DXD8/PTP
PTP Firmware option for the DXD-8 Universal Clock

Operations manual
Version 2.15
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Table of Content

1. Introduction

This manual covers the new functionalities provided by the PTP firmware and is a companion to the main DXD-8 manual. For general instructions n the DXD-8 operations, please refer to DXD-8 manual.

The DXD-8 Universal Clock is designed to be the central source of time in a modern A/V installation. As a master clock generator it provides WC, AES and Video Sync. But with the addition of PTP, the DXD-8 truly becomes universal by keeping traditional audio/video equipment and IP networks in perfect sync.

The DXD-8 has the capability of being a PTP Grandmaster or a PTP slave. As a PTP master, the DXD-8 can lock to external sync sources such as WC, AES, Video Sync and 10 MHz, or to its internal crystal, while generating PTP sync. As a PTP slave, it can lock to a Grandmaster while generating traditional sync signals (word clock, AES, video sync or 10MHz).

DXD-8 DIAGRAM
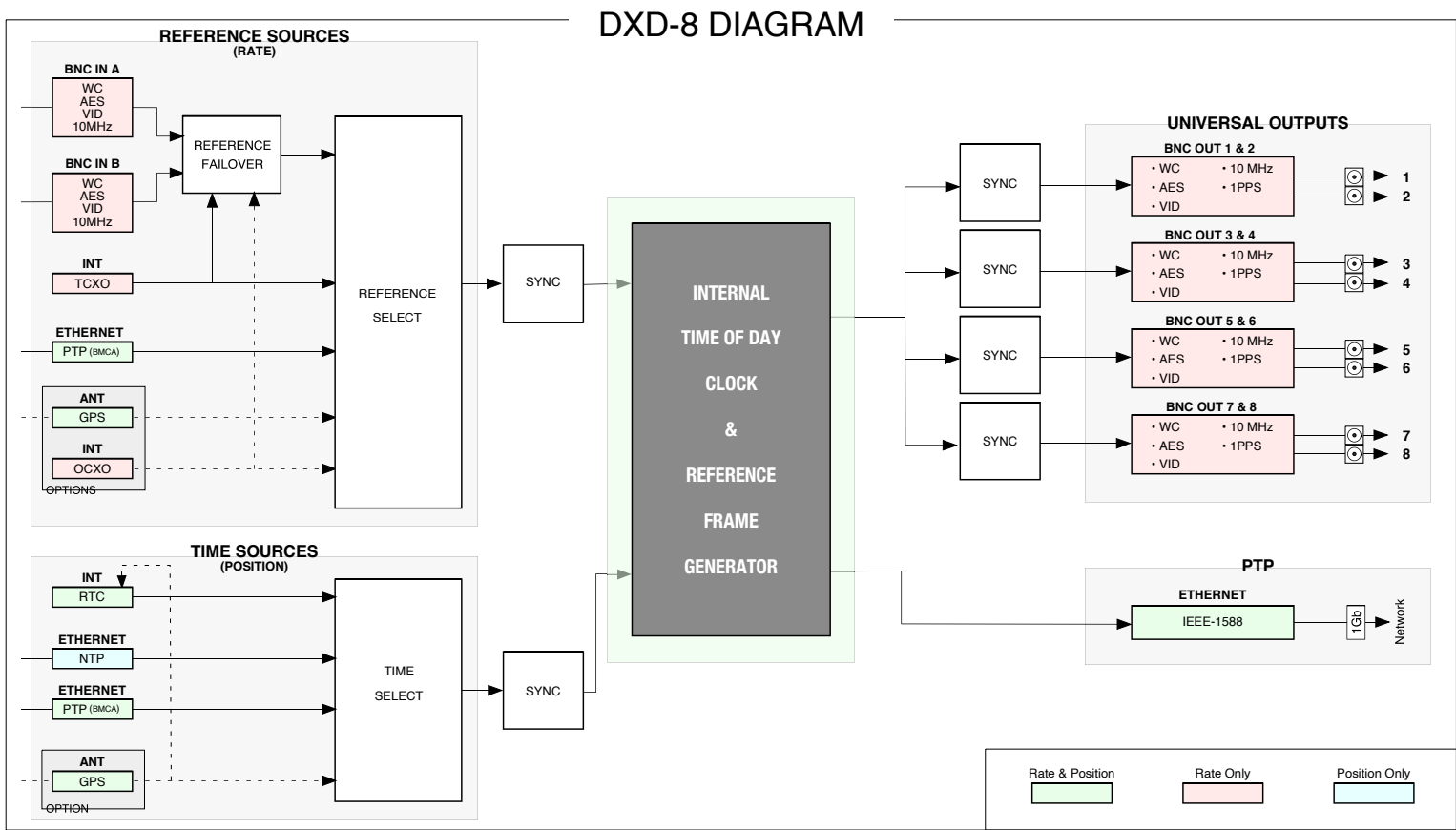
2. Installation

Before installing the DXD8/PTP, be sure to update your DXD-8 with the latest firmware, available on the Brainstorm website.

When you purchased your DXD/PTP, you received a unique authorization key, a series of 4 numbers, separated by periods. This key is only valid for the DXD-8 with the serial number used when you placed the order.

Enter this key in Menu 10.5, FEATURE KEYS in the PTP section and press the ENTER key. You will be prompted to confirm your entry. A message will confirm that the feature key has been set.

This installation procedure only needs to happen once, even with subsequent firmware updates.

3. Reference & Sync Menus

Installing the PTP option will affect some of the menus and offer new choices. Please refer to the DXD-8 manual for instructions on how to navigate through the menus and how to change some of the settings..

3.1 REFERENCE MENU (MENU 1.1)

A new choice is available in the reference menu after installing the PTP option: PTP Mode.

1.1 REFERENCE

SOURCE:	PTP Mode
LOCAL REF WHEN GM:	GPS

The IEEE 1588 Best Master Clock Algorithm determines whether an external device or the DXD-8 itself will be the PTP Grandmaster

- **PTP Mode** is a little different than other references. Selecting PTP Mode is required for the DXD-8 to become a PTP slave, i.e. be 'referenced' to a PTP Grandmaster. However, selecting PTP Mode also means that the DXD-8 will participate in the selection process of the PTP Grandmaster and, depending on the outcome of the BMCA, the DXD-8 will either be a PTP Slave or the Grandmaster (see 9.5 for more on the BMCA). Explanatory text has been added to the REFERENCE menu when PTP Mode is activated.
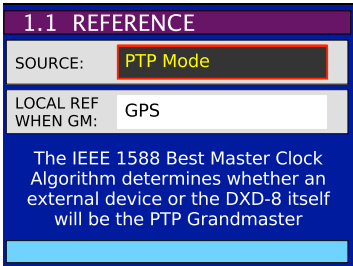
  NOTE: When PTP Mode is selected, the PTP port needs to be turned on (menu 5.1). If not, the DXD-8 will lock to its internal crystal and a 'PTP NO PORT' warning message will appear in the middle of the display. The LOCK bar at the bottom of the Main Rotation display will also indicate NO PORT (for more information, see chapter 14.1 Troubleshooting).

- **LOCAL REF WHEN GM:**

  When PTP Mode is selected , if GPS is available, this fields enables GPS to be set as the reference when the DXD-8 is the Grandmaster. Enabling this field will announce the DXD-8 as GPS referenced, giving it a higher priority at being selected by the BMCA.

  This field only appears if the optional DXD/GPS receiver has been installed.

3.2 SYNC PARAMETERS (MENU 1.2)

New parameters are available in this menu with the PTP options.

1.2 SYNC PARAMETERS

BNC INPUT COLOR FRAMING	On (NTSC/PAL only)
BNC INPUT TIME JAM SOURCE:	PTP
BNC INPUT TIME JAM RESYNC:	Press ENTER to Jam
PTP JUMP THRESHOLD:	5 msec

- **BNC INPUT TIME JAM SOURCE:** Selects the source of a Time Jam (see 5.2).

- **BNC INPUT TIME JAM RESYNC:** Used for a manual Time Jam (see 5.2)

- **PTP JUMP THRESHOLD:** When the difference between the internal TOD and the PTP reference is above the value entered, the DXD will not attempt a smooth transition (slew) but will instead jump instantly to the new time.

  Value can be adjusted from 5 msec to 15 sec, or set to 'Never'. Default value is 5 msec.
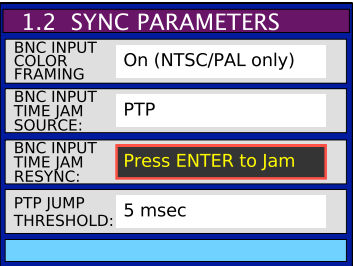
4. PTP Menus

4.1 PORT MODE (MENU 5.1)

This menu allows you to have PTP enabled or disabled. Choices are 'on' and 'off'.

With the port enabled, the DXD-8 automatically becomes a candidate for PTP Grandmaster. Keep in mind however that it's ability to be a PTP slave depends on the reference selection in menu 1.1:

- MASTER/SLAVE: if 'PTP Mode' is selected, the DXD-8 can become a PTP slave.
- MASTER-ONLY: if another reference is selected, the DXD-8 can only be a PTP master, not a PTP slave.

NOTE: When the port is enabled and a reference other than 'PTP Mode' is selected menu 1.1, if the BMCA selects another unit as PTP Grandmaster, the port will automatically go in the PASSIVE state.

4.2 PTP - CLOCK / GRANDMASTER (MENU 5.2)

Menu 5.2 lets you set the following fields for the PTP port.

- **Domain**: 0 to 127; default = 0

- **Priority 1**: 0 to 255

- **Priority 2**: 0 to 255

    Priorities are used in the BMCA to select the grandmaster - lower values have a higher priority (see 9.5 for more information on the Grandmaster selection).

5.2 CLOCK / GRANDMASTER
DOMAIN: 0
PRIORITY 1: 128
PRIORITY 2: 128
Priority: 0=Highest, 255=Lowest

4.3 PORT CONTROLS (MENU 5.3)

- **PTP Version**: Several versions of PTP are available on the DXD-8:
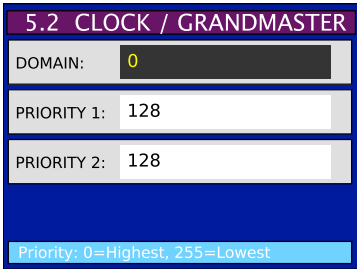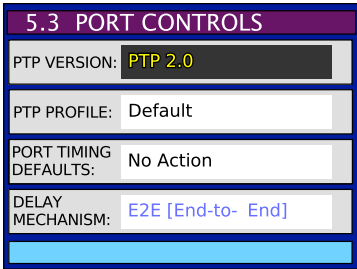
    - PTP 2.0 - Default
    - PTP 2.1
    - PTP (Layer 2) 2.0
    - PTP (Layer 2) 2.1
    - AVB 2011 (option)
    - AVB 2020 (option)
    - PTP v1

5.3 PORT CONTROLS
PTP VERSION: PTP 2.0
PTP PROFILE: Default
PORT TIMING DEFAULTS: No Action
DELAY MECHANISM: E2E [End-to- End]

- **Profile**: Different profiles are supported by the DXD-8:

    - PTP - Default PTP profile
    - AES 67
    - ST2059

- **Profile Port Timing Action:**

    Among other things, IEEE1588 profiles define the range and default values of all configurable attributes. This is very useful as selecting a specific profile on several networks would set all the parameters to the default values and allow for a quick set up.

    Selecting 'Load profile defaults' will cause all the timing values to reset to the profile default values.

    Note that, when changing the PTP version or the profile, a message appears, offering the same option.

VERSION/PROFILE CHANGE

Do you want to RESET Timing values to their Default values?

Press UP to Reset now
Press Any Other Key to Exit
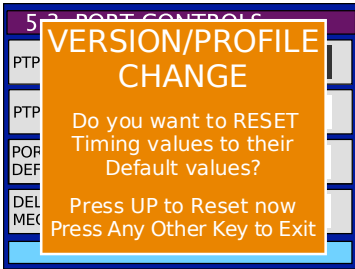
- **Delay Mechanism**: Two different delay mechanism are defined in IEEE 1588:

    - E2E: End to End
    - P2P: Peer to Peer

    Selecting a delay mechanism is done from this menu.

Note that the availability of some of the choices described above for Profile & Delay Mechanism depends on the PTP version currently selected, as sown in the table below. For example, PTP v1 did not offer profiles and only supported End-to-End delay mechanism.

DXD-8 - Menu 5.3 PORT CONTROLS - Choices

PTP Version	PTP Profile			Delay Mechanism	
	Default	SMPTE ST2059	AES67	E2E	P2P
PTP 2.0	√	√	√	√	
PTP 2.1	√	√	√	√	
PTP (Layer 2) 2.0	√	√	√	√	√
PTP (Layer 2) 2.1	√	√	√	√	√
AVB 2011	√	√			√
AVB 2020	√	√			√
PTP Version1	√			√	

4.4 PORT TIMING (MENU 5.4)

5.4 PORT TIMING	
ANNOUNCE INTERVAL:	2 sec [log 1]
ANNOUNCE RECEIPT TIMEOUT:	3 announce intervals
SYNC INTERVAL:	1 sec [log 0]
MIN DELAY REQ INTERVAL:	1 sync interval

- **Announce Interval**: -3 to 4 (1/8sec - 16sec)

  Sets the rate at which the master will send Announce messages. These messages are used to determine which device will be the Grandmaster using the BMCA (Best Master Clock Algorithm)

  Per IEEE 1588 this value should be uniform throughout a domain.

- **Announce Receipt Timeout**: 2 to 10 announce intervals

  Sets the number of Announce messages that can be missed before it is assumed the master is no longer present and the process of selecting a new one begins.

  Per IEEE 1588 this value should be uniform throughout a domain.

- **Sync Interval**: -7 to 1 (1/128sec - 2sec)

  Sets the rate at which the master will send Sync messages.

- **Min Delay Req Interval:** 1 to 32 the number of Sync Interval

  Sets the minimum time interval between 2 adjacent Delay Requests.

  This field shows a quantity of sync intervals: "n sync intervals", where n = 1,2,4,8,16,32 (when n=1 it will say "1 sync interval").

5. Time of Day

Time of Day is an essential part of the DXD-8 design. In a PTP network, the devices all need to know the Time of Day, i.e. year, month, day, hour and seconds, even nanoseconds, to achieve frequency and phase synchronization. At the heart of the DXD-8 is the Main Time of Day Clock (TOD) & Reference Frame Generator. This is where System Time is generated and where the references generated by the DXD-8 are aligned with the PTP epoch.

DXD-8 DIAGRAM
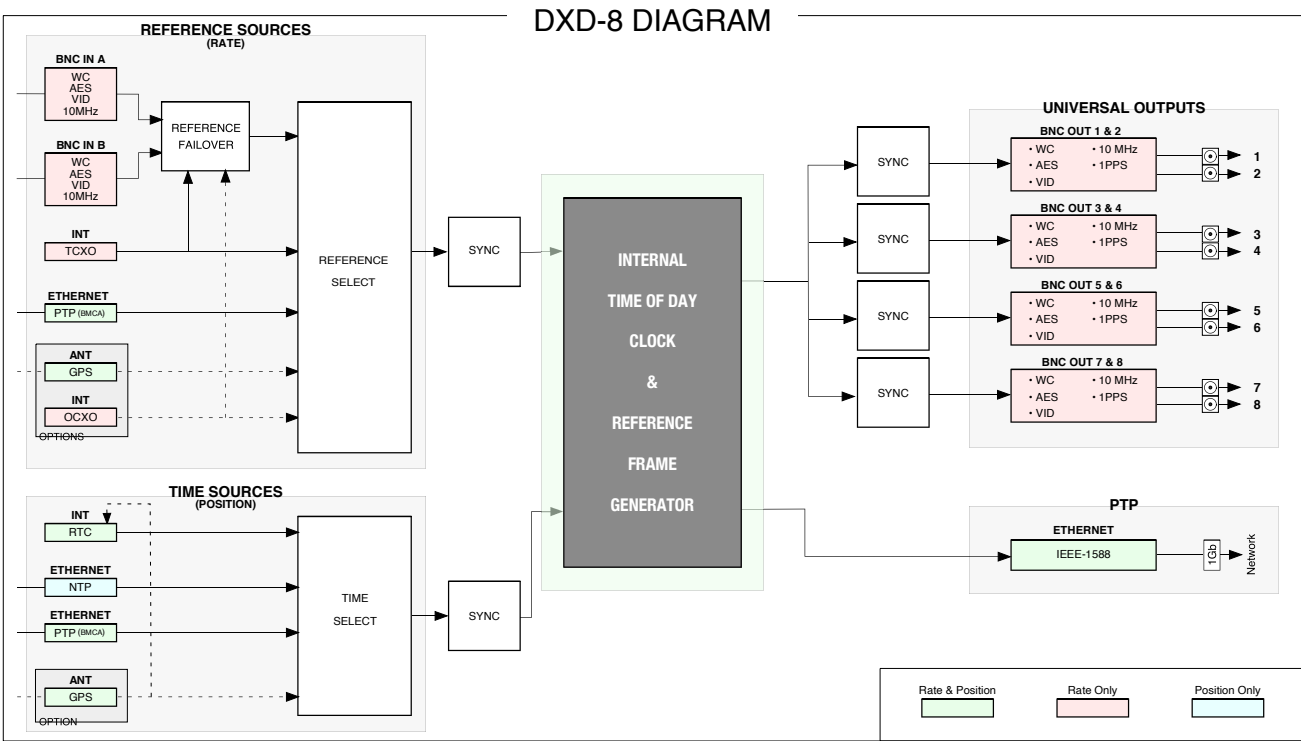
As shown on the diagram above, some of the reference sources include time and rate information. GPS and PTP for example carry precise time and date information as well as frequency. However, traditional reference signals, such as video sync or word clock, only carry the frequency information. When selecting one of those as reference (BNC inputs), the time information needs to be added from another source. The DXD-8 offers several options.

> **IMPORTANT NOTE**
>
> When using a reference without date & time information such as video sync, there will be a date & time adjustment in the TOD count so that video frame edges are correctly aligned. **The internal TOD is always creating internal frame references that are aligned as required with Jan 1, 1970 (PTP epoch).** To lock to an external frame edge the DXD has to move the TOD count by up to +/- half a frame to synchronize the internal TOD frame edge to the incoming edge.

5.1 RTC (Real Time Clock)

A backup clock, called the RTC (Real Time Clock) is included in the DXD-8. It is set at the factory (date & time) and runs continuously, even when the unit is turned off as it is powered by an internal battery.

The DXD uses the date & time information from the RTC just after power up and transfers it to the main TOD (System Time). When locking to a new reference, if that reference does not have date & time, the TOD simply continues counting along its current time sequence; if it has date & time, that information is transferred to the TOD.

Although the RTC is set at the factory, it can also be set manually by the operator or be updated automatically (if GPS is available) via the Real Time Clock menu (menu 7.2).

5.2 Time Jam

Time information can also be received from an external source via the Time Jam mode. This mode is available only when the reference set in menu 1.1 is one of the BNC inputs as the references available at the BNC inputs do not carry time information, only rate (Word Clock, AES, Video Sync or 10 MHz). Current choices for Time Jam source are PTP and GPS. The DXD-8's System Time will be reset to the time of the Time Jam source before locking to the reference connected to the BNC input selected in menu 1.1.

5.2.1 TIME JAM TO PTP

When PTP is selected as the source of TIME JAM (menu 1.2), the DXD-8 will first lock its internal Time of Day clock to PTP. When that is achieved, the DXD-8 will release the PTP Lock and revert to the BNC source selected in the reference menu.

5.4 PORT TIMING	
ANNOUNCE INTERVAL:	2 sec [log 1]
ANNOUNCE RECEIPT TIMEOUT:	3 announce intervals
SYNC INTERVAL:	1 sec [log 0]
MIN DELAY REQ INTERVAL:	1 sync interval

Reasons to PTP time jam DXD-8's include:

- Locking to a common video reference (e.g. NTSC) and wanting all of the cross-frame outputs (25 etc.) to be in correct phase (and epoch), as well as wordclock and AES.
- In a primarily legacy application this is the way to increase the number of legacy outputs and have them all in phase.
- With a timecode license wanting TOD timecode outputs to be in sync, and with correct cross-framing where applicable.

5.2.2 WHAT IS THE SEQUENCE OF A COMPLETE TIME JAM TO PTP?

1. LOCK TO PTP: The DXD-8 Lock status indicates HOLD / PTP SYNC on dark pink background.
2. CONFIRMATION: A message confirms that the date and time information has been transferred to the internal Time of Day successfully (clearing of this message is required).
3. LOCK TO THE BNC INPUT: The DXD-8 indicates it is locked to the BNC reference, Input a / Video in this example.
4. SYSTEM TIME UPDATED: The System Time now indicates the same time as the PTP source

1. Reference must be BNC A or BNC B (menu 1.1). The BNC input must be set properly in menus 2.1 and/or 3.1.
2. The PTP port must be set as the BNC INPUT TIME JAM SOURCE (menu 1.2). The port will now show as set for Time Jam [BNC Inputs] in menu 5.1 (blue letters indicate status and cannot be altered)
3. The PTP domain of the Time Jam Port must be set to the same domain as the PTP source in the proper menu (Menu 5.5)

When Time Jam is set as described, the words [Time Jam] will appear at the bottom of the display in the Reference line.

6. Time Menus

6.1 TIME STANDARDS (MENU 7.1)

The following time standards are available on the DXD-8 in addition to the local time:

- **TAI**: International Atomic Time, (used as a base by other standards such as UTC - no leap seconds).

- **UTC**: Coordinated Universal Time (time zone '0' - w/ leap seconds).

- **GPS**: Global Positioning System time (no leap seconds - 19 sec behind TAI and currently 18 sec ahead of UTC).

- **Loran**: Long Range Navigation time (no leap seconds).

- **Local**: Local time is based on UTC and can have adjustments for time zone and Daylight Saving (menu 7.1).

With the PTP option, 'PTP GM' is added to menu 7.1, for which a time standard can be selected for the display.
- **PTP Grandmaster**, time received on the Ethernet port from the external PTP Grandmaster.

6.2 TIME & DATE DISPLAY (MENU 7.3)

With the PTP option, 'Ext PTP Grandmaster' is added to the list available in menu 7.3, where 2 different DXD times & dates can be selected for the Time & Date display (see 6.1.2 in the DXD-8 manual).

7. Time Code Menus

Time Code is a separate option available for the DXD-8. It is described in a separate manual (DXD/LTC). However, with the PTP option, menu 8.1 SMPTE 2059 SET UP becomes available.

7.1 SMPTE 2059 SETUP (MENU 8.1)

The Daily Jam is a process where the time code generator realigns precisely with the epoch (midnight on Jan 1, 1970 TAI). This process occurs everyday, at the same time, as set in the DAILY JAM TIME field.

8.1 SMPTE 2059 SETUP	
DAILY JAM TIME	01 Hrs 00 Min
JAM TIMES RE-CALCULATE	Off

- **Daily Jam Time:** The value entered in the DAILY JAM TIME field is the amount of time after midnight, local time, at which the daily jam will occur.

  Adjustments can be made in 10 minutes increments. Default value is 01 Hrs 00 Min, i.e. 1:00AM, local time.

- **Jam Time Recalculate**: Pressing the ENTER key while "Press Enter to Jam" is selected will cause the DXD to recalculate both Jam Times, the time of the Previous Daily Jam Event and the time of the Next Daily Jam Event.

  For time code, the Previous Daily Jam Event is the generator's anchor point, until the Next Daily Jam Event. When the local time is too close to the set Daily Jam Time, a manual change will not occur until the next day. By forcing the DXD to recalculate both jam times manually, the operator has the option to make an immediate change.

<u>7.2 LTC GENERATOR 1 & 2 (MENUs 8.2 & 8.3)</u>

Menus 8.2 and 8.3 require the DXD/LTC. Otherwise, when trying to access these menus, a message will appear indicating that the Feature Key has not been found.

> **LTC FEATURE KEY NOT FOUND**
> **To purchase please contact your Brainstorm dealer.**
> **Feature Keys are unique for each serial number.**

Please refer to the DXD/LTC manual for information. To purchase the DXD/LTC, please contact you Brainstorm Electronics dealer.
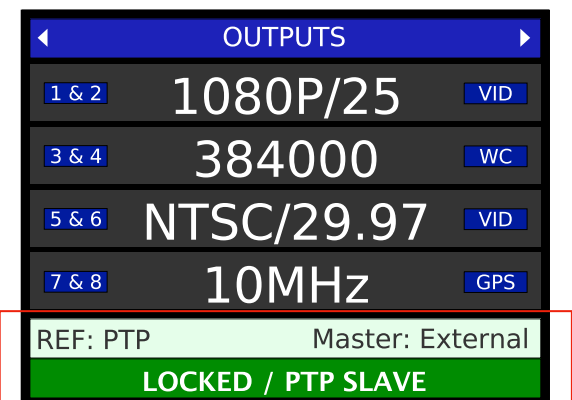
8. Display

8.1 Main Rotation

<u>8.1.1 MAIN ROTATION FOOTER</u>

• **Reference**: When PTP Mode is selected in the reference menu, the display in the Main Rotation pages indicates REF: PTP on the left of the reference line with 4 different options to its right:

- "Master: External"
- "Master: Internal"
- "Master: Internal / OCXO"
- "Master: GPS Receiver"

As explained in 3.1 above, selecting PTP Mode in the reference menu means that the DXD-8 will participate in the PTP Grandmaster selection (see 9.5, Selecting a Grandmaster).

If another unit is selected by the BMCA, "Master: External" will be displayed in the reference line. But, if the DXD-8 is selected, one of the other 3 options above will be displayed: Internal, Internal /OCXO or GPS Receiver.

◀	OUTPUTS	▶
1 & 2	1080P/25	VID
3 & 4	384000	WC
5 & 6	NTSC/29.97	VID
7 & 8	10MHz	GPS
REF: PTP		Master: External
LOCKED / PTP SLAVE		

• **Lock Status**: The bottom line of the display has the usual LOCK status, but in the case where the DXD-8 is the grandmaster, when locked it changes to "LOCKED / GRANDMASTER".

REF: PTP	Master: GPS Receiver
LOCKED / GRANDMASTER	

In case the DXD is or becomes a PTP Salve, when locked it changes to "LOCKED / PTP SLAVE".

REF: PTP	Master: External
LOCKED / PTP SLAVE	

Note that, if another source was selected in the reference menu, such as Video Sync, and the DXD-8 was simultaneously a PTP Grandmaster, the same LOCK status would appear, but the REF line would indicate "REF: Input A/ Vid" (see example at 12.1).

REF: Input A / Vid	
LOCKED / GRANDMASTER	

<u>8.1.2 MAIN ROTATION PAGES</u>

The Main Rotation Pages are the pages appearing on the main display under normal operations, that is when neither the Status nor the Set Up modes are activated. 'Rotating' through those pages is done with the RIGHT and LEFT keys. With the installation of the PTP option, some pages have been modified, others have been added.

● REFERENCE SOURCES - PTP Mode

When PTP Mode is selected in the reference menu, the Reference Sources page indicates the settings and the state of the PTP port in colors for easy identification as well as the PTP domain to its right. For details on the PTP states, see Chapter 10, PTP Ports States.

The small blue box to the right of the PTP state indicates the PTP domain and the PTP version. For example '0:v1' means Domain 0 and PTP v1.

If GPS is available and has been selected in the reference menu as 'LOCAL REF WHEN GM', it will appear on the second section in place of the ALT REF along with its lock status.

When a source other than 'PTP Mode' is selected as the reference, the Reference Sources page will no longer give any information related to the PTP port. The Lock Line at the bottom of the display will indicate if the port is Grandmaster or not. To view all the information on the PTP port (PTP domain, PTP version, port state...), press the STATUS button and look at the PTP PORT STATUS page (see 8.2.3 below).
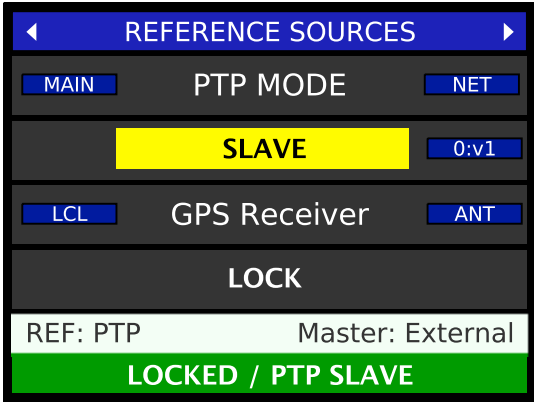
8.2 Status Pages

Status pages are available on the main display while in the STATUS mode. To activate the STATUS mode, press the [STATUS] key. The Status LED illuminates to confirm your selection. This firmware update includes the following new Status pages.

8.2.1 TIMES STATUS PAGE

With the PTP option, 4 additional lines have been added to the TIMES status page:

- Grandmaster: time from the external PTP Grandmaster
- TOD-GM Ofst: indicates the offset between the internal Time Of Day clock and the Grandmaster in μsec.
- Prev Daily: date and time of the previous daily jam
- Next Daily: date and time of the next daily jam

8.2.2 GRANDMASTER ID PAGE

● Primary Clocks:

Three separate Primary Clock ID's are displayed:

- Distant: When the DXD is locked to a Boundary clock, the distant clock is a master clock 'upstream' from the boundary clock.
- Parent: The clock id of the device the DXD is locked to.
- DXD-8: This clock id of this unit, with [GM] when it is the Grandmaster.

● Grandmaster Credentials:

These are the parameters used by the BMCA to determine the Grandmaster clock:

- Priority 1,
- Clock Class,
- Clock Accuracy,
- OfstScalLogVar,
- Priority 2

● Path Trace:

When Path Trace is available (AVB & PTP 2.1), all the different boundary clocks that the Announce message traversed are displayed, up to the grandmaster

Note: Display has been enlarged to show all scrolling options

- 8.2.3 PTP PORT STATUS PAGE

- The upper section of the PTP Port Status page includes:

  - the mode of the port
  - the PTP State
  - the domain number,
  - the delay mechanism,
  - the PTP version and
  - the PTP profile selected for the port.

◀	PTP PORT STATUS	▶
Port Mode:	On	
Port State:	MASTER (Grandmaster)	
Domain:	0	
Delay Mechanism:	P2P [Peer-to-Peer]	
PTP Version:	AVB 2011	
Profile:	Default	
Message Counters:	(Press ENTER to Clear)	
	Receive	Transmit
Announce	2432317	7720
Sync	18959319	61821
DelayReq	0	0
DealyResp	0	0
PdelayReq	2439227	2465565
PdelayResp	2465689	2439979
Mean Path Delay:	0 usec	

Note: Display has been enlarged to show all scrolling options

- Below that, Message counters display the number of messages received and transmitted by the port including:

  - Announce,
  - Sync,
  - Delay Request,
  - Delay Response,
  - Peer Delay Request,
  - Peer Delay Response.

Those are running counters and can be cleared by pressing the ENTER key.

Monitoring the messages exchanged is useful when troubleshooting. Announce and Sync messages for example are sent by Master devices. Delay request & delay response will show PTP activity between Master and slaves and, based on the chosen Delay Mechanism, the messages will be Delay or Pdelay type.

- Mean Path Delay is the mean travel time of PTP packets between master and slave. The Mean Path Delay is displayed in µsec.

9. General Information on PTP

9.1. TIME AND PHASE

Precise time information has always been crucial in traditional production and broadcast environments. To keep the different video and audio sources synchronized properly, two different references were typically used, one providing time information (time code), the other phase information (black & burst or tri-level sync for Video, and DARS or Word Clock for Audio). With IP networks, PTP provides both Time Of Day and phase information, replacing and/or coexisting with the traditional 'legacy' references.

9.2. WHAT IS PTP?

PTP (Precision Time Protocol) is a method for precisely synchronizing devices over a computer network. On a LAN, PTP can achieve clock accuracy to within a microsecond. Originally designed for network measurements, PTP has been broadly adopted in applications ranging from real-time automations to telecom transmissions and financial transactions.

Published in 2002 by IEEE under the 1588-2002 standard (PTP v1) it was revised in 2008 as 1588-2008 (PTP v2). Version 2 brought several improvements but is not backward compatible with version 1.

9.3. A/V OVER IP APPLICATIONS

PTP has been widely adopted in A/V over IP applications. It is the protocol chosen by AES and SMPTE with PTP profiles included in both the AES67 and ST-2059 standards. The SMPTE ST-2110 suite of standards (digital video over IP with audio, video and ancillary data as separate streams) uses PTP for synchronization as it is based on ST-2059.

Major A/V over IP systems such as Dante, Ravenna, Q-LAN, LiveWire and Wheatnet-IP, all use PTP. Although the original Dante used PTP v1, with the release of the Dante Domain Manager version 1.1, a Dante system has the ability to clock to a non-Dante PTP v2 clock.

AVB (Audio Video Bridging) is a set of IEEE standards that facilitate the transport of high performance audio and video on a LAN. One of those standards, IEEE 802.1AS, defines a specific profile of IEEE 1588-2008 with additional timing features called gPTP (Generalized Precision Time Protocol).

9.4. PTP DESCRIPTION

Per IEEE 1588, PTP uses a hierarchical Master-Slave architecture for clock distribution. The primary timing source is called the PTP Grandmaster. Precise timestamps are captured at the Master and Slaves and exchanged to determine the offset between the two and the network latency so that the Slaves can synchronize their internal clocks to the Master's.

With the PTP protocol, two activities continually occur on the network:
- All grandmaster-capable devices negotiate to select a grandmaster.
- All devices synchronize to the grandmaster.

• BMCA: The Grandmaster is elected autonomously without any user interaction. Grandmaster-capable devices broadcast their clock "quality" and other parameters with Announce messages. They each compare the received Announce messages and, independently of the other devices, determine the most suitable grandmaster. This determination is done through the Best Master Clock Algorithm (BMCA), which by design ensures that all clocks reach the same conclusion. This best master clock negotiation continues even after a grandmaster has been selected so that in case the current grandmaster fails another clock can quickly replace it.

• SYNC: Synchronization to the grandmaster is done using a series of messages. Sync messages are broadcasted periodically by the grandmaster and contain timestamps from its internal clock. Slaves read these messages and adjust their internal clocks to match exactly the master's. Every update cycle, the slaves calculate corrections for offset and network latency to achieve high precision synchronization.

9.5. SELECTING A GRANDMASTER

An algorithm called the BMCA (Best Master Clock Algorithm) is used to determine which clock will be used as the PTP Grandmaster. As defined in the IEEE 1588 standard, this selection is done autonomously based on the following criteria and in the following order:

- Priority 1
- Clock Class
- Clock Accuracy
- Clock Variance
- Priority 2
- Source Port ID (MAC Address)

Of those fields, two are set manually by the users, Priority 1 and 2, so that preferred masters can be prioritized. It is important to note that, even though through the use of the Priority fields a user can more or less determine which unit will be selected as Grandmaster, it is still the BMCA that makes that determination.

When a Grandmaster has been selected, all other devices on the domain will sync their internal clocks to that of the Grandmaster. If the Grandmaster fails or disappears, a new one is selected immediately via the BMCA. If a better suited clock is found, it will become the Grandmaster.

9.6. SYNCHRONIZATION

There are several different PTP messages used during synchronization, sequenced as follows:

1. The grandmaster sends a Sync message with its transmit timestamp (t1), and an optional Follow Up message, in case of the two steps operation, which also includes t1.

2. The slave receives the Sync/Follow Up message, keeps its timestamp (t1) and the Sync message arrival time (t2).

3. The slave sends a Delay Request message back to the grandmaster. This message does not include a timestamp, however the slave keeps the time it sent the Delay Request message (t3).

4. The master receives the Delay Request message and keeps its arrival time (t4). The master then sends back a Delay Response message including t4.
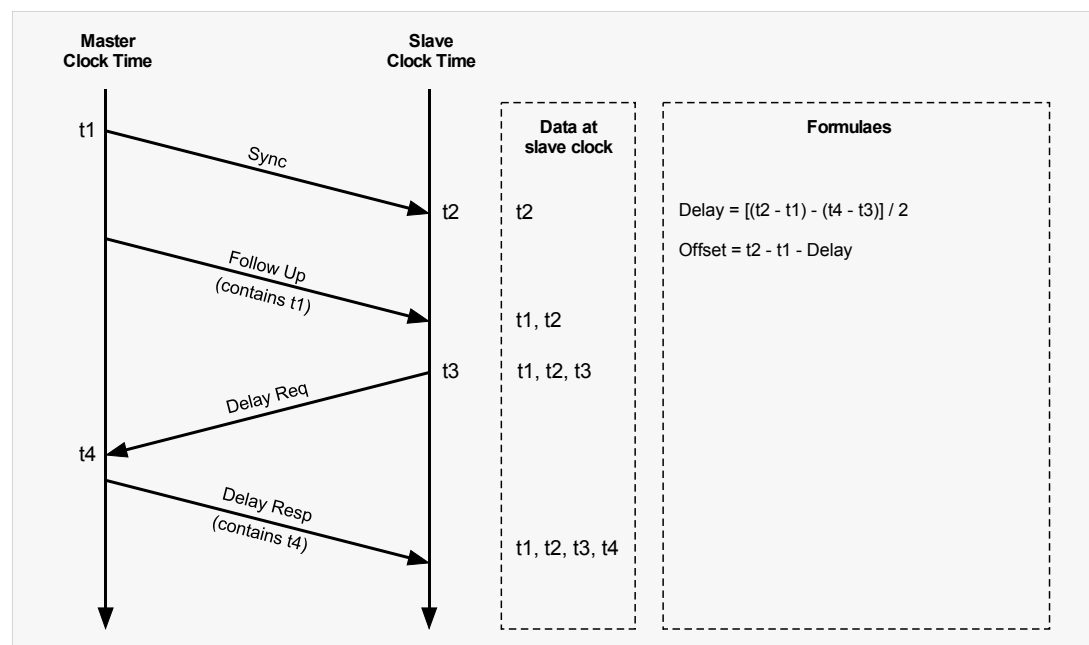
The slave clock now possesses all four timestamps (t1, t2, t3 and t4) that can be used to compute the offset of the slave clock relative to the master, and the propagation time between the two clocks. With this, it can now adjust its clock to match the GM clock.

9.7. DELAY MEASUREMENT MECHANISM

To synchronize clocks, the delay between the clocks must be known. There are two mechanisms to measure the delay called End to End (E2E) and Peer to Peer (P2P).

- The E2E delay mechanism was the only one included in the original IEEE1588-2002. It measures the delay between the master and the slave.

  E2E uses the following messages, as described in 1.6. above: Sync, Follow-up (optional), Delay_Req, and Delay_Resp. It can be used with switches or routers that are not 1588 capable.

- The P2P delay mechanism was introduced in IEEE15880-2008. It measures the delay between directly connected ports. Peer-to-peer delay measurement works "locally", from every node to each of its neighbors. For each pair of directly connected ports, each end periodically measures the round-trip network delay by sending a Pdelay_Req message and receiving in response a Pdelay_Resp message. This way all ports learn the delay on their link.

  P2P uses messages Pdelay_Req, Pdelay_Resp, and Pdelay_Resp_Follow_Up (optional).

NOTE: An ordinary clock, which has just one port, can be configured for end-to-end or for peer-to-peer; a boundary clock, which can have a single slave port and multiple master ports, can be configured for E2E on some ports and P2P on others.

While a single domain can have both end-to-end and peer-to-peer delay mechanisms running simultaneously, all clocks on a single PTP communication path must use the same method to measure the time delay.

9.8. TYPES OF CLOCKS

IEEE 1588 defines three different types of clocks:
- Ordinary Clock (OC)
- Boundary Clock (BC)
- Transparent Clock (TC)

Ordinary Clocks (OC) are devices with a single port, usually at either end of a network such as A/V equipment, DAW's or speakers. They can be master or slave.

Boundary (BC) and Transparent (TC) Clocks are network devices such as switches or routers.

Since the DXD-8 has 1 Ethernet port, it is an ordinary clock (OC).

9.9. PTP DOMAINS

A PTP domain is a network (or a portion of a network) within which all of the clocks are in sync. A single network can have multiple PTP domains operating separately, e. g., one set of clocks synchronized to one time scale and another set of clocks synchronized to an other time scale.

9.10. PTP PROFILES

A PTP Profile defines the range and default values of all configurable attributes as well as all required, permitted, or prohibited clock types and options for a specific application area. Profiles can be created by recognized standards associations such as AES or SMPTE. The DXD supports the AES67 Media profile and the SMPTE ST-2059-2 profile. The DXD also support the 1588 default profile.

9.11. EPOCH

PTP uses the concept of an Epoch clock. This is an absolute time value when the clock was set to zero, and the number of 1GHz clock pulses that have occurred since provides the current time, converted with software into year, month, day, hours, minutes and seconds. The Epoch (or zero time) for PTP was set at midnight on the 1st January 1970 (TAI).
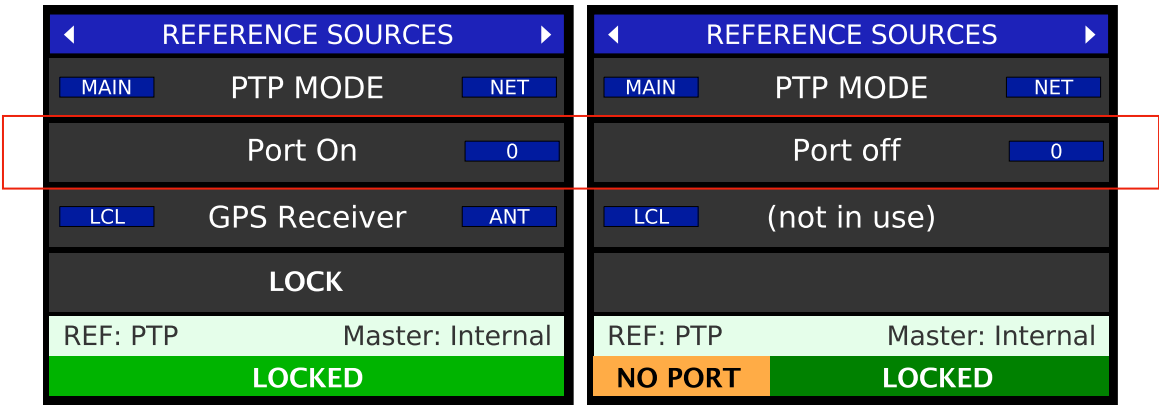
10. PTP Port States

When PTP MODE is selected as the reference, the REFERENCE SOURCES Status Display page indicates the PTP state of the DXD-8. This is similar to the PTP PORTS page on the DXD-16 where all 4 ports are shown.

The different states are:

- **SLAVE**: when another unit has been selected as Grandmaster by the BMCA, the DXD-8 acts as a PTP Slave

- **GRANDMASTER**: when the BMCA chooses the DXD-8 as PTP Grandmaster.

- **MASTER**: transitional state before the Grandmaster state is confirmed by the BMCA

   NOTE: as the DXD-8 has the ability to be a PTP Master or Slave, it means that, per IEEE1588, the state of the port can change. The BMCA determines what unit becomes the Grandmaster. If the current Grandmaster disappears or looses GPS, another Grandmaster is selected. For more on the Grandmaster selection, go to 9.5.

The PTP setting is displayed in white letters on a dark grey background. Choices are: Port on / Port off

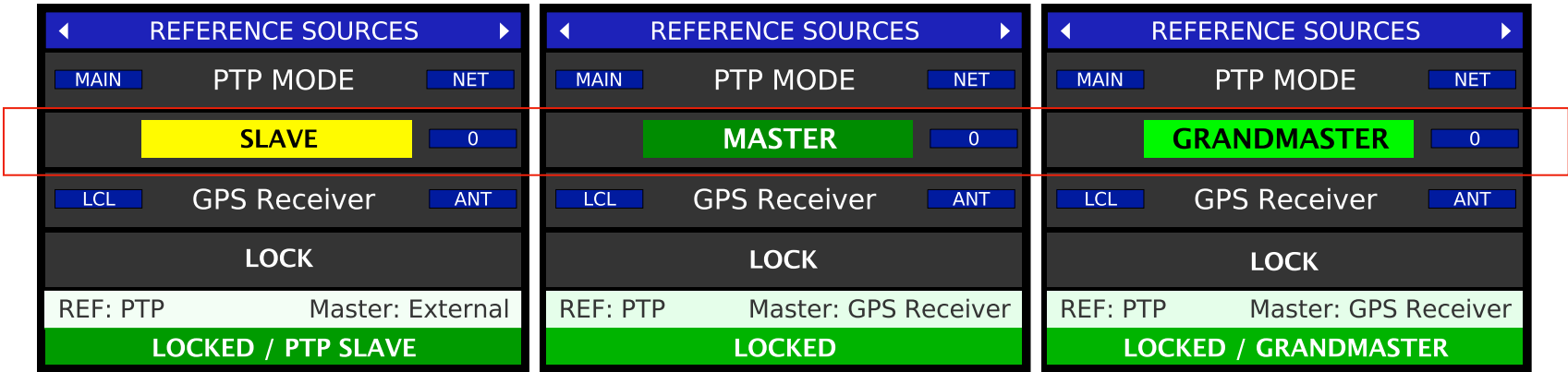| ◀ REFERENCE SOURCES ▶	◀ REFERENCE SOURCES ▶
MAIN PTP MODE NET	MAIN PTP MODE NET
Port On 0	Port off 0
LCL GPS Receiver ANT	LCL (not in use)
LOCK	
REF: PTP Master: Internal	REF: PTP Master: Internal
LOCKED	NO PORT LOCKED

Then the port's PTP State is displayed as it changes, in bold letters with the following colors:

- SLAVE   black letters   yellow background

- GRANDMASTER   black letters   bright green background

- MASTER   white letters   green background

The PTP domain number of the DXD-8, as set in menu 5.2, is indicated to the right of the PTP state in a small blue rectangle.

If GPS is available and has been selected in the reference menu as LOCAL REF WHEN GM, it will appear on the second section in place of the ALT REF with its current lock status right under.

◀ REFERENCE SOURCES ▶	◀ REFERENCE SOURCES ▶	◀ REFERENCE SOURCES ▶
MAIN PTP MODE NET	MAIN PTP MODE NET	MAIN PTP MODE NET
SLAVE 0	MASTER 0	GRANDMASTER 0
LCL GPS Receiver ANT	LCL GPS Receiver ANT	LCL GPS Receiver ANT
LOCK	LOCK	LOCK
REF: PTP Master: External	REF: PTP Master: GPS Receiver	REF: PTP Master: GPS Receiver
LOCKED / PTP SLAVE	LOCKED	LOCKED / GRANDMASTER

11. Positional change from an External PTP Grandmaster

When the DXD is referenced to an external PTP Grandmaster and a disruption or an error causes a positional change in the PTP Grandmaster, the DXD will respond differently based on how it has been set by the operator.

11.1 JUMP TO RELOCK

One of the parameters in menu 1.2 is the PTP Jump Threshold.

When the time difference detected between the external PTP GM and the DXD System Time is above the PTP Jump Threshold value, the DXD will jump to the new time and relock through the normal lock procedure. This will cause disruptions on the output signals but will be the fastest way to be locked with the external PTP GM.

The Jump Threshold can be adjusted in menu 1.2 from 5 msec to 15 sec, or set to 'Never' (default value is 5 msec)..

| 1.2 SYNC PARAMETERS	
BNC INPUT COLOR FRAMING	Off
BNC INPUT TIME JAM SOURCE:	Off
BNC INPUT TIME JAM RESYNC:	Off
PTP JUMP THRESHOLD:	5 msec

Keep in mind that, with a 15 seconds Jump Threshold, it could take the DXD-8 a long time to slew back in sync. During that time, the lock status will indicate HOLD / PTP SYNC (see ch. 11 above).

12. Typical PTP use

The DXD-8 was designed to be a reliable high precision sync generator as well as a very flexible one. Several features were incorporated in the design with flexibility in mind such as the universal outputs. For PTP, several options are available giving the user many choices.

12.1 HYBRID SYNC GENERATOR ACCEPTING MULTIPLE REFERENCES

One of the original concept behind the DXD line was to generate 'legacy' sync and PTP sync simultaneously so that all equipment could be kept perfectly synchronized. But, for added flexibility, the DXD-'s can also be set up to lock to any 'legacy' sync or to PTP as illustrated below. These choices are available in the Reference menu.
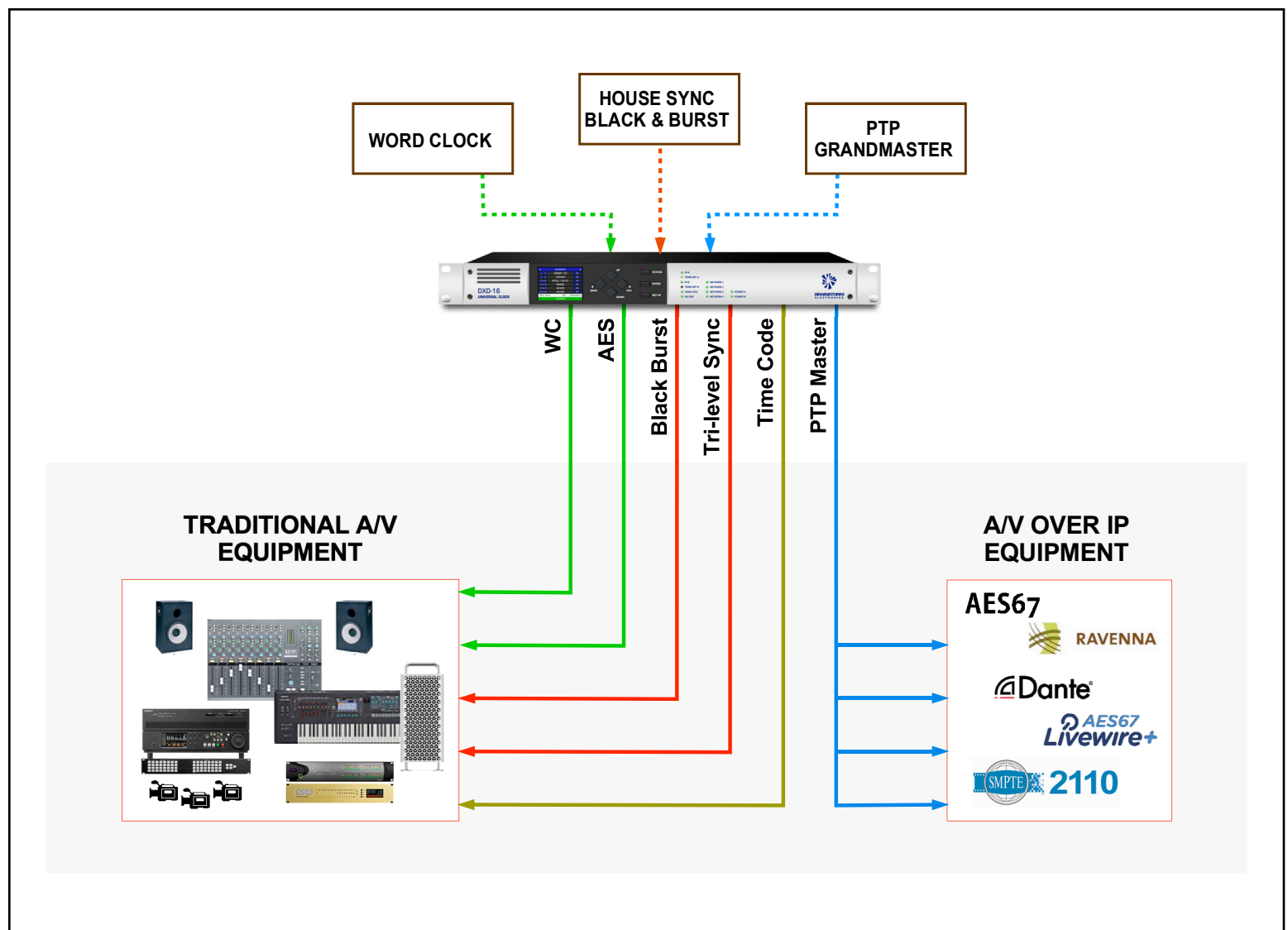
To reference an IP island to black burst (traditional infrastructure), set the DXD-8 as follows:

- Reference = INPUT A/Vid
- Port Mode = On
- Priority 1 = Low enough to win the BMCA (preferred master)

➡The IP Island locks to the PTP port (Master state)

To reference a legacy island to PTP (IP infrastructure), set the DXD-8 as follows:

- Reference = PTP Mode
- Port Mode = On

➡ The Legacy Island locks to BNC outputs (WC, AES, Video Sync, as required)

## 12.2 DISTRIBUTED PTP VS. INDIVIDUAL GRANDMASTERS WITH GNSS

In this example, DXD-8's are installed in several studios. In order to keep them in sync, 2 different options are available:

- Distributed PTP

- Individual Grandmasters with GNSS reference

The first illustration shows distributed PTP where all the DXD-8's are PTP slaves to an external Grandmaster; in the second illustration, the DXD-8's are all Grandmaster for their networks and each is locked to GNSS. This second solution is particularly useful when distances between studios are long and certainly for remote trucks.
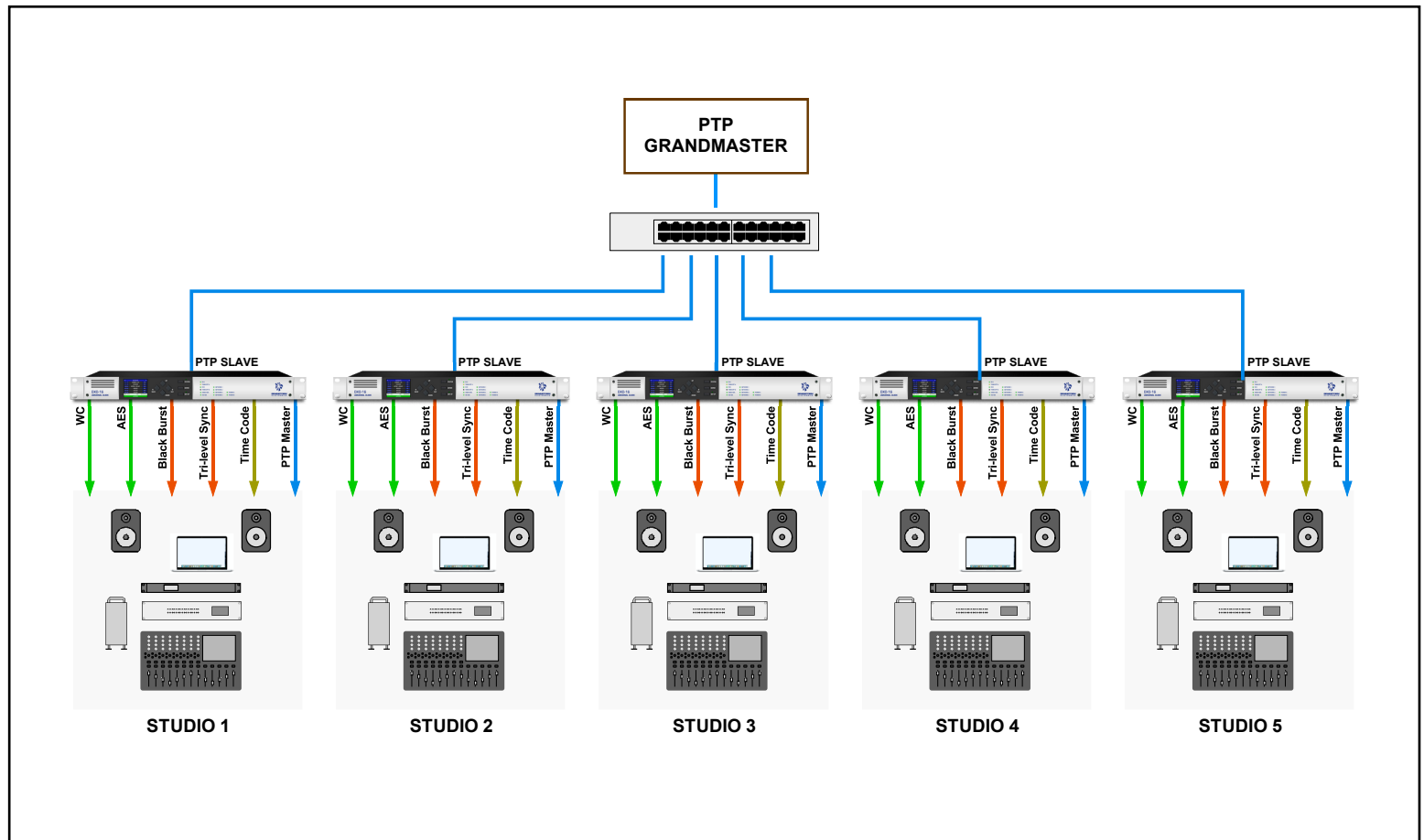
Distributed PTP
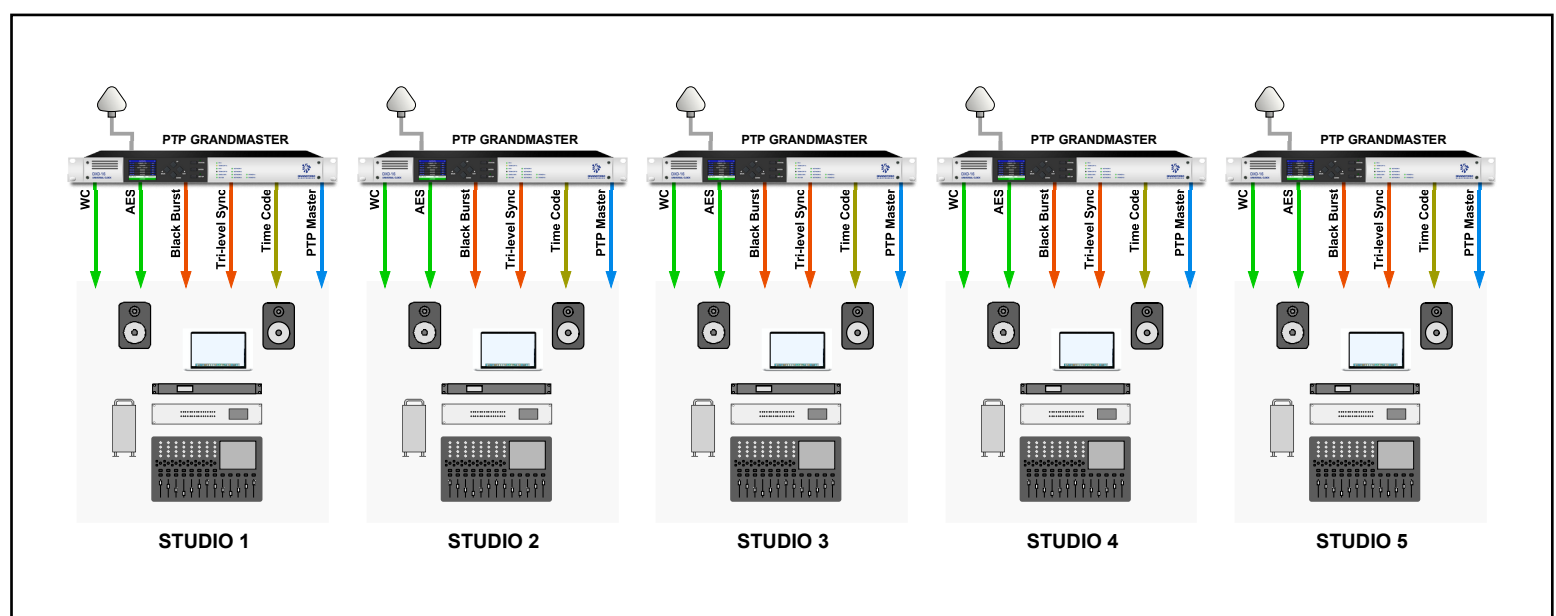
Individual Grandmasters with GNSS Reference

13. PTP v1 (IEEE Std 1588-2002) Implementation - Firmware Option

The translation between PTPv1 and PTPv2 is implemented as specified in section "18. Compatibility Requirements" of IEEE Std 1588-2008 (PTPv2). It is available on the DXD-8 with the PTP option (DXD8/PTP).

13.1 SELECTING PTP V1

PTPv1 mode is selected in the PTP menu PORT CONTROLS. Select "PTP Version 1" in the line "PTP VERSION".

5.3 PORT CONTROLS

PTP VERSION:	PTP Version 1
PTP PROFILE:	Default
PORT TIMING DEFAULTS:	No Action
DELAY MECHANISM:	E2E [End-to- End]

13.2 DIFFERENCES IN SETTINGS FOR PTP MENU '5.2 GRANDMASTER'

- **Domain:**

    The range of Domain numbers in PTPv1 is just 0~3, as opposed to 0~127 for PTPv2.

    If a Domain number greater than 3 is set for a port running in PTPv1 mode, then:
    - The DXD will issue the warning "PTP: Domain Number exceeds PTP-V1 limit"; and
    - The actual number used on the bus will be converted to lie in the range 1~3
      (4 → 1, 5 → 2, 6 → 3, 7 → 1, 8 → 2, etc.).

5.2 GRANDMASTER [GROUP]

ERROR

PTP Domain Number exceeds PTP-V1 limit

Press Any Key to Clear

Priority: 0=Highest, 255=Lowest

- **Priority 1:**

    PTPv1 does not have PRIORITY settings, but it does have the concept of "Preferred Master Clock".
    Translation between the two is as follows:

    PRIORITY 1 = 127 .... Preferred Master Clock = TRUE
    PRIORITY 1 = 128 .... Preferred Master Clock = FALSE

    Other values may be used for PRIORITY 1, with all values less than 127 resulting in Preferred Master Clock being TRUE, and all values greater than 128 making Preferred Master Clock FALSE.

> **CAUTION**: Using values _other_ than 127 and 128 in a system where both V2 and V1 devices are present is _not recommended_ as the V2 devices will recognize the differences between priorities beyond 127 and 128, and their Best Master Clock algorithms will respond accordingly, whereas the V1 devices will not.

- **Priority 2:**

    Translation of this value is more obscure. PTPv1 keeps track of whether or not a device is a Boundary Clock, and PTPv2 PRIORITY 2 is mapped to that setting as follows:

    PRIORITY 2 = 127 (or less) .... Boundary Clock = TRUE
    PRIORITY 2 = 128 (or more) .... Boundary Clock = FALSE

    Changing PRIORITY 2 will not necessarily result in observable operational differences.

13.3 DIFFERENCES IN SETTINGS FOR PTP MENUS 'PORT TIMING'

- **Announce Interval:**

    PTPv1 does not use Announce messages, but the DXD-8 continues to use this timing value internally while operating in PTPv1 mode. The value is not critical, but it is used in the calculation of the SYNC message timeout (see below).

- **Announce Receipt Timeout:**

    Although PTPv1 does not use Announce messages, the DXD-8 port in PTPv1 mode will use this value to determine whether or not PTPv1 SYNC messages have timed out (i.e. stopped arriving). Note that the timeout is measured in ANNOUNCE INTERVAL's (above), whereas PTPv1 measures its SYNC message timeout in SYNC INTERVAL's. The math is not difficult, but it may be simpler if the ANNOUNCE INTERVAL is set the same as the SYNC INTERVAL.

    The PTPv1 default for this setting is 10 SYNC INTERVAL's.

- **Sync Interval:**

  This setting has the same function in PTPv1 as it has in PTPv2.

  The PTPv1 default for this setting is 2 seconds [log 1]. It should be noted however that some Dante devices require that this is 1/2 second [log -1] or less.

- **Min Delay Req Interval:**

  This interval is not supported by PTPv1, but is used internally by the DXD-8 when in PTPv1 mode. You may continue to use the same setting as you would for PTPv2.

14. AVB - IEEE 802.1as (gPTP) Firmware Option

The DXD-8 supports 2 versions of the IEEE 802.1AS standard, the original version published in 2011 (802.1AS-2011) and the latest revision published in 2020 (802.1AS-2020).

AVB support is optional on the DXD-8 and is purchased separately (DXD8/AVB). After the AVB Feature Key has been installed in menu 10.5, the 2 versions of AVB can be selected in the Port Control menus under PTP Version.

AVB is a layer 2 protocol and requires AVB compliant switches.

15. Guidelines for configuring PTP (Precision Time Protocol)

Only a few years ago, setting up a network was not a task most audio or video engineers were concerned with. This was the responsibility of the IT department. Nowadays, it has become an important part of more and more installations and, as we move towards A/V over IP, careful advance planning of the network and proper configuration is necessary, demanding a new set of skills.

Although configuring an A/V network includes many settings that do not concern the DXD-8, PTP is a complex standard and a good understanding of network technology is required. The best source of information for PTP is the IEEE 1588 standard itself available here: https://standards.ieee.org/standard/1588-2019.html. There are also many publications available from different organizations such as SMPTE and AES with best practices recommendations.

PTP's role is to synchronize the real-time clocks of the different nodes on a network but it does not make the network itself synchronous. The traditional master/slave architecture is also very different when dealing with PTP thanks to the BMCA.

The list below only includes some very basic PTP requirements and recommendations and is not meant to be a comprehensive check list.

15.1 REQUIREMENTS

- **PTP Domain**: Devices that need to be synchronized together via PTP must be part of the same domain. Be sure the PTP domain is set properly on your DXD as messages with any other domain number will be ignored.
  (menu 5.2).

- **Ports Timing**: per IEEE 1588, all devices on a PTP domain must have the same value set for these ports timing:
  - Announce Interval
  - Announce Receipt Timeout
  (menu 5.4).

- **Delay Mechanism**: Two different delay mechanisms are available in the IEEE 1588 standard: E2E and P2P. The DXD-8 only supports E2E. However, the following requirement must be observed:
  - All the 1588 nodes on the same messaging path are required to use the same delay mechanism.

15.2 RECOMMENDATIONS

- **PTP Profile**: It is recommended to use the same profile for all units in any particular domain. Failure to do so can lead to unexpected results.
  (menu 5.3).

- **Priority Fields**: If the DXD-8 is your preferred master clock, the simplest way to make it the Grandmaster is to set the Priority 1 field low enough to win the BMCA. However, it is also recommended that all candidate GMs would have the same Priority 1 value to avoid causing hierarchy issues as the Priority 1 field overrides any clock quality changes in the GM.
  (menu 5.2).

  Keep in mind that, with PTP, the BMCA always determines which device becomes Grandmaster. As conditions change (loss of GPS for example), another Grandmaster could be selected, changing the state of the DXD-8 port. But this would only be true if, as recommended above, all candidate GMs would have the same Priority 1 value.

15.3 NETWORKING HARDWARE

• **PTP-aware**: PTP is implemented in some networking hardware often referred to as 'PTP-aware', meaning either as an IEEE 1588 "Transparent Clock" or "Boundary Clock". This includes switches and routers. Transparent Clocks and Boundary Clocks are designed to improve accuracy particularly in large and busy environments.

• **Non-PTP-aware and QoS**: The DXD-8 has been observed to perform very well in small networks with standard non-PTP switches. It adheres to the IEEE 1588 2008 Annex D recommendation that, for PTP event messages, the value of the differentiated service (DS) field in the Type of Service (ToS) field is set to the highest traffic class selector codepoint available, which in this case is the DSCP value "High Priority / Expedited Forwarding (EF)". This means that, with a switch properly configured for Quality-of-Service (QoS), PTP traffic from the DXD-8 will be prioritized over other traffic.

• **Router/DHCP**: It is always required to have a router visible to the DXD on the network when using DHCP. Without the router (and the DHCP server), fixed IP addresses must be used and set manually in menu 4.1.

• **IGMP - internet Group Management Protocol**: The DXD-8 supports IGMPv2. On larger networks, a router is required to manage multicast group membership. Switches that support IGMP Snooping are also recommended.

16. Troubleshooting - Error / Warning Messages

16.1 PTP 'NO PORT' WARNING

With PTP Mode selected as the reference a warning message will appear when the port has not been turned on.

This message indicates 3 possible causes:

    • Port Mode not assigned
    • Missing IP address
    • Network disconnected.

If the port has been turned on but the warning message appears, it would indicate that the PTP initialization request has not been granted. This could happen because the IP address hasn't been set properly, possibly due to a DHCP error.
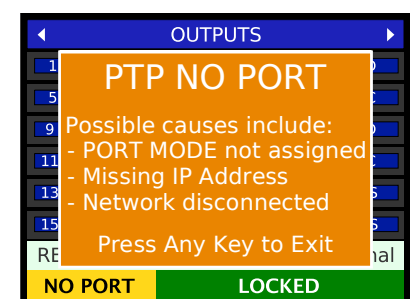
- **Make sure the port has been turned on (menu 5.1)**

- **Make sure the port has an IP address (menu 4.1)**

16.2 PTP PORT IN PASSIVE STATE

Per IEEE 1588, a port in Passive state is not the master on the path nor does it synchronize to a master.

• Master Only: In a case where the DXD-8 is referenced to it's internal crystal, to GPS or to a source connected via one of the 2 BNC inputs, the PTP port becomes master-only. In such a scenario, if another unit is selected by the BMCA as the master for that domain, the port will switch to the Passive state.

- **If the port must be the Master on that domain, make sure Priority 1 is set low enough (menu 5.2)**

16.3 TIME JAM TIME OUT

An error message will appear when the conditions for a requested Time Jam are not met.

1. Menu 1.1: Reference must be Input A or Input B.
2. Menu 1.2: A valid source must be selected as the BNC INPUT TIME JAM SOURCE.
3. Menu 5.1: If PTP was selected, TIME JAM (BNC INPUT) will automatically show in menu 5.1, in blue (blue = status information). The words [Time Jam] will also appear on the REFERENCE line at the bottom of the main rotation pages.
4. Menu 5.5: If PTP was selected, the PTP domain of the Time Jam must be set to the same domain as the external PTP Grandmaster source in menu 5.5.

- **Make sure the menus listed above are set properly.**
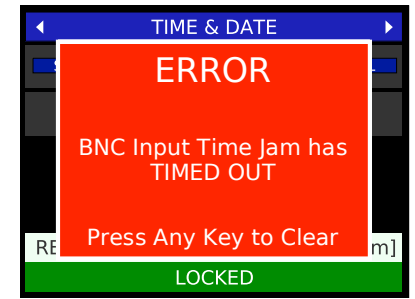
17. Appendix

17.1 Appendix A: Factory Presets

The following are the factory default settings for the new DXD menus:

1.2 SYNC PARAMETERS	**BNC INPUT COLOR FRAMING**	Off
	BNC INPUT TIME JAM SOURCE	Off
	BNC INPUT TIME JAM RESYNC	Off
	PTP JUMP THRESHOLD	5 msec
5. PTP	**PORT MODE**	Off
	DOMAIN	0
	PRIORITY 1	128
	PRIORITY 2	128
	PTP VERSION	PTP 2.0
	PTP PROFILE	Default
	PROFILE PORT TIMING ACTION	No Action
	DELAY MECHANISM	E2E (End-to-End)
	ANNOUNCE INTERVAL	2 sec [log 1]
	ANNOUNCE RECEIPT TIMEOUT	3 announce intervals
	SYNC INTERVAL	1/2 sec [log -1]
	MINIMUM DELAY REQUEST INTERVAL	2 sync intervals
	PORT TIME JAM DOMAIN	100
7. TIME	**SYSTEM TIME**	TAI
	RT CLOCK	TAI
	PTP GM TIME	TAI
	GPS TIME	TAI
	LOCAL TIME ZONE	-8 Hr 0 Min
	LOCAL DAYLIGHT SAVING	0 Hr 0 Min
	SET TIME: YYYY/MM/DD (RTC)	2020/01/01
	SET TIME: HH:MM:SS (RTC)	00:00:00
	SYTEM TIME JAM FROM RT CLOCK	Off
	AUTO UPDATE RT CLOCK	Off
	UPPER DISPLAY (TIME & DATE DISPLAY)	System Time
	LOWER DISPLY (TIME & DATE DISPLAY)	No Display
	UTC LEAP SECONDS	37
	AUTO UPDATE (LEAP SECONDS)	Off