

NENA PSAP Master Clock Standard

Abstract: This standard provides a standard method of connecting an accurate time source to the various elements of a PSAP's E9-1-1 equipment that depend on time information for operation.



NENA PSAP Master Clock Standard

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1 Executive Overview

Purpose and Scope of Document

This Standard is a guide for designers and manufacturers of PSAP equipment for use in an E9-1-1 environment. These specifications are not for use for NG9-1-1 time synchronization; those specifications can be found in the Timer Server section of NENA-STA-010. This Standard identifies engineering and technical requirements to be met before the purchase of such equipment; it may also be of value to purchasers, maintainers and users of such equipment.

This document is not intended to provide complete design specifications for a PSAP Master Clock. It will neither ensure the quality of the performance of the equipment nor should it serve as an exclusive procurement specification.

Reason to Implement

This standard provides a standard method of connecting an accurate time source to the various elements of a PSAP's equipment that depend on time information for operation. When this standard is used to guide the design, development, and acquisition of equipment, successful system integration of the time source equipment with the systems that depend on accurate time may be achieved.

Benefits

Adoption of this Standard enables time synchronization interoperability among the devices using the interfaces described.

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Document Terminology

This section defines keywords, as they should be interpreted in NENA documents. The form of emphasis (UPPER CASE) shall be consistent and exclusive throughout the document. Any of these words used in lower case and not emphasized do not have special significance beyond normal usage.

1. **MUST, SHALL, REQUIRED:** These terms mean that the definition is a normative (absolute) requirement of the specification.
2. **MUST NOT:** This phrase, or the phrase "SHALL NOT", means that the definition is an absolute prohibition of the specification.
3. **SHOULD:** This word, or the adjective "RECOMMENDED", means that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.
4. **SHOULD NOT:** This phrase, or the phrase "NOT RECOMMENDED" means that there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
5. **MAY:** This word, or the adjective "OPTIONAL", means that an item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because the vendor feels that it enhances the product while another vendor may omit the same item. An implementation which does not include a particular option "must" be prepared to interoperate with another implementation which does include the option, though perhaps with reduced functionality. In the same vein an implementation which does include a particular option "must" be prepared to interoperate with another implementation which does not include the option (except, of course, for the feature the option provides.)

These definitions are based on IETF [RFC 2119](https://www.rfc-editor.org/rfc/2119).

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Reason for Issue/Reissue

NENA reserves the right to modify this document. Upon revision, the reason(s) will be provided in the table below.

Document Number	Approval Date	Reason For Issue/Reissue
NENA 04-002, v1	01/28/1996	Initial Document
NENA 04-002, v2	04/28/1998	Issued to add Glossary of Terms, Acknowledgments, Paragraph 4-Section 2 and update Section 4, Output Signal, Paragraph A and B.
NENA 04-002, v3	05/17/2000	Issued to change Paragraph 3 - Section 2 to include an Ethernet interface and add (section 5) describes Ethernet Interface.
NENA 04-002, v4	09/22/2005	Issued to add new ASCII data code Format "8" to include 4-digit year information to enhance the original NENA-approved Format "0" that does not include this. This issue also incorporates the current NENA standard template which, among other things, updates NENA's address.
NENA-STA-026.5-2016	12/21/2016	Accommodate evolving technology and changes in external references and create ANSI accredited standard.
NENA-STA-026.5-2022	02/28/2022	No substantive edits. ANSI reaffirmation.
NENA-STA-026.5-2026	06/09/2026	Reaffirmation



2 MASTER CLOCK Description and Feature Definitions

To ensure consistency of time stamps added to event records, reports and voice recordings, it will be required that equipment such as CAD, ANI/ALI Controllers, Logging Recorders, Radio Consoles, etc., will have the ability to synchronize internal clocks to a PSAP master clock.

2.1 Common Requirements

The PSAP master clock SHALL be traceable to Coordinated Universal Time (UTC) and have a continuous accuracy of .1 seconds relative to UTC when locked to the UTC time source. In the event the PSAP master clock becomes unlocked from the external UTC source and must "free run", it MUST NOT exceed an error accumulation of more than 1 second per day.

The PSAP master clock system SHALL have a front panel Display to indicate time and SHALL have the optional capability to provide time codes via an RS-232 serial, IRIG (Inter-Range Instrumentation Group), and Ethernet interfaces. These interfaces will provide a time code that will be used by the PSAP equipment to synchronize their internal clocks. The master clock MUST have the capability to automatically adjust the Master Clock Display, RS-232 and IRIG time codes for Daylight Saving Time. It MUST have a selectable 12 or 24 hour display of Hours, Minutes and Seconds. It MUST have a means to indicate its status; locked / unlocked and time synchronized or unsynchronized to the external UTC time source. The master clock SHALL have alarm dry contact closures that are activated upon loss of power or when the clock has lost time synchronization. Optionally, equipment synchronizing to the ASCII time code data MAY derive alarm status by monitoring the Time Sync Status character within the data stream.

When developing site requirements for a PSAP it is important to consider that the type and number of time code interfaces required for each site will vary according to equipment type, quantity, and manufacturer. The PSAP Master Clock system therefore MUST be configured accordingly to meet the quantity and types of time code interfaces required.

It is recommended that the PSAP master clock be connected to an uninterruptible power supply (UPS) or be equipped with internal batteries which are continually charged from main power. If equipped with internal batteries, the batteries MUST be capable of powering the equipment for a minimum of 15 minutes.

2.2 TIA-232-F ASCII Time Code

The [TIA-232-F](#) ASCII time code SHALL be selectable from one of the formats described below. The TIAA-232-F interface SHALL conform to the specifications described in [NENA-STA-027](#) (originally 04-001) and the baud rate SHALL be selectable from these

speeds: 1200 bps, 2400 bps, 4800 bps, and 9600 bps. A character consists of 1 start bit, 8 data bits, 1 stop bit, and no parity bit.

The ASCII time code is sent in one of two modes:

- The broadcast mode, in which the code is sent once per second at the beginning of the second.
- The response mode in which the code is sent at the beginning of the second following the receipt of a Carriage Return character from the client device.

The ASCII time code **MUST** be available on both a bi-directional serial communications port and a broadcast port.

The bi-directional serial port **MUST** send time code when requested by the client. The broadcast port **SHALL** automatically send time code once per second at the beginning of the second.

Format "8" is the preferred format because it includes the year.

A character consists of 1 start, 8 data, and 1 stop bit, no parity. The data stream contains a time sync status character, day of year, time zone setting, DST/Standard Time Indicator, and the time zone switch setting. Data structures for the formats are shown below:

Format "0"

CR LF I ^ ^ DDD ^ HH:MM:SS ^ DTZ=XX CR LF

Format "1"

CR LFI ^ WWW ^ DDMMYY ^ HH:MM:SS CR LF

Format "8"

CR LF I ^ ^ YYYY ^ DDD ^ HH:MM:SS ^ D±ZZ CR LF

where:

: = Colon separator
^ = space separator
± = Either "+" or "-"
CR = Carriage Return
D = Daylight Savings Time indicator (S,I,D,0)
DDD = Day of Year (001 - 366)
HH = Hours (00-23)
I = Time Sync Status (space, ?, *) See description below.
LF = Line Feed
MM = Minutes (00-59)
MMM = JAN|FEB|MAR|APR|MAY|JUN|JUL|AUG|SEP|OCT|NOV|DEC
SS = Seconds (00 - 60)
TZ = Time Zone
WWW = SUN|MON|TUE|WED|THU|FRI|SAT
XX = Time Zone Offset (in hours, values 00-23)
YY = Two digit year indication
YYYY = Four digit year indication
ZZ = Time Zone Offset (in hours relative to UTC, values 00-12)

The leading edge of the first character (CR) marks the on-time point of the data stream.

Time sync status character I is described below:

I = (space) when the master clock is synchronized to UTC source.
= * when the master clock time is set manually.
= ? when the master clock has not achieved or has lost synchronization to UTC source.

The Daylight Saving Time indicator provides notice whether Standard Time or DST is in effect and warns of upcoming transitional periods. The Daylight Saving Time indicator D is described below:

D = S during periods of Standard Time.
= I on the day of the change INTO Daylight Saving Time.
= D during periods of Daylight Saving Time.
= O on the day of the change OUT of Daylight Saving Time.

The data is output in a 24-hour time format. The time may be offset to a local time by setting the time zone switches to the appropriate value.

2.3 IRIG Specifications

Signal Type:

- A. IRIG B: B000, B120
- B. IRIG E: E001, E111

Accuracy: Within 0.3 milliseconds of the on-time pulse.

Output Connector: BNC

Output Signal: Amplitude modulated or pulse width coded, switch selectable.

- A. Amplitude Modulated Output:
 - Signal level SHALL have a mark to space ratio of 3.3 to 1.
 - Mark amplitude levels SHALL be adjustable over a range of 2.0 to 7.0 volts peak to peak into a 600-ohm load.
- B. Pulse Width Coded TTL Output:
 - Open circuit levels: High \geq 4.0 volts
 - Low \leq 0.6 volts.
 - Loading: Output TTL-compatible into loads \geq 600 ohms.

The IRIG B or E time code will be in the following format and may be configured as amplitude modulated or pulse width coded.

The IRIG B output contains the Binary Coded Decimal (BCD) and Straight Binary Seconds (SBS) time data per IRIG B specification. The IRIG E output provides BCD data per specification and additionally SBS data in the Control Function Field. A time sync status character and year information SHALL be encoded in the Control Function Field for both formats.

2.3.1 IRIG Formats

Selectable IRIG formats from the PSAP master clock will be:

- IRIG B
- IRIG B with Signature Control
- IRIG E
- IRIG E with Signature Control

The IRIG output will be selectable in either amplitude modulated or pulse width coded.

2.3.2 Signature Control

Signature control removes the time code modulation from the IRIG output whenever the master clock has lost time sync to UTC. Under signature control only the full or mark amplitude carrier will be output for amplitude modulated signals. A TTL logical high will be

output for pulse width coded signals. Once the master clock reacquires time sync to the UTC source, the full IRIG output is restored.

2.3.3 IRIG B Output

The IRIG B output contains BCD and SBS time data per IRIG specifications. The PSAP master clock MAY output local time by using the time zone offsets.

2.3.4 IRIG B General Description

1. Time frame: 1.0 seconds.
2. Code digit weighting:
 - A. Binary Coded Decimal time-of-year.
Code word - 30 binary digits.
Seconds, minutes, hours, and days.
Recycles yearly.
 - B. Straight Binary Seconds time-of-day.
Code word - 17 binary digits.
Seconds only, recycles daily.
3. Code word structure:

BCD: Word seconds digits begin at index count 1. Binary coded elements occur between position identifier elements P0 and P5 (7 for seconds, 7 for minutes, 6 for hours, and 10 for days) until the code word is complete. An index marker occurs between decimal digits in each group to provide separation for visual resolution. Least significant digit occurs first.

SBS: Word begins at index count 80. Seventeen Straight Binary Coded elements occur with a position identifier between the 9th and 10th binary coded elements. Least significant digit occurs first.
4. Pulse rates:
 - A. Element rate: 100 per second.
 - B. Position identifier rate: 10 per second.
 - C. Reference marker rate: 1 per second.
5. Element identification: The "on time" reference point for all elements will be the pulse leading edge.
 - A. Index marker (Binary 0 or uncoded element): 2-millisecond duration.
 - B. Code digit (Binary 1): 5-millisecond duration.
 - C. Position identifier: 8-millisecond duration.
 - D. Reference marker, 1 per second. The reference marker appears as two consecutive position identifiers. The second position identifier marks the on-time point for the succeeding code word.
6. Resolution:

Pulse width coded signal: 10 milliseconds.
Amplitude modulated signal: 1 millisecond.

7. Carrier frequency: 1 kHz when modulated.

Control Function Field

<i>ELEMENT #</i>	<i>C.F. DIGIT #</i>	<i>FUNCTION</i>
50	1	Space
51	2	Space
52	3	Space
53	4	Space
54	5	Space
55	6	Time Sync Status
56	7	Space
57	8	Space
58	9	Space
59	PID P6	Position Identifier
60	10	Years Units Y1
61	11	Years Units Y2
62	12	Years Units Y4
63	13	Years Units Y8
64	14	Space
65	15	Years Tens Y10
66	16	Years Tens Y20
67	17	Years Tens Y40
68	18	Years Tens Y80
69	PID P7	Position Identifier
70	19	Space
71	20	Space
72	21	Space
73	22	Space
74	23	Space
75	24	Space
76	25	Space
77	26	Space
78	27	Space

Figure 2-1 IRIG B CONTROL FUNCTION FIELD

Element 55 is the time sync status bit. Element 55 is a Binary 1 when the master clock is synchronized, and a Binary 0 when unsynchronized.

Year information consists of the last two digits of the current year (94, 95...00 = 2000). Elements 60 through 63 contain the binary equivalent of year units. Elements 65 through 68 contain the binary equivalent of tens of years. All unused control functions are filled with a space (Binary 0).

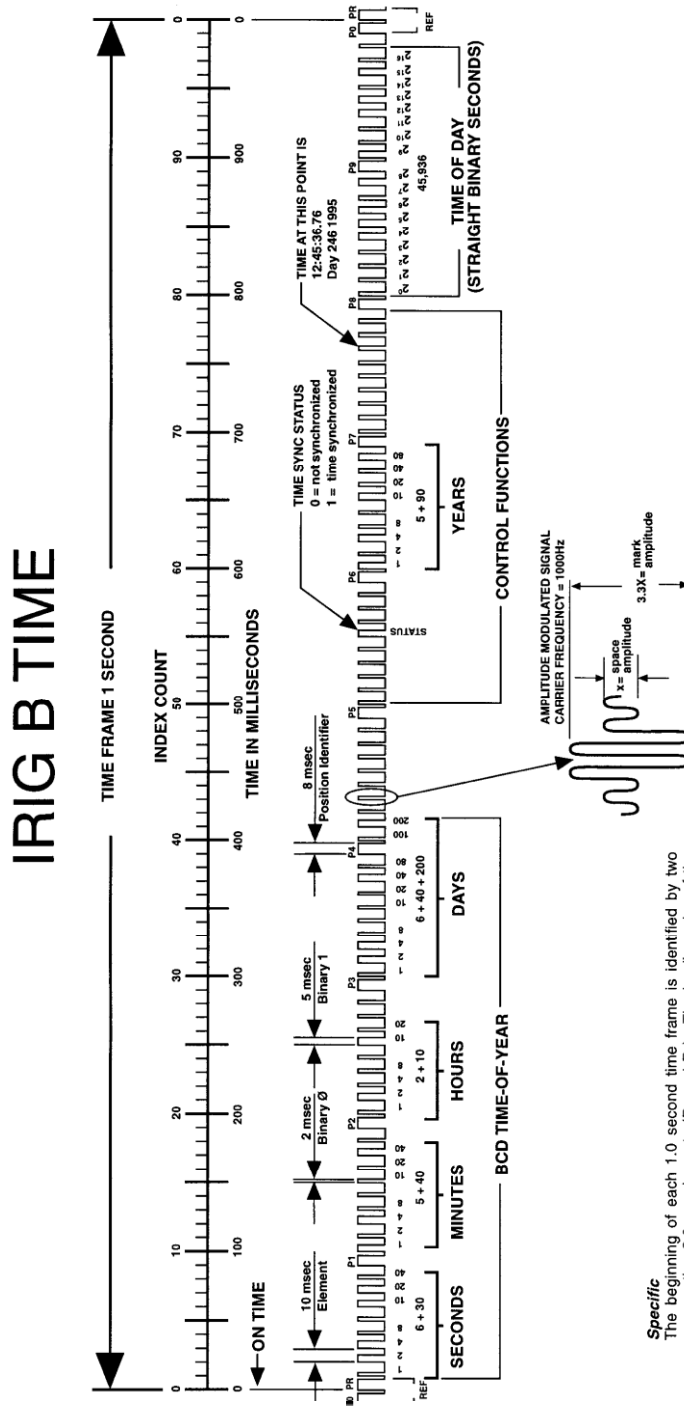


Figure 2-2 IRIG B TIME CODE

Specific

The beginning of each 1.0 second time frame is identified by two consecutive 8.0 ms elements (P₀ and P₁). The leading edge of the second 8.0 ms element (P₁) is the "on time" reference point for the succeeding time code. 10 pps position identifiers P₂, P₃, ..., P₉ (8.0 ms duration) occur 10 ms before 10 pps "on time" and refer to the leading edge of the succeeding element.

The two time code words and the control functions presented during the time frame are pulse width coded. The binary "zero" and index markers have a duration of 2.0 ms, and the binary "one" has a duration of 5.0 ms. The leading edge is the 100 pps "on time" reference point for all elements.

The binary coded decimal (BCD) time-of-year code word consists of 30 digits beginning at index count 1. The binary coded subword elements occur between position identifiers P₀ and P₁₉ (7 for seconds; 7 for minutes; 6 for hours; 10 for days) until the code word is complete. An index marker occurs between the decimal digits in each subword to provide separation for visual resolution. The least significant digit occurs first. The BCD code recycles yearly.

Twenty-seven control functions occur between position identifiers P₂ and P₁₉. Any control function element or combination of control function elements can be programmed to read a binary "one" during any specified number of time frames. Each control element is identified on the Control Function Field Table.

The straight binary (SB) time-of-day code word occurs between position identifiers P₁₀ and P₁₉. Seventeen digits give the time-of-day in seconds with the least significant digit occurring first. A position identifier occurs between the 9th and 10th binary coded elements. The straight binary code recycles every 24 hours.

2.3.5 IRIG E Output

The IRIG E Output contains BCD time data per IRIG specifications. The PSAP master clock MAY output local time by using the time zone offsets.

2.3.6 IRIG E General Description

1. Time frame: 10 seconds.
2. Code Digit Weighting:
Binary Coded Decimal time of year.
Code word - 26 binary digits.
Tens of seconds, minutes, hours, and days.
Recycles yearly.
3. Code Word Structure: BCD word tens of seconds digits begin at index count 6.

Binary coded elements occur between position identifier elements P0 and P5 (3 for seconds, 7 for minutes, 6 for hours, and 10 for days) until the code word is complete. An index marker occurs between decimal digits in each group to provide separation for visual resolution. Least significant digit occurs first.

4. Pulse rates:
 - A. Element rate: 10 per second.
 - B. Position identifier rate: 1 per second.
 - C. Reference marker rate: 1 per 10 seconds.
5. Element identification: The "on-time" reference point for all elements is the pulse leading edge.
 - A. Index marker (Binary 0 or uncoded element): 20 milliseconds duration.
 - B. Code digit (Binary 1): 50-millisecond duration.
 - C. Position identifier: 80-millisecond duration.
 - D. Reference marker: 80-millisecond duration, 1 per 10 seconds. The reference marker appears as two consecutive position identifiers. The second position identifier or reference marker is the on time point for the succeeding code word.
6. Resolution:
Pulse width coded signal: 0.1 second.
Amplitude modulated signal: 0.01 second.
7. Carrier frequency: 100 Hz when modulated.

2.3.7 Control Function Field

IRIG formats reserve a set of elements known as Control Functions (CF) for the encoding of various control, identification, or other special purpose functions. IRIG E has 45 Control Functions located between elements 50 and 98. The master clock uses the control function field to encode year data, time sync status, and SBS time data. Table 4-4 lists the Control Function Field and each element's function.

Element 55 is the time sync status bit. Element 55 is a Binary 1 when the master clock is synchronized, and a Binary 0 when unsynchronized.

Year information consists of the last two digits of the current year (94, 95...00 = 2000). Elements 60 through 63 contain the binary equivalent of year units. Elements 65 through 68 contain the binary equivalent of tens of years.

Elements 80 through 97 are encoded with the Straight Binary Seconds (SBS) time data. The SBS time data is incremented in 10-second steps and recycles every 24 hours.

BIT #	CF ELEMENT #	FUNCTION
50	1	SPACE
51	2	SPACE
52	3	SPACE
53	4	SPACE
54	5	SPACE
55	6	TIME SYNC STATUS
56	7	SPACE
57	8	SPACE
58	9	SPACE
59	PID P6	POSITION IDENTIFIER
60	10	YEAR UNITS Y1
61	11	YEAR UNITS Y2
62	12	YEAR UNITS Y4
63	13	YEAR UNITS Y8
64	14	SPACE
65	15	YEAR TENS Y10
66	16	YEAR TENS Y20
67	17	YEAR TENS Y40
68	18	YEAR TENS Y80
69	PID P7	POSITION IDENTIFIER
70	19	SPACE
71	20	SPACE
72	21	SPACE
73	22	SPACE
74	23	SPACE
75	24	SPACE
76	25	SPACE
77	26	SPACE
78	27	SPACE
79	PID P8	POSITION IDENTIFIER
80	28	SBS 2 ⁰
81	29	SBS 2 ¹
82	30	SBS 2 ²
83	31	SBS 2 ³
84	32	SBS 2 ⁴
85	33	SBS 2 ⁵
86	34	SBS 2 ⁶
87	35	SBS 2 ⁷
88	36	SBS 2 ⁸
89	PID P9	POSITION IDENTIFIER
90	37	SBS 2 ⁹
91	38	SBS 2 ¹⁰
92	39	SBS 2 ¹¹



BIT #	CF ELEMENT #	FUNCTION
93	40	SBS 2 ¹²
94	41	SBS 2 ¹³
95	42	SBS 2 ¹⁴
96	43	SBS 2 ¹⁵
97	44	SBS 2 ¹⁶
98	45	SPACE
99	PID P0	POSITION IDENTIFIER

Figure 2-3 IRIG E CONTROL FUNCTION FIELD

IRIG E TIME

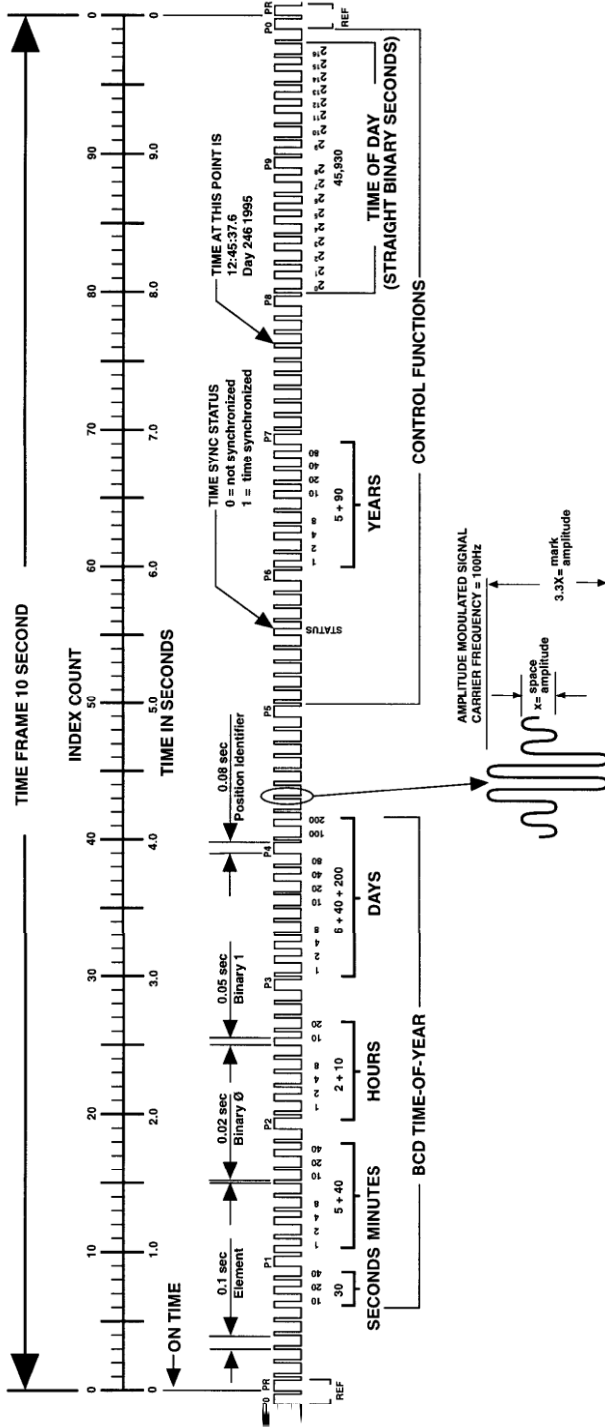


Figure 4-4 IRIG E TIME CODE

The binary coded decimal (BCD) time-of-year code word consists of 26 digits beginning at index count 6. The binary coded subword elements occur between position identifiers P₅ and P₉ (3 for seconds; 7 for minutes; 6 for hours; 10 for days) until the code word is complete. An index marker occurs between the decimal digits in each subword to provide separation for visual resolution. The least significant digit occurs first. The BCD code recycles yearly.

Forty-five control functions occur between position identifiers P₀ and P₉. Any control function element or combination of control function elements can be programmed to read a binary "one" during any specified number of time frames. Each control element is identified on the Control Function Field Table.

Specific
 The beginning of each 10 second time frame is identified by two consecutive 80 ms elements (P₀ and P₁). The leading edge of the second 80 ms element (P₁) is the "on time" reference point for the succeeding time code. 1 pps position identifiers P₀, P₁, ..., P₉ (80 ms duration) occur 0.1 second before 1 pps "on time" and refer to the leading edge of the succeeding element.

The time code word and the control functions presented during the time frame are pulse width coded. The binary "zero" and index markers have a duration of 20 ms, and the binary "one" has a duration of 50 ms. The leading edge is the 10 pps "on time" reference point for all elements.

0

2.4 Ethernet Network Time Protocol

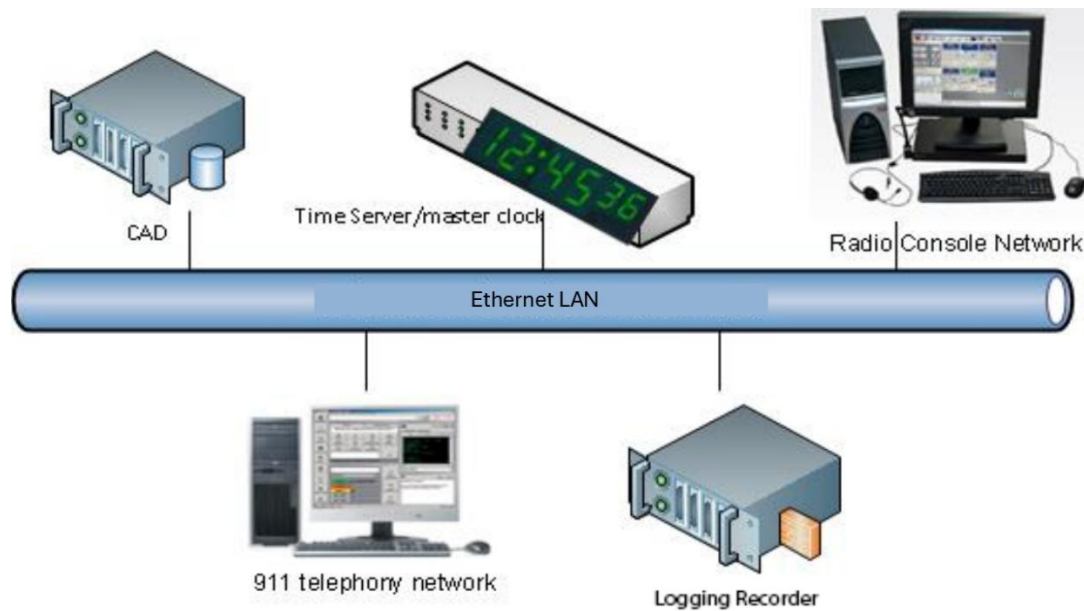
The Ethernet network interface will support NTP (Network Time Protocol) and SNTP (Simple Network Time Protocol). For a complete description of the NTP and SNTP protocols, refer to the Internet Engineering Task Force (IETF) [RFC 5905](#).

Because it is difficult to specify timing accuracy over Wi-Fi networks, it is preferable for PSAP to rely on Ethernet where possible. Timing accuracy over Wi-Fi SHOULD be considered as a best effort approach since accuracy may not necessarily meet the standards for wired Ethernet.

For situations where the master clock is located on another network, the NTP or SNTP protocols require UDP port 123 (or other configured ports) to be open on the firewall(s) between the networks.

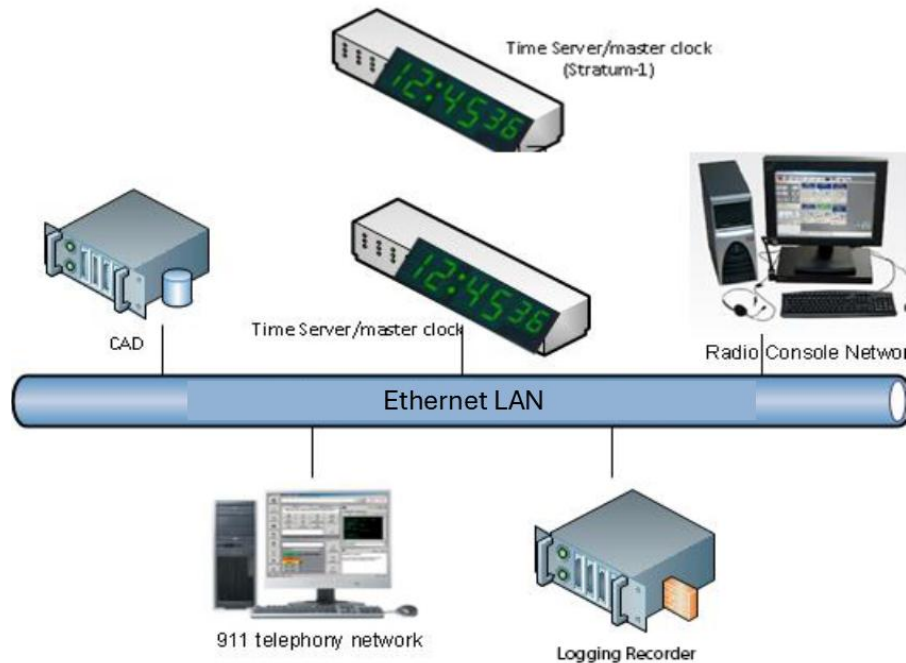
Sample Ethernet Interfaces:

Scenario 1: Integrated Ethernet connection within the Master Clock device



Scenario 2: External Ethernet connection to the Master Clock device

Time Server Master Clock – Scenario 2



3 Impacts, Considerations, Abbreviations, Terms, and Definitions

3.1 Operations Impacts Summary

Implementation and management of a standard time source in a PSAP is significantly improved when products are selected that conform to this standard.

3.2 Technical Impacts Summary

Implementations based on specifications in the section of this document titled "Ethernet Network Time Protocol" should result in more reliable and secure time synchronization mechanisms as a result of improvements in the Network Time Protocol (NTP) and Simple Network Time Protocol (SNTP) standards. The IRIG and ASCII time code protocol standards described herein have not changed since the previous revision of this document. Therefore, no technical impacts related to those are expected.

3.3 Security Impacts Summary

Implementations that follow the specifications in the "Ethernet Network Time Protocol" section of this document should be significantly more secure than those based on the previous revision of this document, due to security improvements in the current NTP and

SNTP specifications. The IRIG and ASCII time code protocol standards described herein have not changed since the previous revision of this document. Therefore, no security impacts related to those are expected.

3.4 Recommendation for Additional Development Work

No additional development work is anticipated.

3.5 Cost Factors

The cost factors associated with the adoption of this Standard are not determined.

3.6 Cost Recovery Considerations

Normal business practices are assumed to be the cost recovery mechanism.

3.7 Additional Impacts (non-cost related)

The information or requirements contained in this NENA document are not expected to have additional impacts, based on the analysis of the authoring group.

3.8 Abbreviations, Terms, and Definitions

See the [NENAKb Glossary](#) of terms and abbreviations used in NENA documents. Abbreviations and terms used in this document are listed below with their definitions.

Term or Abbreviation (Expansion)	Definition / Description
<i>ASCII (American Standard Code for Information Interchange)</i>	A standard for defining codes for information exchange between equipment produced by different Manufacturers. A code that follows the American Standard Code for Information Interchange.
<i>BCD (Binary Coded Decimal)</i>	A coding system in which each decimal digit from 0 to 9 is represented by four binary (0 or 1) digits.
<i>IRIG (Inter-Range Instrumentation Group)</i>	This group, in 1959, proposed a series of time code formats now known as IRIG or NASA time codes. The best known IRIG standard is the IRIG timecode used to timestamp video, film, telemetry, radar, and other data collected at test ranges. https://irig.org/

<i>NIST (National Institute of Standards and Technology)</i>	A part of the United States Department of Commerce that oversees the operation of the U.S. National Bureau of Standards. NIST works with industry and government to advance measurement science and to develop standards in support of industry, commerce, scientific institutions, and all branches of government. Their mission is to promote innovation and industrial competitiveness. www.nist.gov
<i>NTP (Network Time Protocol)</i>	A networking protocol for clock synchronization between computer systems over packet-switched, variable-latency data networks.
<i>SBS (Straight Binary Seconds)</i>	A binary number that appears in the IRIG time code which represents the total number of seconds since Midnight.
<i>SNTP (Simple Network Time Protocol)</i>	A utility for synchronizing system clocks over a TCP/IP network. This protocol is similar to NTP and is used when the ultimate performance of the full NTP implementation is not needed.
<i>TTL (Transistor to Transistor Logic)</i>	An internal transfer standard for electronics devices in which a 1 state is +5 volts and a zero state is 0 volts.
<i>UPS (Uninterruptible Power Supply)</i>	A device that provides battery backup when the electrical power fails or drops to an unacceptable voltage level. Small UPS systems provide power for a few minutes; enough to power down the computer in an orderly manner, while larger systems have enough battery for several hours.
<i>UTC (Coordinated Universal Time)</i>	The primary time standard in the world based on the time zone in Greenwich, England. Also known as Zulu or Greenwich Mean Time (GMT). Time provided by National Institute of Standards and Technology (NIST) and United States Naval Observatory (USNO).

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