IP Conversion of Broadcasting

Part 5 | References

PTP System Commissioning: A Series of Grandmaster Changeover tests for PTP systems in IP media networks

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About this guide

This guide has been created to describe how Leader Test and Measurement products are deployed and utilized within broadcast facilities. It details the operation of the Leader LT4670 SPG 'True Hybrid' IP/SDI Sync Pulse Generator (SPG) and the LT4448 ECO Emergency Changeover Unit in hybrid IP/SDI infrastructures.

The guide also outlines a series of commissioning tests designed to verify the performance and reliability of BlackBurst, Tri-Level Sync, Digital Audio, SDI, and PTP reference sources - ensuring stable operation even in the event of a failure.

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Introduction - The Requirement for PTP in Broadcast Facilities

Accurate and stable timing references are the foundation of every broadcast facility. Without precise synchronization, video and audio signals drift, lip-sync errors emerge, and seamless switching between sources becomes impossible.

As broadcast operations transition from traditional SDI to IP-based infrastructures, the need for a unified and reliable timing reference has never been greater. Precision Time Protocol (PTP) has become the industry standard for IP-based timing, enabling frame-accurate synchronization across distributed systems and hybrid production environments.

However, the hybrid nature of modern broadcast facilities compounds the challenge. Legacy SDI systems continue to rely on Black Burst and Tri-Level Sync, while IP systems require PTP. Maintaining phase coherence between these timing domains is critical to prevent frame sync and lip-sync issues.

Because timing stability underpins every broadcast operation, facilities demand complete resilience from their reference sources. Yet in PTP environments, the traditional architecture of a primary and backup Sync Pulse Generator (SPG) with an Emergency Changeover Unit no longer guarantees seamless transition across both Black Burst/Tri-Level Sync and PTP domains in the event of a failure.

The Leader LT4670 SPG “True Hybrid” IP/SDI Sync Pulse Generator (SPG) and Leader LT4448 ECO together provide a complete, resilient reference solution for modern broadcast facilities. The LT4670 SPG combines PTP Grandmaster functionality with traditional sync outputs in a single, unified platform. By continuously monitoring the health and status of both LT4670 SPG units - including their PTP and Black Burst/Tri-Level Sync references - along with the operational status of the LT4448 ECO, the system ensures uninterrupted synchronization across the entire facility.

This intelligent integration effectively bridges the gap between IP and baseband systems, delivering a robust, fully redundant, and GPS-independent timing architecture that guarantees continuous and reliable reference signals, even during disruption or failure events.

1. System Architecture

A resilient hybrid timing solution requires:

- Primary LT4670 SPG as the central reference source, capable of generating both PTP (IP) and Blackburst/Tri-Level Sync (SDI) & Digital Audio references.

- Backup LT4670 SPG, capable of generating both PTP (IP) and Blackburst/Tri-Level Sync (SDI) & Digital Audio references.

- LT4448 ECO monitoring both LT4670 SPG's SPGs and instantly switching reference outputs upon detecting a failure.

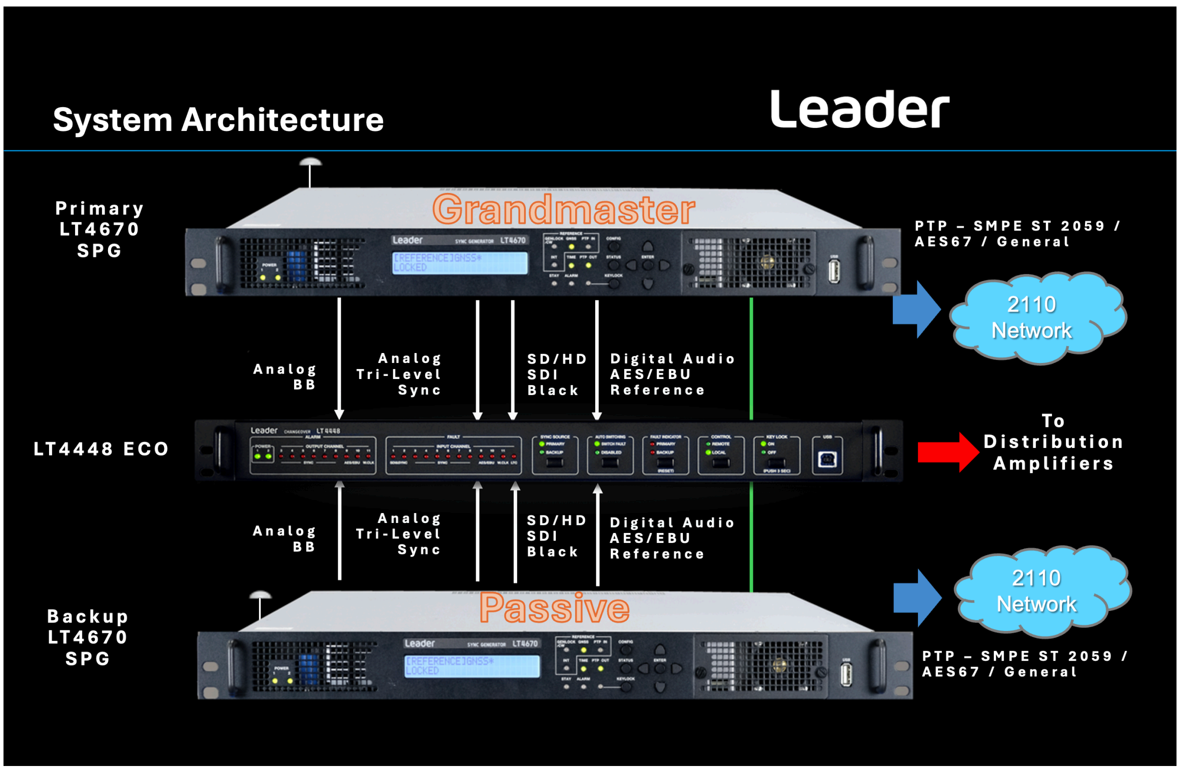


Figure 1: Primary and BAckup LT4670 SPG's feeding on LT4448 ECO, distributing timing to IP and SDI systems

This ensures continuous reference stability for hybrid IP/SDI facilities, OB trucks, and remote production hubs.

Precision Time Protocol (PTP) provides IP media networks with the timing accuracy required for video synchronization within a broadcast facility. PTP requires precise configuration and syntax for correct operation, making it critical to fully understand these requirements and perform comprehensive testing of your facility's system timing during installation. This ensures reliable operation and avoids discovering potential pitfalls only once the system is live.

Professional broadcast PTP systems typically deploy multiple PTP Grandmasters (GMs), designed to provide seamless redundancy. It is therefore essential to validate system behavior when conditions trigger a switch from one GM to another.

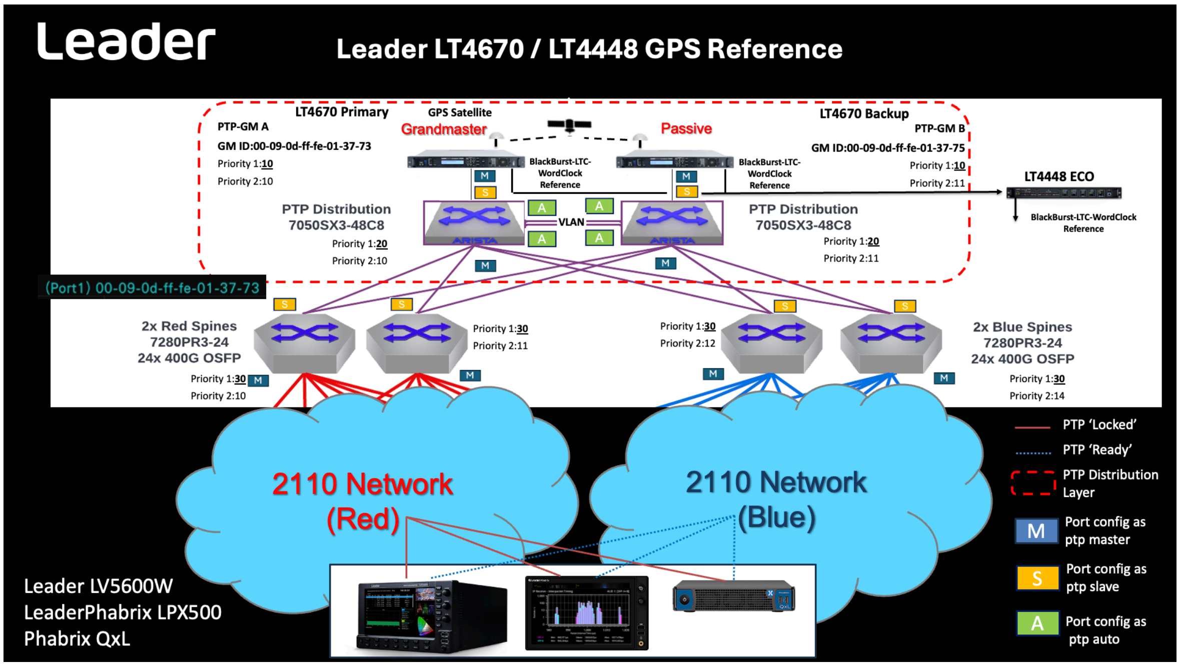


Figure 2: Typical Hybrid IP/SDI 'Air-gapped PTP Reference Architecture

2. Boundary Clock (BC) Switches

In a broadcast facility's PTP network, especially one built around SMPTE ST 2110, using Boundary Clock (BC) switches isn't just a "nice to have." It's the architectural choice that keeps the timing layer stable, scalable, and predictable as your facility grows. Here's why BC switches matter and why they are the right companion to a Grandmaster (GM):

Boundary Clocks:

- Reduce load on the Grandmaster
- Stabilize timing and reduce jitter
- Scale the network cleanly
- Enable predictable GM failover
- Isolate faults and maintain up time
- Improve overall ST 2110 system robustness

If the GM is the heartbeat of your timing system, Boundary Clock switches are the arteries - distributing stable, regenerated timing to every corner of the broadcast facility.

The use of a properly configured Boundary Clock (BC) should:

- Terminate the PTP domain at its upstream (GM-facing) interface. (The BC will normally be the same Domain as the incoming GM).
- Distribute its own regenerated PTP timing downstream that is 100% locked to the GM as the *only visible clock source* of sync to endpoints on that segment. The end points will see the GM's ID as the network clock but the timing is regenerated by the BC that is locked to the GM to the end point.
- Hide all upstream timing dynamics (e.g. BMCA elections, GM failover, jitter, path asymmetry) from the end devices, because the BC re-times packets and sends them out with its own stable timestamping.

So, from the endpoint's perspective, "everything happens behind the Boundary Clock":

- Endpoints don't see multiple Grandmasters - they only ever see the BC as their parent clock.
- Any Grandmaster switchover upstream of the BC should be invisible to the endpoints, apart from a small and well-controlled phase shift that the BC manages.
- QoS, congestion, or failover events that occur on the core network are absorbed by the BC's regeneration, so long as the BC itself has a stable timebase and good holdover.

That's why the BC placement is so critical in a SMPTE 2110 red/blue design: if you deploy BCs at the leaf or aggregation layer, they form the clean timing boundary between your WAN/core behavior and the "deterministic timing island" where your media devices live.

Figure 1 & 2 illustrates a block diagram of a typical hybrid SDI/IP video facility using Leader LT4670 SPG units, though configurations will vary depending on network requirements. Every system is unique, and testing your PTP architecture during design validation or commissioning will ensure robust operation under fault conditions.

GM changeovers are managed using the PTP Best Master Clock Algorithm (BMCA). This algorithm evaluates clock quality parameters in PTP Announce messages to select the lead clock.

LT4670 SPG PTP-GM A

LT4670 SPG PTP-GM B

Figure 3: LT4670 SPG's web browser status page

Figure 3 shows the LT4670 SPG's intuitive web browser interface, displaying the PTP configuration, current source state, clock identity, and BMCA values (Priority 1, Clock Class, Clock Accuracy, and Priority 2) used to determine the active Grandmaster.

In a typical configuration, a PTP system may deploy a Primary LT4670 SPG with a Backup LT4670 SPG.

To simplify monitoring, it is recommended to note the unique Clock Identity of each LT4670 SPG to quickly identify which is acting as Grandmaster during a changeover.

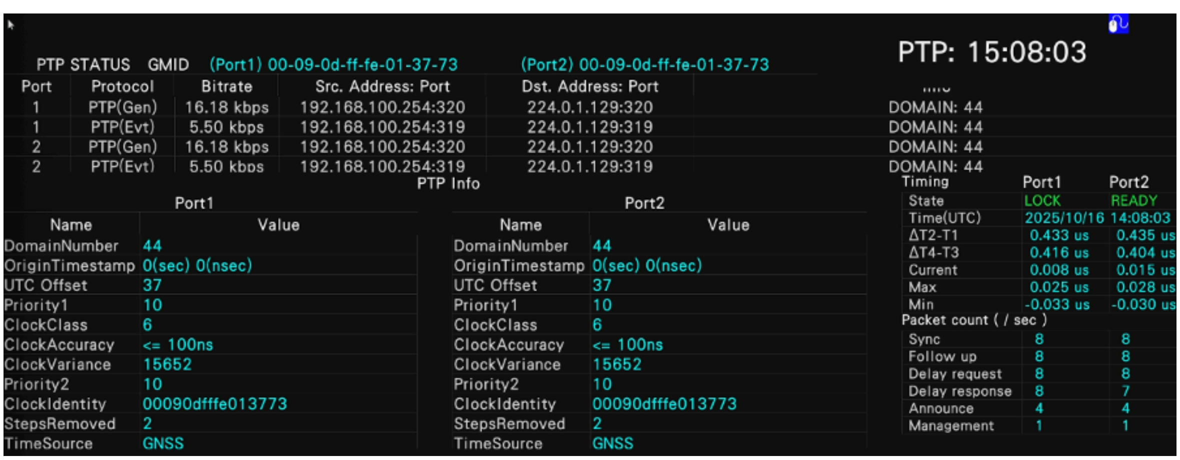


Figure 4: PTP Status - GMID

Leader recommends carrying out a series of GM changeover tests as part of commissioning. While not every test applies to every system, they often reveal unexpected network or device behaviors. Most tests involve an initial failure that triggers a changeover, followed by recovery when the fault is resolved and the system can be manually restored to its original state.

During these tests it is important to monitor the operation of the system. Are all the video, audio and ancillary data (ANC) streams working correctly? Are there any clicks, pops, drop-outs, flashes, or freeze frames that occur in the program stream? Are all the end-point devices reporting a good PTP lock? Is NMOS running and providing connectivity? Is the scheduling system still on track? It can be challenging to verify these changes manually so often it helps to run stream captures during the test to analyze what is happening during the changeover.

A PTP and BB/TLS monitor such as the Leader LV5600W/LV7600W, can analysis and display graphs of how well the system is tracking the reference PTP, this will help in seeing if the PTP and BB/TLS reference is shifting, and which device is the active GM. Analyzing the switch and device logs can be useful as well.

3. BMCA (Best Master Clock Algorithm) / BTCA (Best Time Transmitter Clock Algorithm)

All of the recommended GM Changeover test utilize the BMCA (Best Master Clock Algorithm) / BTCA (Best Time Transmitter Clock Algorithm) which is the decision-making process that ensures only one clock in a PTP domain is elected as the Grandmaster, while all others synchronize to it. It runs continuously on all PTP-enabled devices, so if conditions change (e.g., failure, degradation, new device joins), the election can be redone automatically.

Each clock periodically sends Announce Messages that include its “dataset,” which contains:

- **Priority1** (administrator-set, highest precedence factor)
- **Clock Class** (derived from clock’s source, e.g., GPS, atomic, holdover)
- **Clock Accuracy** (how precisely the clock represents UTC)
- **Priority2** (secondary administrator-set tiebreaker)
- **Clock Identity** (unique EUI-64 address, final tiebreaker if all else equal)

Each PTP device evaluates the Announce messages it receives and applies the following hierarchy of comparisons to select the “best” clock:

1. **Priority1** (lowest value wins)
2. **Clock Class** (lower value means higher quality, e.g., GPS-disciplined > House Blackburst > free-running)

3. **Clock Accuracy** (smaller value = better accuracy)

4. **Priority2** (lowest value wins)

5. **Clock Identity** (lowest numerical value wins, used as a tiebreaker)

At each step, if one clock is better, the comparison stops. If equal, the algorithm moves to the next field.

- The "best" clock becomes the Grandmaster.
- All other devices synchronize to it as followers.
- If the GM fails, loses reference (e.g., GNSS), or is withdrawn, the BMCA automatically re-runs and selects the next best candidate as the new GM.

Example

In Figure 4. Best Master Clock Algorithm (BCMA) there are two PTP clocks:

- **PTP GM A**: Priority1=10, GPS reference, Accuracy=ClockClass 6, Priority2=10
- **PTP GM B**: Priority1=10, GPS reference, Accuracy=ClockClass 6, Priority2=11

BMCA outcome:

- **PTP GM A** wins (lower Priority2, 10 < 11).
- If **PTP GM A** fails, then **PTP GM B** is selected (better accuracy than **PTP GM A**).

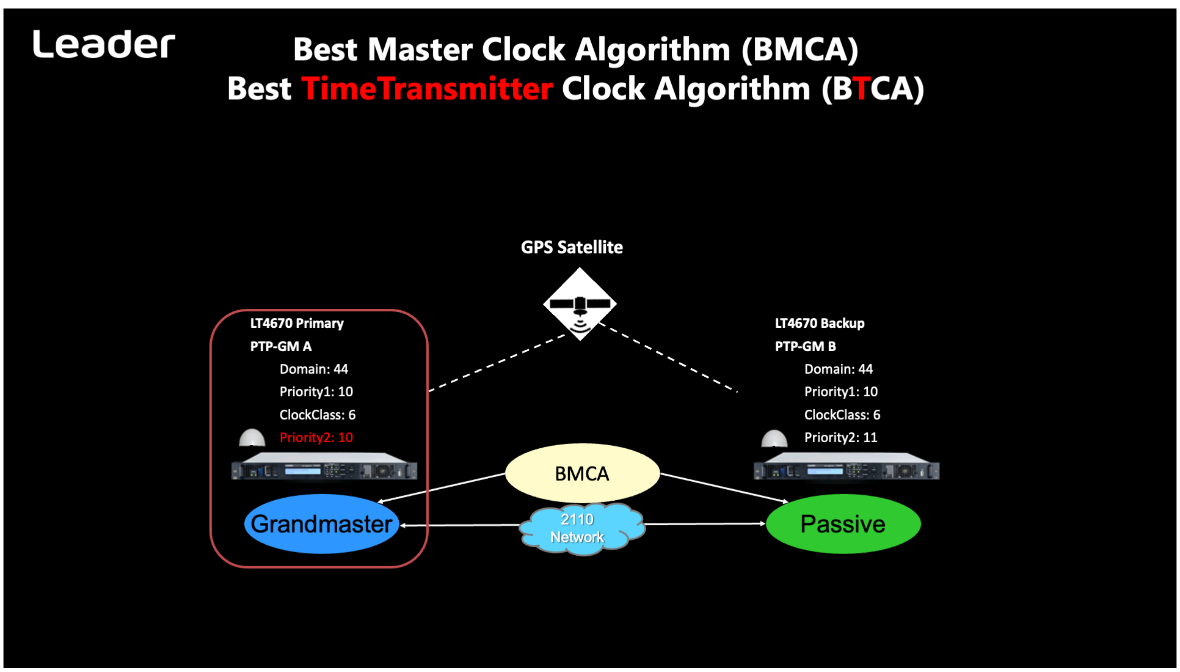


Figure 5: Best Master Clock Algorithm (BMCA)

4. Recommended GM Changeover Tests

1. Smooth changeover with continuous PTP messages
    a) Disabling GNSS
    b) Adjusting Priority

2. Abrupt changeover with loss of PTP from Grandmaster

3. Abrupt changeover on failure of link carrying PTP

4. Power outage on active Grandmaster

Test #1a – Graceful Changeover with continuous PTP messages – Change of Clockclass

One of the most important PTP commissioning tests is verifying that the system performs a seamless Grandmaster (GM) transition when the BMCA initiates a new GM election due to a change in ClockClass. This test ensures that the timing network behaves correctly when a Grandmaster enters holdover and advertises a degraded clock quality, allowing another GM to take over without disturbing downstream devices.

In a typical SMPTE ST 2059 deployment using the LT4670 SPG, a ClockClass change is triggered when the primary GM loses its reference and moves into holdover (Stay-In-Sync). During this state, the primary LT4670 SPG continues to transmit Announce and Sync messages, but with a degraded ClockClass - typically ClockClass 7. This indicates that while the clock is still stable, it is no longer disciplined by its reference and should not remain the system Grandmaster.

The BMCA responds as follows:

- The backup LT4670 SPG GM evaluates the degraded ClockClass of the primary and concludes that it is now the “better” clock. It asserts itself by transmitting its own Announce and Sync messages.

- For a brief interval, both GMs transmit simultaneously. This is expected and is part of the normal BMCA transition behavior.

- The primary LT4670 SPG then detects that the backup has superior clock quality and transitions to the passive state. Once passive, it stops acting as a candidate GM and withdraws from contention.

Because PTP messages remain continuous throughout the entire transition, Boundary Clocks and Followers do not lose lock. They simply realign to the new Grandmaster with minimal correction and without experiencing timing jumps, message gaps or re-lock events.

A successful Test 1a demonstrates that ClockClass-driven BMCA transitions are deterministic, stable and non-disruptive - critical for maintaining uninterrupted timing in hybrid IP/SDI broadcast environments.

Procedure

1. Initiate a graceful changeover by:

   Disabling the GNSS or other reference input to the active Grandmaster, causing it to enter holdover (Stay-In-Sync).

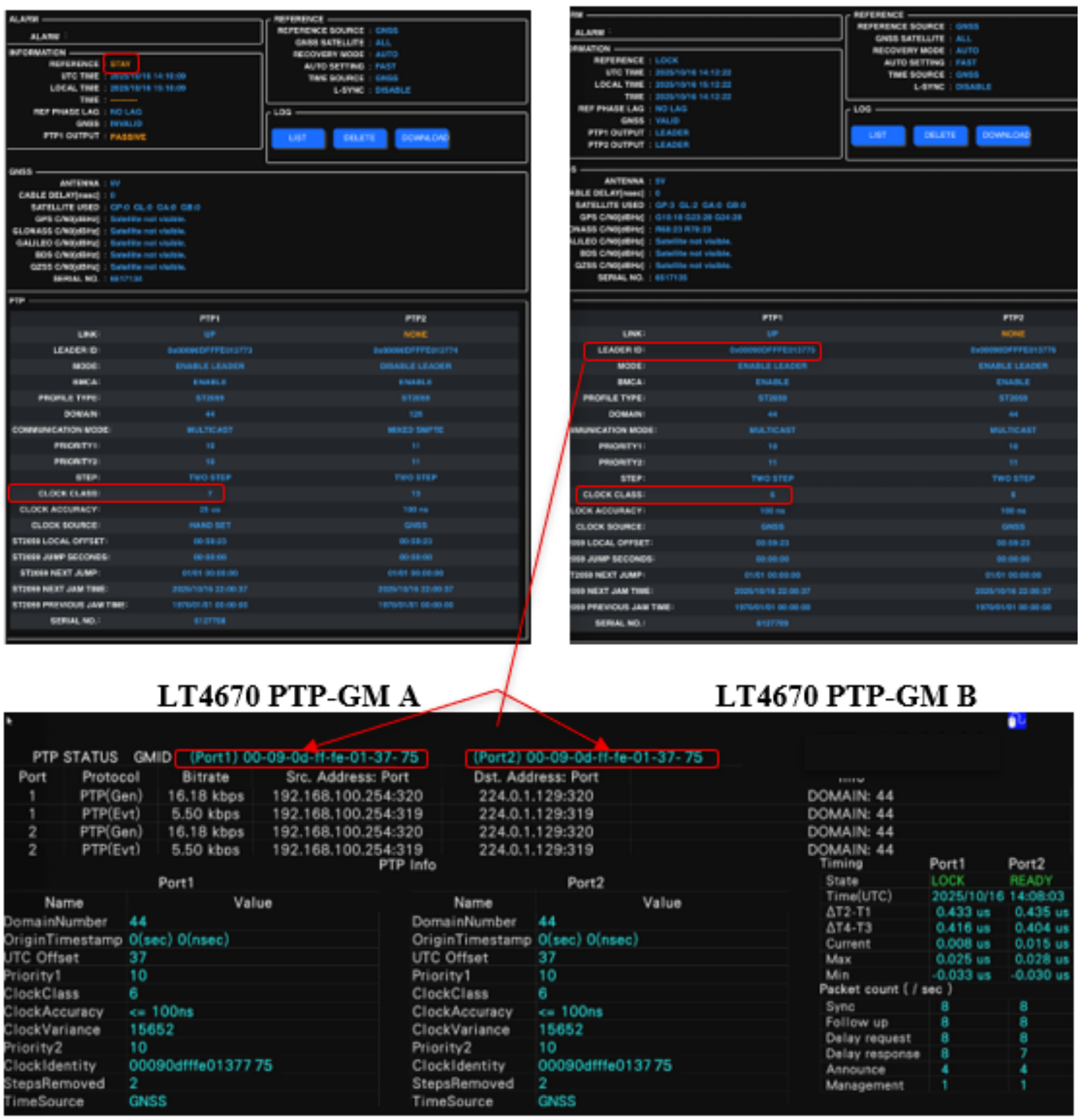


Figure 6: Disabling the GNSS

Observed behavior

- In holdover (Stay-In-Sync), the primary LT4670 SPG GM continues to transmit PTP Announce and Sync messages, but with a degraded clock quality. (Clockclass 7)
- The backup LT4670 SPG GM applies the BMCA and determines that it is better and so it starts transmitting Announce and Sync messages.
- For a brief period, both GMs transmit simultaneously.
- The primary LT4670 SPG GM then detects that the backup is now “better” and transitions to the passive state.
- Because PTP messages continue throughout, the followers experience minimal disruption and remain locked.

A video demonstrating this operation can be viewed on our YouTube channel.

Test 1a - Graceful Changeover with Continuous PTP Messages - Change of ClockClass

Test #1b – Graceful Changeover with continuous PTP messages – Change of Priority1 & Priority2

Another of the most important PTP commissioning tests is verifying that the system performs a seamless Grandmaster (GM) transition when the BMCA initiates a change of GM because of modifying either the Priority1 or Priority2 values. This test confirms that the PTP domain can gracefully re-elect a new Grandmaster *without* creating timing disturbances, message gaps or follower re-locks.

In a well-designed SMPTE ST 2059 / IEEE 1588 network, Priority1 and Priority2 are essential engineering tools used to control which device becomes Grandmaster and how the timing hierarchy behaves during normal operation, failover scenarios and planned maintenance. These values provide deterministic BMCA outcomes, prevent unexpected elections and ensure that time distributions remain stable across hybrid IP/SDI infrastructures.

By intentionally changing Priority1 or Priority2 on the currently active GM, engineers can confirm that all Boundary Clocks and Followers correctly identify the new “best” clock and switch to it *without interruption*. This capability is vital when undertaking maintenance or firmware updates on the primary GM because it allows another clock to take over seamlessly, without requiring rebooting and without disrupting PTP lock across the facility.

A successful Test #1b demonstrates that:

- BMCA responds instantly and deterministically to recalculated priorities.
- The timing network transitions to the new GM with no packet loss, no phase jumps and no disturbance events.
- Boundary Clocks and Followers maintain continuous PTP message reception throughout the handover.
- The design supports stable operational workflows, controlled maintenance windows and predictable redundancy behavior.

This test validates both the robustness of the timing design and the correctness of the Priority1/Priority2 strategy used across the network.

Procedure

1. Initiate a graceful changeover by:

   Adjusting the priority setting of one of the Grandmasters to force the BMCA to favor the backup.

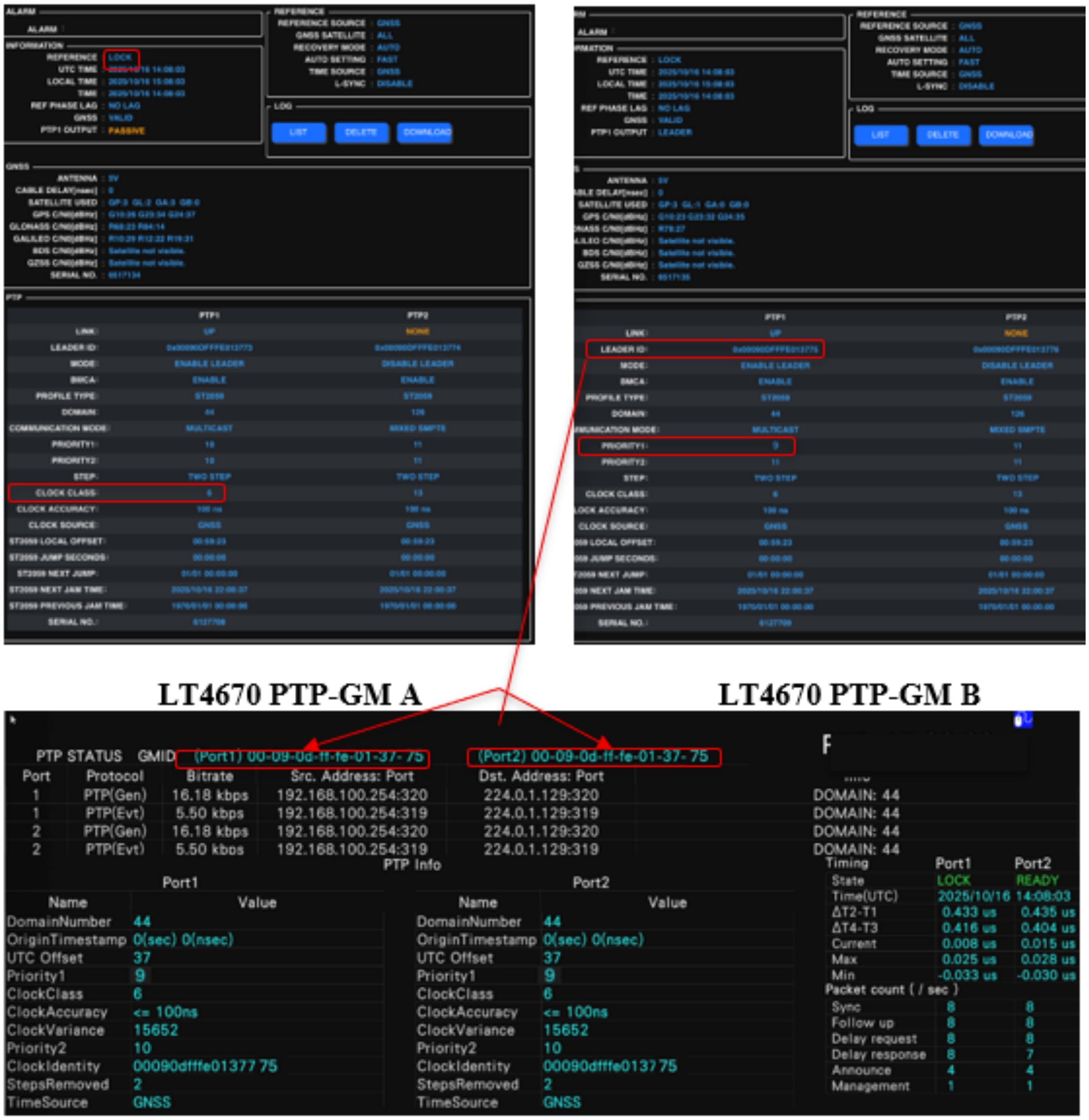
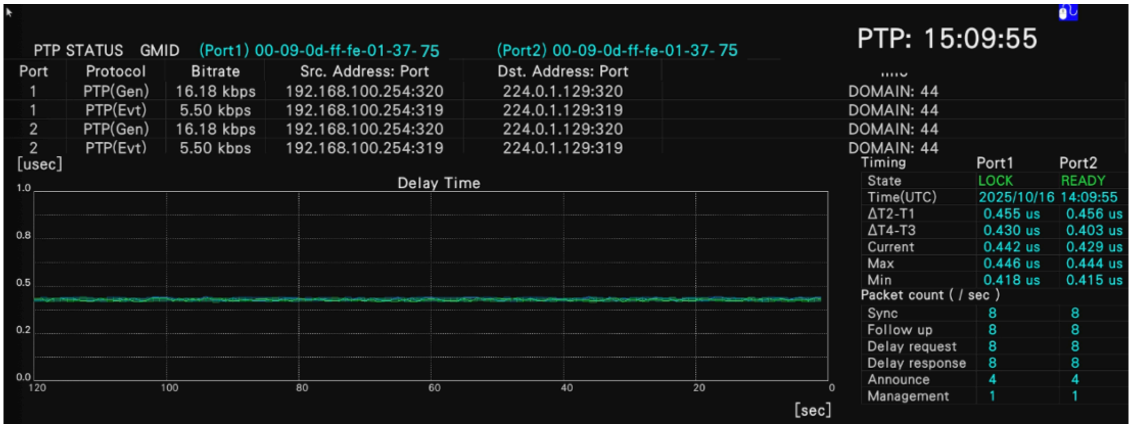


Figure 7: Adjusting Priority (Priority1 0 set to 9 instead of 10)

2. Observe follower behavior during the transition to the backup GM on both the Delay Time and Time Offset



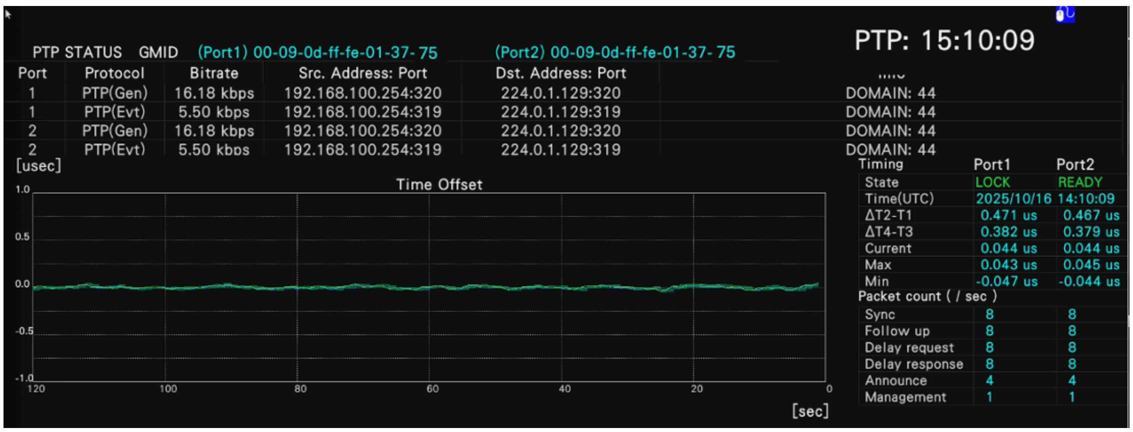


Figure 8: Delay time & Time offset graphs (PTP-GM A -> PTP-GM B)

The Delay Time and Time Offset graphs should show minimal variation as the backup GM takes over. The overlap in GM messages allows continuous lock.

Observed Behavior

- The primary LT4670 SPG GM continues to transmit PTP Announce and Sync messages.
- The backup LT4670 SPG GM detects the degraded quality, applies the BMCA, and begins transmitting Announce and Sync messages.
- For a brief period, both GMs transmit simultaneously. The primary GM then detects that the backup is now “better” and transitions to the passive state.
- Because PTP messages continue throughout, the followers experience minimal disruption and remain locked.

A video demonstrating this operation can be viewed on our YouTube channel.

Test 1a - Graceful Changeover with Continuous PTP Messages - Change Priority 1 and 2

Test #2 – Abrupt Changeover on loss of PTP Grandmaster by disabling PTP with BC intervention

During normal operation, an abrupt changeover event may occur if the active Grandmaster (GM) is disabled, reconfigured, loses its reference, or is manually switched from leader mode to follower mode. In these scenarios, the GM stops transmitting its Announce and Sync messages without warning. This type of failure represents the most common real-world GM outage condition and validates how quickly and cleanly the PTP network responds to a hard loss of timing.

Announce Timeout Behavior

- All Boundary Clocks and Followers on the PTP network continuously monitor incoming Announce messages to verify the presence and health of the active GM.
- Each device uses an Announce Timeout Count, which defines how many consecutive Announce messages can be missed before the GM is declared lost.
- This timeout count is typically configurable between 2 and 10, with the industry-standard default set to 3.
- With a typical Announce interval of 1 second, missing three consecutive Announce messages means that followers and boundary clocks will declare the GM lost after approximately 3 seconds.
- Once the timeout expires, all devices immediately trigger the Best Master Clock Algorithm (BMCA) to identify and select a new Grandmaster.

Preferred Test Method

Test procedure and observations — Grandmaster disable

Procedure

1. Disable PTP on the primary Grandmaster (primary LT4670 SPG) by administratively disabling PTP Port 1.
2. Observe system behavior during the changeover to the backup Grandmaster.
3. It is not uncommon when an abrupt failure occurs on the Primary LT4670 SPG GM for the Boundary Clock switch to become the Grandmaster momentarily, as the backup LT4670 SPG is initially 'Passive' and not transmitting Announce and Sync messages.
4. Because PTP messages continue throughout, the followers experience minimal disruption and remain locked.

Observed behavior

- The abrupt loss of the Primary LT4670 SPG GM caused the media node (LV5600W/LV7600W/QxL/QxP/LPX500) to report a loss of lock while the IP media switches and network BMCA transitions to the Backup LT4670 SPG GM.
- Figure 9 shows a substantially larger disturbance - several milliseconds - that can occur resulting in the Boundary Clock switch momentarily becoming the GM, before the backup LT4670 SPG is selected as GM by the BMCA.

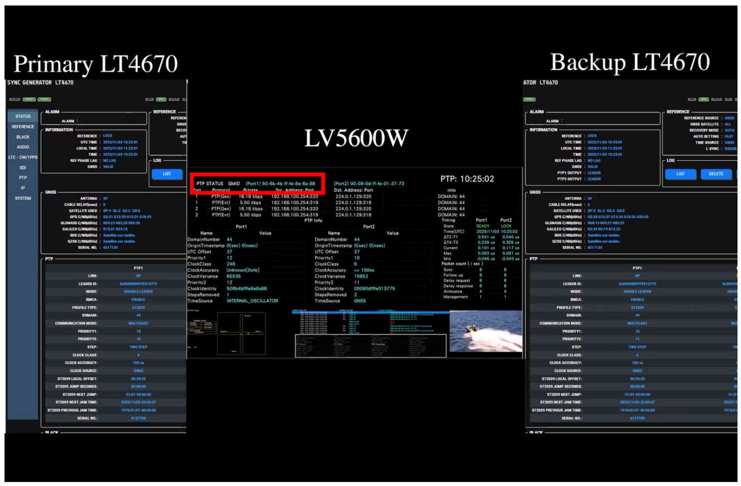


Figure 9: Boundary Clock GM Intervention

Interpretation

- The small, short-lived offset when switching to a backup GM (a few 10s–100s of microseconds or less, depending on equipment) is expected and acceptable: it is caused by slight time differences between the GNSS receivers and is corrected by the follower's PTP servo loop.
- The multi-millisecond disturbance seen with legacy boundary clocks indicates a slower or less stable internal servo/holdover behavior in the boundary clock, or abrupt timestamp/queueing anomalies introduced by the switch. While the BMCA process still provides continuity of PTP messages, the larger offset may impact media alignment or time-critical workflows and therefore needs remediation.

Suggested mitigations / follow-up tests

1. **Evaluate boundary clock firmware and replacement** - if older BCs produce multi-ms disturbances, consider firmware upgrades or replacement with boundary clocks known to have fast holdover and low jitter.

2. **Tune follower servo / holdover parameters** - where configurable, adjust servo loop filters and holdover behavior to smooth transitions and reduce overshoot during GM changeover.

3. **Topology / redundancy review -** reduce single points of failure (e.g., avoid chain switch topologies where a boundary clock masks loss until it becomes GM), or introduce a more deterministic switchover path (dedicated sync distribution or prioritized GM candidates).

A video demonstrating this operation can be viewed on our YouTube channel.

Test 2- Abrupt Changeover on loss of PTP Grandmaster by Disabling PTP with Boundary Clock Intervention

Test #3 – Abrupt Changeover on loss of Loss of Link carrying PTP from GM

During live operation, a Grandmaster (GM) changeover may not only be triggered by GM configuration changes or loss of reference, but also by physical layer failures. These failures interrupt the transport of PTP Announce and Sync messages even though the GM itself may still be functioning correctly.

Typical causes include:

- Fiber or copper cable disconnection
- SFP (Small Form-factor Pluggable) transceiver failure
- Switch port failure or port shutdown
- Optical power drop or connector contamination
- Faulty patch panel or distribution frame connection

Any of these issues can abruptly stop PTP packets from reaching downstream Boundary Clocks and Followers.

When the physical link carrying PTP from the Grandmaster fails, the effect at the receiving end is identical to a sudden GM outage. Devices immediately stop receiving Announce and Sync messages from the active GM, triggering the Announce Timeout mechanism.

Once the configured Announce Timeout (typically 3 seconds) expires, all affected devices declare the GM lost and initiate the Best Master Clock Algorithm (BMCA) to elect a new Grandmaster.

Description

During live operation, a changeover can also be triggered by physical layer issues such as:

- Fiber or copper cable disconnection
- SFP (Small Form-factor Pluggable) transceiver failure

Observed behavior

- In some cases, the resulting changeover is indistinguishable from Test 2 (Grandmaster port disable), since the loss of PTP traffic forces the BMCA process after the Announce timeout expires.
- In other cases, the switch hardware detects the link-down event immediately and triggers the BMCA process more rapidly, reducing the detection delay compared to the normal Announce timeout.

Interpretation

- Overall, this type of failure is typically equivalent to, or less stressful than, Test 2, because the system is reacting to a clear physical link-down condition rather than an abrupt but still "up" port.
- However, when monitoring PTP traffic, the sequence of events may look quite different, since the transition to the backup GM is triggered by link state rather than missed Announce messages.

Procedure

Disconnect the PTP link at the GM and monitor the system behavior during the changeover. Wait five minutes then reconnect the link to initiate the recovery and observe the system behavior during the recovery.

A video demonstrating this operation can be viewed on our YouTube channel.

Test 3- Abrupt Changeover on loss of Link carrying PTP from GM

Test #4 – Loss of Power to the Active GM

During live operations, the loss of power to the active GM will result in the interrupt of the transport of PTP Announce and Sync messages.

Procedure

1. Remove power from the active Grandmaster (e.g., by disconnecting its power supply or tripping the circuit).
2. Monitor the behavior of the PTP system during the changeover to the backup Grandmaster.
3. After several minutes, restore power to the original GM and observe the behavior during its recovery and re-election.

Observed behavior

- A complete loss of power to the GM is typically equivalent to Test 2 or Test 3, depending on the GM design and network configuration. The PTP traffic stops abruptly, and the backup GM is selected through the BMCA process.

  - The critical difference occurs during recovery. When the GM reboots, it takes time to:
    - Initialize its hardware
    - Lock to its GNSS or external reference
    - Stabilize its internal oscillator

  - If the GM begins transmitting Announce and Sync messages before it is fully stabilized, followers may re-select it prematurely. This can result in a significant timing jump when the GM clock shifts to align with its reference.

  - The Leader LT4670 SPG features the ability to be configured so that it cannot automatically return to being the GM, by setting the PTP BMCA Setup to Enable Only Once.

Interpretation

- This test highlights the importance of a well-designed GM startup sequence. The GM must suppress PTP message transmission until its timing is accurate and stable.

- Recovery is most graceful when:
  - The GM advertises itself only after achieving reference lock.
  - The BMCA process then naturally promotes it back to Grandmaster without introducing a large phase disturbance.

- Poor implementations may cause noticeable service disruptions during GM recovery.

A video demonstrating this operation can be viewed on our YouTube channel.

[Test 4 - Abrupt lose of PTP - Power Outage]

Summary comparison table with the SMPTE ST 2059-2 parameters

TEST	TRIGGER CONDITION	CHANGEOVER BEHAVIOUR	DISRUPTION RISK	KEY CONSIDERATIONS	RELEVANT ST 2059-2 PARAMETERS
1 GRACEFUL CHANGEOVER WITH CONTINUOUS PTP MESSAGES	GM loses GNSS/reference (holdover) or priority changed	Both GMs briefly send; backup elected; primary goes passive	Minimal — followers stay locked	Ensure recovering GM does not re-transmit PTP until stable	Announce Interval (commonly 1s); Priority1/Priority2 values determine BMCA outcome
2 LOSS OF REFERENCE INPUT (ANNOUNCE TIMEOUT)	GM stops sending valid Announce messages	Backup elected after Announce Timeout expires	Short disturbance during timeout	Failover speed depends on timeout configuration	Announce Interval (default 1s); Announce Timeout Count = 3 (typ. 3s switchover)
3 LOSS OF LINK/SFP/FIBER	Interface or fiber failure	Switch detects link down → BMCA triggers	Equivalent or less stressful than Test 2	Timing of BMCA depends on switch detection speed	Announce Interval, Sync Interval; switch failure detection time dominates
4 GM POWER LOSS	Power removed from active GM	Backup elected after loss; recovery requires reboot	Disturbance on failover; risk of phase step on recovery	GM must re-stabilize before re-announcing	Announce Timeout Count, Sync Interval, GM holdover/re-init behavior

Table 1: GM Changeover Tests with Key ST 2059-2 Parameters

This way, engineers commissioning a system can map each test to the protocol timers that control failover and recovery behavior.

Preventing unnecessary PTP Grandmaster Changeover

IT systems typically use a main/backup architecture where, if the main system fails, it automatically switches to the backup and then automatically reverts to the main system once the issue is resolved—without engineer intervention.

In traditional SDI infrastructures using a pair of Leader LT4670 SPG units with an LT4448 ECO, the behavior is different. Once the LT4448 ECO switches to the backup LT4670 SPG due to a fault on the primary, the system continues operating from the backup even after the primary has recovered. Restoring the primary

LT4670 SPG as the active reference requires a manual reset of the LT4448 ECO unit by a broadcast engineer.

To replicate this operational behavior in a PTP environment, the primary LT4670 SPG should be configured with BMCA Enable Only Once. This prevents the primary unit from automatically reclaiming Grandmaster status after it recovers, even if the BMCA process would normally promote it again.

This configuration ensures that the PTP system mirrors the familiar SDI failover and recovery behavior of the LT4670 SPG/LT4448 ECO setup.

Figure 10 illustrates how to configure 'Enable Only Once' on the primary LT4670 SPG to prevent a second unnecessary Grandmaster changeover.

Figure 10: PTP - BMCA - Enable only once

Videos demonstrating this operation can be viewed on our YouTube channel.

[Enable Only Once : Preventing Unnecessary PTP Grandmaster Changeover]

Reference Mismatch

A BB/TLS and PTP reference mismatch occurs when broadcast equipment that relies on both a Black Burst/Tri-Level Sync (BB/TLS) reference and a Precision Time Protocol (PTP) reference detects a discrepancy between the two-timing sources.

To overcome this issue, most broadcast facilities use products such as the Leader LT4670 SPG 'True Hybrid' IP and SDI SPG, that feature a single oven controlled internal oscillator, that all the references output sources are synchronised to.

However, in larger systems that employ redundant LT4670 SPG units in combination with an LT4448 ECO unit, additional failure scenarios can arise.

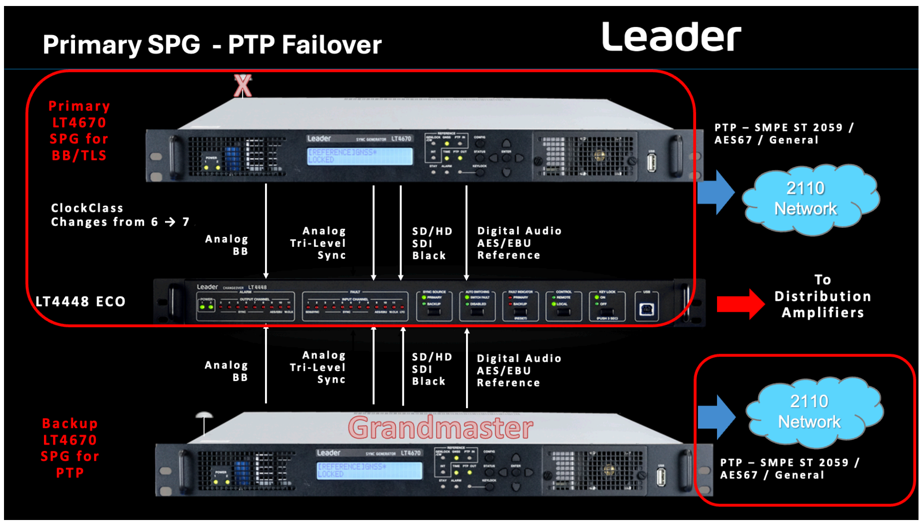
These can introduce conditions where the BB/TLS and PTP references end up coming from different LT4670 SPG's and causing reference signals to drift out of alignment, resulting in a reference mismatch.

These include the following scenarios:

Reference Mismatch – Scenaro#1 - Change of Grandmaster

When the PTP Grandmaster changes its ClockClass - for example, switching from a GPS-locked state (ClockClass 6) to 'Stay-In-Sync' mode (ClockClass 7) - the system indicates that its timing accuracy or stability has degraded.

If another LT4670 SPG on the network remains GPS-locked and therefore offers a higher-quality reference, the Best Master Clock Algorithm (BMCA) will automatically select it as the new Grandmaster.



This can result in a reference mismatch, where the PTP reference and BB/TLS reference are sourced from different LT4670 SPG units. Such a condition may lead to frame sync errors, video phase offsets, or lip-sync issues in mixed SDI/IP environments.

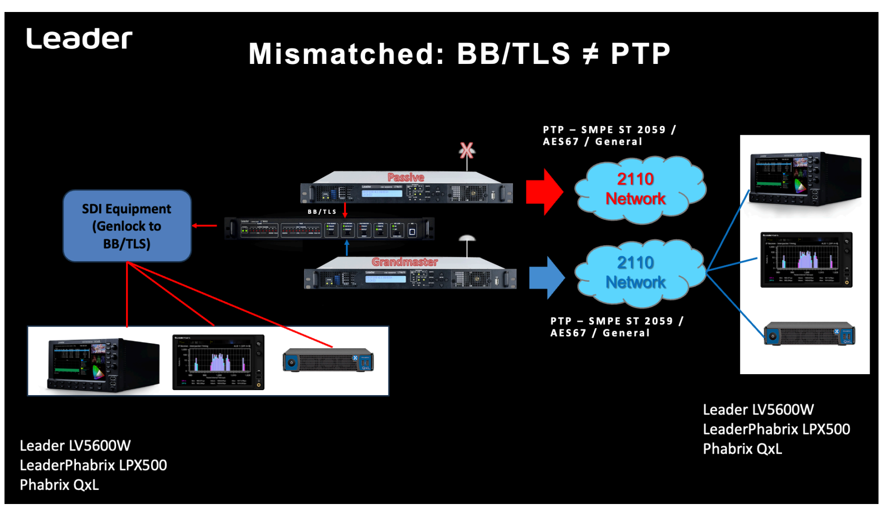
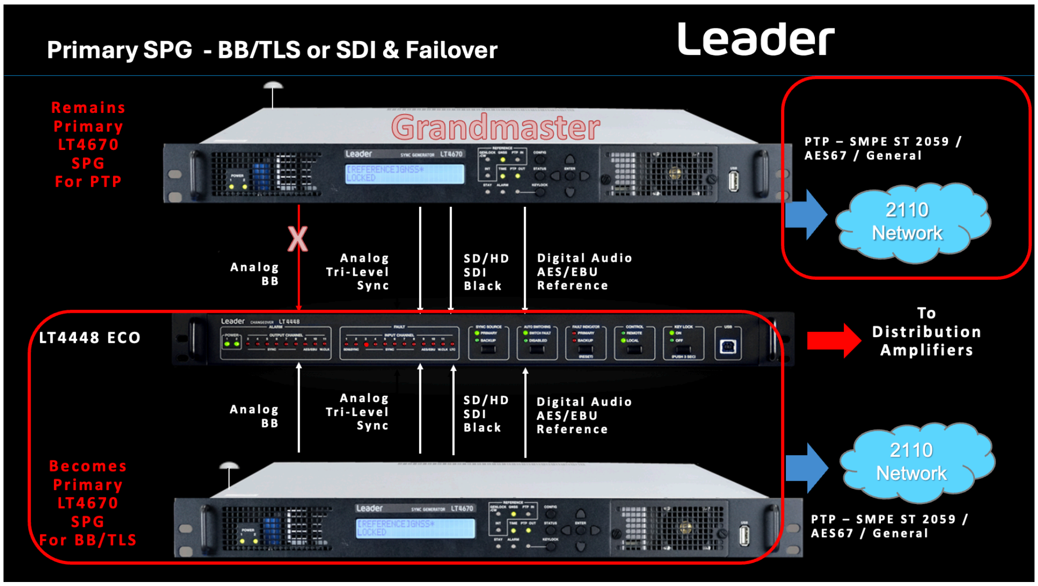


Figure 11: Mismatched: BB/TLS Failure PTP Phase-Aligned

Reference Mismatch – Scenario #2 – BB/TLS Failure

When the primary LT4670 SPG experiences a BB/TLS or SDI reference output failure, the LT4448 ECO Unit detects the fault and automatically switches to the backup LT4670 SPG. However, because the LT4448 ECO Unit is not part of the Best Master Clock Algorithm (BMCA), the primary LT4670 SPG continues to act as the PTP Grandmaster, even though its baseband reference has failed.



This results in a reference mismatch, where the BB/TLS and PTP references originate from different LT4670 SPG units. This condition can lead to frame sync errors, video phase offsets, or lip-sync issues in mixed SDI/IP environments.

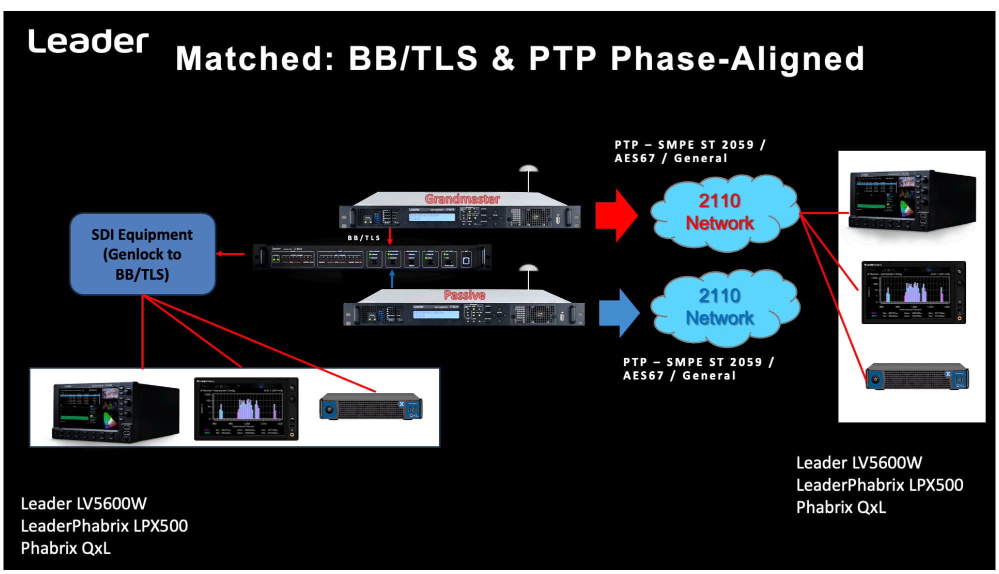


Figure 12: Matched: BB/TLS & PTP Phase-Aligned

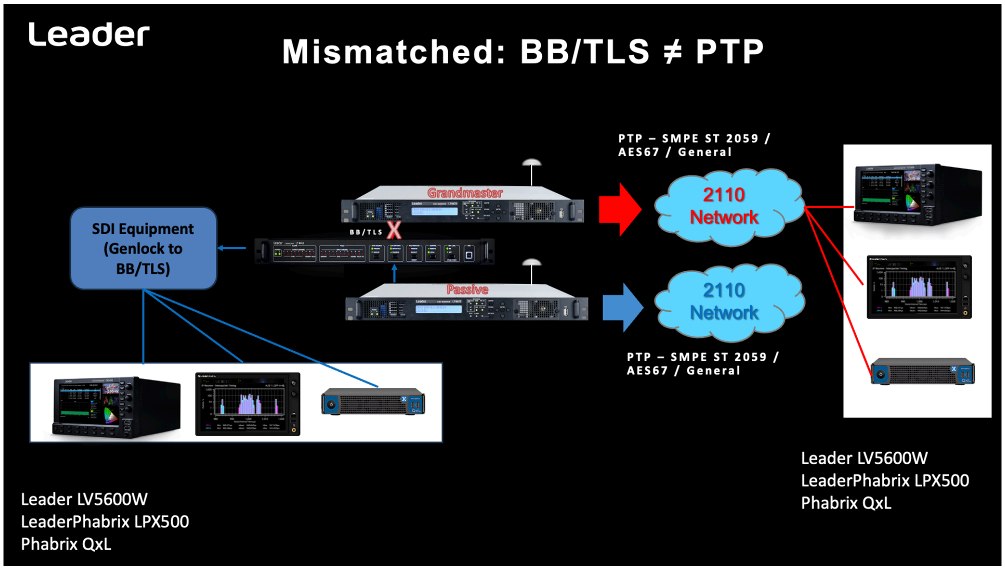


Figure 13: Mismatched: Loss of GPS - BB/TLS PTP Phase Aligned

In broadcast timing, a **reference mismatch** between **Black Burst/Tri-Level Sync (BB/TLS)** and **PTP** occurs when the two-timing reference systems within a facility are no longer **phase-aligned** or **coherent** with each other.

This typically happens when the **PTP time** and the **BB/TLS reference** are not derived from the **same master Sync Pulse Generator (SPG)**, resulting in timing discrepancies between IP and SDI-based systems.

Why It Matters

- In **hybrid environments** (SDI + IP), many devices still require **both references simultaneously**, even those that are IP only.
- If BB/TLS and PTP don't exactly match, signals will not be properly aligned, making it impossible to do frame-accurate IP↔SDI transitions.
- Changeover units and hybrid SPGs (like Leader LT4670 SPG and LT4448 ECO are designed to ensure **phase-coherent generation of both BB/TLS and PTP** from a single master reference.

Recommended Reference Mismatch Tests

1. Test#5 - Change of Grandmaster LT4670 SPG
2. Test#6 BB/TLS Failure

Test 5 – Reference Mismatch – BB/TLS, Digital Audio and SDI switching on PTP failure

When the primary LT4670 SPG is no longer designated as the Grandmaster by the Best Master Clock Algorithm (BMCA), a reference mismatch can occur. In this condition, the BB/TLS, SDI, Digital Audio, and PTP reference sources may originate from different LT4670 SPG units.

Such mismatches can introduce frame synchronization errors, video phase offsets, and lip-sync discrepancies, especially in hybrid SDI/IP production environments where precise timing alignment is critical.

To resolve this issue, Leader developed the LC-2185 Interconnect Cable, which directly links two LT4670 SPG units and the LT4448 ECO Unit. This hardware connection enables coordinated failover control between the reference sources.

In the event of a Grandmaster change, the primary LT4670 SPG can monitor PTP1 and/or PTP2 status and trigger a Black or SDI failure condition as needed. This is achieved by enabling the "Link to PTP1/2 BMCA" function in the primary LT4670 SPG configuration menu.

This coordinated operation ensures that both SDI and IP reference systems remain phase-aligned, maintaining seamless timing integrity and synchronization continuity across the entire production workflow.

Procedure

1. Configure Primary LT4670 SPG Enable Black1 to BMCA Link. The black output is stopped in linkage with BMCA of the selected PTP.
2. Remove GPS so Primary LT4670 SPG switches from Clockclass 6 to 7 and backup LT4670 SPG becomes Grandmaster
3. Observe system behavior during the changeover to the backup Grandmaster.
4. Monitor the BB output during the changeover

Any of the previously mentioned (4) four tests can be used to introduce a PTP failure.

1. Smooth changeover with continuous PTP messages
2. Abrupt changeover with loss of PTP from Grandmaster
3. Abrupt changeover on failure of link carrying PTP
4. Power outage on active Grandmaster

And you will be able to verify via the test and measurement product event log, that the PTP failure has resulted in the select of a new GM.

Videos demonstrating this operation can be viewed on the Leader YouTube channel.

Reference Mismatch - Test #5 - Grandmaster Changeover

Test 6 – Reference Mismatch – BB/TLS/Digital Audio/SDI failure

When the primary LT4670 SPG experiences a Black Burst/Tri-Level Sync (BB/TLS) or SDI reference output failure, the LT4448 ECO Unit automatically detects the fault and switches the reference outputs to the backup LT4670 SPG.

However, because the LT4448 ECO unit operates independently of the Best Master Clock Algorithm (BMCA), the primary LT4670 SPG continues to act as the PTP Grandmaster, even though its baseband reference has failed.

This creates a reference mismatch condition in which the BB/TLS and PTP reference sources originate from different LT4670 SPG units. Such a mismatch can result in frame sync errors, video phase offsets, and lip-sync issues, particularly in hybrid SDI/IP production environments.

To eliminate this issue, Leader has developed the LC-2185 Interconnect Cable, which links the two LT4670 SPG units and the LT4448 ECO Unit. In the event of a BB/TLS failure, the LC-2185 automatically adjusts the Priority 1 value of the backup LT4670 SPG, prompting the BMCA to re-elect it as the PTP Grandmaster.

This coordinated failover ensures that both the baseband and IP reference systems remain phase-aligned, maintaining seamless timing integrity across the entire production chain.

Procedure

1. Configure Backup LT4670 SPG Link to Changeover
    a. When BB/TLS, Digital Audio or SDI output fails, the backup LT4670 SPG will change Priority1 to 0 and the BMCA will switch Grandmaster
2. Switch BB off on Primary LT4670 SPG
3. Observe system behavior during the changeover to the backup Grandmaster.
4. Monitor the PTP output during the changeover

Videos demonstrating this operation can be viewed on our YouTube channel.

Reference Mismatch - Test #6 - BB TLS Changeover

Conclusion

Precision Time Protocol (PTP) can provide a highly reliable timing system for IP media networks. However, understanding how changeover occurs between primary and backup Grandmasters under different system configurations is critical to ensuring error-free operation.

The series of tests outlined in this document represent an important part of the commissioning process. In addition to Grandmaster failover scenarios, engineering staff should also conduct tests involving the switching fabric, IP media node endpoints, and other GM-specific behaviours.

By performing these tests during the initial design and commissioning of the installation, engineering teams gain valuable familiarity with the operational performance of PTP. They can directly observe system behaviour in response to network changes and validate that Grandmaster changeovers occur smoothly and within specification.

A solid understanding of PTP - and specifically how changeovers impact switches, boundary clocks, and media nodes - enables engineers to quickly diagnose and resolve timing issues if they arise. Ultimately, structured testing provides confidence that the PTP system will maintain robust synchronization and deliver reliable performance in live production environments.

Learn more

Find out more information on the LT4670 SPG and LT4448 ECO unit timing reference system

https://leaderphabrix.com/products/LT4670 SPG-sync-generator/

https://leaderphabrix.com/products/LT4448 ECO-changeover/

Essential Guide to PTP