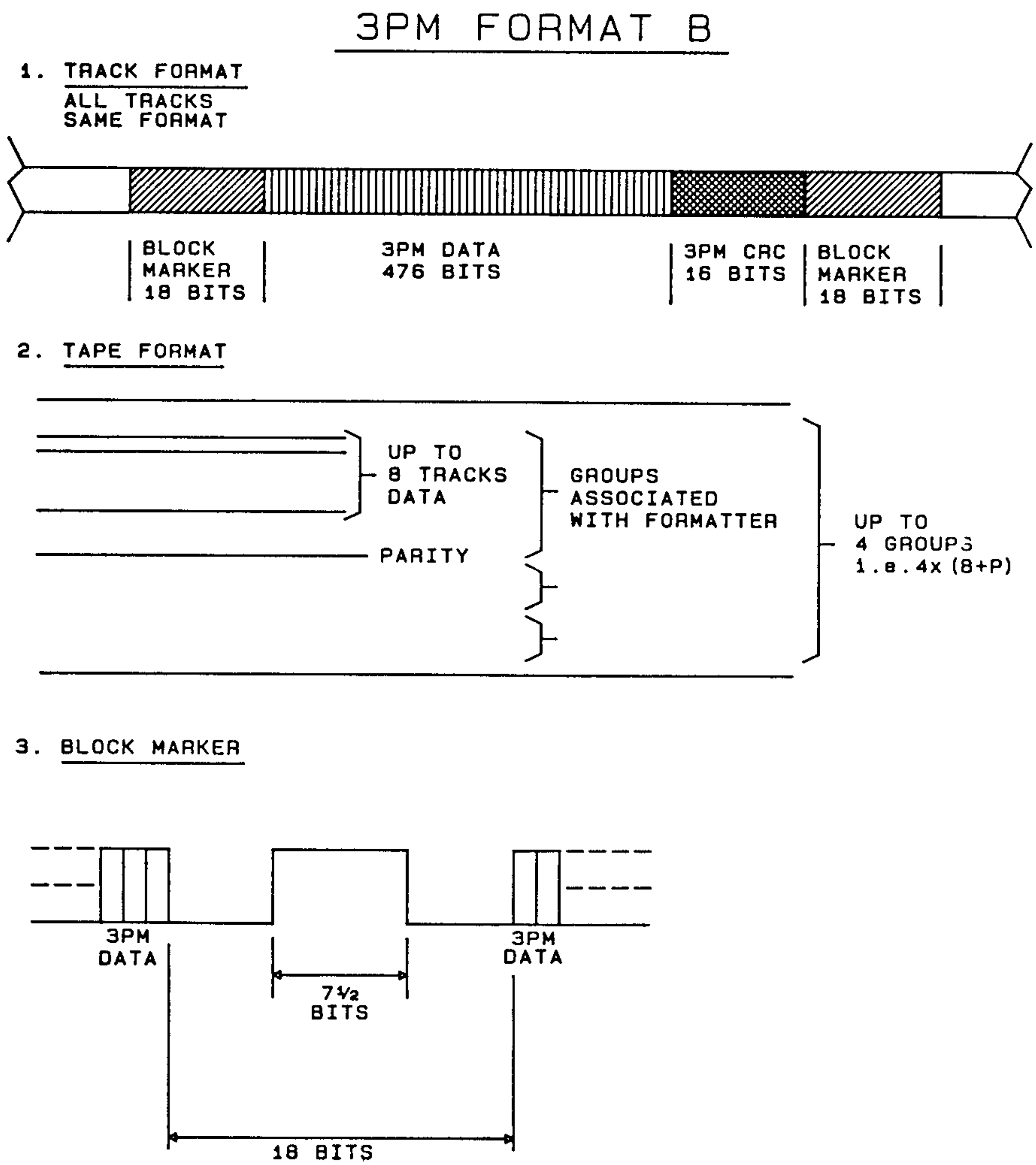


FIG. 2.


3PM FORMAT B
1. TRACK FORMAT
ALL TRACKS SAME FORMAT
BLOCK MARKER 18 BITS
3PM DATA 476 BITS
3PM CRC 16 BITS
BLOCK MARKER 18 BITS
2. TAPE FORMAT
UP TO 8 TRACKS DATA
GROUPS ASSOCIATED WITH FORMATTER
PARITY
UP TO 4 GROUPS i.e. 4x (8+P)
3. BLOCK MARKER
3PM DATA
7½ BITS
3PM DATA
18 BITS