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A Grouped Binary Time Code for Telemetry and Space Applications

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AND SPACE APPLICATIONS

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A GROUPED BINARY TIME CODE FOR TELEMETRY AND SPACE APPLICATIONS*

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ABSTRACT

A computer oriented time code designed for users with various time resolution requirements is presented. It is intended as a time code for spacecraft and ground applications where direct code compatibility with automatic data processing (ADP) equipment is of primary consideration. The principal features of this time code are: byte oriented format, selectable resolution options (from seconds to nanoseconds); and long ambiguity period.

The time code is compatible with the new data handling and management concepts such as the NASA End-to-End Data System (NEEDS) and the Telemetry Data Packetization format [1].

INTRODUCTION

The use of codes for communication of messages has long been recorded in history and folklore. Various time coding formats have been used from drum beats, a primitive way to communicate time of day, to bells and chimes, a modern way to communicate hour, half-hour, and quarter hour, etc. As computer technology and information theory was advanced, analog codes gave way gradually to binary codes and pseudo-random noise (PN) codes. PN codes are increasingly used in communications for many reasons, among them the high data rate transmission capabilities. As mini-computers and microprocessors become feasible and economical to implement, their inherent

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capability for automatic data handling and analysis provides further impetus toward the adoption of machine readable codes. While the time code design is undergoing an evolution, attention must be also given to the time units and the way they are constructed traditionally. For example, the day count system can recycle in any number such as 7, 28, 29, 30, and 31 if week or month is used and 365 and 366 if year is used. For time units less than a day, hours, minutes, seconds, milliseconds, etc., are conventionally used. These counting systems are more complicated, if not impossible, in a system design if a simple code is desired. The series of binary coded decimal (BCD) time codes, which have been adopted by the Inter-Range Instrumentation Group (IRIG) of the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), and the National Bureau of Standards (NBS) of the Department of Commerce, etc., are good examples of this attempt. Although these time codes meet the users' needs, they are nevertheless a compromise and cumbersome for automated data handling and analysis. [See Appendix 1]

PREVIOUSLY ADOPTED PARALLEL GROUP BINARY TIME CODES

This time code extends the family of four parallel grouped binary time codes which had been adopted as standards by IRIG and NASA in 1978. These four codes, as well as the new code, are shown in Table 1. The new code is designed specifically, although not exclusively, for spacecraft applications.
DESIGN CONCEPT AND DESCRIPTION OF TIME CODE

CONCEPT - The trend of data handling and management in space programs is directed toward automatic data processing [2]. This trend owes its impetus to another concept, i.e., the spacecraft autonomy. Spacecraft autonomy means self-sufficiency in all respects in the spacecraft from navigation, timekeeping, sensor control, data collection, communication, and transmission. In the background of these future needs, this time code is designed. Additionally, attention is also given to an overall system design for satellite-to-satellite time transfer from a ground station to achieve autonomy in the spacecraft clock [3].

Primary consideration in the design of this code is, therefore, given to automatic data processing and machine interface. It is in 8-bit byte format and has four resolution options: seconds, milliseconds, microseconds, and nanoseconds. This code also contains a four decimal digit of day count which gives a long ambiguity period of 27.4 years. The long ambiguity day count system is thus ideal for spacecraft archival data storage and retrieval. It further provides an unique reference calendar to record satellite launch dates and orbit numbers. It also removes the need to annotate the year, month, and leap year information.

DESCRIPTION OF TIME CODE - The parallel grouped binary time code, PB-5 consists of five groups of binary numbers, each of which is designated for a unit of time. In descending order, the five groups of binary numbers give the day, seconds, milliseconds, microseconds, and nanoseconds. Each time
unit is coded in a pure binary number. The overflow in a lower resolution unit results in an increment of one in the next higher resolution unit. This is accomplished by a properly designed feedback loop.

The Day Count System - The four decimal digit day count system is derived from the truncation of the three most significant numbers of the present seven decimal digits of Julian Day Number (JDN), thus the name the Truncated Julian Day (TJD). TJD is arbitrarily chosen to begin from 0 at midnight May 24, 1969, and ends 9999 at midnight October 9, 1995 after which it recycles to zero. The repetition period is 27.4 years. A conversion table from TJD to calendar data in year, month, and day is given in Table II. The four decimal digits of a TJD number are represented by a 14-bit binary number.

Seconds of Day - The second(s) of a day counts from 0 to 86399 after which it overflows to the increment of a day and recycles to zero. The five decimal digital number is represented by a 17-bit binary number.

Time Units Less Than a Second - The millisecond (ms) of a second counts from 0 to 999 after which it overflows to the increment of a second and recycles to zero. The three decimal digital number is represented by a 10-bit binary number.

The microsecond (μs) of a millisecond counts from 0 to 999 after which it overflows to the increment of a millisecond and recycles to zero. The three decimal digital number is represented by a 10-bit binary number.
The nanosecond (ns) of a microsecond, like the millisecond and microsecond, counts from 0 to 999 after which it overflows to the increment of a microsecond and recycles to zero. The three decimal digital number is represented by a 10-bit binary number.

RESOLUTION OPTIONS AND IDENTIFICATIONS

RESOLUTION OPTIONS - The four resolution options of the PB-5 time code and the integer numbers of the 8-bit bytes for each option are shown in Figure 1.

The nanosecond code is represented by 8 bytes as shown at the bottom of Figure 1. It is the first option and is the untruncated code. The microsecond code is the second option and is represented by 7 bytes. It is obtained by truncating the nanosecond code group. The millisecond code is the third option and is represented by 6 bytes. It is obtained by truncating the microsecond and nanosecond code groups. The "second" code is the fourth option and is represented by 4 bytes. It is obtained by truncating the millisecond, microsecond and nanosecond code groups.

CODE OPTION IDENTIFICATION - The identification code used for the four options is a variable prefix code consisting of 1 to 3 bits. The variable prefix code is adopted to achieve the efficient use of the available bits in forming an integer number of 8-bit bytes. Thus for the "second" resolution code, the prefix code contains and can contain only one bit in the first bit position. It is encoded by the logic "1", as shown in Figure 1. For the nanosecond, microsecond, and millisecond resolution codes, three bits are used to represent the numbers 1, 2, and 3 respectively in the prefix code.
In this format, see Figure 1, only two and four filler bits are needed to form the integral 8-bit bytes for the microsecond and millisecond resolution codes respectively. To avoid confusion, the filler bits are always encoded by the logic "0".

ACKNOWLEDGEMENT

The author takes pleasure in acknowledging the contributions by the members of his Subcommiteee on Timing Standards of Goddard's Data Systems Requirements Committee, in particular Messrs., William P. Poland, Jr., and William H. Stallings, III.
Table 1
NASA Parallel Grouped Binary Time Codes

<table>
<thead>
<tr>
<th></th>
<th>D/Y</th>
<th>ms/D</th>
<th>μs/D</th>
<th>μs/ms</th>
<th>ns/μs</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB-1</td>
<td>(9)</td>
<td>(27)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PB-2</td>
<td>(9)</td>
<td>(37)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PB-3</td>
<td>(9)</td>
<td>(17)</td>
<td>(10)</td>
<td>(10)</td>
<td></td>
</tr>
<tr>
<td>PB-4</td>
<td>(9)</td>
<td>(27)</td>
<td>(10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PB-5</td>
<td>(14)</td>
<td>(17)</td>
<td>(10)</td>
<td>(10)</td>
<td>(10)</td>
</tr>
</tbody>
</table>
Table 2
Truncated Julian Day Count System

TJD. TJD\(^1\) is a day count system which is truncated from Julian Day Number (JDN)\(^2\) giving year and day information in four digits. TJD has an ambiguity period of 27.379 years.\(^3\)

<table>
<thead>
<tr>
<th>Date</th>
<th>TJD</th>
<th>JDN</th>
</tr>
</thead>
<tbody>
<tr>
<td>680524</td>
<td>0</td>
<td>2440000</td>
</tr>
<tr>
<td>691006</td>
<td>500</td>
<td>2440500</td>
</tr>
<tr>
<td>710218</td>
<td>1000</td>
<td>2441000</td>
</tr>
<tr>
<td>720702</td>
<td>1500</td>
<td>2441500</td>
</tr>
<tr>
<td>731114</td>
<td>2000</td>
<td>2442000</td>
</tr>
<tr>
<td>750329</td>
<td>2500</td>
<td>2442500</td>
</tr>
<tr>
<td>760810</td>
<td>3000</td>
<td>2443000</td>
</tr>
<tr>
<td>771223</td>
<td>3500</td>
<td>2443500</td>
</tr>
<tr>
<td>790507</td>
<td>4000</td>
<td>2444000</td>
</tr>
<tr>
<td>800918</td>
<td>4500</td>
<td>2444500</td>
</tr>
<tr>
<td>820131</td>
<td>5000</td>
<td>2445000</td>
</tr>
<tr>
<td>830615</td>
<td>5500</td>
<td>2445500</td>
</tr>
<tr>
<td>841027</td>
<td>6000</td>
<td>2446000</td>
</tr>
<tr>
<td>860311</td>
<td>6500</td>
<td>2446500</td>
</tr>
<tr>
<td>870724</td>
<td>7000</td>
<td>2447000</td>
</tr>
<tr>
<td>881205</td>
<td>7500</td>
<td>2447500</td>
</tr>
<tr>
<td>900419</td>
<td>8000</td>
<td>2448000</td>
</tr>
<tr>
<td>910901</td>
<td>8500</td>
<td>2448500</td>
</tr>
<tr>
<td>930113</td>
<td>9000</td>
<td>2449000</td>
</tr>
<tr>
<td>940528</td>
<td>9500</td>
<td>2449500</td>
</tr>
<tr>
<td>951010</td>
<td>0</td>
<td>2450000</td>
</tr>
</tbody>
</table>

\(^{1}\)To convert JDN to TJD, the truncation number is 2,440,000.5. The 0.5 day is due to the change of the epoch of a calendar day from mid-day to midnight at Greenwich Meridian on January 1, 1925. The epoch of a Julian Day always begins mid-day.

\(^{2}\)The epoch of Julian Day Number began on January 1, 4713 B.C., which predates recorded history. It is derived from the least common multiple of the Roman cycle of indication (15 years), the metonic cycle (19 years), and the solar cycle (28 years). When the three cycles all begin together in 4713 B.C. they will not come together again until 3267 A.D.

\(^{3}\)The ambiguity period is calculated based on 1 year = 365.2422 days.
Figure 1. Resolution Options and Identifications of Parallel Grouped Binary Time Code, PB-5
REFERENCES


APPENDIX I

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

NASA AND IRIG STANDARD TIME CODES

In the early 1970's, the Subcommittee on Timing Standards reviewed the existing NASA time codes [1] then in use by the data processing facilities and NASA satellite tracking and data network to determine if they should be included as standard time codes in the Aerospace Data Standards. From this review, four of the five existing time codes were recommended for adoption as NASA standard time codes [2a, 2b]. These codes are shown in Figures A1 through A4. Additionally, the subcommittee recommended three parallel binary (PB) time codes (PB1 through 3) for those users who require direct interfacing between time code and automatic data processing equipment. These three time codes, although in the opinion of the members of the subcommittee at the time provided the resolution requirements for most users who needed binary time code, soon proved to be inadequate. This was due to two major NASA programs, notably the Space Shuttle and the Tracking and Data Relay Satellite System, each implemented a PB time code, namely PB1 and PB3. It soon became obvious and followed by a request that a single time code which is compatible with both systems is desired. Such a time code which combines PB1 and PB3 obviously meets the requirement. Thus PB4 is proposed and adopted [2c, 3b]. The four parallel binary time codes are shown in Figures A5 and A6 and the detailed specifications are given in References 2c and 3b.

For ease of reference, the IRIG standard time code formats A, B, D, E, G, and H are reproduced from reference 3a in Figures A7 through 12 and the NBS time codes are reproduced from reference 4 in Figures 13 and 14.
Figure A.1. NASA One-per-second BCD Time Code

Figure A.2. NASA One-per-hour BCD Time Code
Figure A.3. NASA Serial Decimal Time Code-A

Figure A.4. NASA Serial Decimal Time Code-B
Figure A.5. NASA Parallel Grouped Binary Time Codes (1977-08-08)
Figure A.6. IRIG Standard Parallel Binary Time Codes
Figure A.7. Format A, Signal A00

TIME AT POINT A = 21:18:42 + 0.8 + 0.07 + 0.005
= 21 HOUR 18 MINUTE 42.875 SECOND ON DAY 173

Figure A.8. Format B, Signal B00

TIME AT POINT A = 21:18:42 + 0.7 + 0.05
= 21 HOUR 18 MINUTE 42.75 SECOND ON DAY 173
Figure A.9. Format D, Signal D00

Figure A.10. Format E, Signal E00
Figure A.11. Format G, Signal G001

Figure A.12. Format H, Signal H001
FORMAT H, SIGNAL H001, IS COMPOSED OF THE FOLLOWING:
1) 1 ppm FRAME REFERENCE MARKER R = (P0 AND 1.03 SECOND "HOLE")
2) BINARY CODED DECIMAL TIME-OF-YEAR CODE WORD (23 DIGITS)
3) CONTROL FUNCTIONS (9 DIGITS) USED FOR UT1 CORRECTIONS, ETC.
4) 6 ppm POSITION IDENTIFIERS (P2 THROUGH P8)
5) 1 pps INDEX MARKERS

TIME FRAME 1 MINUTE INDEX COUNT (1 SECOND)

ON TIME POINT A

UTC AT POINT A = 173 DAYS 21 HOURS 10 MINUTES

UT1 AT POINT A = 173 DAYS 21 HOURS 10 MINUTES 0.3 SECONDS

NOTE: BEGINNING OF PULSE IS REPRESENTED BY POSITIVE-GOING EDGE.

Figure A.13. WWV and WWVH Time Code Format
Figure A.14. WWVB Time Code Format
REFERENCES


   All of the above standards are prepared by the GSFC Data Systems Requirements Committee, Goddard Space Flight Center, Greenbelt, MD.

[3] Inter-Range Instrumentation Group
   a. Standard Time Formats, IRIG Document 104-70 (104-60 Revised)
   b. Standard Parallel Binary Time Code Formats, IRIG Standard 128-77

   All of the above standards are published by Secretariat, Range Commanders Council, White Sands Missile Range, New Mexico.

**Abstract**

A computer oriented time code designed for users with various time resolution requirements is presented. It is intended as a time code for spacecraft and ground applications where direct code compatibility with automatic data processing (ADP) equipment is of primary consideration. The principal features of this time code are: byte oriented format, selectable resolution options (from seconds to nanoseconds); and long ambiguity period.

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**Key Words (Selected by Author(s))**

Grouped Binary Time Code, Parallel Binary (PB) Time Code; NASA, IRIG and NBS time Code Standards