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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 specificially, although not exculsively, 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".

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Table 1

NASA Parallel Grouped Binary Time Codes

	D/Y	ms/D
PB-1	(9)	(27)

	D/Y	μs/D
PB-2	(9)	(37)

	D/Y	s/D	ms/s	μs/ms
PB-3	(9)	(17)	(10)	(10)

	D/Y	ms/D	μs/ms
PB-4	(9)	(27)	(10)

	TJD	s/D	ms/s	μs/ms	ns/μs
PB-5	(14)	(17)	(10)	(10)	(10)

Table 2

Truncated Julian Day Count System

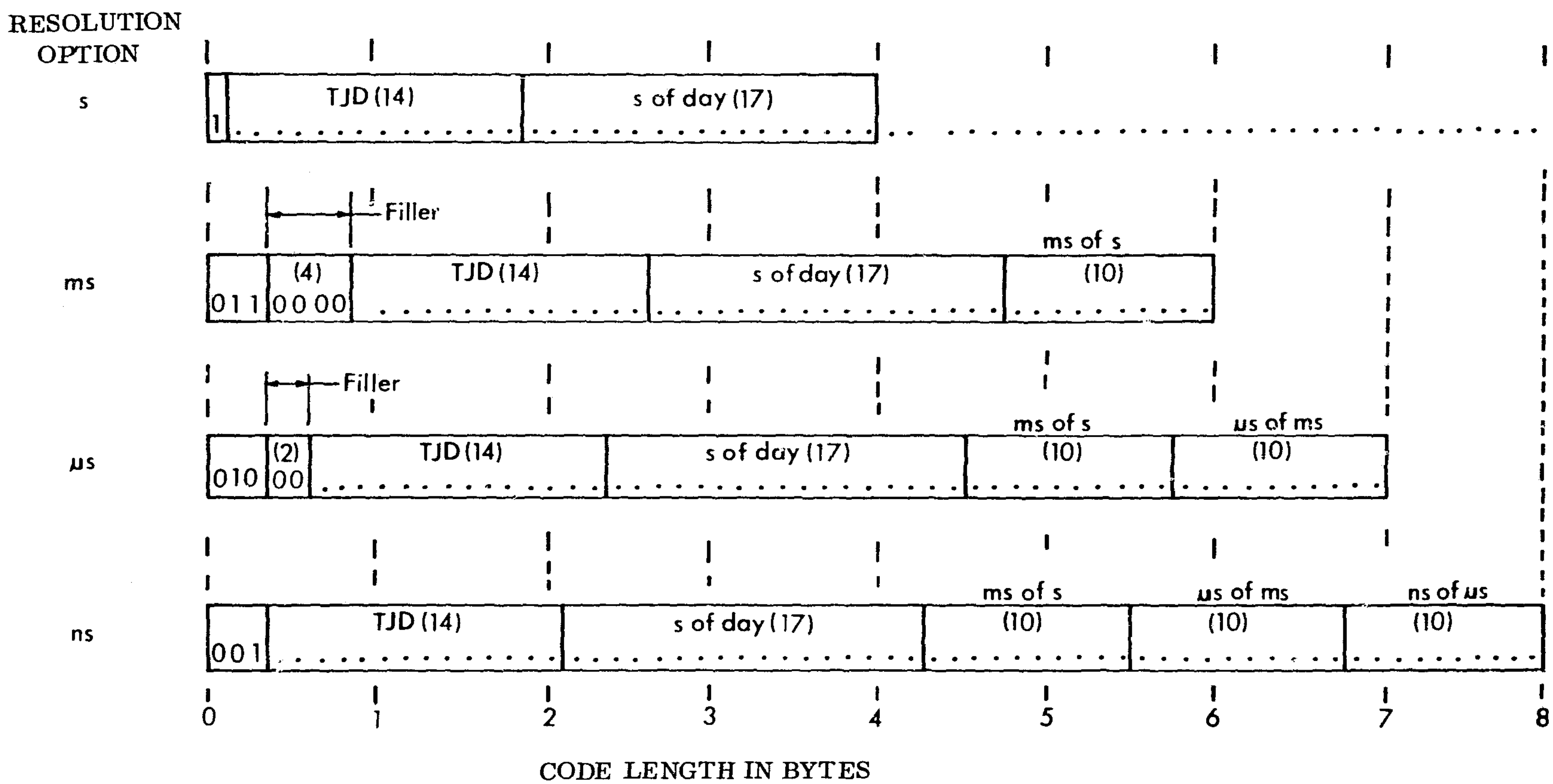
TJD. TJD[1] is a day count system which is truncated from Julian Day Number (JDN)[2] giving year and day information in four digits. TJD has an ambiguity period of 27.379 years.[3]

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

[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.



NOTE:

THE DOTS REPRESENT BITS.

THE NUMBERS IN PARENTHESES REPRESENT THE NUMBER OF BITS IN EACH GROUP.

Figure 1. Resolution Options and Identifications of Parallel Grouped Binary Time Code, PB-5

REFERENCES

[1] Telemetry Standards, Part 3 of the Aerospace Data Systems Standards Guideline 3.3, Space Data Packetization Guideline, November 1979.

[2] Ferris, A. G. and E. F. Greene, "A Proposed Concept for Improved NASA Mission Data Management Operations," NASA/GSFC Document X533-76-81, October 1976.

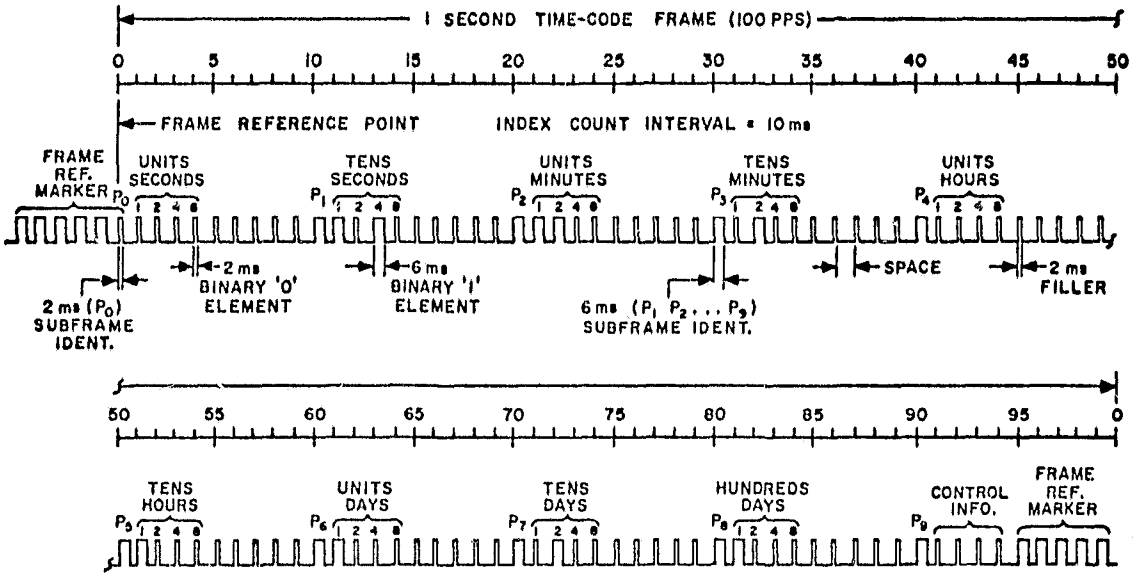
[3] Blanchard, David L., Arthur J. Fuchs and Andrew R. Chi, "A New Approach to Data Management and Its Impact on Frequency Control Requirements," Proceedings of the 33rd Annual Symposium on Frequency Control, Atlantic City, NJ, May 1979.

APPENDIX I

NASA AND IRIG STANDARD TIME CODES

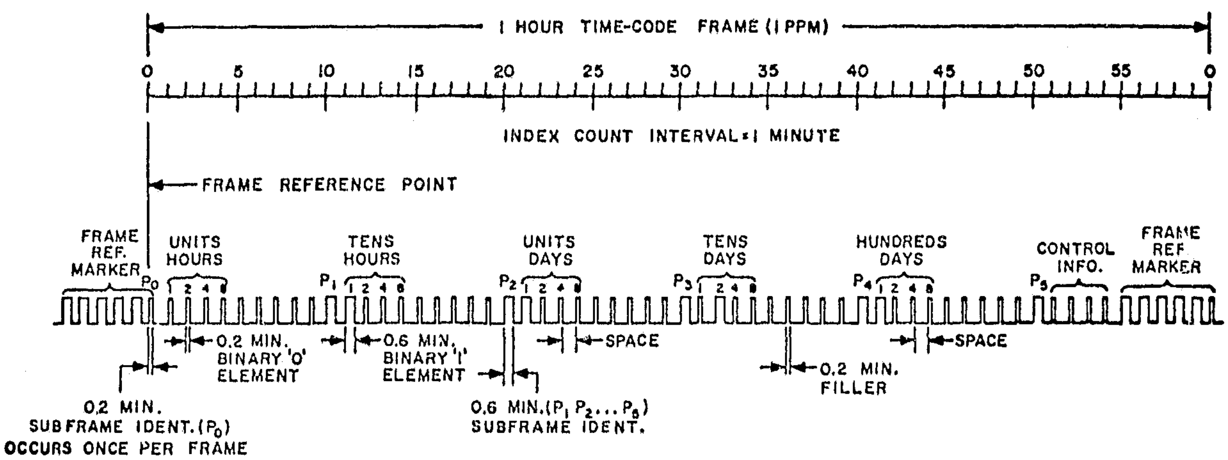
In the early 1970's, the Subcommittee on Timing Standards reviewed the existing NASA time codes [1] then in use by the data processing facilities and NASA satellite tracking and data network to determine if they should be included as standard time codes in the Aerospace Data Standards. From this review, 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 for time tagging 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.



TIME AT START OF P_0 IS 121 DAYS, 10 HOURS, 23 MINUTES, 50 SECONDS.

Figure A.1. NASA One-per-second BCD Time Code



TIME AT START OF P_0 IS 121 DAYS, 10 HOURS.

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

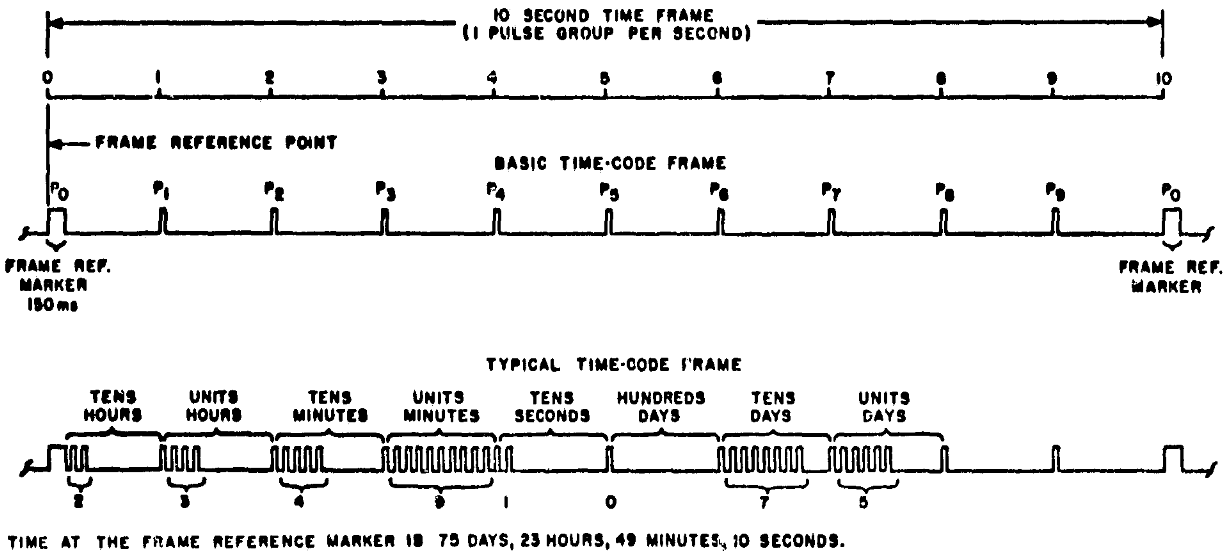


Figure A.3. NASA Serial Decimal Time Code-A

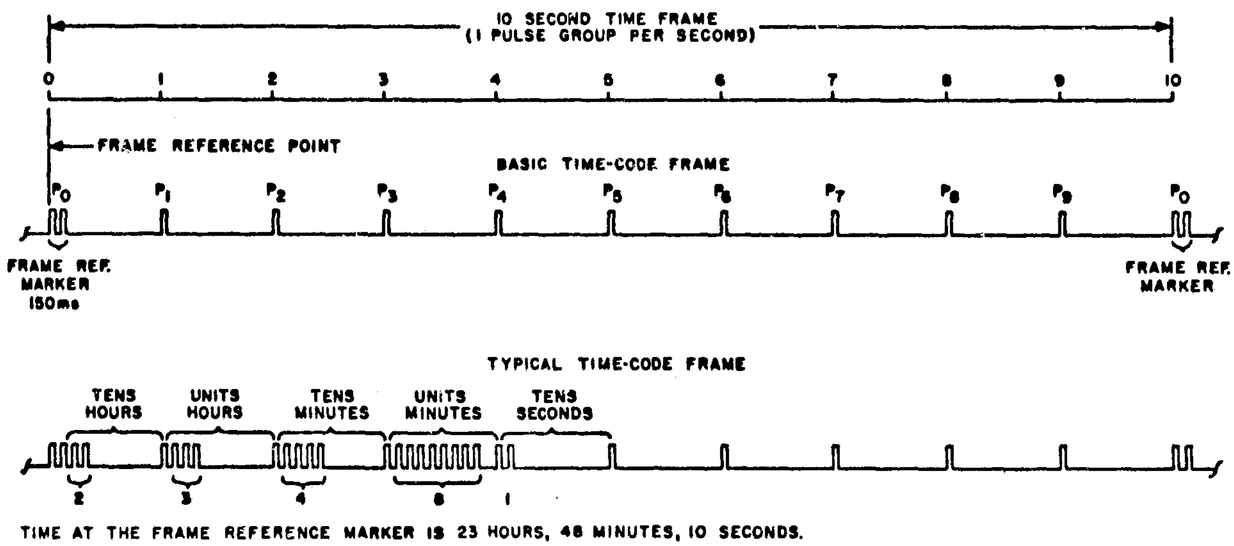


Figure A.4. NASA Serial Decimal Time Code-B

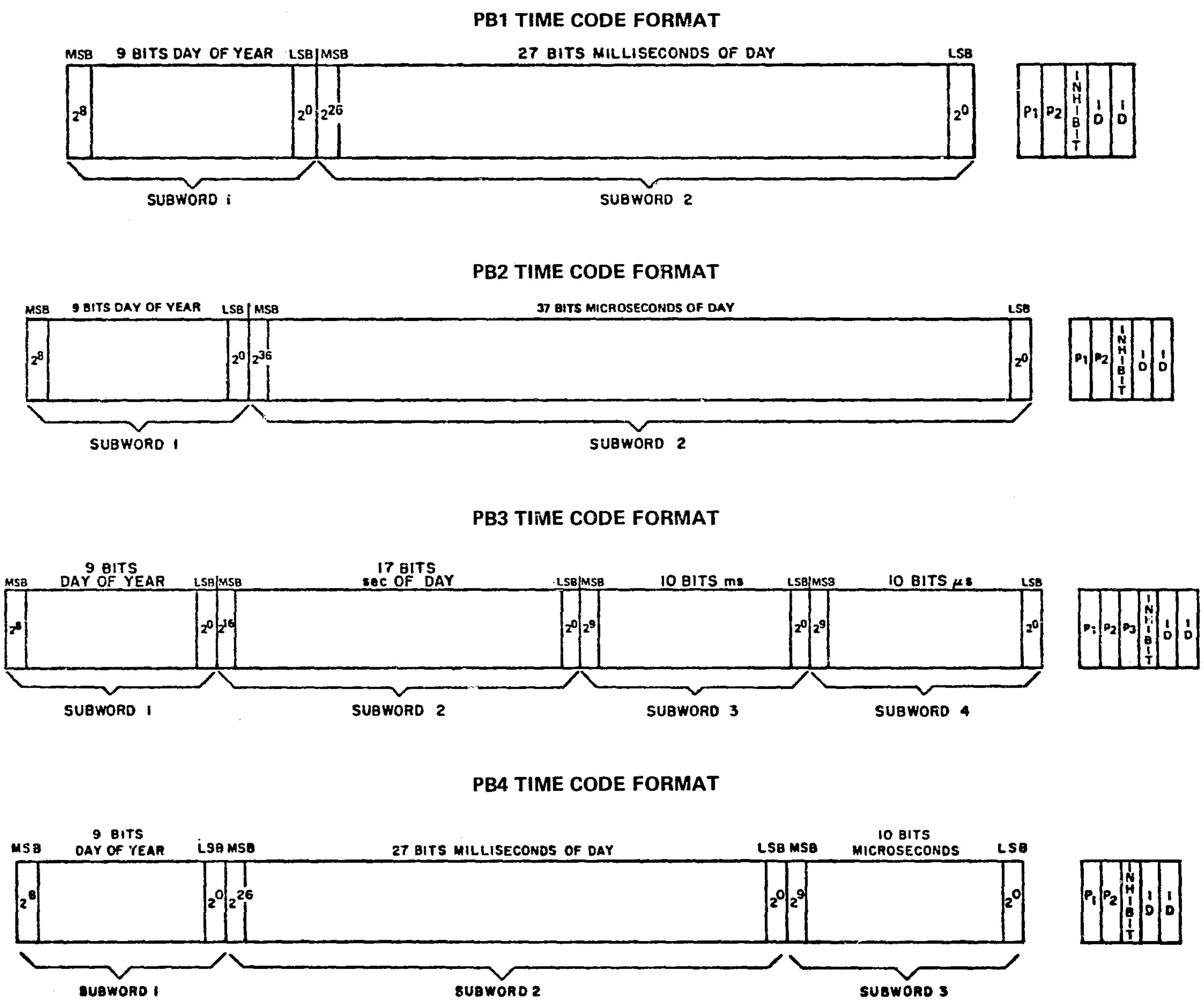


Figure A.5. NASA Parallel Grouped Binary Time Codes (1977-08-08)

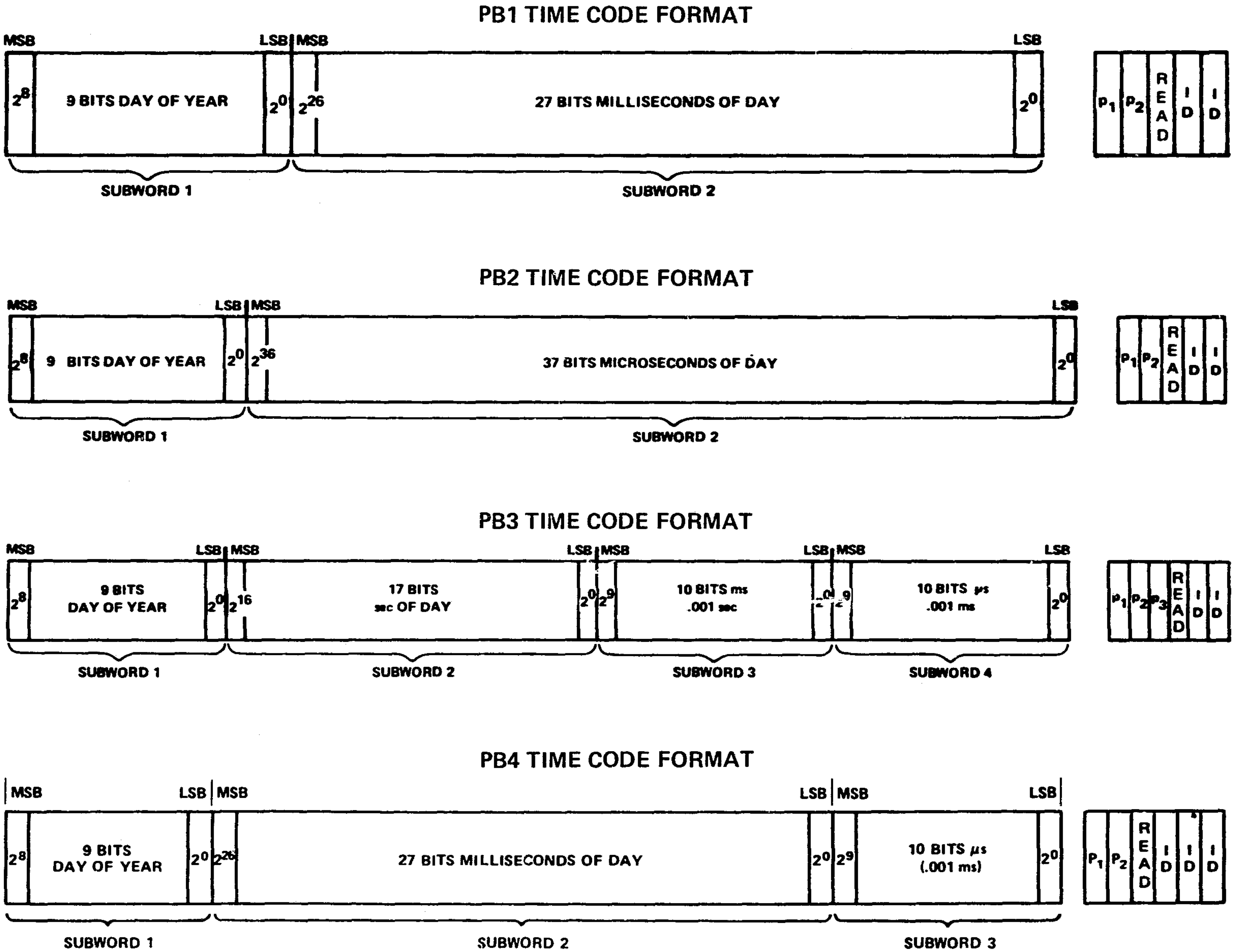
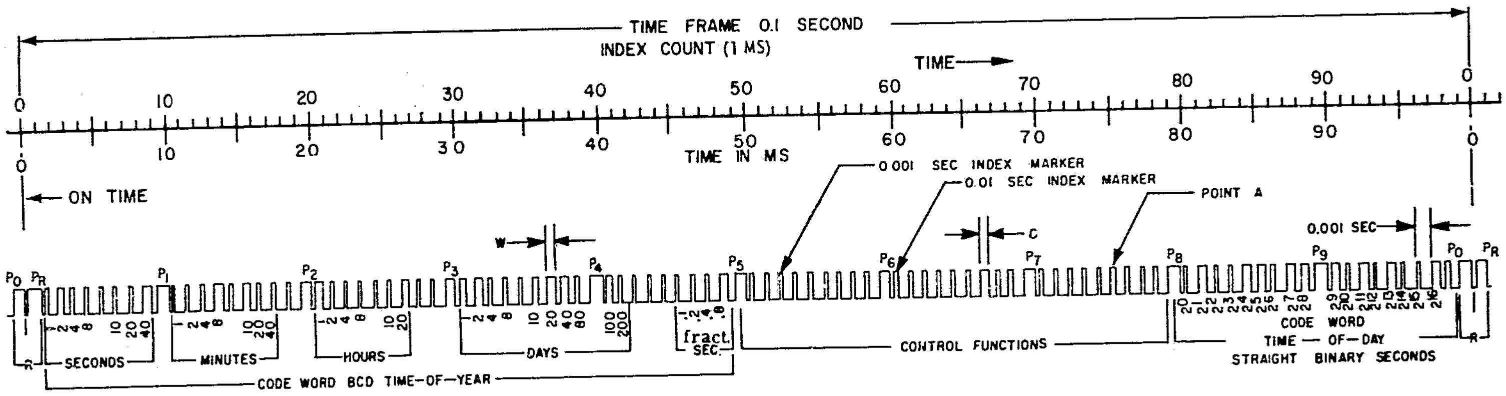
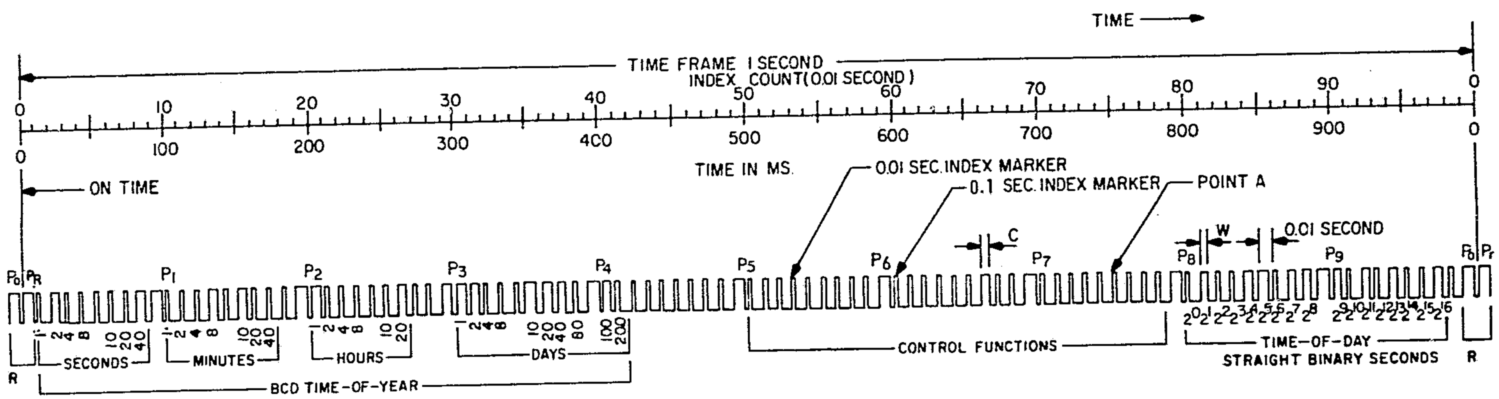


Figure A.6. IRIG Standard Parallel Binary Time Codes



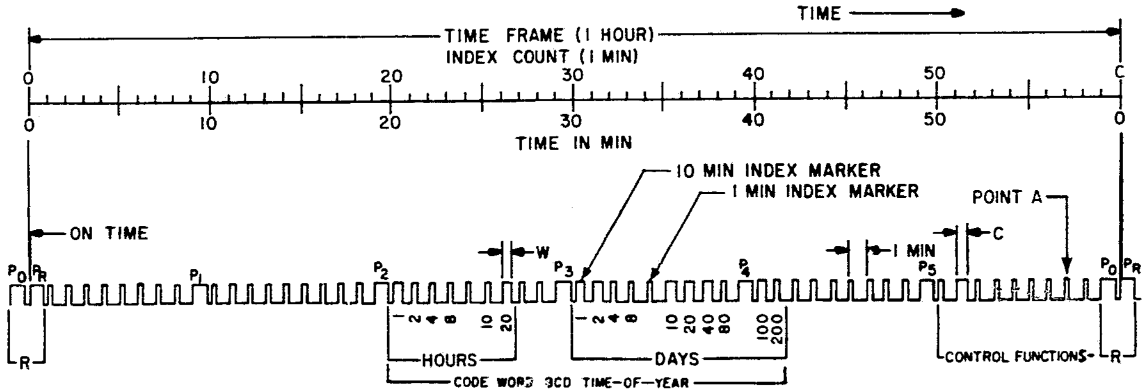
TIME AT POINT A = 21:18:42 + 0.8 + 0.07 + 0.005
= 21 HOUR 18 MINUTE 42.875 SECOND ON DAY 173

Figure A.7. Format A, Signal A00



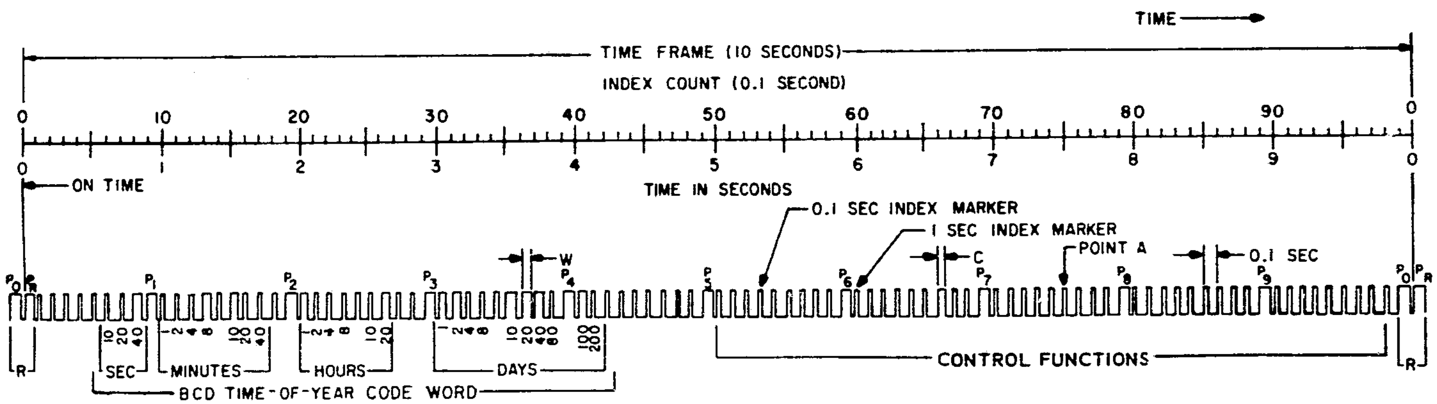
TIME AT POINT A = 21:18:42 + 0.7 + 0.05
= 21 HOUR 18 MINUTE 42.75 SECOND ON DAY 173

Figure A.8. Format B, Signal B00



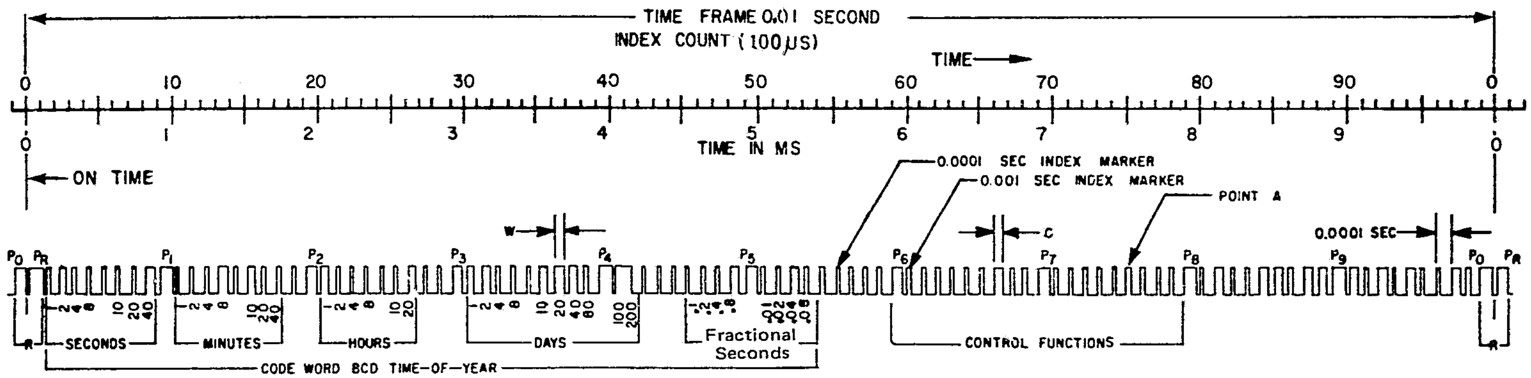
TIME AT POINT A = 21:57:00
= 21 HOUR + 57 MINUTE ON DAY 173

Figure A.9. Format D, Signal D00



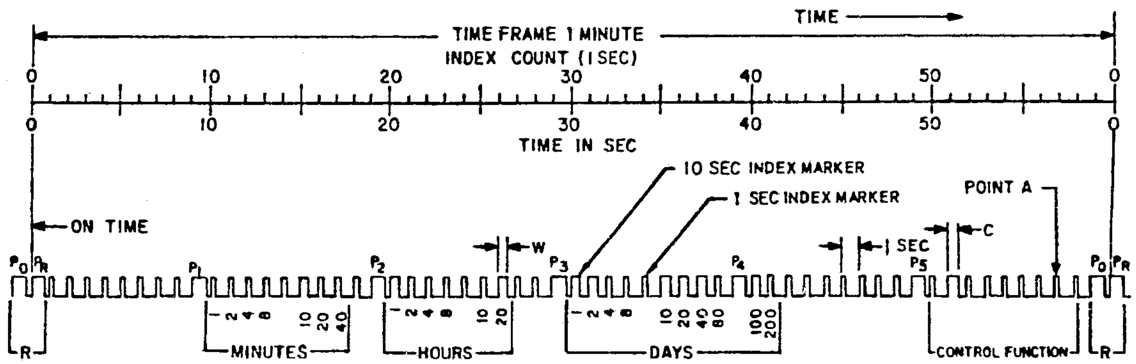
TIME AT POINT A = 21:18:40 + 7 + 0.5
= 21 HOUR 18 MINUTES 47.5 SECONDS ON DAY 173

Figure A.10. Format E, Signal E00



TIME AT POINT A = 21:18:42 + 0.8 + 0.04 + 0.0075
= 21 HOUR 18 MINUTE 42.8475 SECOND ON DAY 173

Figure A.11. Format G, Signal G001

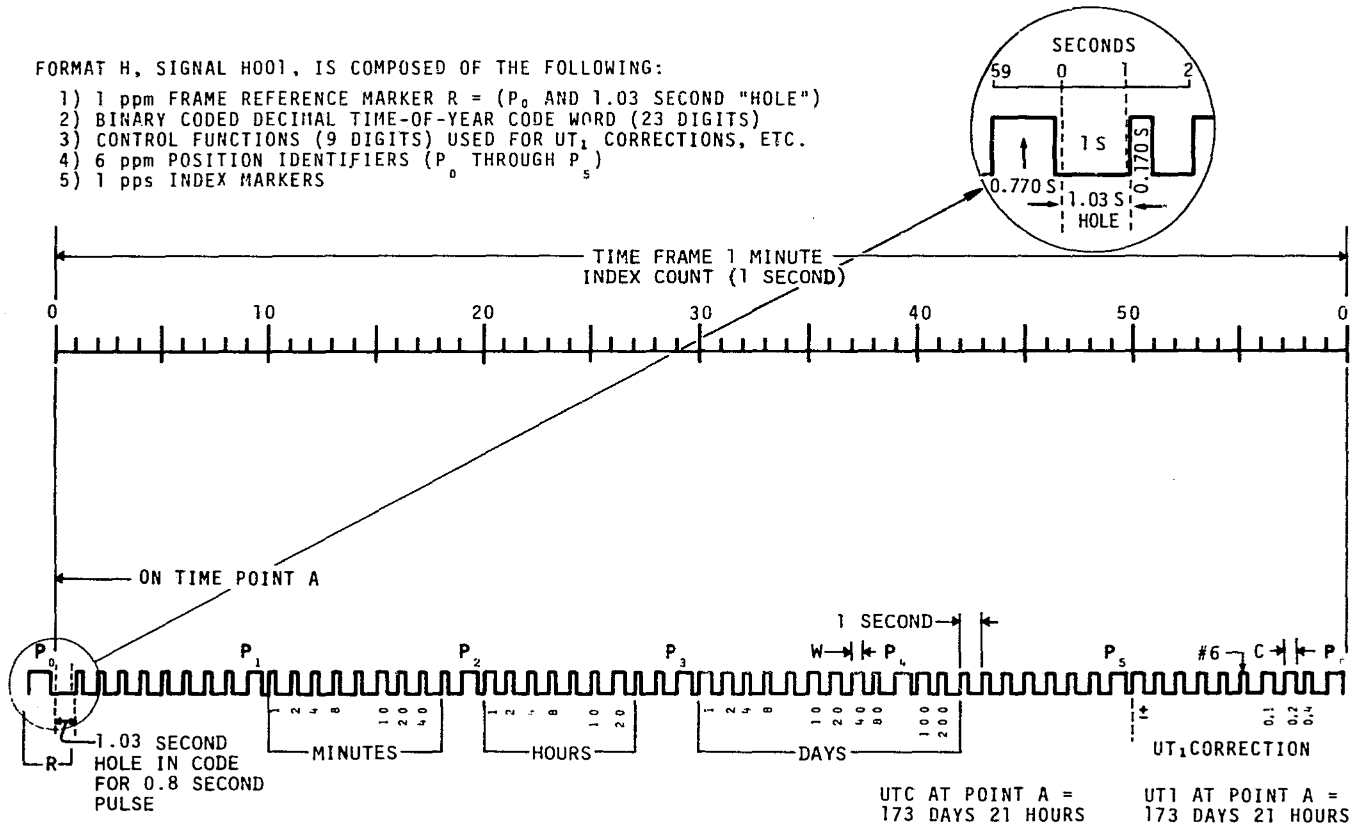


TIME AT POINT A = 21:10:57
= 21 HOUR 10 MINUTE 57 SECOND ON DAY 173

Figure A.12. Format H, Signal H001

FORMAT H, SIGNAL H001, IS COMPOSED OF THE FOLLOWING:

1) 1 ppm FRAME REFERENCE MARKER R = (P_0 AND 1.03 SECOND "HOLE")
2) BINARY CODED DECIMAL TIME-OF-YEAR CODE WORD (23 DIGITS)
3) CONTROL FUNCTIONS (9 DIGITS) USED FOR UT_1 CORRECTIONS, ETC.
4) 6 ppm POSITION IDENTIFIERS (P_0 THROUGH P_5)
5) 1 pps INDEX MARKERS



P_0-P_5 POSITION IDENTIFIERS (0.770 SECOND DURATION)

W WEIGHTED CODE DIGIT (0.470 SECOND DURATION)

C WEIGHTED CONTROL ELEMENT (0.470 SECOND DURATION) CONTROL FUNCTION #6 {BINARY ONE DURING 'DAYLIGHT' TIME / BINARY ZERO DURING 'STANDARD' TIME

DURATION OF INDEX MARKERS, UNWEIGHTED CODE, AND UNWEIGHTED CONTROL ELEMENTS = 0.170 SECONDS

NOTE: <u>BEGINNING</u> OF PULSE IS REPRESENTED BY POSITIVE-GOING EDGE.

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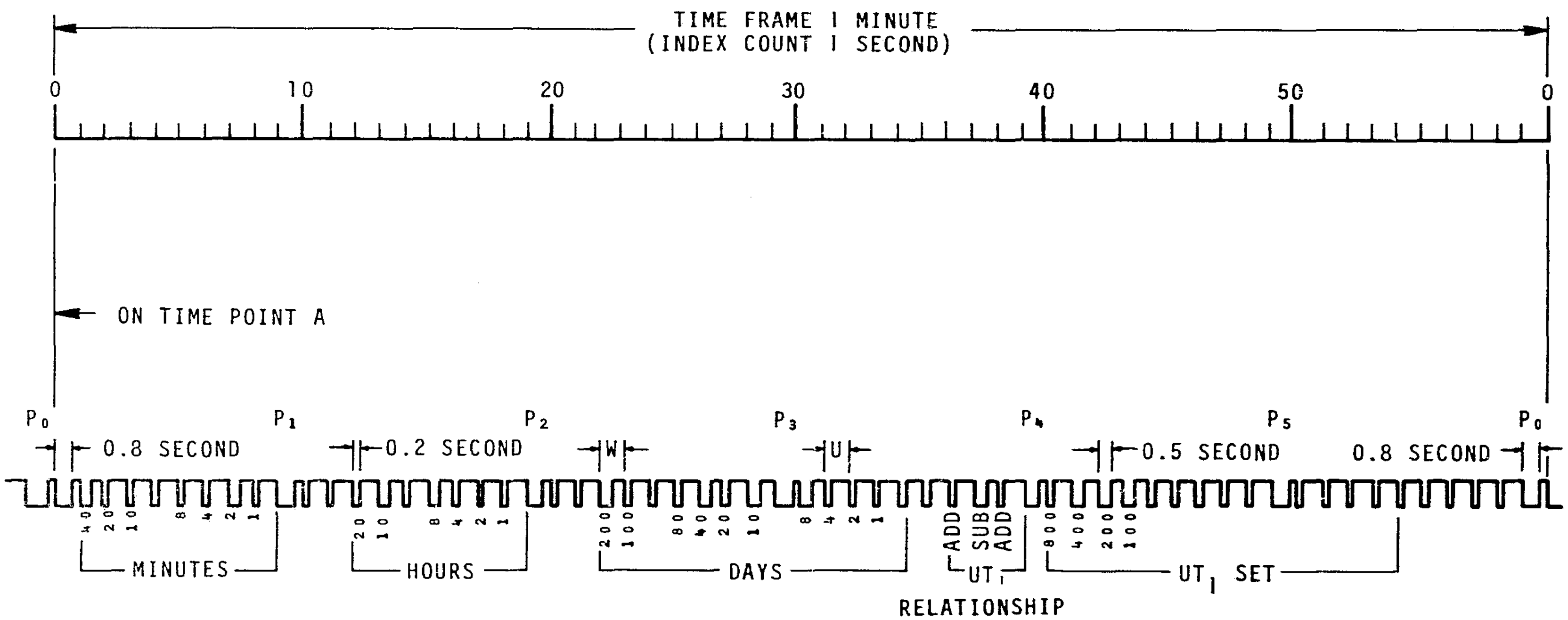
Figure A.13. WWV and WWVH Time Code Format



1 PPM FRAME REFERENCE MARKERS
BINARY CODED DECIMAL TIME-OF-YEAR CODE WORD (23 DIGITS)
CONTROL FUNCTIONS (15 DIGITS) USED FOR UT_1 CORRECTIONS
6 PPM POSITION IDENTIFIER MARKERS AND PULSES (P_0 THRU P_5)
(REDUCED CARRIER 0.8 SECOND DURATION PLUS 0.2 SECOND DURATION PULSE)
W - WEIGHTED CODE DIGIT (CARRIER RESTORED IN 0.5 SECOND - BINARY ONE)
U - UNWEIGHTED CODE DIGIT (CARRIER RESTORED IN 0.2 SECOND - BINARY ZERO)

UTC AT POINT A
258 DAYS
18 HOURS
42 MINUTES

UT1 AT POINT A
258 DAYS
18 HOURS
41 MINUTES
59.3 SECONDS

Figure A.14. WWVB Time Code Format

REFERENCES

[1] Time Codes used by Goddard Space Flight Center, NASA/GSFC Document X810-71-289, December 1970.

[2] Clock and Time Code Standards, Part 5 of the Aerospace Data Systems Standards.

a. Standard 5.2, Binary Coded Decimal Time Code Standard, Sept 1976

b. Standard 5.3, Serial Decimal Time Code Standard, Sept 1976

c. Standard 5.4, Parallel Binary Time Code Standard, Aug 1977

d. Standard 5.6, Parallel Grouped Binary Time Code for Space and Ground Applications, Oct 1979

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.

[4] NBS Time and Frequency Dissemination Services, National Bureau of Standards Special Publication 432, Time and Frequency Division, National Bureau of Standards, Boulder, CO, January 1976.

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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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