Range Commanders Council

TELECOMMUNICATIONS GROUP

IRIG STANDARD 205-87

PARALLEL BINARY AND PARALLEL BINARY CODED DECIMAL TIME CODE FORMATS

WHITE SANDS MISSILE RANGE
KWAJALEIN MISSILE RANGE
YUMA PROVING GROUND
DUGWAY PROVING GROUND
ELECTRONIC PROVING GROUND
COMBAT SYSTEMS TEST ACTIVITY

ATLANTIC FLEET WEAPONS TRAINING FACILITY
NAVAL AIR WARFARE CENTER WEAPONS DIVISION
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
NAVAL UNDERSEA WARFARE CENTER DIVISION, NEWPORT
PACIFIC MISSILE RANGE FACILITY

30TH SPACE WING
45TH SPACE WING
AIR FORCE FLIGHT TEST CENTER
AIR FORCE DEVELOPMENT TEST CENTER
AIR FORCE WEAPONS AND TACTICS CENTER
SPACE AND MISSILE SYSTEMS CENTER,
SPACE TEST AND EXPERIMENTATION PROGRAM OFFICE

IRIG STANDARD 205-87

PARALLEL BINARY
AND
PARALLEL BINARY CODED
DECIMAL TIME CODE FORMATS

AUGUST 1987

Prepared by

TIMING COMMITTEE
TELECOMMUNICATIONS GROUP
RANGE COMMANDERS COUNCIL

Published by

Secretariat
Range Commanders Council
White Sands Missile Range
New Mexico 88002

PREFACE

The need for time-of-year information with millisecond, microsecond and nanosecond resolution by data handling and instrumentation timing systems makes the use of parallel time codes highly desirable for correlation of data with time. The intent of this document is to provide ground rules for maximum compatibility between present and future time generating equipment and the user interface (spaceborne and ground systems).

All timing equipment for new installations where parallel time is required shall follow this standard. For those ranges and facilities where large investment in parallel time generating equipment has already been made, the changeover to the new standard parallel time codes can be made over a period of years as equipment is replaced or as new equipment is installed to meet timing requirements.

The designations or nomenclatures for the codes in this standard were selected so as to minimize the impact on existing documentation and to conform to what has become standard notation. This standard should be adhered to even though use of the parallel time codes may be limited initially to the selection of one code or even particular portions of a code because of a lack of equipment to generate the complete code.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

APPENDIXES

LIST OF FIGURES

LIST OF FIGURES (CONT'D)

LIST OF TABLES

ABBREVIATIONS

Abbreviation	Term
y	year
d	day
h	hour
m	minute
s	second
ms	millisecond (10^{-3}s)
µs	microsecond (10^{-6}s)
ns	nanosecond (10^{-9}s)
ps	picosecond (10^{-12}s)
pps	pulses per second
JD	Julian Day (Date)
MJD	Modified Julian Day (Date)
TJD	Truncated Julian Day (Date)
Mo	Month
DoY	Day-of-year
DoM	Day-of-month
HoD	Hours-of-day
MoH	Minutes-of-hour
SoD	Seconds-of-day ($86.4x10^3$)
MoD	Milliseconds-of-day ($86.4x10^6$)

ABBREVIATIONS (CONT'D)

Abbreviation	Term
MioD	Microseconds-of-day ($86.4x10^9$)
NoD	Nanoseconds-of-day ($86.4x10^{12}$)
MoS	Milliseconds-of-second (.001 s)
MioM	Microseconds-of-millisecond (.00l ms)
NoMi	Nanoseconds-of-microsecond (.001 µs)

Code	Name
PB1	Parallel Binary Millisecond Time Code
PB1-A	Parallel Binary Microsecond Time Code
PB1-B	Parallel Binary Nanosecond Time Code
PB3	Parallel Grouped Binary Microsecond Time Code
PB3-A	Parallel Grouped Binary Nanosecond Time Code
PB4	Parallel Grouped Binary Millisecond/Microsecond Time Code
PB4-A	Parallel Grouped Binary Millisecond/Microsecond/ Nanosecond Time Code
PB5	Parallel Grouped Binary TJD Nanosecond Time Code
PBCD1	Parallel Binary Coded Decimal Millisecond Time Code
PBCD1-A	Parallel Binary Coded Decimal Microsecond Time Code
PBCD1-B	Parallel Binary Coded Decimal Nanosecond Time Code

SUMMARY OF PARALLEL TIME CODES

PB TIME CODES

PB1	Day-of-Year, Milliseconds-of-Day
PB1-A	Day-of-Year, Microseconds-of-Day
PB1-B	Day-of-Year, Nanoseconds-of-Day
PB2	Open for future codes
PB3	Day-of-Year, Seconds-of-Day, Milliseconds-of-Second, Microseconds-of-Millisecond
PB3-A	Day-of-Year, Seconds-of-Day, Milliseconds-of-Second, Microseconds-of-Millisecond, Nanoseconds-of-Microsecond
PB4	Day-of-Year, Milliseconds-of-Day, Microseconds-of-Millisecond
PB4-A	Day-of-Year, Milliseconds-of-Day,Microseconds-of-Millisecond, Nanoseconds-of-Microsecond
PB5	Truncated Julian Day, Seconds-of-Day, Milliseconds-of-Second, Microseconds-of-Millisecond, Nanoseconds-of Microsecond

PBCD TIME CODES

PBCD1	Day-of-Year, Hours-of-Day, Minutes-of-Hour, Seconds-of-Minute, Milliseconds-of-Second
PBCD1-A	Day-of-Year, Hours-of-Day, Minutes-of-Hour, Seconds-of-Minute, Milliseconds-of-Second, Microseconds-of-Millisecond
PBCD1-B	Day-of-Year, Hours-of-Day, Minutes-of-Hour, Seconds-of-Minute, Milliseconds-of-Second, Microseconds-of-Millisecond, Nanoseconds-of-Microsecond

DEFINITIONS

The following terms are used in this document:

ACCURACY -- Systematic uncertainty (deviation) of a measured value with respect to a standard reference.

BINARY CODED DECIMAL (BCD) -- A numbering system which uses decimal digits encoded in a binary representation (8n 4n 2n 1n) where n=1, 10, 100, 1K, 10K...N. Time code digit values less than N are considered zero and are encoded as a binary "0" (see tables III and IV, appendix B).

BINARY NUMBER SYSTEM -- A numbering system which has two as its base and uses two symbols, usually denoted by 0 and 1 (see tables II and IV, appendix B).

BIT (element) -- An abbreviation of binary or binary coded decimal digits of which a word or subword is composed.

BIT TRANSITION TIME -- The time required for a bit in the time code or subword to change from one logic level to the next, that is, a logic 0 to a logic 1 or vice versa.

IDENTIFICATION BITS (ID) -- Bits with a fixed state (logic level) used for time code identification.

INHIBIT/READ BIT -- A bit generated with the time code which prohibits a user from reading the code during the time code update.

INSTRUMENTATION TIMING -- A parameter serving as the fundamental independent variable in terms of which data may be correlated.

LEAP SECOND -- See appendix A.

LEAP YEAR -- See appendix A.

LSB -- Least significant bit.

MSB -- Most significant bit.

ON-TIME -- The state of any bit being coincident with the Standard Time Reference (U. S. Naval Observatory or National Bureau of Standards).

DEFINITIONS (CONT'D)

PARITY BIT -- Confidence bits derived from and generated with the bits in the time code word or subword.

PRECISION -- An agreement of measurement with respect to a defined value.

RESOLUTION (of a time code) -- The smallest increment of time or least significant bit which can be defined by a time-code word or subword.

SECOND -- Basic unit of time or time interval in the International System of Units (SI) which is equal to 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of Cesium 133.

SUBWORD -- A subdivision of the time code word containing only one type of time unit, for example, days, milliseconds or microseconds.

TIME CODE -- A system of symbols used for identifying specific instants of time.

TIME CODE WORD -- A specific set of time code symbols which identify one instant of time. A time code word may be subdivided into subwords.

TIME REFERENCE -- The basic repetition rate chosen as the common time reference for all instrumentation timing (usually 1 pps).

Truncated Julian Day (TJD) -- The TJD is used by the scientific community for recording astronomical and historical events and for archival data storage and is useful in the space sciences area. The TJD has an epoch of 24 May 1968 with a repetition period (recycle time) of 10,000 days (27.379 years) and will recycle 9 October 1995 (see table I, appendix B).

T_0 -- The initial time $0^h\ 0^m\ 0^s$ 1 January.

V_1 -- Logic 1 or true (bit high).

V^0 -- Logic 0 or false (bit low).

ΔV -- Peak-to-peak transition of voltage between V^0 and V^1, expressed as $(V^0\text{-}V^1)$.

GLOSSARY OF SELECTED TIME TERMS

These definitions of time-related terms are useful in understanding the text of the standard and the relationship between various time scales.

EPOCH -- signifies the beginning of an event or era.

TIME INTERVAL -- is the duration between two instants read on the same time scale.

TIME SCALE -- is a reference system for specifying occurrences with respect to time.

SOLAR TIME -- is based on the rotation of the earth about the sun.

SIDEREAL TIME -- is determined and defined by observations of the earth with respect to the stars. A mean sidereal day is approximately $23^h\ 56^m\ 4.09^s$. A solar year contains 366.24 sidereal days.

EPHEMERIS TIME (ET) -- is obtained from observations of the motion of the moon about the earth.

UNIVERSAL TIME (UT) -- is the mean solar time of the prime meridian plus 12^h, determined by measuring the angular position of the earth about its axis. The UT is sometimes designated GMT, but this designation should be avoided. Communicators use the designation "Z" or Zulu for UT.

UT0 -- measures UT with respect to the observer's meridan (position on earth) which varies because of the conical motion of the poles.

UT1 -- is UT0 corrected for variations in the polar motion and is proportional to the rotation of the earth in space. In their monthly "Circular-D," the Bureau International de l-Heure (BIH) publishes the current values of UT1 with respect to International Atomic Time (TAI).

UT2 -- is UT1 corrected empirically for annual and semiannual variations in the rotation rate of the earth. The maximum correction is about 30 ms.

TIME UNIVERSAL COORDINATED (UTC) -- is maintained by the Bureau International de l'Heure (BIH) which forms the basis of a coordinated dissemination of standard frequencies and time signals. A UTC clock has the same rate a TAI clock does but differs by an integral number of seconds. The step-time adjustments are called "leap seconds." Leap seconds are subtracted or added to UTC to keep in synchronism with UT1 to within ±0.9 second (see appendix A).

DUT1 -- is the predicted differences between UT1 and UTC and is given by DUT1 = UT1-UTC.

INTERNATIONAL ATOMIC TIME (TAI) -- An atomic time scale based on data from a worldwide set of clocks and is the internationally agreed to time reference. The TAI is maintained by BIH, Paris, France. Its epoch was set such that TAI was in approximate agreement with UT1 on 1 January 1958.

INTERNATIONAL ATOMIC TIME (TAI) TIME CODE -- The TAI time code represents a binary count of the elasped time in seconds since the 1 January 1958 epoch. The Bureau International de l'Heure (BIH), the United States Naval Observatory (USNO) and other national observatories and laboratories maintained this count which is a very large number accumulating at 86,400 seconds per day.

JULIAN DAY NUMBER (JDN) -- A number of a specific day from a continuous day count having an initial epoch of 12 hours UT on 1 January 4713 B.C.--the start of Julian Day zero.

Example: The day extending from 1900 January 0.5 days UT to 1900 January 1.5 days UT has the number 2415020.

MODIFIED JULIAN DATE (MJD) -- is the Julian Day less 2 400 000.5 days.

TRUNCATED JULIAN DAY (TJD) -- The JDN 2 440 000.5 occurred on 24 May 1968 and defines the origin of the TJD time scale used in the PB5 time code.

INTRODUCTION

Present and proposed communication systems, missile and spacecraft tracking, and data handling systems require real-time parallel formatted time that will efficiently interface between the timing system (time source) and the users. Standardization of parallel time codes is necessary to meet the needs of automated (computer controlled) data handling equipment, to provide reliable time tagging of events in a binary format, and to ensure system compatibility among spacecraft projects, ground networks, data processing facilities, and the various international cooperative projects.

This standard defines the characteristics of the parallel binary and parallel binary coded decimal time codes. The selected codes contain most, if not all the features, of the various parallel binary time codes presently in use. Only those portions of a code required for existing application need be used. This point is important because it permits simplifying the code and its use and allows the use of various portions (resolution) of the codes as desired.

The task of standardizing parallel binary time codes was assigned to the Telecommunications Group (TCG) of the Range Commanders Council (RCC) by the Executive Committee in June 1972. The first document, IRIG Standard 128-73, contained PB1, PB2, and PB3 time codes. Time code PB4 was added to the family of parallel codes in IRIG Standard 205-77 (formerly 128-77).

The present addition of codes to document 205-77 includes four parallel binary time codes, PB1-B, PB3-A, PB4-A and PB5, and three parallel binary coded decimal time codes, PBCD1, PBCD1-A and PBCD1-B. The addition of these codes gives millisecond, microsecond and nanosecond resolutions in parallel binary and parallel binary coded decimal formats.

NOTE: The PB2 time code nomenclature is redesignated PBl-A so that the PB1 family of codes include ms, μs and ns resolutions. The PB2 designation shall remain open for a possible family of future codes.

This standard reflects the state-of-the-art and is not intended to constrain research and development in the area. The standard will be revised as required.

1.0 GENERAL DESCRIPTION OF TIME CODE

This standard describes three parallel binary time codes, five parallel grouped binary time codes and three parallel binary coded decimal time codes. All contain day-of-year information with various resolutions including hours, minutes, seconds, milliseconds, microseconds, and nanoseconds.

1.1 PARALLEL BINARY MILLISECOND TIME CODE (PB1)

The 36-bit parallel binary time code word contains binary day-of-year and binary milliseconds-of-day information.

1.2 PARALLEL BINARY MICROSECOND TIME CODE (PB1-A)

The 46-bit parallel binary time code word contains binary day-of-year and binary microseconds-of-day information.

1.3 PARALLEL BINARY NANOSECOND TIME CODE (PB1-B)

The 56-bit parallel binary time code word contains binary day-of-year and binary nanoseconds-of-day information.

1.4 PARALLEL GROUPED BINARY MICROSECOND TIME CODE (PB3)

The 46-bit parallel grouped binary time code word contains binary day-of-year, binary seconds-of-day, binary milliseconds-of-second (.001s) and binary microseconds-of-millisecond (.001ms) information.

1.5 PARALLEL GROUPED BINARY NANOSECOND TIME CODE (PB3-A)

The 56-bit parallel grouped binary time code word contains binary day-of-year, binary seconds-of-day, binary milliseconds-of-second (.001s), binary microseconds-of-millisecond (.001ms) and binary nanoseconds-of-microsecond (.001 s) information.

1.6 PARALLEL GROUPED BINARY MILLISECOND/MICROSECOND TIME CODE (PB4)

The 46-bit parallel grouped binary time code word contains binary day-of-year, binary milliseconds-of-day and binary microseconds-of-millisecond (.001ms) information.

1.7 PARALLEL GROUPED BINARY MILLISECOND/MICROSECOND/ NANOSECOND TIME CODE (PB4-A)

The 56-bit parallel grouped binary time code word contains binary day-of-year, binary milliseconds-of-day, binary microseconds-of-millisecond (.001ms), and binary nanoseconds-of-microsecond (.001 μs) information.

1.8 PARALLEL GROUPED BINARY TJD NANOSECOND TIME CODE (PB5)

The 61-bit parallel grouped binary time code contains Truncated Julian Day, binary seconds-of-day, binary milliseconds-of-second (.001s), binary microseconds-of-millisecond (.001ms), and binary nanoseconds-of-microsecond (.001 μs) information.

1.9 PARALLEL BINARY CODED DECIMAL MILLISECOND TIME CODE (PBCD1)

The 42-bit parallel binary coded decimal time code word contains day-of-year, hours, minutes, seconds, and milliseconds-of-second (.001s) information.

1.10 PARALLEL BINARY CODED DECIMAL MICROSECOND TIME CODE (PBCD1-A)

The 54-bit parallel binary coded decimal time code word contains day-of-year, hours, minutes, seconds, milliseconds-of-second (.001s), and microseconds-of-millisecond (.001ms) information.

1.11 PARALLEL BINARY CODED DECIMAL NANOSECOND TIME CODE (PBCD1-B)

The 66-bit parallel binary coded decimal time code word contains day-of-year, hours, minutes, seconds, milliseconds-of-second (.001s), and microseconds-of-millisecond (.001ms), and nanoseconds-of-microsecond (.001 μs) information.

2.0 FORMATS (GENERAL)

An overview of the parallel time codes is described below.

2.1 TIME CODE WORD STRUCTURE

The basic time code word is composed of subwords. Each subword is formed by binary bits (elements) which determine the granularity (resolution) of the time code subword. Each subword represents a particular resolution of the time being identified. For example, the PB1 family of codes contains as part of their basic word structure, a subword composed of 9 bits for binary day-of-year information. PB1 also contains 27 bits for binary milliseconds-of-day. PB1-A and PB1-B extend PB1 to microsecond and nanosecond resolution.

The parallel grouped binary codes PB3 and PB3-A both contain 9-bits day-of-year, 17-bits seconds-of-day, 10-bits milliseconds-of-second, and 10-bits micro-seconds-of-millisecond. PB3-A extends PB3 to nanosecond resolution. The PB5 time code is identical to PB3-A except that it contains TJD rather than DoY in its format.

The family of PBCD1 codes all contain 10-bits BCD day-of-year information with hours (6-bits BCD), minutes (7-bits BCD), seconds (7-bits BCD), and 12-bits milliseconds-of-second (.001s) information. The PBCD1-A and PBCD1-B extend PBCD1 to microsecond and nanosecond resolution.

A feature of the nanosecond codes (excluding PB1-B) is that they can all be truncated at any desirable resolution. For example, the PB4-A time code which has nanosecond resolution can be truncated at microseconds to provide milli-seconds-of-day resolution.

2.2 INHIBIT/READ BIT

An inhibit/read bit (pulse) is generated with each code for optional use by external equipment interfacing with the time code source and is not propagated beyond the first interface. The purpose of the inhibit/read pulse is to prevent the user of the time code from reading the code immediately prior to and just after the time code update. The inhibit pulse occurs at the appropriate rate for the various codes, usually at the code update rate.

2.3 PARITY BIT

Parity bits are generated with each time code for optional use by external devices when users desire a degree of confidence in the correct transmission of the time code (see table VI, appendix B).

2.4 CODE IDENTIFICATION BITS

Identification (ID) bits are established for each time code for optional use by external devices when users desire to distinguish one time code from another (within a family) by noting the fixed state (logic level) of the ID bits (see table V, appendix B).

2.5 TIME CODE WORD BIT DESIGNATION

The LSB in the time code word format is the lowest granularity bit within a subword. The MSB is the highest granularity bit within each subword. For example, the LSB for the binary codes is the (2^0) bit and the MSB is the (2^n) bit. Each subword, therefore, contains (n+1) bits. In a pictorial presentation of the codes, the MSB is shown on the left and the LSB on the right of each subword.

3.0 SIGNAL CHARACTERISTICS

For each parallel time code, the signal has the following characteristics.

3.1 BIT LEVEL (TRUE/FALSE CONVENTION)

Positive logic is standard. If the voltage level of an output data bit is high, the indication is true. For the binary codes, logic 1 is true and logic 0 is false. The same is true for the BCD codes. The true voltage level (V_1) is always more positive than the false voltage level V_0 (see figure 1).

3.2 VOLTAGE LEVEL TOLERANCE

The voltage level tolerance at either logic 1 (V_1) or logic 0 (V_0) shall not exceed 15 percent of the difference between logic levels (ΔV).

3.3 BIT TRANSITON

Overshoot and undershoot during each bit transition shall not exceed 10 percent of the final steady-state value.

3.4 BIT TRANSITION TIME

The voltage level change of all bits from the time code generator (rise and fall time) of the parallel data from true to false or vice versa shall occur within 200 picoseconds[1] for the nanosecond codes, within 200 nanoseconds for the micro-second codes and within 1 microsecond for the millisecond codes.

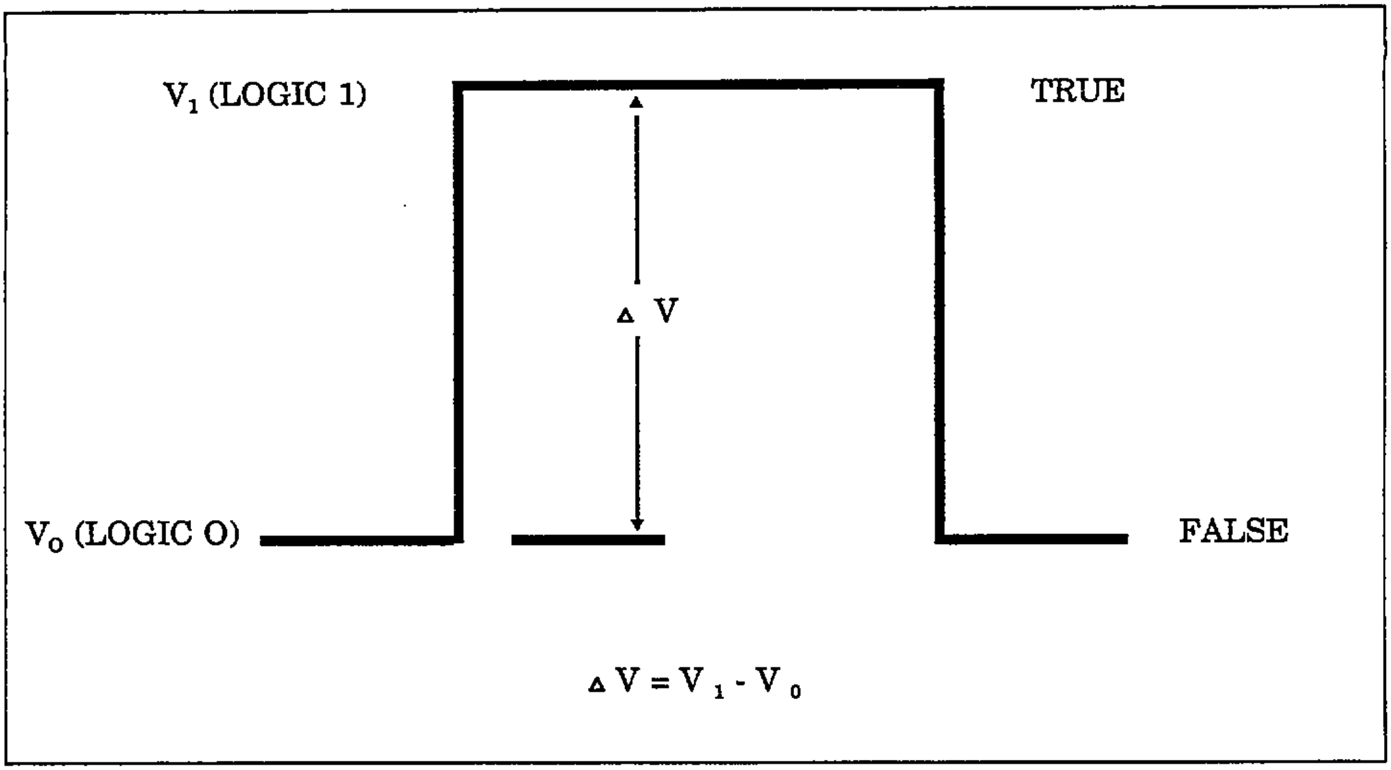


Figure 1. Bit voltage level transition.

3.5 CODE RIPPLE-DOWN TIME

The total counter ripple-down time (update) in a time code generator from LSB to the MSB for the nanosecond codes shall not be greater than 300 picoseconds[1] and 300 nanoseconds for the microsecond and millisecond codes.

3.6 INHIBIT/READ BIT PULSE CHARACTERISTICS

The inhibit/read pulse for the nanosecond codes shall not exceed 500 picoseconds[1]. The inhibit/read pulse for the microsecond codes shall not exceed 500 nanoseconds, and the inhibit/read pulse for the millisecond codes shall not exceed 100 microseconds.

---

[1]One hundred picosecond rise times or sub-nanosecond code update of the parallel time word LSB for the nanosecond codes may not be within the practical state-of-the-art for many hardware/software systems/logic families. However, update of the nanosecond codes could be at other intervals such as 10ns or 100ns. Sub-nanosecond inhibit/read pulses may also be difficult to generate. These pulses can also occur at a 10ns or 100ns rate to be compatible with the code update rate. As the state-of-the-art advances for high speed logic, higher data rates can be achieved.

The leading edge of the inhibit/read pulse is coincident with or slightly ahead of the on-time bits. For the inhibit condition, the bit is high. For the read condition, the bit is low as shown in the various time code timing charts. (For examples, see figures 3, 5 and 7).

3.7 PARITY BIT LOGIC LEVEL

Odd parity is adopted in this standard; that is, a parity bit is true (logic 1) when the code bits it spans have an even number of bits true.

4.0 FORMATS (SPECIFIC)

A detailed description of individual time codes is described in the following paragraphs.

4.1 PARALLEL BINARY MILLISECOND TIME CODE (PB1)

The PB1 time code format is shown in figure 2A. The time code word is composed of two subwords.

Subword one contains 9 bits for binary day-of-year (DoY). The LSB is the 2^0 bits and the MSB is the 2^8 bit. The range of DoY is 1 through 365 (366 for leap year).

Subword two contains 27 bits for binary milliseconds-of-day. The LSB is the 2^0 and the MSB is the 2^{26} bit. The range of milliseconds-of-day is 0 through 86 999 999.

Two odd parity bits (P_1 and P_2) are generated. P_1 is generated from the 9-bit DoY and the 27-bit milliseconds-of-day. P_2 is generated from the 27-bit millisecond-of-day (see table IV, appendix B).

Three ID bits (0, 0, 1) are generated for code identification (see paragraph 2.4).

Figure 2B shows time code displays for times t_0 (DoY 1) and t_n (DoY 365). Also shown is the state (levels) of the parity bits for each time displayed and the ID bits.

Figure 3 shows the PB1 time code LSB configuration (logic levels) for DoY and milliseconds-of-day starting at time t_0 followed by t_1, t_2, t_3...t_{1-n} (DoY 364) and t_n (DoY 365). The inhibit/read bit time position is also shown.

4.2 PARALLEL BINARY MICROSECOND TIME CODE (PB1-A)

The PB1-A time code format is shown in figure 4A. The time code word is made up of two subwords.

Subword one contains 9 bits for binary DoY. The LSB is the 2^0 bit and the MSB is the 2^8 bit. The range of DoY is 1 through 365 (366 for leap year).

Subword two contains 37 bits for binary microseconds-of-day. The LSB is the 2^0 bit and the MSB is the 2^{36} bit. The range of microseconds-of-day is 0 through 86 399 999 999.

Two odd parity bits (P_1 and P_2) are generated. P_1 is generated from the 9-bit DoY and the 37-bit microseconds-of-day. P_2 is generated from the 37 bit microseconds-of-day (see paragraph 3.7).

Three ID bits (0, 1, 1) are generated for code identification (see paragraph 2.4).

Figure 4B shows time code displays for times t_0 (DoY 1) and t_n DoY 365). Also shown is the state of the parity bits for each time displayed and the ID bits.

Figure 5 shows the PB1-A time code LSB configuration (logic levels) for DoY and microseconds-of-day starting at the time t_0 followed by t_1, t_2, t_3...t_{n-1} (DoY 364) and t_n (DoY 365). The inhibit/read bit time position is also shown.

4.3 PARALLEL BINARY NANOSECOND TIME CODE (PB1-B)

The PB1-B time code format is shown in figure 6A. The time code word is made up of two subwords.

Subword one contains 9 bits for binary DoY. The LSB is the 2^0 bit and the MSB is the 2^8 bit. The range DoY is 1 through 365 (366 for leap year).

Subword two contains 47 bits for binary nanoseconds-of-day. The LSB is the 2^0 bit and the MSB is the 2^{46} bit. The range of nanoseconds-of-day is 0 through 86 399 999 999 999.

Two odd parity bits (P_1 and P_2) are generated. P_1 is generated from the 9-bit DoY and the 47-bit nanoseconds-of-day. P_2 is generated from the 47 bit nanoseconds-of-day.

Three ID bits (1, 0, 1) are generated for code identification.

Figure 6B shows time code displays for times t_0 (DoY 1) and t_n (DoY 365). Also shown is the state (level) of the parity bits for each time displayed and the ID bits.

Figure 7 shows the PB1-B time code LSB configuration (logic levels) for DoY and nanoseconds-of-day starting at time t_0 followed by t_1, t_2, t_3...t_{n-1} (DoY 364) and t_n (DoY 365). The inhibit/read bit time position is also shown.

4.4 PARALLEL GROUPED BINARY MICROSECOND TIME CODE (PB3)

The PB3 time code format is shown in figure 8A. The time code word is made up of four subwords.

Subword one contains 9 bits for binary DoY. The LSB is the 2^0 bit and the MSB is the 2^8 bit. The range of DoY is 1 through 365 (366 for leap year).

Subword two contains 17 bits for binary seconds-of-day. The LSB is the 2^0 bit and the MSB is the 2^{16} bit. The range of seconds-of-day is 0 through 86 399.

Subword three contains 10 bits for milliseconds-of-second (.001s). The LSB is the 2^0 bit and the MSB is the 2^9 bit. The range of milliseconds-of-second is 0 through 999.

Subword four contains 10 bits of microseconds-of-millisecond (.001ms). The LSB is the 2^0 bit and the MSB is the 2^9 bit. The range of microseconds-of-millisecond is 0 through 999.

Three odd parity bits (P_1, P_2, P_3) are generated. P_1 is generated from the 9-bit DoY, 17-bit seconds-of-day, 10-bit milliseconds-of-second, and the 10-bit microseconds-of-millisecond. P_2 is generated from the 17-bit seconds-of-day and 10-bit milliseconds-of-second. P_3 is generated from the 10-bit milliseconds-of-second and the 10-bit microseconds-of-millisecond.

Three ID bits (0, 1, 1) are generated for code identification.

Figure 8B shows time code displays for times t_0 (DoY 1) and t_n (DoY 365). Also shown is the state of the parity bits for each time displayed and the ID bits.

Figure 9 shows the PB3 time code LSB configuration (logic level) for DoY, seconds-of-day, milliseconds-of-second and microseconds-of-millisecond starting at time t_0 followed by t_1, t_2, t_3...t_{n-1} (DoY 364) and t_n (DoY 365). The inhibit/read bit time position is also shown.

4.5 PARALLEL GROUPED BINARY NANOSECOND TIME CODE (PB3-A)

The PB3-A time code format is shown in figure 10A. The time code word is made up of five subwords.

Subword one contains 9 bits for binary DoY. The LSB is the 2^0 bit and the MSB is the 2^8 bit. The range of DoY is 1 through 365 (366 for leap year). Subword two contains 17 bits for binary seconds-of-day. The LSB is the 2^0 bit and the MSB is the 2^{16} bit. The range of seconds-of-day is 0 through 86 399. Subword three contains 10 bits for milliseconds-of-second (.001s). The LSB is the 2^0 bit and the MSB is the 2^9 bit. The range of milliseconds-of-second is 0 through 999.

Subword four contains 10 bits for microseconds-of-millisecond (.001ms). The LSB is the 2^0 bit and the MSB is the 2^9 bit. The range of microseconds-of-millisecond is 0 through 999.

Subword five contains 10 bits for nanoseconds-of-microsecond (.001 µs). The LSB is the 2^0 bit and the MSB is the 2^9 bit. The range of nanoseconds-of-microsecond is 0 through 999.

Four odd parity bits (P_1, P_2, P_3, and P_4) are generated. P_1 is generated from the 9-bit DoY, 17-bit seconds-of-day, 10-bit milliseconds-of-second, 10-bit microseconds-of-millisecond, and 10-bit nanoseconds-of-microsecond. P_2 is generated from 17-bit seconds-of- day and 10-bit milliseconds-of-second. P_3 is generated from 10-bit milliseconds-of-second and 10-bit microseconds-of-millisecond. P_4 is generated from 10-bit nanoseconds-of-microsecond.

Three ID bits (1, 1, 1) are generated for code identification.

Figure 10B shows time code displays for times t_0 (DoY 1) and t_n (DoY 365). The state of the parity bits and ID bits are also shown.

Figure 11 shows the PB3-A time code LSB configuration (logic levels) for DoY, seconds-of-day, milliseconds-of-second (.001s), microseconds-of-millisecond (.001ms), and nanoseconds-of-microsecond (.001 µs) starting at time t_0 followed by t_1, t_2, $t_3 ... t_{n-1}$ (DoY 364) and t_n (DoY 365). The inhibit/read bit time position is also shown.

4.6 PARALLEL GROUPED BINARY MILLISECOND/MICROSECOND TIME CODE (PB4)

The PB4 time code format is shown in figure 12A. The code word is composed of three subwords.

Subword one contains 9 bits for binary DoY. The LSB is the 2^0 bit and the MSB is the 2^8 bit. The range of DoY is 0 through 365 (366 for leap year).

Subword two contains 27 bits for binary milliseconds-of-day. The LSB is the 2^0 bit and the MSB is the 2^{26} bit. The range of milliseconds-of-day is 0 through 86 399 999

Subword three contains 10 bits for microseconds-of-millisecond (.001ms). The LSB is the 2^0 bit and the MSB is the 2^9 bit. The range of microseconds-of-millisecond is 0 through 999.

Two odd parity bits (P_1 and P_2) are generated. P_1 is generated from the 9-bit DoY and 27-bit milliseconds-of-day. P_2 is generated from the 27-bit milliseconds-of-day and 10-bit microseconds-of-millisecond.

Four ID bits (0, 1, 0, 0) are generated for code identification.

Figure 12B shows time code displays for times t_0 (DoY 1) and t_n (DoY 365). Also shown is the state of the parity and ID bits.

Figure 13 shows the PB4 time code LSB configuration (logic levels) for DoY, milliseconds-of-day and microseconds-of-millisecond starting at time t_0 followed by t_1, t_2, t_3...t_{n-1} (DoY 364) and t_n (DoY 365). The inhibit/read bit time position is also shown.

4.7 PARALLEL GROUPED BINARY MILLISECOND/ MICROSECOND/ NANOSECOND TIME CODE (PB4-A)

The PB4-A time code format is shown in figure 14A. The time code word is composed of four subwords.

Subword one contains 9 bits for binary DoY. The LSB is the 2^0 bit and the MSB is the 2^8 bit. The range of DoY is 1 through 365 (366 for leap year).

Subword two contains 27 bits for binary milliseconds-of-day. The LSB bit is the 2^0 and the MSB is the 2^{26} bit. The range of milliseconds-of-day is 0 through 86 399 999.

Subword three contains 10 bits for microseconds-of-millisecond (.001ms). The LSB is the 2^0 bit and the MSB is the 2^9 bit. The range of microseconds-of-millisecond is 0 through 999.

Subword four contains 10 bits for nanoseconds-of-microsecond (.001 µs). The LSB is the 2^0 and the MSB is the 2^9 bit. The range of nanoseconds-of-microsecond is 0 through 999.

Three odd parity bits (P_1, P_2, P_3) are generated. P_1 is generated from the 9-bit DoY, 27-bit milliseconds-of-day, 10-bit microseconds-of-millisecond and 10-bit nanoseconds-of-microsecond. P_2 is generated from 27-bit milliseconds-of-day and 10-bit microseconds-of- millisecond. P_3 is generated from 10-bit microseconds-of-millisecond and 10-bit nanoseconds-of-microsecond.

Four ID bits (1, 1, 0, 0) are generated for code identification.

Figure 14B shows the time code displays for times t_0 (DoY 1) and t_n (DoY 365). Also shown is the state of the parity and ID bits.

Figure 15 shows the PB4-A time code LSB configuration (logic levels) for DoY, milliseconds-of-day, microseconds-of-millisecond and nanoseconds-of-microsecond starting at time t_1 followed by t_2, t_3, t_4...t_{n-1} (DoY 364) and t_n (DoY 365). The inhibit/read bit time position is also shown.

4.8 PARALLEL GROUPED BINARY TJD NANOSECOND TIME CODE (PB5)

The PB5 time code uses Truncated Julian Day (TJD) rather than Day-of-Year.

The PB5 time code format is shown in figure 16A. The time code word is composed of five subwords.

Subword one contains 14 bits for binary TJD. The LSB is the 2^0 bit and the MSB is the 2^{13} bit. The range of TJD is from an epoch of 24 May 1968 repeated every 10,000 days or 27.379 years.

Subword two contains 17 bits for binary seconds-of day. The LSB is the 2^0 bit and the MSB is the 2^{16} bit. The range of seconds-of-day is 0 through 86 399.

Subword three contains 10 bits for binary milliseconds-of-second (.001s). The range of milliseconds-of-second is from 0 through 999.

Subword four contains 10 bits for binary microseconds-of-millisecond (.001ms). The range of microseconds-of-millisecond is 0 through 999.

Subword five contains 10 bits for binary nanoseconds-of-microsecond (.001 µs). The range of nanoseconds-of-microsecond is 0 through 999.

Four odd parity bits (P_1, P_2, P_3, P_4) are generated. P_1 is generated from the 14-bit TJD, 17-bit seconds-of-day, 10-bit milliseconds-of-second, 10-bit microseconds-of-millisecond, and 10-bit nanoseconds-of-microsecond. P_2 is generated from 17-bit seconds-of-day and 10-bit milliseconds-of-second. P_3 is generated from 10-bit milliseconds-of-second and 10-bit microseconds-of- millisecond. P_4 is generated from 10-bit nanoseconds-of-microsecond.

Three ID bits (1, 0, 1) are generated for code identification.

Figure 16B shows the time code displays for times t_0 (TJD 6431) and t_n (TJD 6795). Also shown is the state of the parity and ID bits.

Figure 17 shows the PB5 time code LSB configuration (logic levels) for TJD, seconds-of-day, milliseconds-of-second (.001s), microseconds-of-millisecond (.001ms), and nanoseconds-of-microsecond (.001 µs) starting at time t_0 followed by t_1, t_2, t_3...t_{n-1}, and t_n.... The inhibit/read bit time position is also shown.

4.9 PARALLEL BINARY CODED DECIMAL MILLISECOND TIME CODE (PBCD1)

The PBCD1 time code format is shown in figure 18A. The time code word is composed of five subwords. Each subword is made up of BCD bits following standard notation of (1, 2, 4, 8)...(1n, 2n, 4n, 8n) numbering system where n is 1, 10, 100, 1K....

Subword one contains 10 BCD bits for DoY. The LSB is the BCD bit 1 and the MSB is the BCD bit 200. The range of DoY is 1 through 365 (366 for leap year).

Subword two contains 6 BCD bits for hours-of-day. The LSB is the BCD bit 1 and the MSB is the BCD bit 20. The range of hours-of-day is 0 through 23.

Subword three contains 7 BCD bits for minutes-of-hour. The LSB is the BCD bit 1 and the MSB is the BCD bit 40. The range of minutes-of-hour is 0 through 59.

Subword four contains 7 BCD bits for seconds-of-minute. The LSB is the BCD bit 1 and the MSB is the BCD bit 40. The range of seconds-of-minute is 0 through 59.

Subword five contains 12 BCD bits for milliseconds-of-second (.001s). The LSB is the BCD bit 1 and the MSB is the BCD bit 800. The range of milliseconds-of-second is 0 through 999.

Four odd parity bits (P_1, P_2, P_3, P_4) are generated. P_1 is generated from the 10-bit DoY, 6-bit hours-of-day, 7-bit minutes-of-hour, 7-bit seconds-of-minute, and 12-bit milliseconds-of-second. P_2 is generated from 6-bit hours-of-day and 7-bit minutes-of-hour. P_3 is generated from 7-bit minutes-of-hour and 7-bit seconds-of minute. P_4 is generated from 12-bit milliseconds-of-second.

Three ID bits (0, 0, 1) are generated for code identification.

Figure 18B shows the time code displays for times t_0 (DoY 1) and t_n (DoY 365). Also shown is the state of the parity and ID bits.

Figure 19 shows the PBCD1 time code LSB configuration (logic levels) for DoY, hours-of-day, minutes-of-hour, seconds-of-minute, and milliseconds-of-second starting at time t_0 followed by t_1, t_2, t_3...t_{n-1} (DoY 364) and t_n (DoY 365). The inhibit/read bit time position is also shown.

4.10 PARALLEL BINARY CODED DECIMAL MICROSECOND TIME CODE (PBCD1-A)

The PBCD1-A time code format is shown in figure 20A. The time code word is composed of six subwords. Each subword is made up of BCD bits following standard notation of (1, 2, 4, 8)...(1n, 2n, 4n, 8n) numbering system where n is 1, 10, 100, 1K....

Subword one contains 10 BCD bits for DoY. The LSB is the BCD bit 1 and the MSB is the BCD bit 200. The range of DoY is 1 through 365 (366 for leap year).

Subword two contains 6 BCD bits for hours-of-day. The LBS is the BCD bit 1 and the MSB is the BCD bit 20. The range for hours-of-day is 0 through 23.

Subword three contains 7 BCD bits for minutes-of-hour. The LSB is the BCD bit 1 and the MSB is the BCD bit 40. The range of minutes-of-hour is 0 through 59.

Subword four contains 7 BCD bits for seconds-of-minute. The LSB is the BCD bit 1 and the MSB is the BCD bit 40. The range of seconds-of-minute is 0 through 59.

Subword five contains 12 BCD bits for milliseconds-of-second (.001s). The LSB is the BCD bit 1 and the MSB is the BCD bit 800. The range of milliseconds-of-second is 0 through 999.

Subword six contains 12 BCD bits for microseconds-of-millisecond (.001ms). The LSB is the BCD bit 1 and the MSB is the BCD bit 800. The range of microseconds-of-millisecond is 0 through 999.

Four odd parity bits (P_1, P_2, P_3, P_4) are generated. P_1 is generated from the 10-bit DoY, 6-bit hours-of-day, 7-bit minutes-of-hour, 7-bit seconds-of-minute, 12-bit milliseconds-of-second, and 12-bit microseconds-of-millisecond. P_2 is generated from 6-bit hour-of-day, 7-bit minutes-of-hour and 7-bit seconds-of-minute. P_3 is generated from 7-bit minutes-of-hour and 12-bit milliseconds-of-second. P_4 is generated from 7-bit seconds-of-minute and 12-bit microseconds-of-millisecond.

Three ID bits (0, 1, 1) are generated for code identification.

Figure 20B shows the time code displays for times t_0 (DoY 1) and t_n (DoY 365). Also shown is the state of parity and ID bits.

Figure 21 shows PBCD1-A time code LSB configuration (logic levels) for DoY, hours-of-day, minutes-of-hour, seconds-of-minute, milliseconds-of-second, and microseconds-of-millisecond starting at time t_0 followed by t_1, t_2, t_3...t_{n-1} (DoY 364) and t_n (DoY 365). The inhibit/read bit time position is also shown.

4.11 PARALLEL BINARY CODED DECIMAL NANOSECOND TIME CODE (PBCD1-B)

The PBCD1-B time code format is shown in figure 22A. The time code word is composed of seven subwords. Each subword is made up of BCD bits following standard notation of (1, 2, 4, 8)...(1n, 2, 4, 8n) numbering system where n is 1, 10, 100, 1K....

Subword one contains 10 BCD bits for DoY. The LSB is the BCD bit 1 and the MSB is the BCD bit value 200. The range of DoY is through 365 (366 for leap year).

Subword two contains 6 BCD bits for hours-of-day. The LSB is the BCD bit 1 and the MSB is the BCD bit 20. The range for hours-of-day is 0 through 23.

Subword three contains 7 BCD bits for minutes-of-hour. The LSB is the BCD bit 1 and the MSB is the BCD bit 40. The range of minutes-of-hour is 0 through 59.

Subword four contains 7 BCD bits for seconds-of-minute. The LSB is the BCD bit 1 and the MSB is the BCD bit 40. The range of seconds-of-minute is 0 through 59.

Subword five contains 12 BCD bits for milliseconds-of-second (.001s). The LSB is the BCD bit 1 and the MSB is the BCD bit 800. The range of milliseconds-of-second is 0 through 999.

Subword six contains 12 BCD bits for microseconds-of-millisecond (.001ms). The LSB is the BCD bit 1 and the MSB is the BCD bit 800. The range of microseconds-of-millisecond is 0 through 999.

Subword seven contains 12 BCD bits for nanoseconds-of-microsecond (.001 µs). The LSB is the BCD bit 1 and the MSB is the BCD bit 800. The range of nanoseconds-of-microsecond is 0 through 999.

Four odd parity bits (P_1, P_2, P_3, P_4) are generated. P_1 is generated from the 10-bit DoY, 6-bit hour-of-day, 7-bit minutes-of-hour, 7-bit seconds-of-minute, 12-bit milliseconds-of-second, 12-bit microseconds-of-millisecond, and 12-bit nanoseconds-of-millisecond. P_2 is generated from 6-bit hours-of-day, 7-bit minutes-of-hour and 7-bit seconds-of-minute. P_3 is generated from 7-bit minutes-of-hour, 12-bit milliseconds-of-second, and 12-bit microseconds-of-millisecond. P_4 is generated from 7-bit seconds-of-minute, 12-bit milliseconds-of-second and 12-bit nanoseconds-of-microsecond.

Three ID bits (1, 0, 1) are generated for code identification.

Figure 22B shows the time code displays for times t_0 (DoY 1) and t_n (DoY 365). Also shown is the state of the parity and ID bits.

Figure 23 shows the PBCD1-B time code LSB configuration (logic levels) for DoY, hours-of-day, minutes-of-hour, seconds-of-minute, milliseconds-of-second, microseconds-of-millisecond, and nanoseconds-of-microsecond starting at time t_0 followed by t_1, t_2, t_3...t_{n-1} (DoY 364) and t_n (DoY 365). The inhibit/read bit time position is also shown.

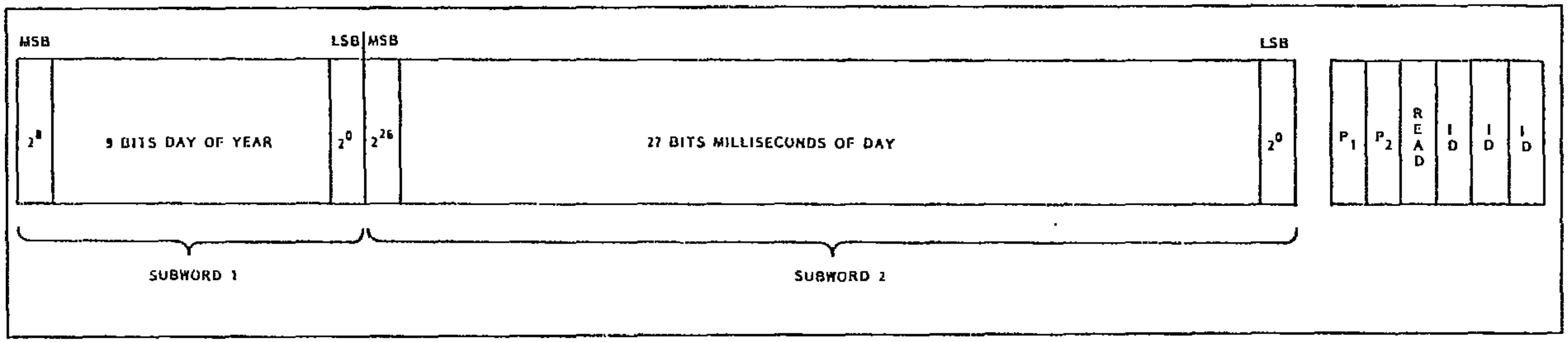


Figure 2A. PB1 Time Code Format.

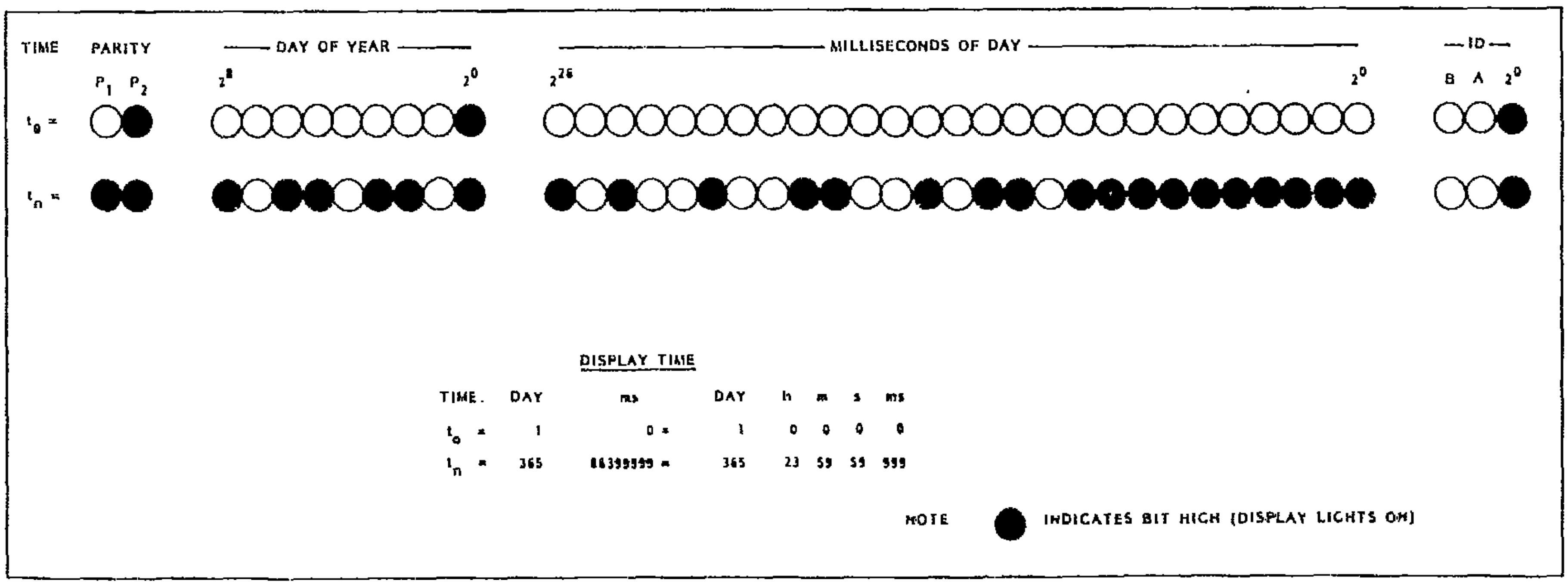
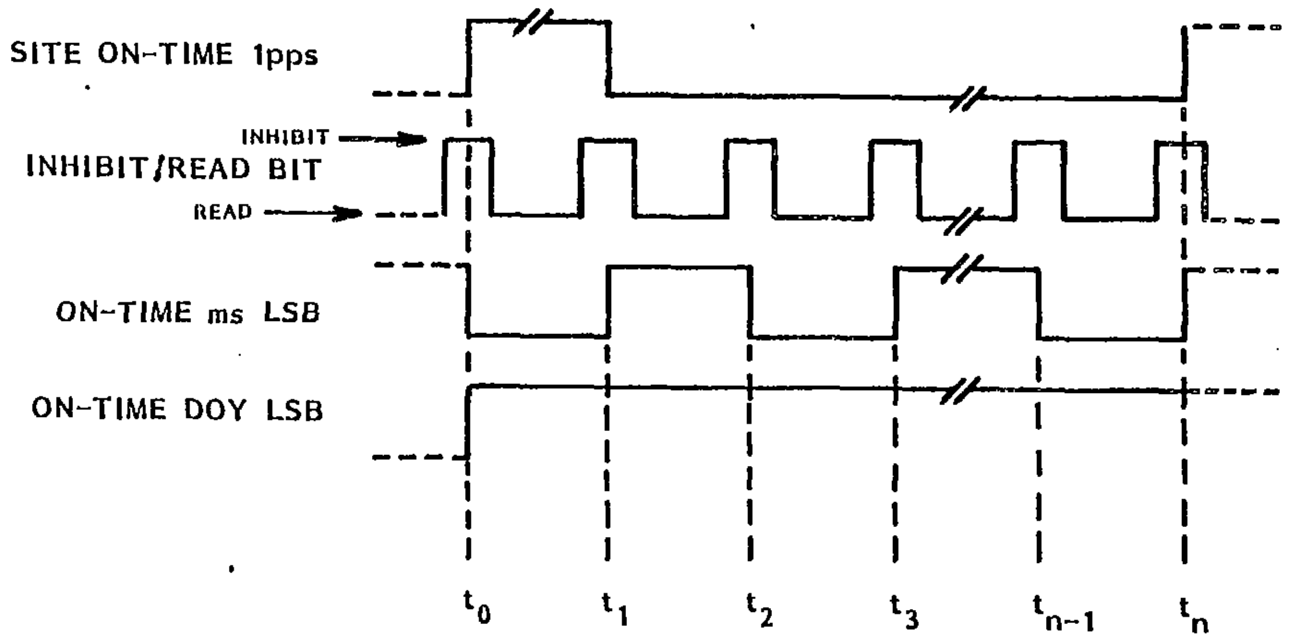


Figure 2B. Possible Displays.



The on-time shown (t_0) is $0^h\ 0^m\ 0^s\ 0^{ms}$ 1 January. The t_1 is the next ms of time followed by t_2, t_3 ... t_n. The ms-of-day counter resets to 0 after a count of 86 399 999. The DoY counter resets to 1 after a count of 365 (366 for leap year).

Figure 3. Relationship between PB1 time code and station 1 pps at t_0.

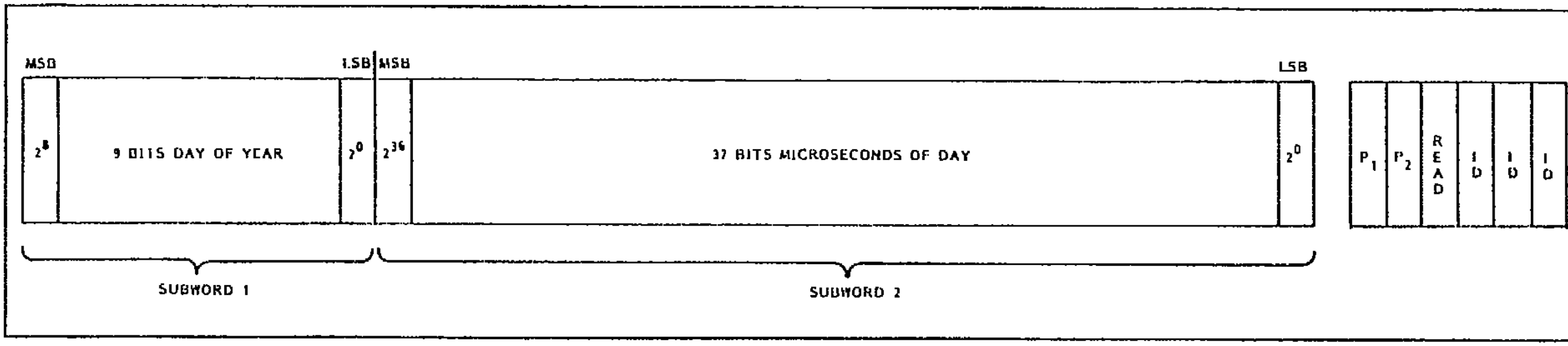


Figure 4A. PB1-A Time Code Format.

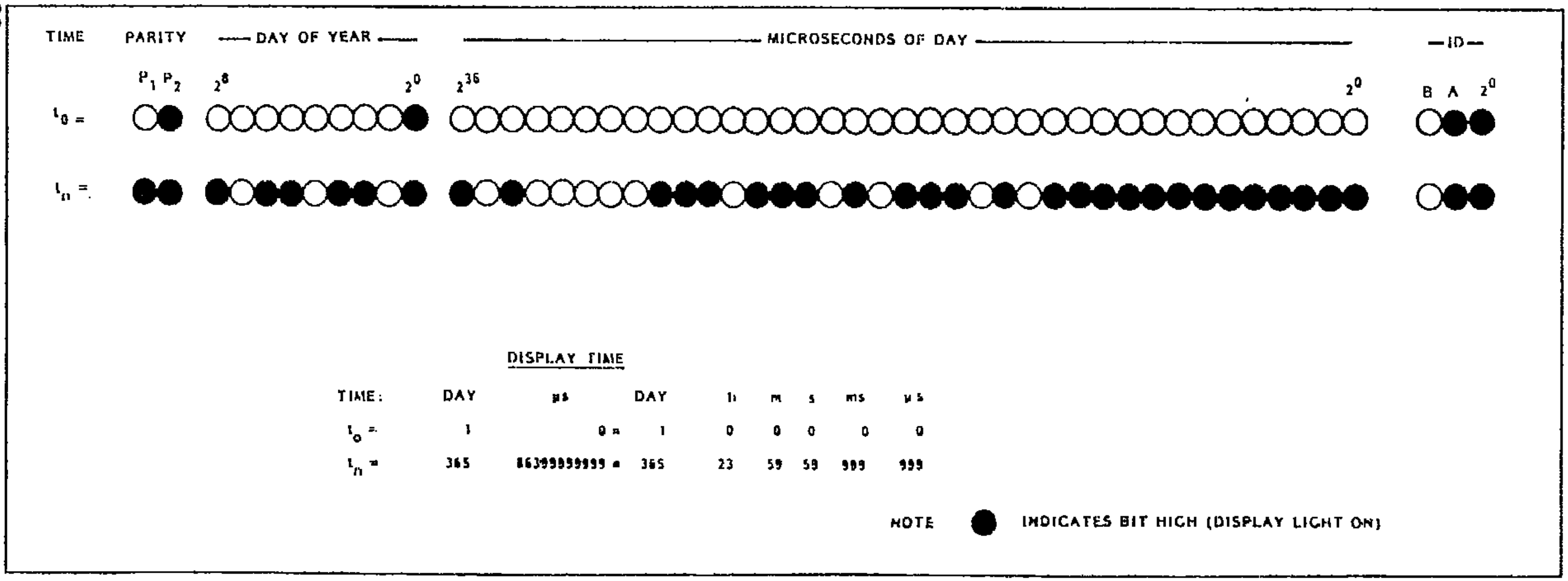
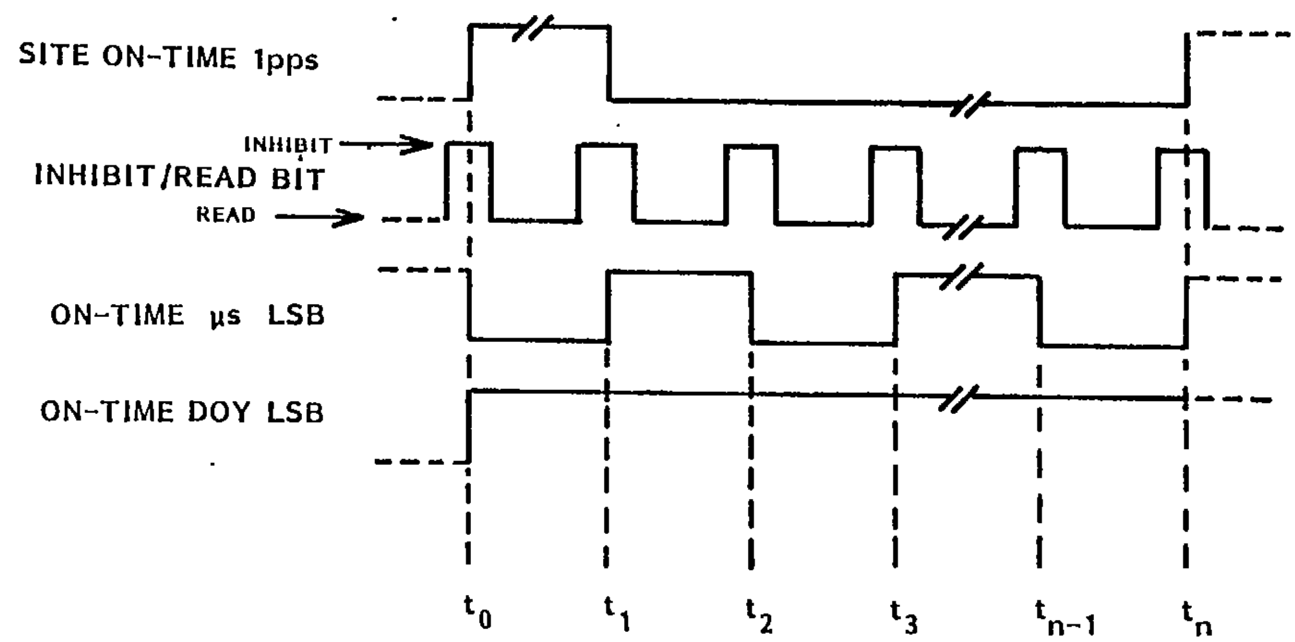


Figure 4B. Possible Displays.



The on-time shown (t_0) is 0^h 0^m 0^s 0^s 1 January. The t_1 is the next µs of time followed by t_2, t_3 ... t_n. The µs-of-day counter resets to 0 after a count of 86 399 999 999. The DoY counter resets to 1 after a count of 365 (366 for leap year).

Figure 5. Relationship between PB1-A time code on-time and station 1 pps at t_0.

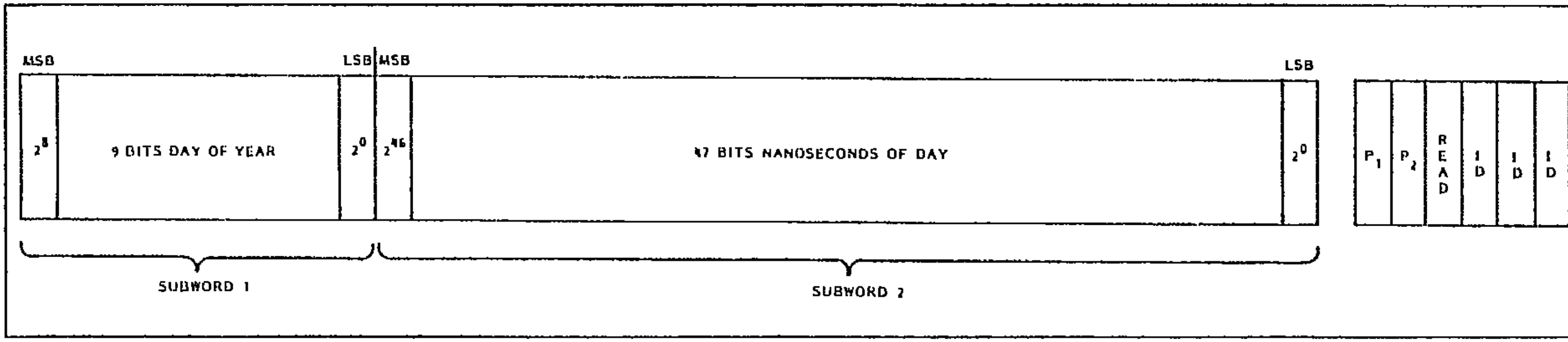


Figure 6A. PB1-B Time Code Format.

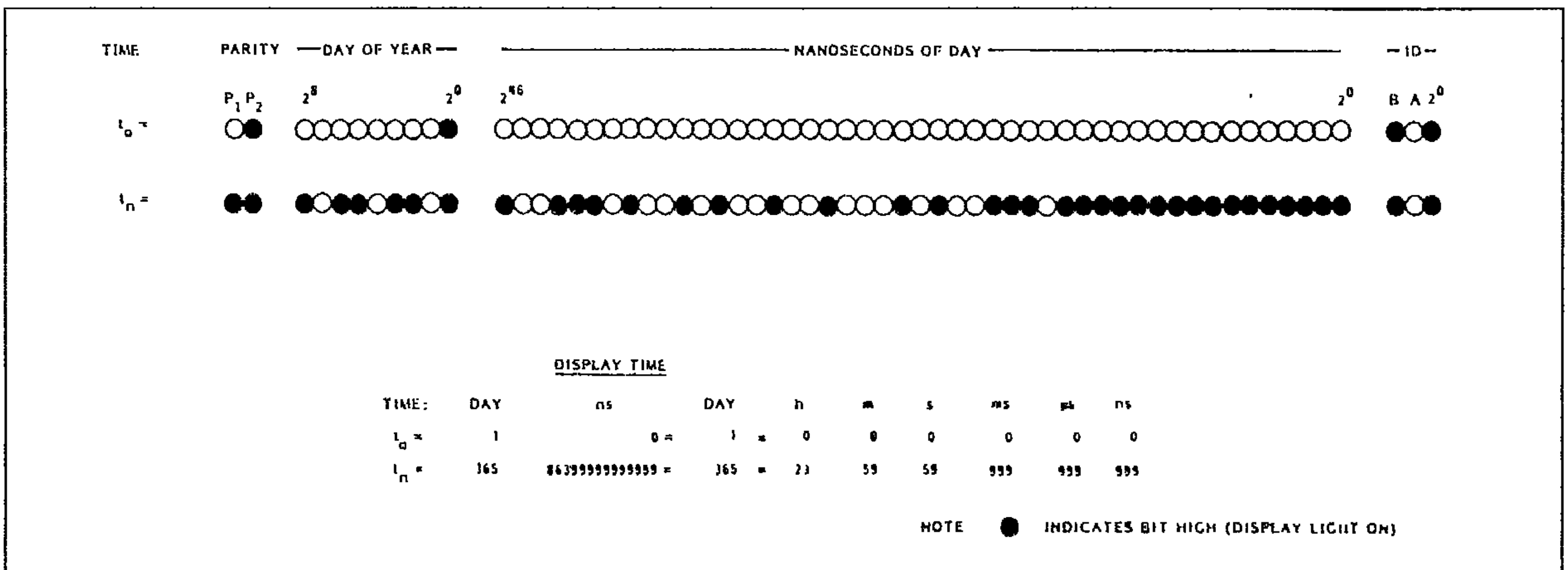
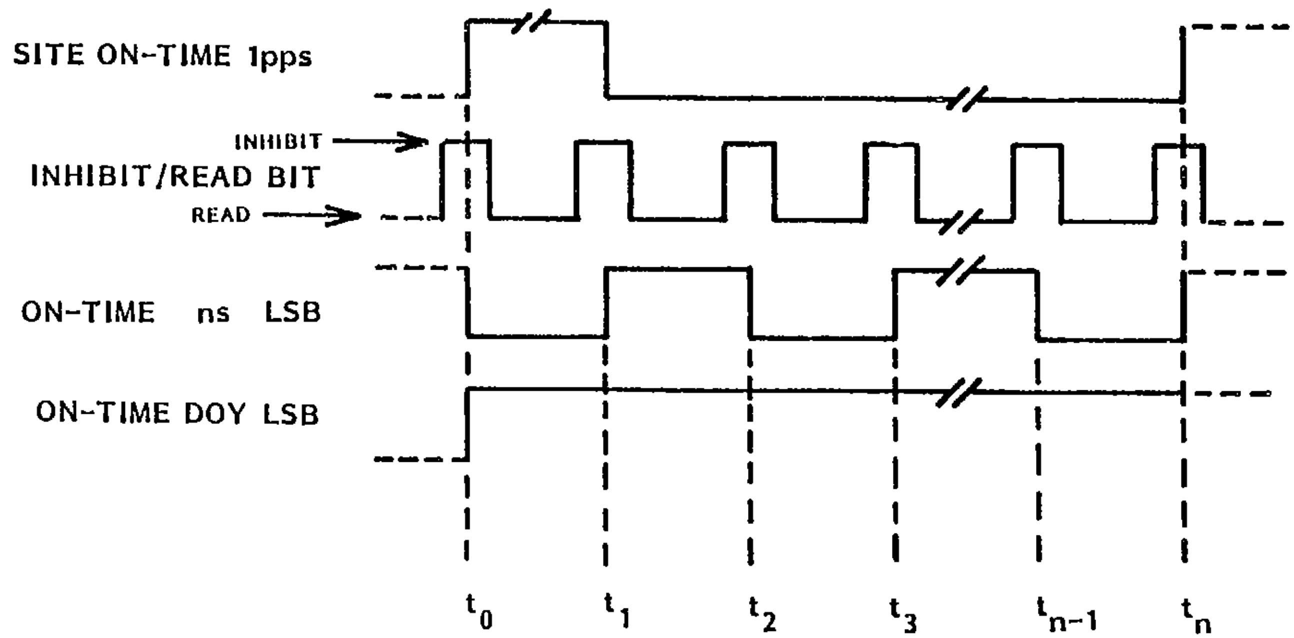


Figure 6B. Possible Displays.



The on-time shown (t_0) is $0^h\,0^m\,0^s\,0^{ns}$ 1 January. The t_1 is the next ms of time followed by t_2, t_3 ... t_n. The ns-of-day counter resets to 0 after a count of 86 399 999 999 999. The DoY counter resets to 1 after a count of 365 (366 for leap year).

Figure 7. Relationship between PB1-B time code on-time and station 1 pps at t_0.

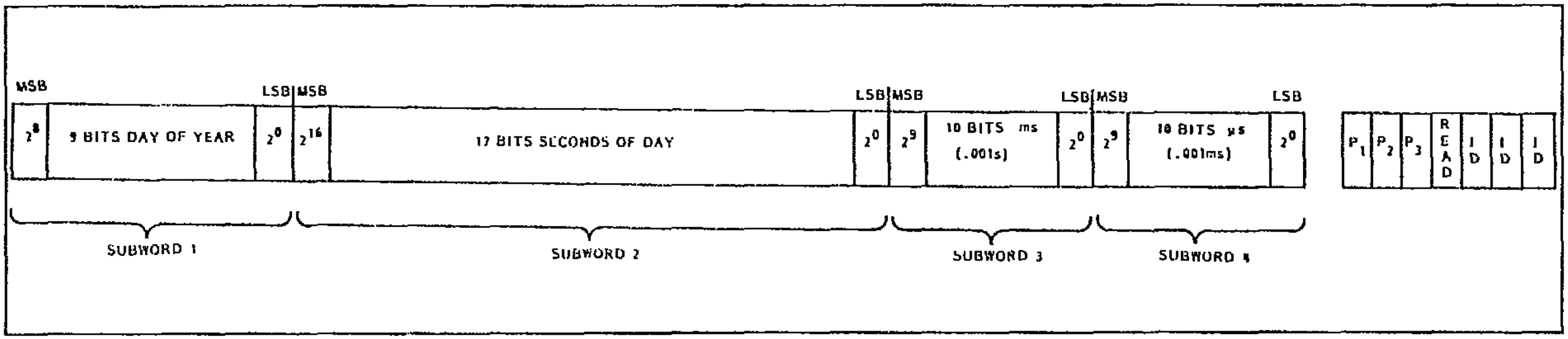


Figure 8A. PB3 Time Code Format.

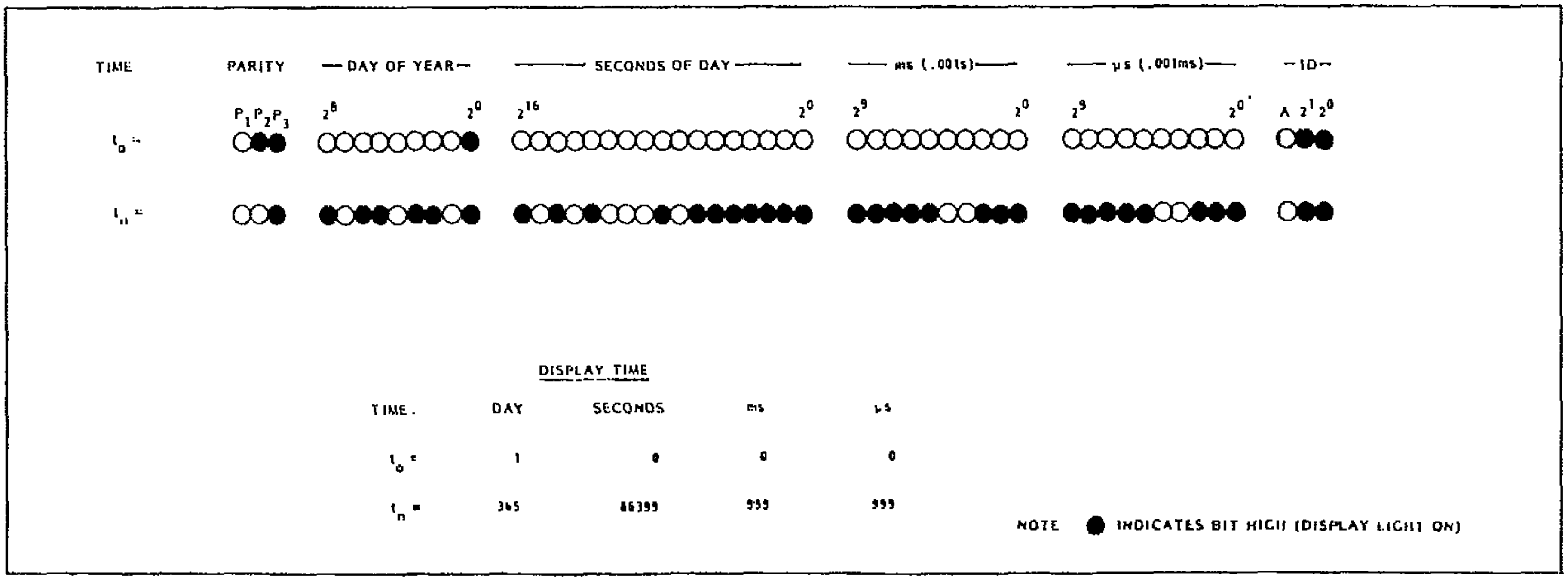
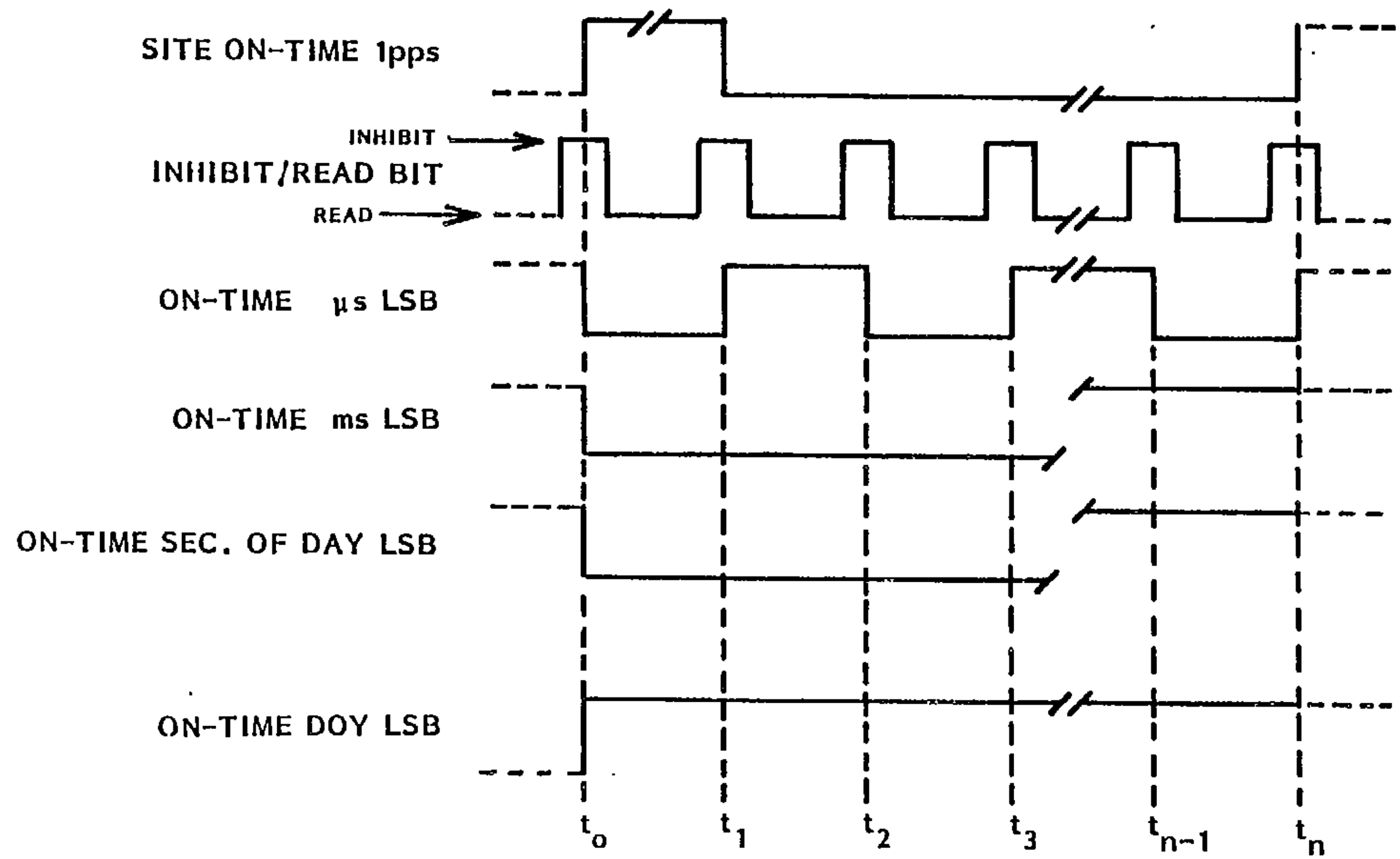


Figure 8B. Possible Displays.



The on-time shown (t_0) is $0^h\ 0^m\ 0^s$ 1 January. The t_1 is the next μs of time followed by t_2, t_3 ... t_n. The μs and ms counters reset to 0 after a count of 999. The seconds-of-day counter resets to 0 after the 86 399th second. The DoY counter resets to 1 after a count of 365 (366 for leap year).

Figure 9. Relationship between PB3 time code on-time and station 1 pps at t_0.

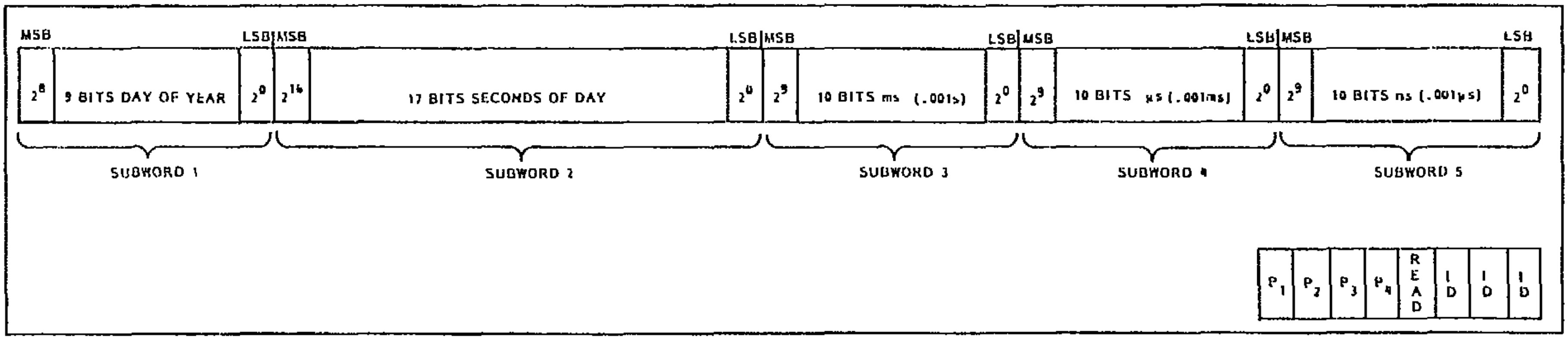


Figure 10A. PB3-A Time Code Format.

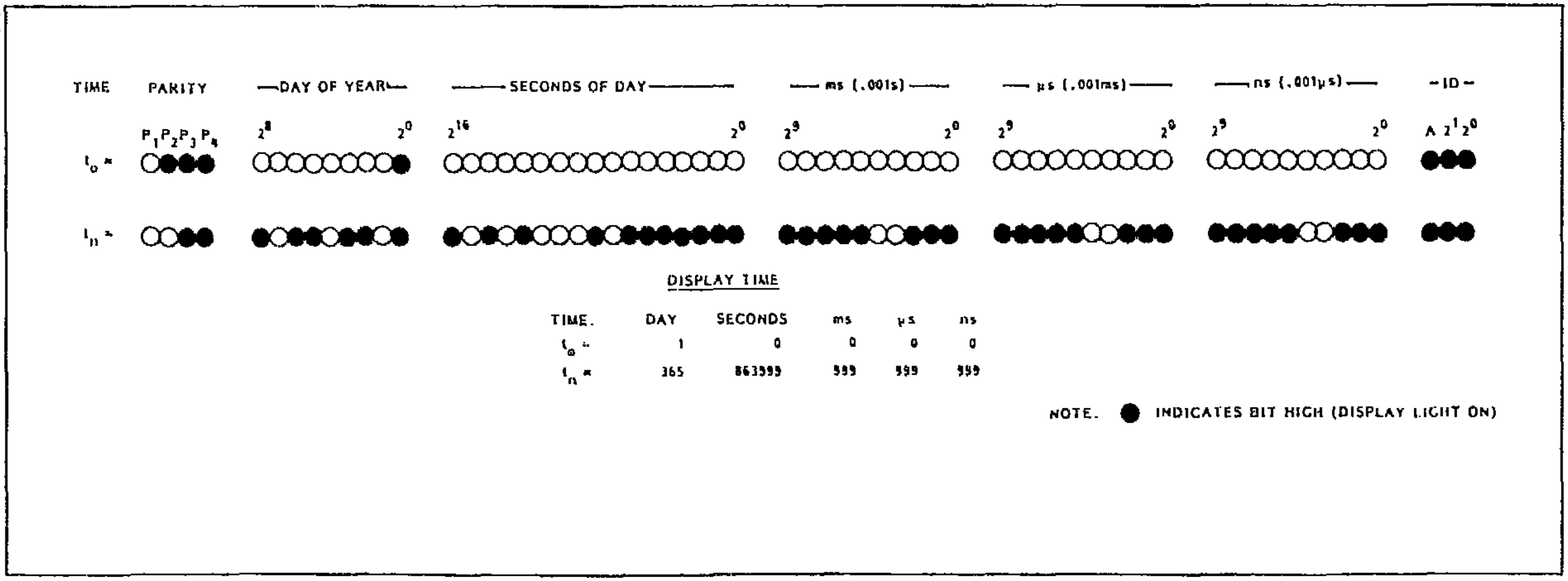
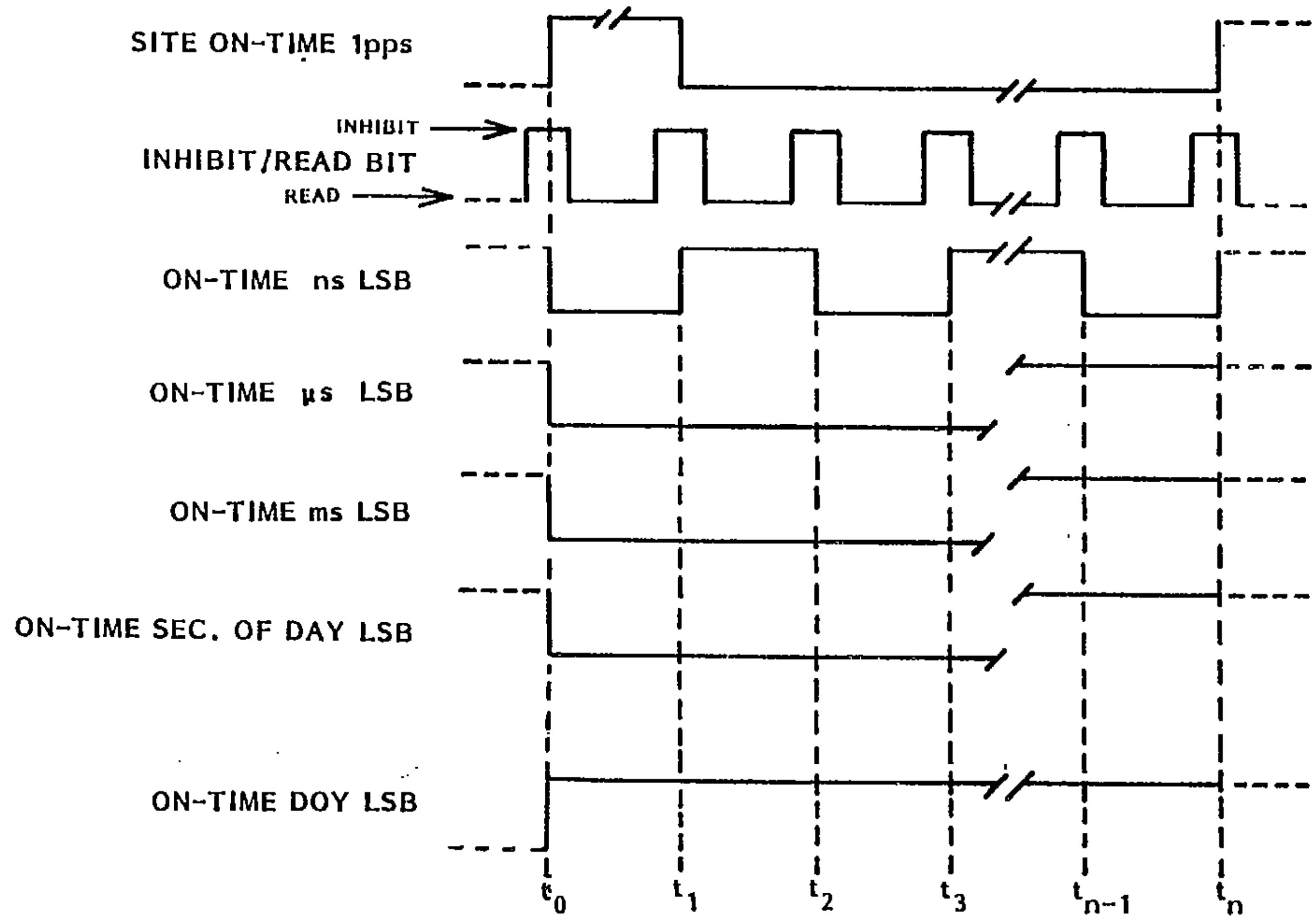


Figure 10B. Possible Displays.



The on-time shown (t_0) is $0^h\ 0^m\ 0^s$ 1 January. The t_1 is the next ns of a µs followed by t_2, t_3 ... t_n. The ns, µs and ms counters reset to 0 after a count of 999. The seconds-of-day counter resets to 0 after the 86 399th second. The DoY counter resets to 1 after a count of 365 (366 for leap year).

Figure 11. Relationship between PB3-A time code on-time and station 1 pps at t_0.

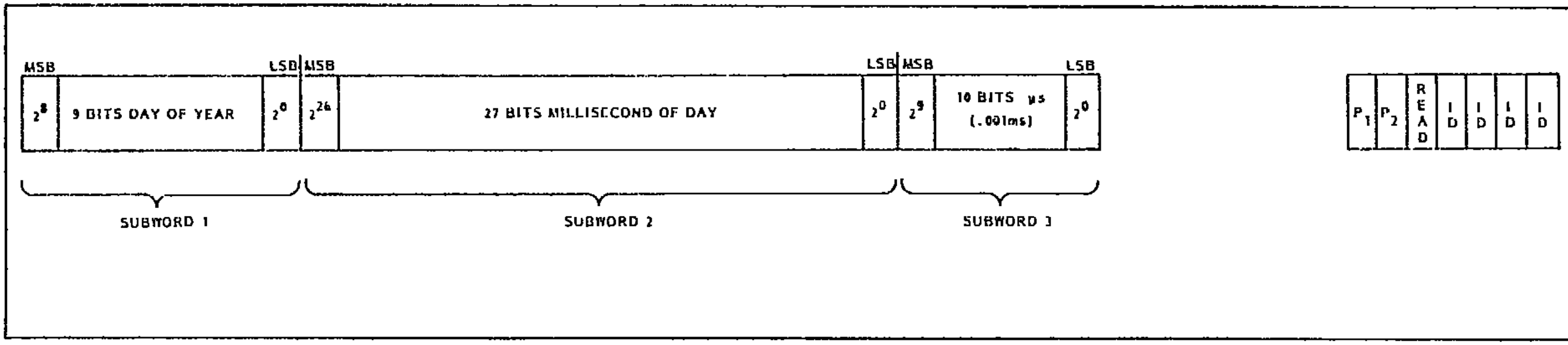


Figure 12A. PB4 Time Code Format.

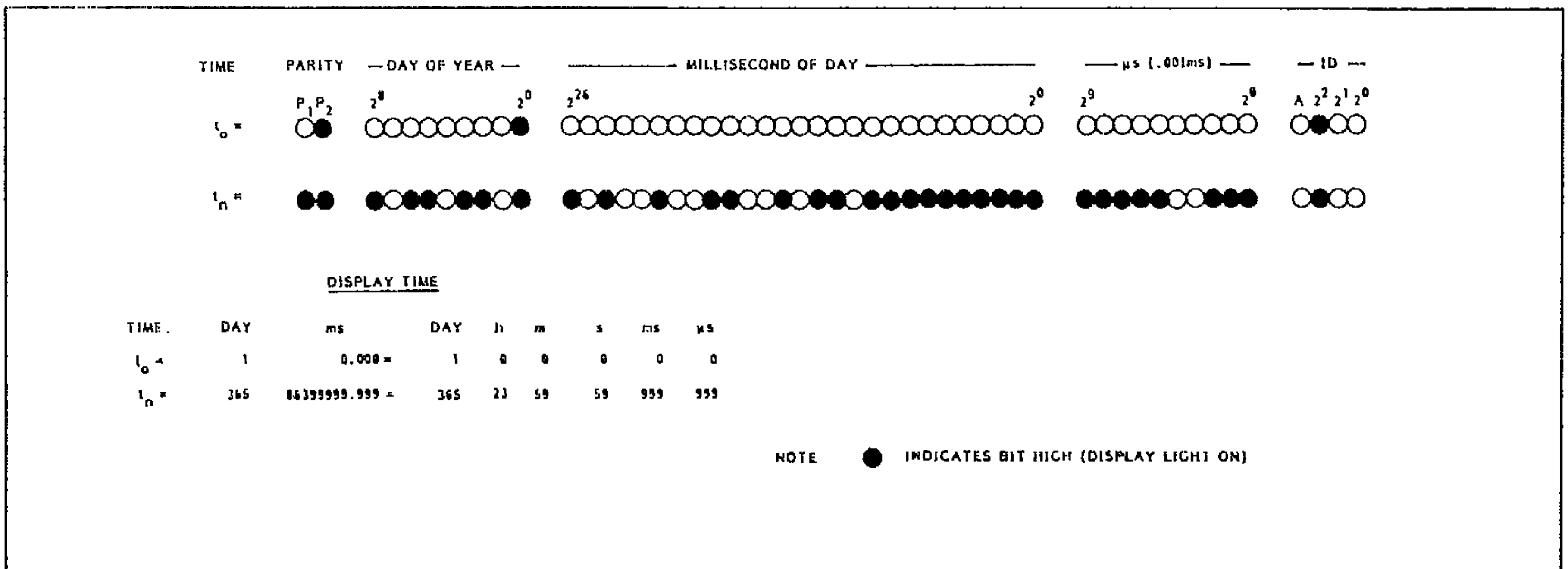
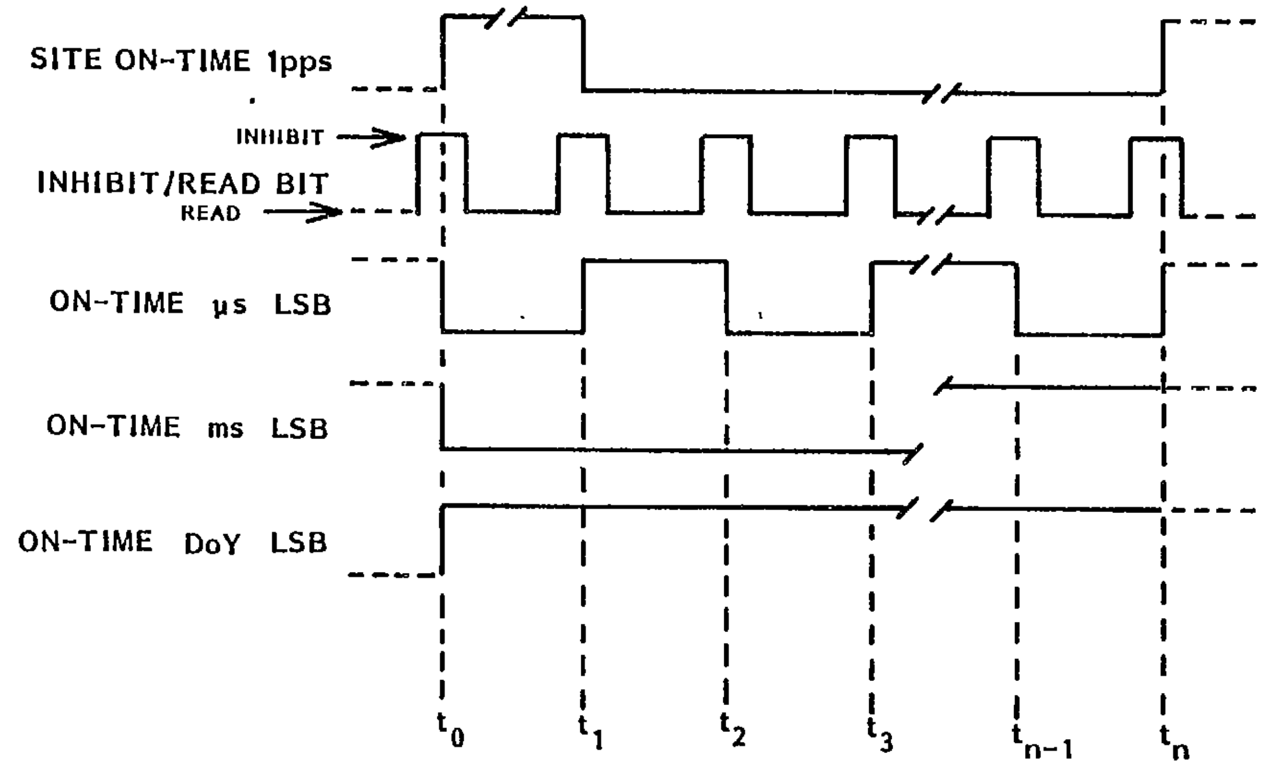


Figure 12B. Possible Displays.



The on-time shown (t_0) is $0^h\ 0^m\ 0^s$ 1 January. The t_1 is the next μs of a ms followed by t_2, t_3 ... t_n. The μs counter resets to 0 after a count of 999. The ms counter resets to 0 after a count of 86 399 999. The DoY counter resets to 1 after a count of 365 (366 for leap year).

Figure 13. Relationship between PB4 time code on-time and station 1 pps at t_0.

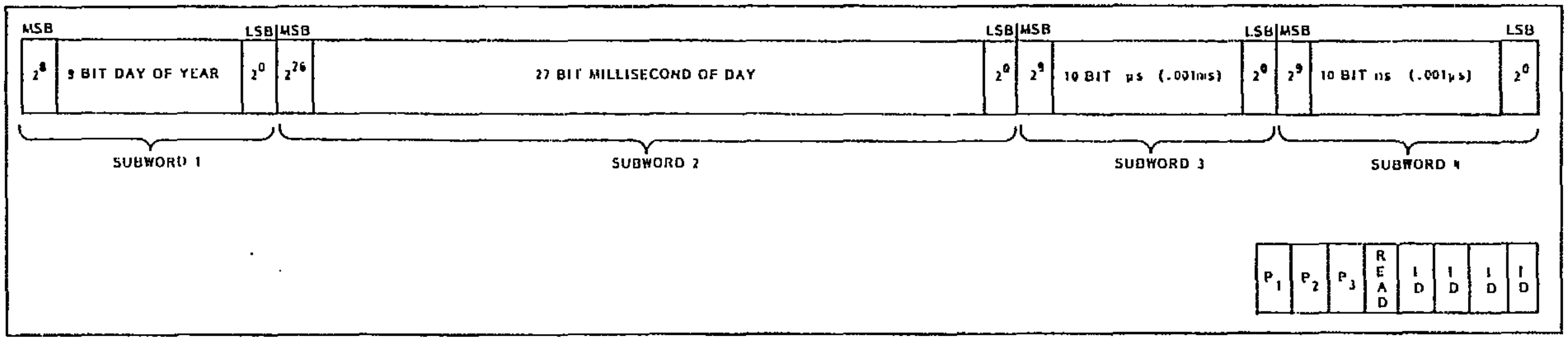


Figure 14A. PB4-A Time Code Format.

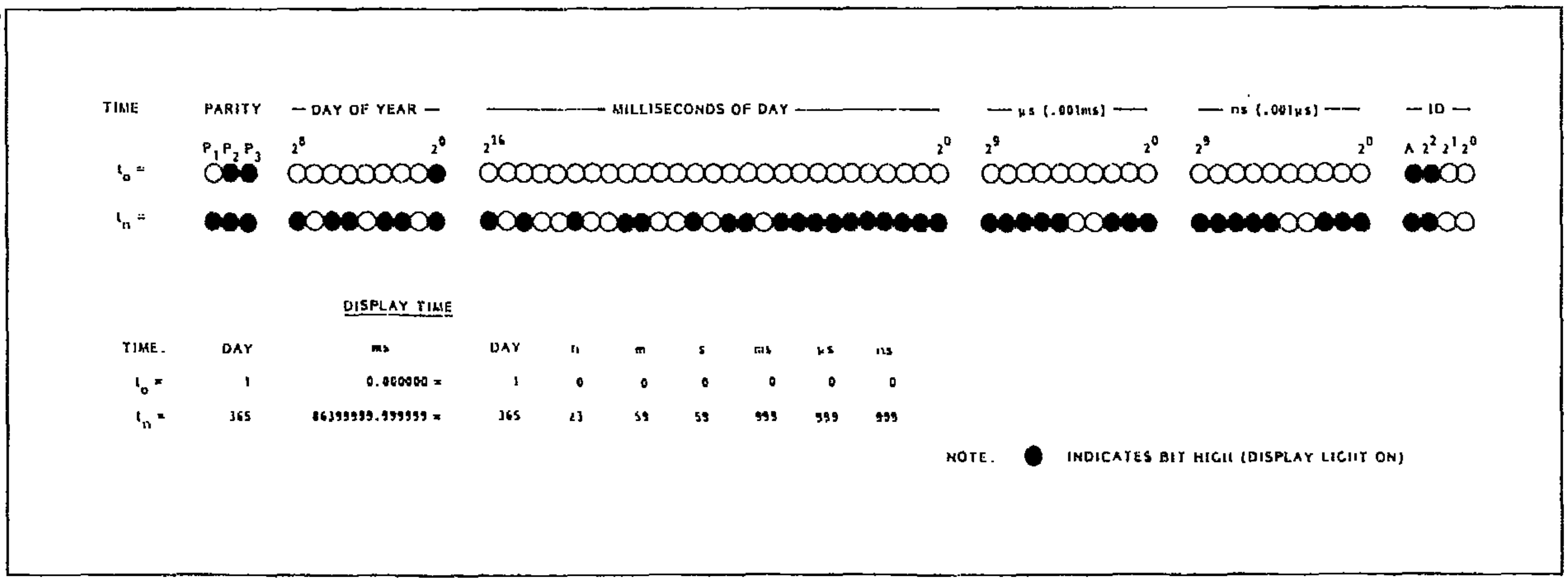
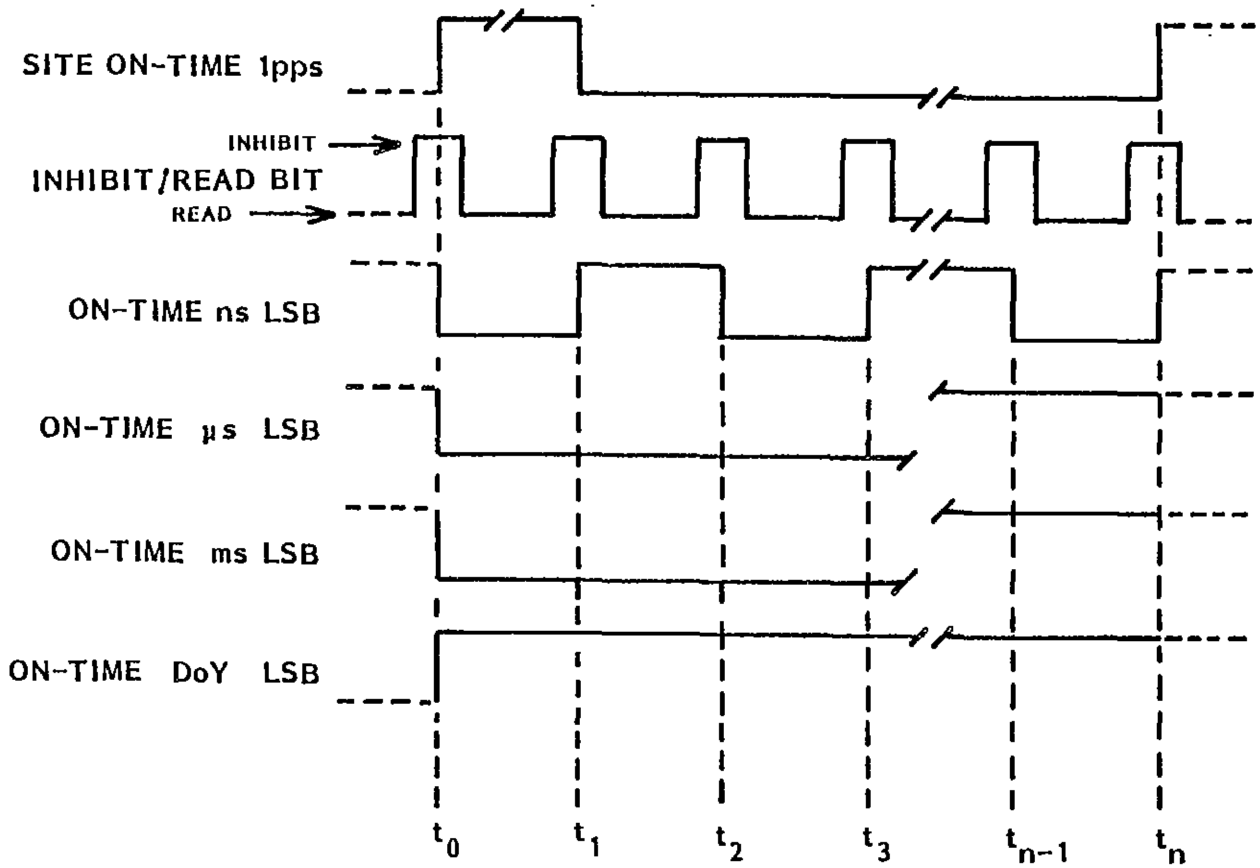


Figure 14B. Possible Displays.



The on-time shown (t_0) is $0^h\ 0^m\ 0^s$ 1 January. The t_1 is the next ns of a μs followed by t_2, t_3 ... t_n. The ns and μs counters reset to 0 after a count of 999. The ms counter resets to 0 after a count of 86 399 999. The DoY counter resets to 1 after a count of 365 (366 for leap year).

Figure 15. Relationship between PB4-A time code on-time and station 1 pps at t_0.

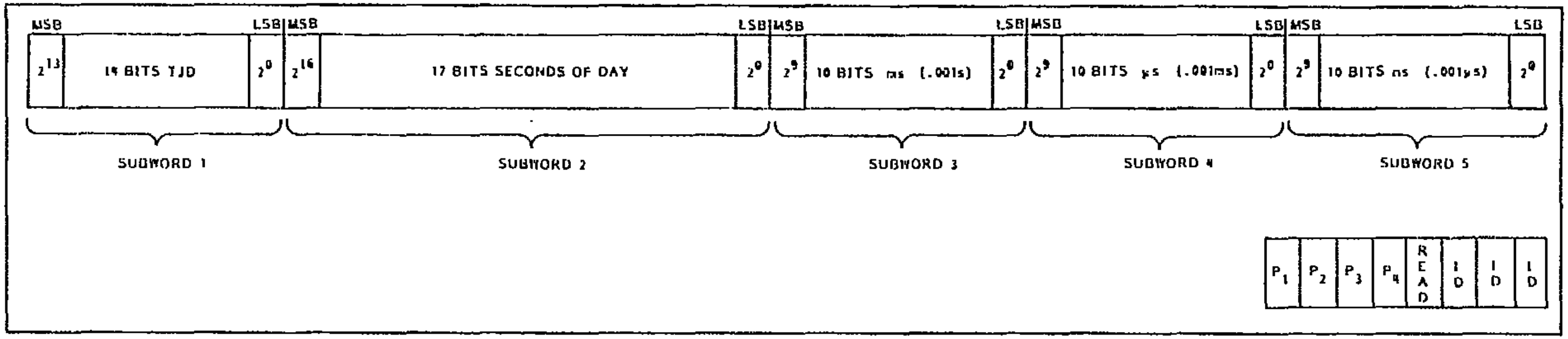


Figure 16A. PB5 Time Code Format.

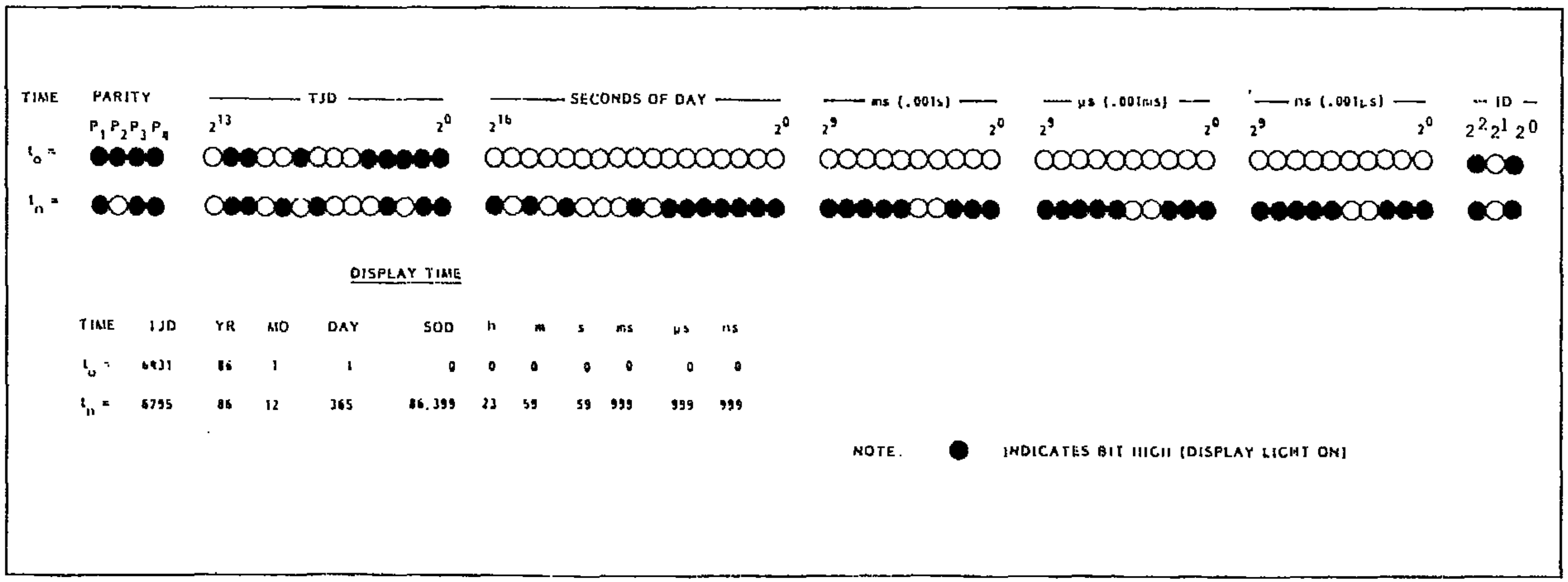
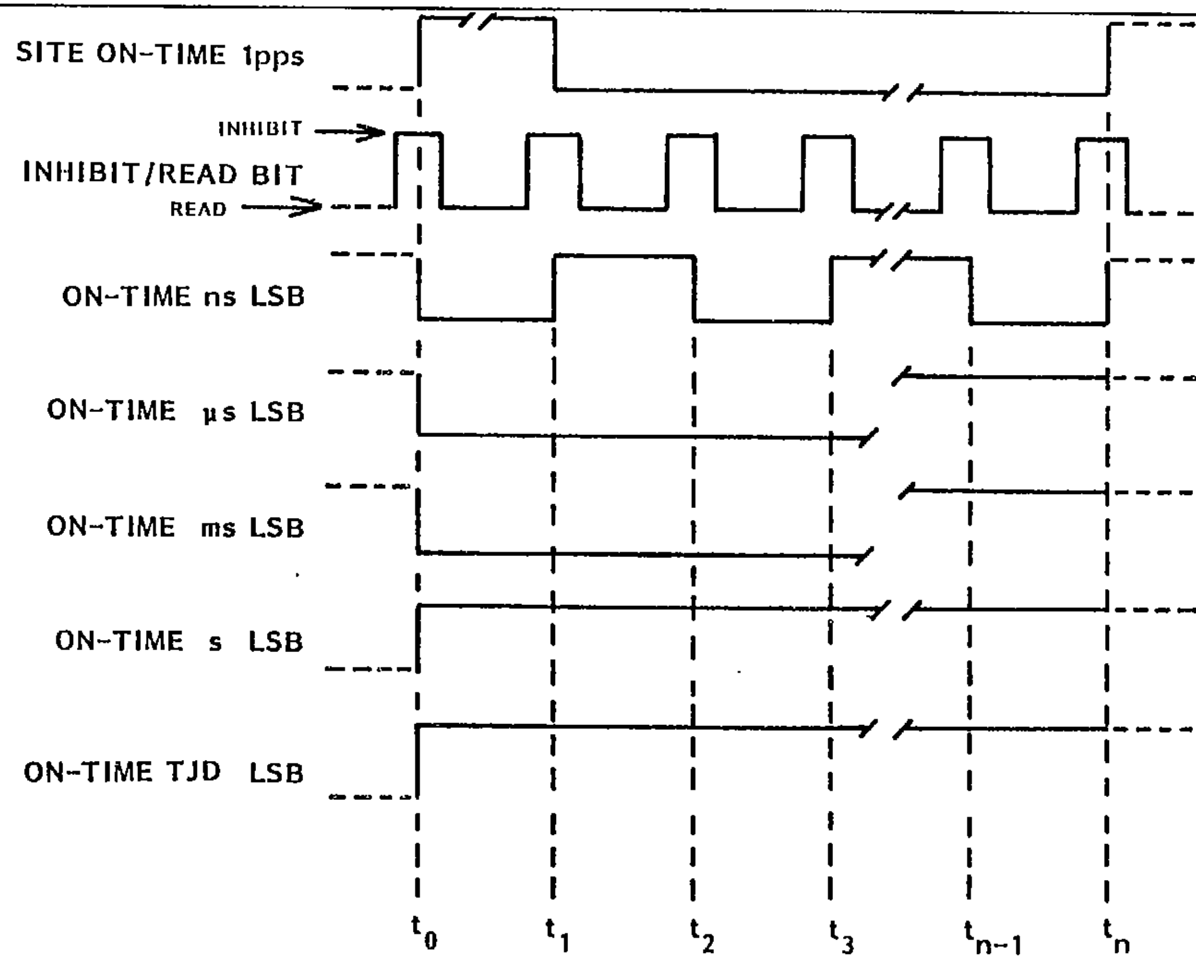


Figure 16B. Possible Displays.



The on-time shown (t_0) is $0^h\ 0^m\ 0^s$ 1 January, TJD 6796. The t_1 is the next ns followed by t_2, t_3 ... t_n. The ns, μs and ms counters reset to 0 after a count of 999. The seconds-of-day counter resets to 0 after a count of 86 399th second. The TJD counter resets to 1 after 27.379 years, or after 10,000 days, which is the ambiguity period.

Figure 17. Relationship between PB5 time code on-time and station 1 pps at t_0.

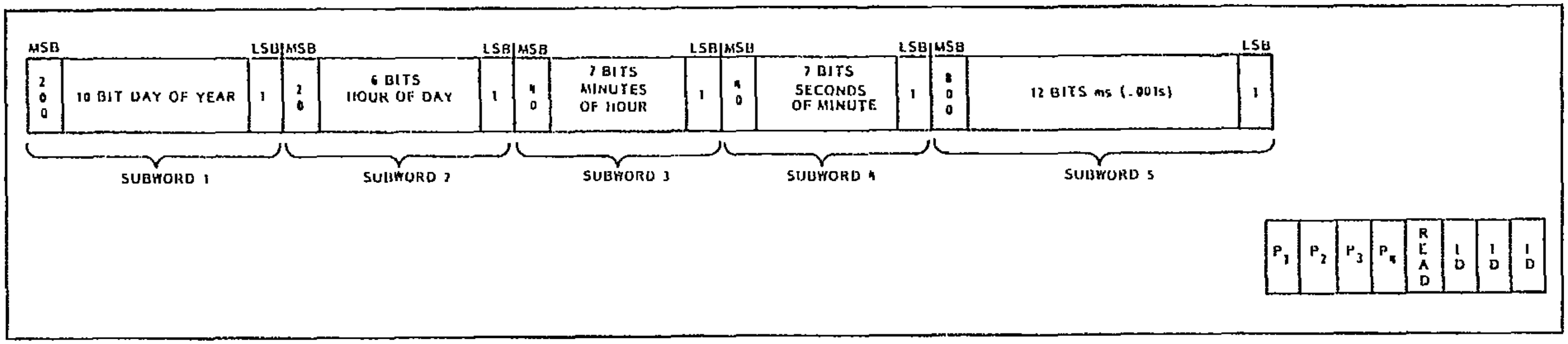


Figure 18A. PBCD 1 Time Code Format.

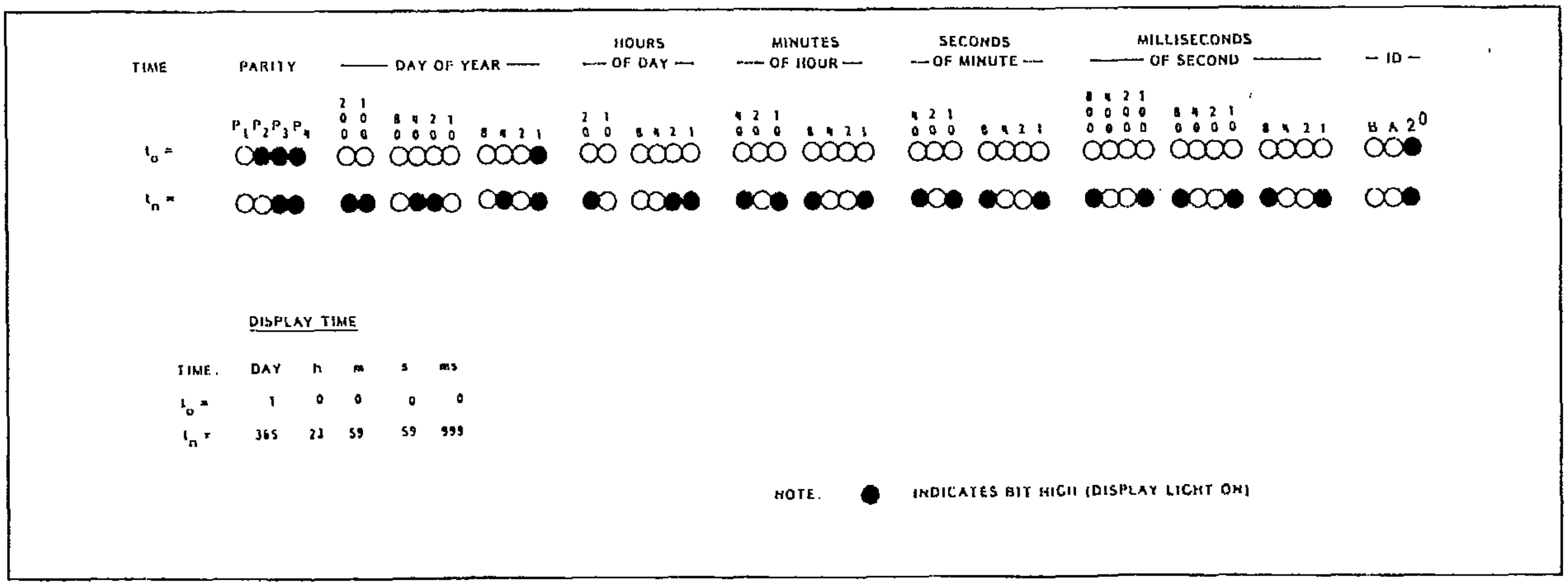
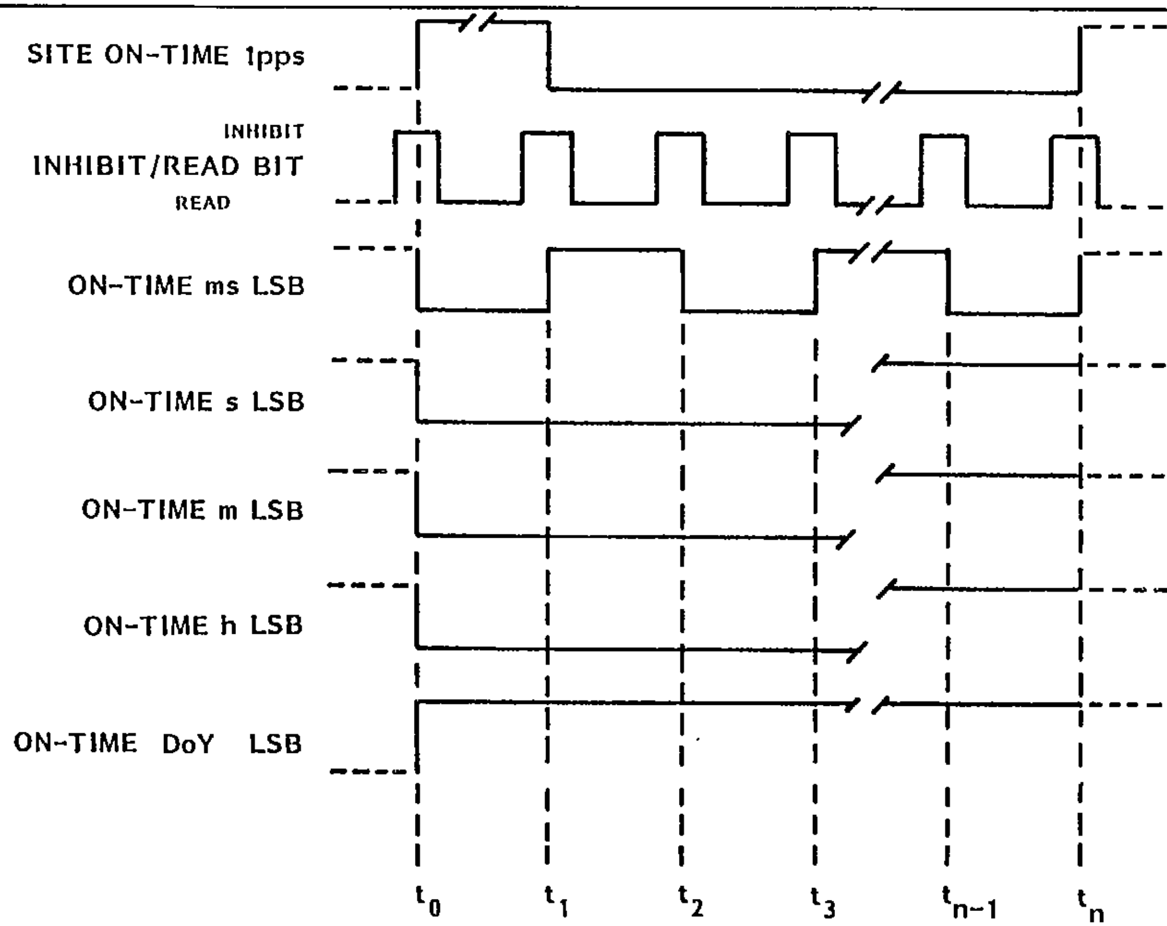


Figure 18B. Possible Displays.



The on-time shown (t_0) is $0^h\ 0^m\ 0^s\ 0^{ms}$ 1 January. The t_1 is the next ms followed by t_2, t_3 ... t_n. The ms counter resets to 0 after a count of 999. The sec and m counters reset to 0 after counts of 59. The h counter resets to 0 after a count of 23. The DoY counter resets to 1 after a count of 365 (366 for leap year).

Figure 19. Relationship between PBCD1 time code on-time and station 1 pps at t_0.

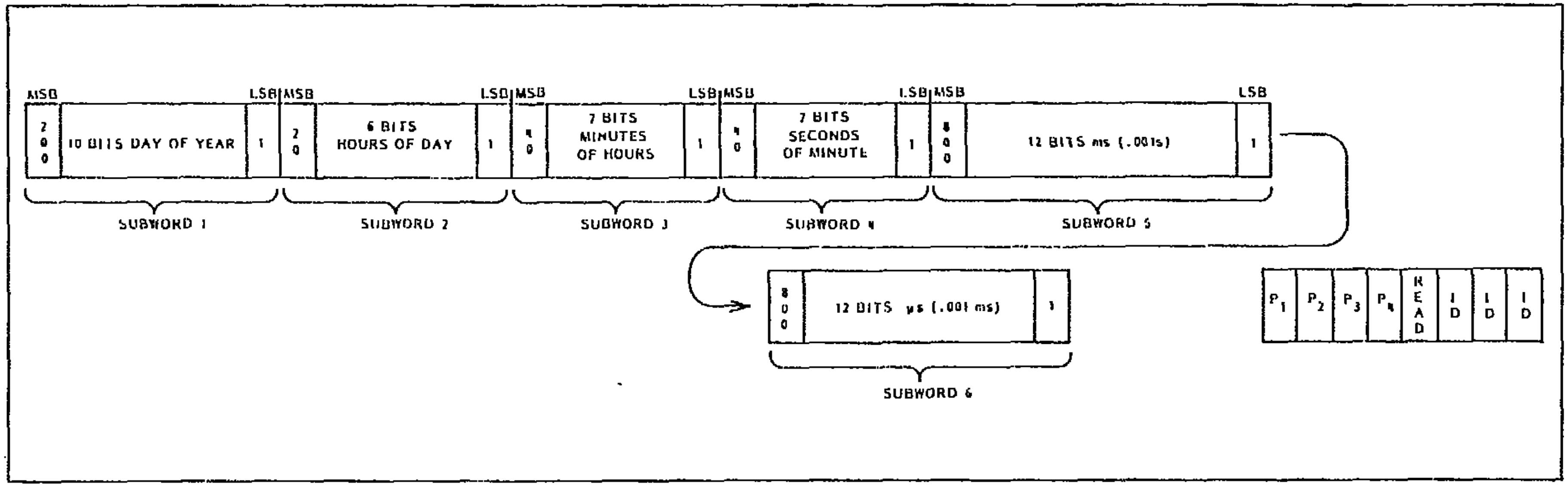


Figure 20A. PBCD 1-A Time Code Format.

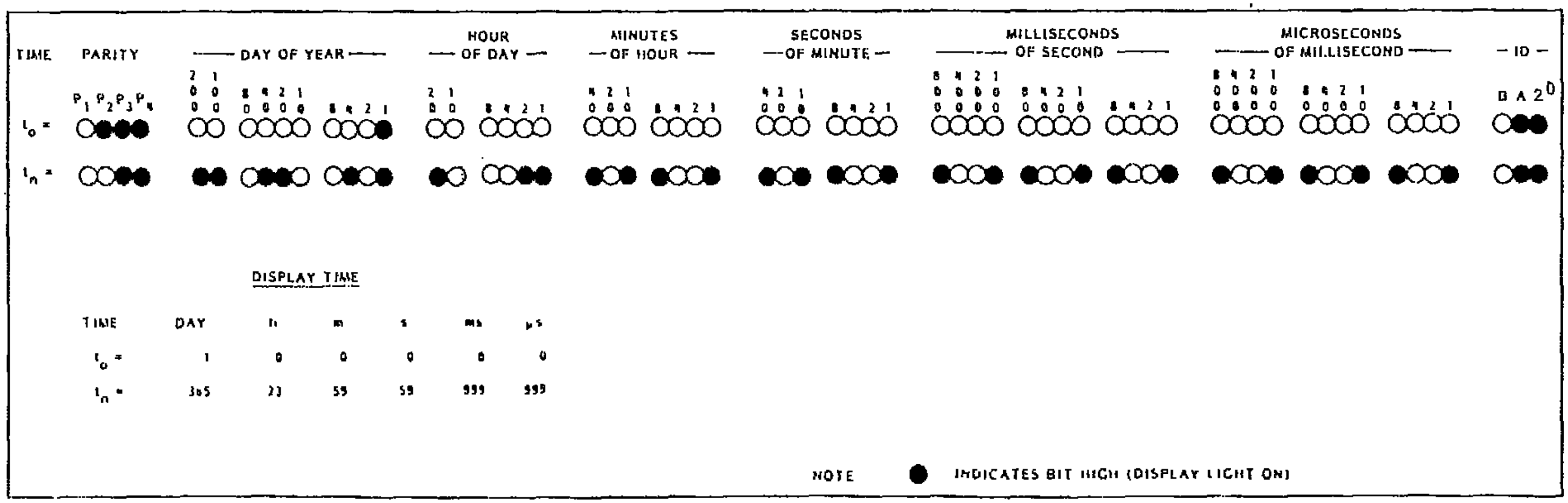
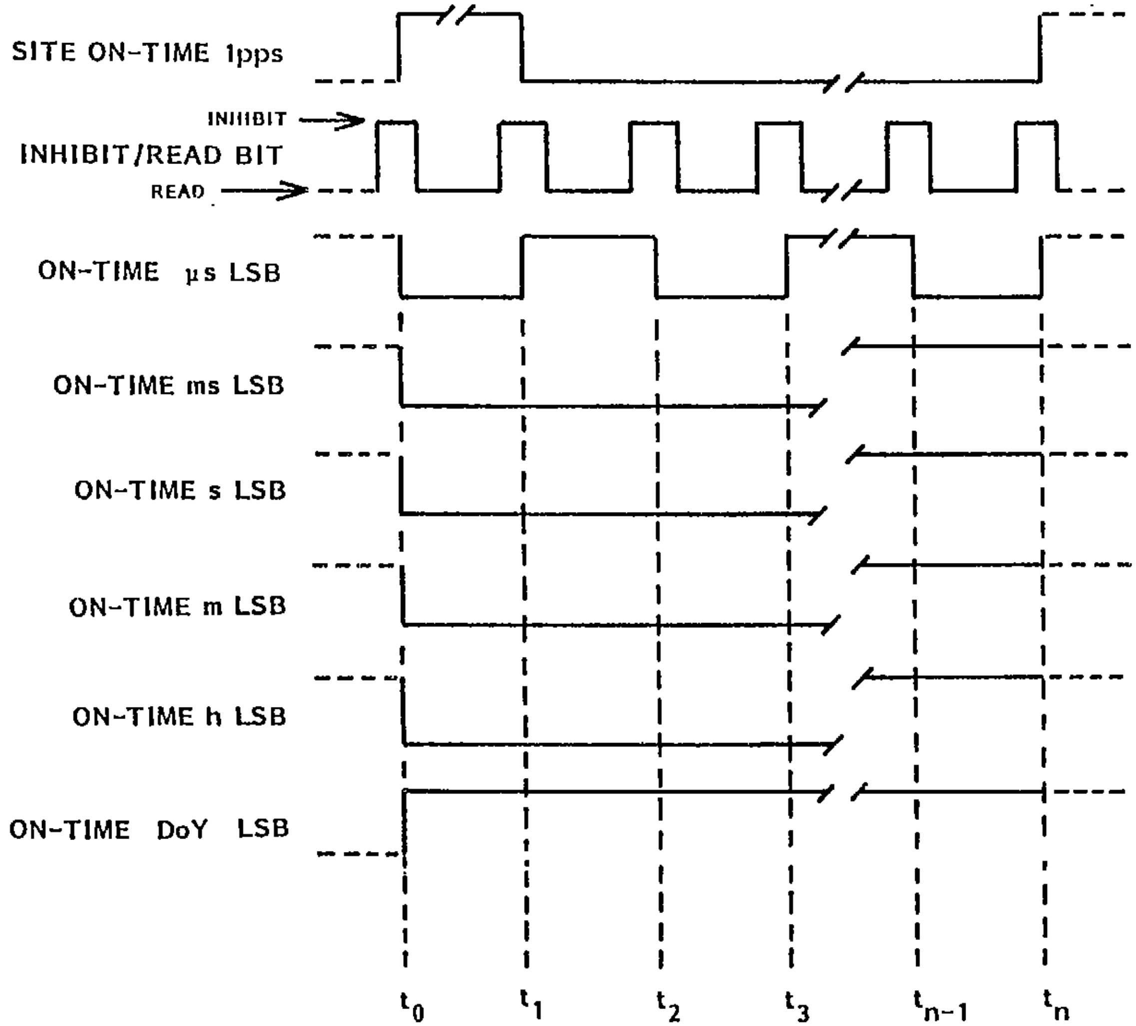


Figure 20B. Possible Displays.



The on-time shown (t_0) is 0^h 0^m 0^s 0^{ms} $0^{\mu s}$ 1 January. The t_1 is the next μs followed by t_2, t_3 ... t_n. The μs and ms counters reset to 0 after a count of 999. The sec and m counters reset to 0 after counts of 59. The h counter resets to 0 after a count of 23. The DoY counter resets to 1 after a count of 365 (366 for leap year).

Figure 21. Relationship between PBCD1-A time on-time and station 1 pps at t_0.

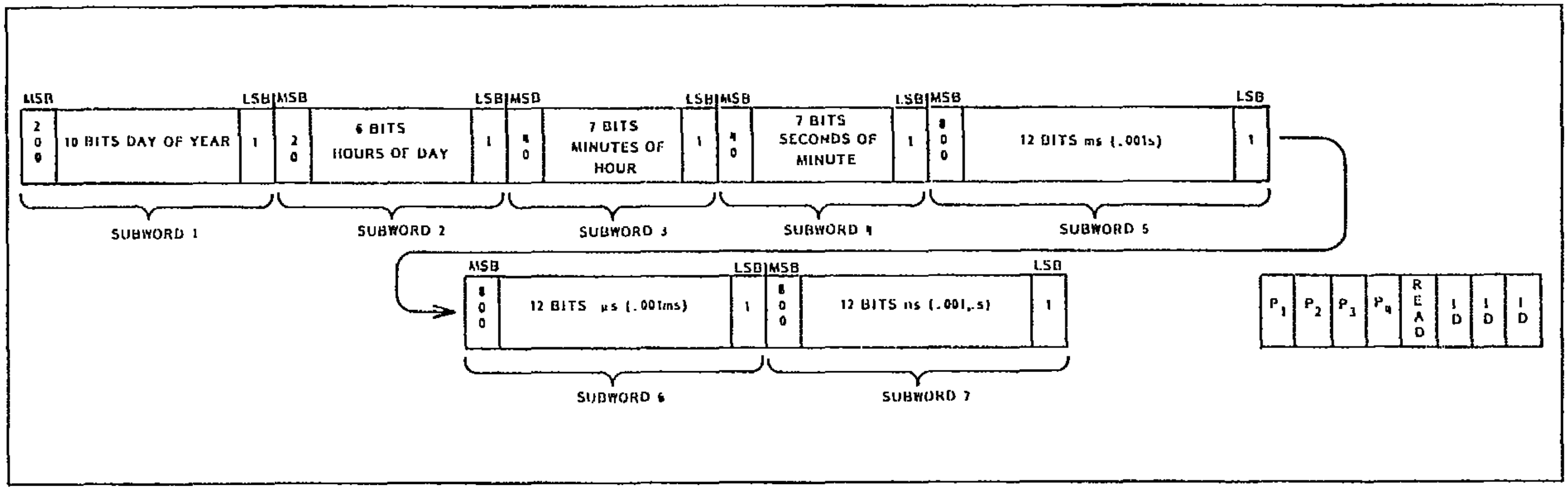


Figure 22A. PBCD 1-B Time Code Format.

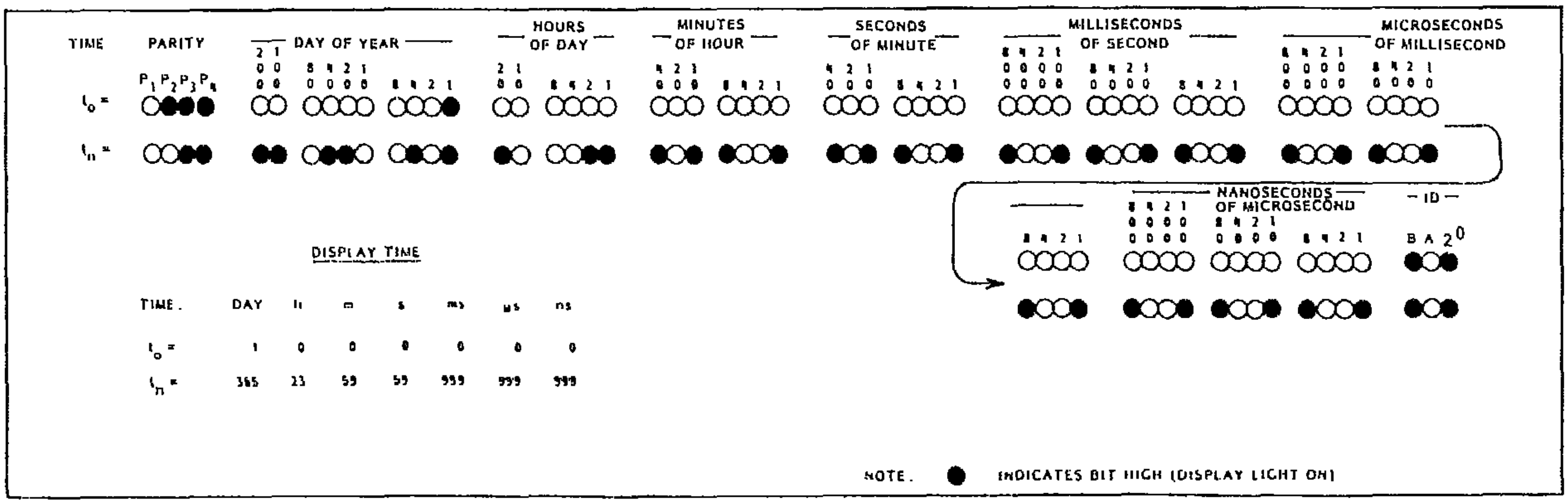
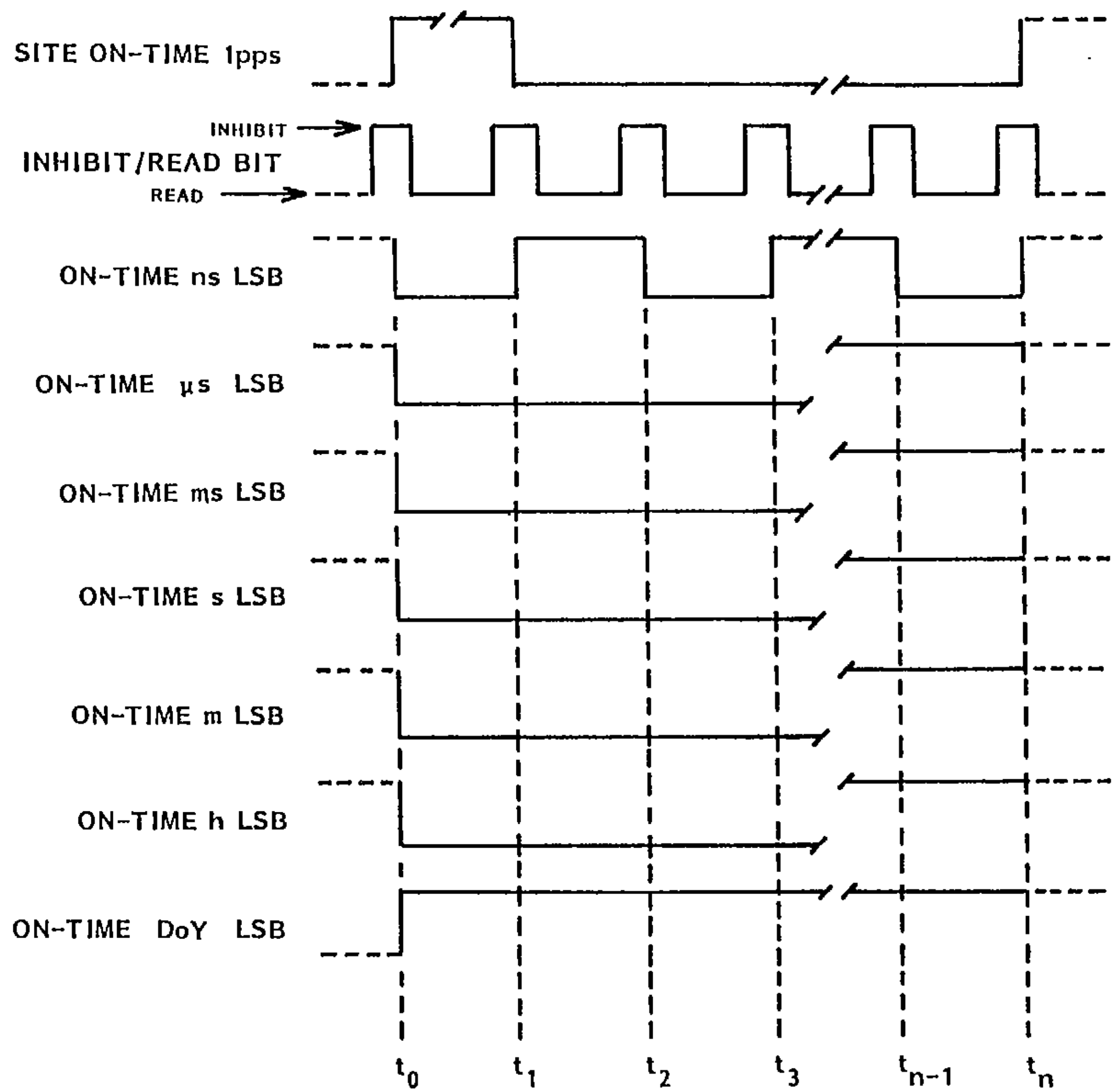


Figure 22B. Possible Displays.



The on-time shown (t_0) is $0^h\,0^m\,0^s\,0^{ms}\,0^{\mu s}\,0^{ns}$ 1 January. The t_1 is the next ns followed by t_2, t_3 ... t_n. The ns, μs and ms counters reset to 0 after counts of 999. The sec and m counters reset to 0 after counts of 59. The h counter resets to 0 after a count of 23. The DoY counter resets to 1 after a count of 365 (366 for leap year).

Figure 23. Relationship between PBCD1-B time code on-time and station 1 pps at t_0.

APPENDIX A

LEAP YEAR/LEAP SECOND CONVENTION

LEAP YEAR/LEAP SECOND CONVENTION

LEAP YEAR:

The length of a year is not an even multiple of days. The year is about 365.25 days. Thus, every four years there is an extra day, 29 February, provided the year is divisible by 4. If the year is divisible by 100, it is not a leap year. Years divisible by 400 are leap years. Consequently, the years 1988, 1992, 1996, and 2000 are leap years. The year 2100 will not be a leap year because it is not divisible by 400. With the addition of leap years, the calendar stays in step with the seasons.

ACCUMULATED LEAP SECOND:

Since 1 January 1972, the relationship between International Atomic Time (TAI) and Time Universal Coordinated (UTC) has been given by a simple accumulation of leap seconds occurring approximately once per year.

At any instant (i), T_i = TAI time
U_i = UTC time expressed in seconds
$T_i = U_i + L_i$

where (L_i) is the accumulated leap second additions between the epoch and the instant (i). The following table contains a reference list of the accumulated leap second additions (L_i) between 1972.0 and 1986.0:

Time Period	L_i
1972 Jan 1 - 1972 Jul 1	10.000 000 0 s
1972 Jul 1 - 1973 Jan1	11.000 000 0 s
1973 Jan 1 - 1974 Jan1	12.000 000 0 s
1974 Jan 1 - 1975 Jan1	13.000 000 0 s
1975 Jan 1 - 1976 Jan1	14.000 000 0 s
1976 Jan 1 - 1977 Jan1	15.000 000 0 s
1977 Jan 1 - 1978 Jan1	16.000 000 0 s
1978 Jan 1 - 1979 Jan1	17.000 000 0 s
1979 Jan 1 - 1980 Jan1	18.000 000 0 s
1980 Jan 1 - 1981 Jul 1	19.000 000 0 s
1981 Jul 1 - 1982 Jul 1	20.000 000 0 s
1982 Jul 1 - 1983 Jul 1	21.000 000 0 s
1983 Jul 1 - 1985 Jul 1	22.000 000 0 s
1985 Jul 1 - 1986 Jan1	23.000 000 0 s
1986 Jan 1 -	

NOTE: Time changes are made on 31 December and 30 June at 2400^h. As of the date of publication, there has not been a leap second since 30 June 1985.

APPENDIX B

TABLES

TABLE I. JULIAN CALENDAR TO TJD CONVERSION							
Date			TJD	TJD	DATE		
Yr	Mo	Day			Yr	Mo	Day
68	05	24	0	0	68	05	24
				200	68	12	10
69	01	01	222	600	70	01	14
70	01	01	587	800	70	08	02
71	01	01	952	1200	71	09	06
72	01	01	1317	1400	72	03	24
73	01	01	1683	1800	73	04	28
74	01	01	2048	2000	73	11	14
75	01	01	2413	2400	74	12	19
76	01	01	2778	2600	75	07	07
77	01	01	3144	3000	76	08	10
78	01	01	3509	3200	77	02	26
79	01	01	3874	3600	78	04	02
80	01	01	4239	3800	78	10	19
81	01	01	4605	4200	79	11	23
82	01	01	4970	4400	80	06	10
83	01	01	5335	4800	81	07	15
84	01	01	5700	5000	82	01	31
85	01	01	6066	5400	83	03	07
86	01	01	6431	5600	83	09	23
87	01	01	6796	6000	84	10	27
88	01	01	7161	6200	85	05	15
89	01	01	7527	6600	86	06	19
90	01	01	7892	6800	87	01	05
91	01	01	8257	7200	88	02	09
92	01	01	8622	7400	88	08	27
93	01	01	8988	7800	89	10	01
94	01	01	9353	8000	90	04	19
95	01	01	9718	8400	91	06	02
95	10	10	0	8600	91	12	10
		-	-	9000	93	01	13
		-	-	9200	93	08	01
		-	-	9600	94	09	05

TABLE II. BINARY COUNT (2^n)

Decimal Number	Binary Number	Decimal Number	Binary Number
n	2^n	n	2^n
0	1		
1	2	26	671 08864
2	4	27	1342 17728
3	8	28	2684 35456
4	16	29	5368 70912
5	32	30	10737 41825
6	64	31	21474 83648
7	128	32	42949 67296
8	256	33	85899 34592
9	512	34	1 71798 69184
10	1024	35	3 43597 38368
11	2048	36	6 87194 76736
12	4096	37	13 74389 53472
13	8192	38	27 48779 06944
14	16384	39	54 97558 13888
15	32768	40	109 95116 27776
16	65536	41	219 90232 55552
17	1 31072	42	439 80465 11104
18	2 62144	43	879 60930 22208
19	5 24288	44	1759 21860 44416
20	10 48576	45	3518 43720 88832
21	20 97152	46	7036 87441 77664
22	41 94304	47	14073 74883 55328
23	83 88608	48	28147 49767 10656
24	167 77216	49	56294 99534 21312
25	335 54432	50	112589 99068 42624

EXAMPLE:

2^{16} 2^{12} 2^{8} 2^{4} 2^{0}

86,400 s/d = ●○●○●○○○●●○○○○○○○ (17 BINARY BITS)

TABLE III. BCD COUNT
(8n 4n 2n 1n)

Decimal Number	n	BCD Bits
1	1	1
5	1	3
10	10	5
15	10	5
150	100	9
1 500	1K	13
15 000	10K	17
150 000	100K	21
1 500 000	1M	25
15 000 000	10M	29
150 000 000	100M	33
1 500 000 000	1B	37
15 000 000 000	10B	41
150 000 000 000	100B	45
1 500 000 000 000	1T	49
15 000 000 000 000	10T	53
150 000 000 000 000	100T	57

WHERE K = thousand, M = million, B = billion, T = trillion

```
EXAMPLE:          8  1           8  1
                  0  0  8  1  0  0  8  1
                  K  K  K  K  0  0  0  0  8421
    86,400 s/d =  ●○○○ ○●●○ ○●○○ ○○○○ ○○○○ (20 BCD Bits)
```

TABLE IV. NUMBERING SYSTEM EQUIVALENTS			
Quantity	Decimal Digit	Parallel Binary Bits	Parallel Binary Coded Decimal Bits
y	1 or 2	4 or 7	4 or 8
MJD	5	17	20
TJD	4	14	16
Mo	2	4	5
DoY	3	9	10
DoM	2	5	6
HoD	2	5	6
MoH	2	6	7
SoM	2	6	7
SoD	5	17	20
MoD	8	27	32
MioD	11	37	44
NoD	14	47	56
MoS	3	10	12
MioS	3	10	12
NoMi	3	10	12

TABLE V. PARALLEL TIME CODE IDENTIFICATION (ID) BITS

Time Code	Number of ID Bits	ID Bit "Weighting"	ID Bit Configuration
PB1	3	B, A, 2^0	0 0 0 (0,0,1)
PB1-A	3	B, A, 2^0	0 0 0 (0,1,1)
PB1-B	3	B, A, 2^0	0 0 0 (1,0,1)
PB3	3	A, 2^1, 2^0	0 0 0 (0,1,1)
PB3-A	3	A, 2^1, 2^0	0 0 0 (1,1,1)
PB4	4	A, 2^2, 2^1, 2^0	0 0 0 0 (0,1,0,0)
PB4-A	4	A, 2^2, 2^1, 2^0	0 0 0 0 (1,1,0,0)
PB5	3	2^2, 2^1, 2^0	0 0 0 (1,0,1)
PBCD1	3	B, A, 2^0	0 0 0 (0,0,1)
PBCD1-A	3	B, A, 2^0	0 0 0 (0,1,1)
PBCD1-B	3	B, A, 2^0	0 0 0 (1,0,1)

TABLE VI. EXAMPLES OF PARITY BIT DETERMINATION			
Time Code	Parity Bits	Time Code Subwords	Subword Error Indication
PB1	P_1	1 2	P_1=1
	P_2	2	P_1+P_2=2
PB3	P_1	1 2 3 4	P_1=1
	P_2	2 3	P_1+P_2=2
	P_3	3 4	P_1+P_3=4
PB4	P_1	1 2	P_1=1
	P_2	2 3	P_1+P_2=2
			P_2=3
PBCD1	P_1	1 2 3 4 5	P_1=1
	P_2	2 3	P_1+P_2=2
	P_3	3 4	P_1+P_2+P_3=3
	P_4	5	P_1+P_3=4
			P_1+P_4=5

NOTE: In the column labeled "SUBWORD ERROR INDICATION," subwords are given in which errors are implied by the allowable combinations of parity bit error-indications. These examples are only valid for single-error conditions.

BIBLIOGRAPHY

1. NASA/GSFC Standard, IRIG Standard Parallel Binary Time Code Formats, GSFC X-814-77-64, May 1977, supersedes X-814-74-346.

2. NASA Aerospace Data Systems Standards, Part 5, Standard 5.4, Parallel Binary Time Code Standard, 1977-08-22.

   NOTE: References 1 and 2 contain PB1, PB2, PB3, and PB4.

3. NASA Aerospace Data Systems Standards, Part 5, Standard 5.6, Parallel Grouped Binary Time Code for Space and Ground Applications, 1982-05-27. Contains the PB5 code.

4. RCC/TCG IRIG Standard Time Formats, Document 200-70, August 1970 (Formerly 104-70). Contains IRIG A, B, D, E, G, and H. IRIG C was eliminated in Document 104-70 and IRIG G and IRIG H were added.

5. Time Codes used by GSFC, NASA/GSFC Document X-810-71-289, December 1970. Contains

   a. NASA 1/Second BCD Time Code (referred to as NASA 36 Bit Time Code)

   b. NASA 1/Minute BCD Time Code or NASA 28 Bit Time Code

   c. NASA 1/Hour BCD Time Code or NASA 20 Bit Time Code

   d. NASA Apollo Serial Decimal Time Code or Gemini Time Code

   e. NASA Serial Decimal Time Code or Mercury or Minitrack Time Code

6. IRIG Count Down Code. Standard Format Interrange Distribution of Visual Count Status Information, Document 109-1964. (Also referred to as NASA-75 and the Vandenberg Count Down Elapse Time Code.)

7. Consultative Committee for Space Data Systems. "Red Book," Issue 4, February 1986. Time Code Formats Recommended for Data System Standards. National Aeronautics and Space Administration, Code-TS, Washington, D.C. 20546.