
QSC™ SYSTEMS



Technical Notes

Q-LAN™ Networking Overview



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Q-SYS™

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Introduction

The intention of this document is to provide network administrators with the requirements necessary to implement the Q-SYS Platform on a converged network. Q-LAN™ is a suite of network protocols and requirements required for the Q-SYS Platform.

The Q-SYS Network

All Q-LAN protocols are Internet Protocol (IP) based and can easily reside on either Layer-2 (single VLAN) or Layer-3 (multi-VLAN and Routed) networks. Since Q-SYS is a live audio and control system, real-time performance is critical within the network environment.

On a Layer-3 network, routers (or Layer-3 switches) replace some, or all of the Layer-2 network switches. Therefore, Layer-3 network devices must have the same performance (or better) and minimum features as the Layer-2 switches they replace.

Q-LAN Protocol Suite for use with Q-SYS Designer Software v4.0 or later

(for differences in prior releases, see Appendix)

Sampling Clock

- Q-LAN sample clock requires real-time performance (QoS Strict Priority Queuing)
- Marked DSCP 46 (EF) for QoS prioritization - **See Quality of Service section**
- IEEE 1588-2008 Precision Time Protocol (PTPv2) for synchronization
- A Q-SYS Core is, by default, the PTP Grandmaster for all Q-SYS peripheral devices
- UDP on Ports 319 and 320 (registered to NIST/IEEE)
- Destination IP is 224.0.1.129 (multi cast – registered to NIST/IEEE)
- ≤100 packets per second
- ≤100 bytes per packet

Audio Streams

- Q-LAN audio streams require real-time performance (QoS Strict Priority Queuing).
- Marked DSCP 34 (AF41) for QoS prioritization - **See Quality of Service section**
- Unicast from Source to Destination (Q-SYS Core to peripheral or vice-versa)
- Destination Port UDP 6517 for all audio streams
- Source Port UDP range 6518-7030 (one port per stream) assigned to each stream
- Destination Ports UDP 6518-7030 are used for RTCP control of each audio stream.
- 100 acknowledgements are sent every second and contain receiver-side stats.
 - » Although not real-time critical, provisions should be made to ensure that RTCP packets are not dropped, thus, these packets are also marked as DSCP 34 (AF41).
- Each audio stream packet contains 16 samples of up to 16 audio channels.



- 3000 packets per second, per stream
- 100 to 1100 bytes per packet or 3.31 ~ 26.41 Mbps per stream – packet size depends on channel count per stream
- Audio sampling is 32-bit floating-point format (RTP)
- Audio Streams:
 - » Up to 256 in and/or out of each Q-SYS Core (varies by Core model)
 - » One stream in and/or out for each Q-SYS I/O-Frame, I/O-22 or Page Station
 - » Up to eight streams in and/or out for an I/O-Frame-8s
 - » Duplicate, identical, simultaneous streams are generated on Q-LAN-B ports if Network Redundancy is enabled

Control

- TCP and HTTP for Control Data and Core redundancy
- 10 Mbps or less
 - » Typically less than 2Mbps for non-redundant Q-SYS Systems
 - » Actual bandwidth depends upon connections to User Control Interfaces (UCI's), Redundant Core processors or 3rd party control systems

Latency

- Typical time on wire @ 1 GB $\leq 12\mu\text{s}$ (microseconds)
- Typical time on switch @ 1 GB $\leq 15\mu\text{s}$ (Packet Decision Time)
- Maximum time on switch @ 1 GB with overloaded Egress Queue $\leq 40\mu\text{s}$
- Maximum cumulative time on network = $333\mu\text{s}$ (transmitter to receiver)
 - » This is enough allowable latency to accommodate 7 switch hops at 1Gb/s under the worst QoS conditions.
- Option to increase Network Receive buffer size via Q-SYS Designer Software to accommodate very large or unusual network topologies.

IP Addressing

- Three methods are used to assign Q-SYS device IP addresses;
 - » Manual – (recommended)
 - » DHCP
 - » IPv4LL (Auto-IP)
- Q-SYS currently does not support IPv6

Quality of Service (QoS)

QoS considerations and requirements for a Q-SYS Networked Audio system

- Ensures timely delivery of time-sensitive Q-LAN packets
- Employs DiffServ, a.k.a. Differentiated Services Code Point (DSCP) packet marking
 - » DSCP 46 EF (Expedited Forwarding) for PTPv2
 - » DSCP 34 AF41 (Assured Forwarding) for Audio streams
 - » DSCP 0 for control data
- Minimum of four egress queues per switch port
- Strict Priority queue scheduling
 - » Other selection schemes (e.g. weighted round robin, shaped round robin, fair queuing, guaranteed minimum bandwidth) are not recommended
- Due to the sub-millisecond maximum-time-allowed on the network (333µs), Q-LAN is far more time-sensitive than typical Voice, Video or VC applications.
 - » Q-LAN PTP traffic must be assigned to the highest available priority queue
 - With some switch manufacturers, this is one level below a restricted network device communication and control queue
 - » Q-LAN Audio traffic must be assigned to the priority queue one level beneath the queue to which PTP is assigned
 - » All other traffic must be assigned to any of the remaining lower priority queues

QUEUE 4	• HIGHEST PRIORITY- QLAN PTP CLOCK
QUEUE 3	• QLAN AUDIO STREAMS
QUEUE 2	• VoIP / VIDEO
QUEUE 1	• LOWEST PRIORITY- ALL OTHER DATA

Suggested QoS table for converged network. Q-SYS is high-priority due to time-sensitive nature.

- The PTP and Q-LAN Audio queue priorities must also be maintained across any uplinks and cannot be shared with any identically-queued packets from other VLANs being sent via the same uplinks in a VLAN Trunk.



- Each network switch port used for Q-LAN packets must provide a minimum 40kB of Egress queue memory (including any uplink ports which carry Q-LAN traffic).
 - » This memory is typically referred to in network switch data-sheets as ‘Packet Buffer Memory.’
 - » In many fixed-port switches, the total amount of Packet Buffer Memory is automatically divided evenly amongst all ports with no ability to assign varying amounts of memory to different ports.
 - **Switch Example 1:** 512KB Packet Buffer Memory ÷ 24 Ports = 21.33KB/port < 40KB/port
 - » Result = Disqualified
 - **Switch Example 2:** 1.5MB Packet Buffer Memory ÷ 24 Ports = 62.5KB/port ≥40KB/port
 - » Result = Not Disqualified
- Do not enable bandwidth throttling (a.k.a. Traffic Shaping / Policing) on ports connected to Q-SYS Cores or I/O devices or on any uplinks passing Q-LAN traffic.

Troubleshooting suspected QoS issues

Q-LAN Audio packets must pass from Source to Destination within 333µs or they will be considered “too late”. As a real-time audio system, timely delivery of Q-SYS Clock and Audio packets is critical. With Verbose mode enabled on Q-SYS Core and Peripheral device Status components, detailed network performance statistics can be viewed.

Status
IOfFrame-1

Slot D	Blank
Verbose	No <input type="checkbox"/>
	Yes <input type="checkbox"/>
	No <input type="checkbox"/>

Verbose mode settings found in the properties of a Q-SYS Core & peripheral device Status Component

- “drop_count” shows the number of packets that were delivered too late (outside of the 333µs time allowed on the network) and have therefore been disregarded by the destination Q-SYS device. This also applies to packets received out of sequential order.
- “missing_count” is a count of expected packets which were not received by the destination Q-SYS Device.

```
accept_count 27813141
drop_count 4
on_time 27813141
too_late 2
very_late 2
```

Example Verbose Status window showing network QoS performance issues

“Too_late” and “very_late” indicate that these packets were delivered outside of the 333µs limit. This results in poor QoS performance.

```
accept_count 26434603
missing_count 1380287
on_time 26434603
```

Example Verbose Status window showing network delivery issues

“Missing_count” indicates those packets were not received by the Q-SYS device. They were dropped by the network.

Device Discovery and Multicast Routing

Multicast Routing

For Q-SYS to function properly when spread across a Layer-3 network, the network must be configured to route Q-SYS unicast packets between subnets, but also must be configured to route the multicast traffic used by the Device Discovery (QDP) and PTPv2 sample-clock protocols. The most common (and recommended) protocol for routing multi cast data is Protocol Independent Multi cast Sparse Mode (PIM-SM) as it is the most efficient on network resources for paths and ports which don't need Q-LAN multicast data.

- QDP (Q-SYS Discovery Protocol)
 - » UDP Destination IP 224.0.23.175 – registered exclusively to QSC Audio, LLC by IANA. Used to identify Q-SYS products on the network by name regardless of IP address
- IEEE 1588 PTPv2
 - » UDP Destination IP 224.0.1.129 – registered to NIST/IEEE

IGMP

Q-SYS devices implement Internet Group Management Protocol Version 2 (IGMPv2). IGMP allows Q-SYS devices to register with the switched network to receive specific multi cast transmissions.

For IGMP to function properly, an IGMP Querier must be present on the VLAN. Otherwise, Q-SYS devices, which depend upon multi cast packets for device discovery and sample clock, will cease to function. This is because the IGMP Snooping filters in switches belonging to this VLAN will restrict multi cast transmissions to any switch ports for which it has not detected a Membership Group Report for a period of time (typically two to three minutes).

Q-SYS devices are designed to generate IGMPv2 Multi cast Group Requests once upon startup, and then only when queried by an IGMP Querier somewhere on the VLAN. If no switch or router on a given VLAN has an IGMP Querier enabled, IGMP Snooping must be disabled on all switches or on ports assigned to VLANs utilizing multi cast data.

To mix Q-LAN with other sources of multi cast, such as video encoders, IGMP is required to prevent foreign multi-casts from being sent to ports used for Q-SYS equipment (and vice-versa).



Troubleshooting Tip 1: Disable IGMP Snooping if Q-SYS hardware objects disappear from the Q-SYS Designer Configurator window after they have previously appeared.

Troubleshooting Tip 2: If Q-SYS equipment appears and disappears from Q-SYS Designer Configurator repeatedly over the course of several minutes, it indicates the presence of an IGMP Querier, yet the IGMP Snooping member expiration settings on a network switch are set to be shorter than the interval of queries from the Querier. For example, if an IGMP Querier sends queries every 300 seconds, yet the IGMP Snooping rules are defined to remove members from multi cast group tables after 125 seconds, devices will disappear for 175 seconds until the next query is sent.



Using Q-LAN with other common Networked Audio Protocols

Dante

Dante requires a different QoS configuration when compared to Q-LAN so Dante audio may only be shared on a single VLAN with Q-LAN if other metrics besides DSCP markings are used to classify both Q-LAN and Dante data. This is because Dante uses DSCP 56 and 46 for PTP and audio (respectively), whereas Q-LAN uses DSCP 46 and 34 for PTP and audio. Therefore, the DSCP 46-tagged Dante Audio traffic is likely to disrupt the DSCP 46-tagged Q-LAN PTP packet latency.

If Dante and Q-LAN are required to share a switch featuring only one QoS rule table (most lower-end switches), the only option is to keep Dante and Q-LAN ports on separate VLANs, but the QoS classification rules can be set up this way (note: no VLAN trunking allowed);

- Highest Queue: Dante PTP (DSCP 56 – CS7)
- Medium-High Queue: Q-LAN PTP & Dante Audio (DSCP 46 – EF)
- Medium-Low Queue: Q-LAN audio (DSCP 34 – AF41)
- Lowest Queue: Everything Else

If the switch has the capability of classifying packets based on Ethernet encapsulation type and/ or UDP Source port then Q-LAN and Dante can be made to function within the same VLAN.

In this case, it can be safe to assign both Q-LAN PTP and Dante PTP to the highest priority queue. Likewise, assigning Q-LAN audio and Dante audio within the same next highest priority queue can also be safe.

Audio Video Bridging (AVB)

Q-LAN and AVB cannot be made to co-exist on a single VLAN on a given switch or across shared uplinks under any circumstances (in separate VLANs or not). Bandwidth Reservation schemes required by AVB specifically request dynamic switch configurations that are contradictory and harmful to the PTP Clock and RTP Audio packet priority requirements of Q-LAN.

Typically, even with the availability of a Q-SYS AVB Bridge I/O Card, Q-LAN is rarely transported across an AVB-compliant switch that has its IEEE 802.1AS / 802.1Qat / 802.1Qav features enabled. Enabling this functionality effectively overrides the normal QoS functionality of the switch.

Some AVB-capable switches are also approved for use with Q-LAN as long as the AVB functionality is disabled.

Voice and Video over IP

VoIP and Video / VC systems are designed to tolerate network latencies between 50-150 milliseconds, while Q-LAN requires maximum network latencies measured in microseconds.

As a result, Q-LAN PTP and audio must always be placed in a higher priority queue than Voice, Video or Video Conferencing applications.

SIP Softphone Interface

The Q-SYS system is capable of generating multiple software-based SIP endpoints (called Softphones) to enable VoIP functionality, commonly used in Audio Conferencing applications or integration with broader VC or UC&C environments. In order to do so, the following considerations are important;

- Standard SIP and Media UDP protocols on Port 5060
- Supports out-of-band DTMF RTP Events (RFC2833), Caller ID, Redial, Auto-Answer, and Do Not Disturb

Analog Telephone Interface

Q-SYS can support POTS (analog) telephone lines with the addition of an FXO Gateway (a.k.a. ATA or Analog Telephone Adapter).

- The following devices have been successfully tested with the Q-SYS Softphone:
 - » Multiport models (do not purchase any model featuring an FXS port):
 - Patton Smart Node SN4112 FXO* / SN4114 FXO* (2 or 4 port models)
 - AudioCodes MP-114-FXO / MP-118-FXO (4 or 8 port models)
 - Grandstream GXW4104 / GXW4108 (4 or 8 port models)
 - Audio Codes Mediant 1000* (up to 24 FXO ports or T1/PRI in 1 Rack Unit)
 - » Single port models
 - Cisco SPA232D*
 - Obihai OBi110 (no longer recommended by QSC, but works)
 - Cisco SPA3102 (end-of-life has been issued by Cisco, but works)

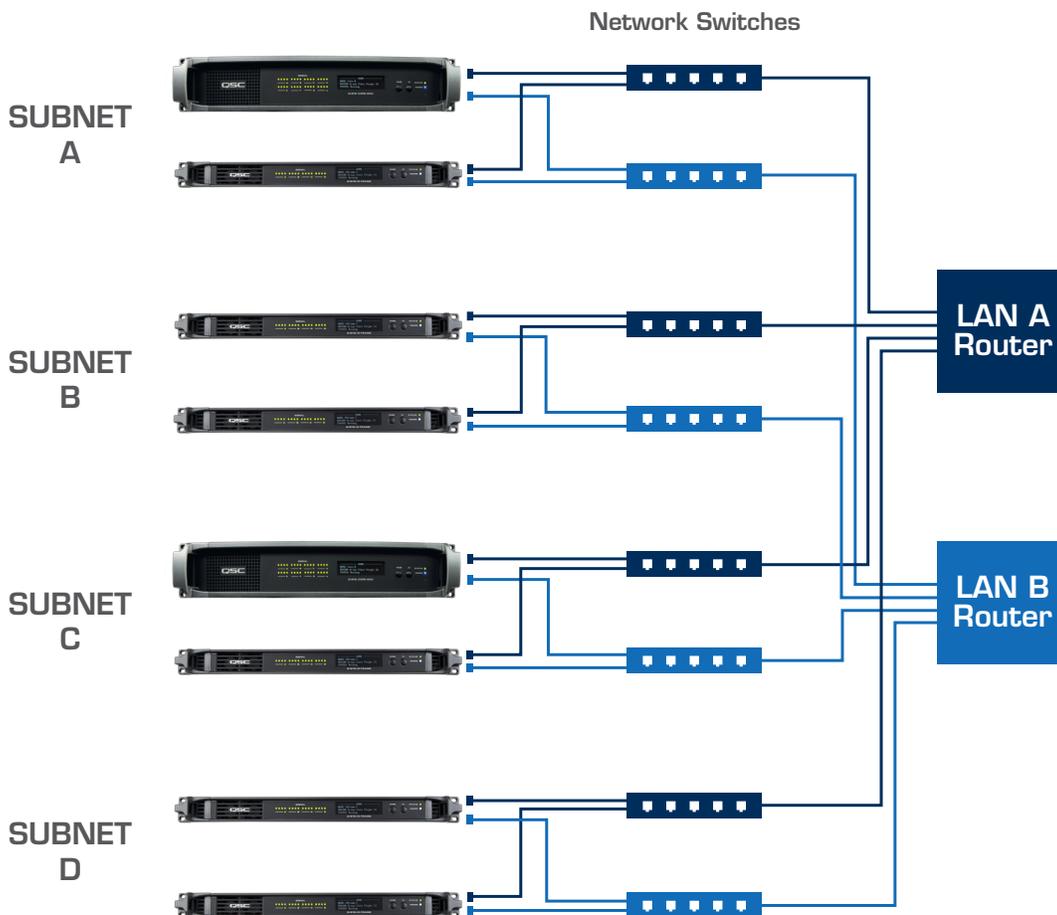
*QSC recommends these models.



Configuring Q-SYS Cores with Redundant Routed Networks

Background:

In very large Q-SYS networks, multiple subnets may be desired, requiring the use of routers for successful communication between different network segments. If the redundant network connections on the Q-SYS devices (LAN A and LAN B) are being used in this model, two independent routed networks may exist. This document addresses the configuration of the Q-SYS devices on such networks.



In the above example, consider four redundant subnets with a router for each of “LAN A” and “LAN B”. Each subnet will have an IP gateway through which traffic to other subnets will be forwarded. The appropriate gateway entries are added to each unit’s Ethernet settings in Q-SYS Configurator.

LAN A MAC : 00:19:0F:26:0F:1C
Wired To : c4:12:f5:e9:c8:ba : on
Mode : Static
IP Address : 192.168.1.101 Net Mask : 255.255.255.0 Gateway : 192.168.1.1
Static Routes +

LAN B MAC : 00:19:0F:26:0F:1B
Mode : Static
IP Address : 19.216.2.101 Net Mask : 255.255.255.0 Gateway : 0.0.0.0
Static Routes +

Note, however that it is **NOT VALID** practice to enter a gateway for each of LAN A and LAN B.

LAN A MAC : 00:19:0F:26:0F:1C
Wired To : c4:12:f5:e9:c8:ba : on
Mode : Static
IP Address : 192.168.1.101 Net Mask : 255.255.255.0 Gateway : 192.168.1.1
Static Routes +

LAN B MAC : 00:19:0F:26:0F:1B
Mode : Static
IP Address : 19.216.2.101 Net Mask : 255.255.255.0 Gateway : 192.168.1.1
Static Routes +

If this is done, then network communication will be unreliable, often resulting in “LAN A Communication Error” or “LAN B Communication Error” faults in the unit’s status.



To remedy this, “Static Routes” must be configured to reach the other subnets. Static routes represent a mask of addresses to be contacted (outside the device’s subnet) and what gateway should be used to contact them. They are exposed a units configuration by clicking on “+” to the right of the Static Routes heading, below the Gateway entry.

LAN A		MAC : 00:19:0F:26:0F:1C Wired To : c4:12:f5:e9:c8:ba : on	
IP Address :	192.168.1.101	Net Mask :	255.255.255.0
Mode :	Static		
Gateway :	0.0.0.0		
Static Routes +			
✘ IP Address :	192.1.168.0	Net Mask :	255.255.255.0
Gateway :	192.168.1.1		
LAN B		MAC : 00:19:0F:26:0F:1B	
IP Address :	19.216.2.101	Net Mask :	255.255.255.0
Mode :	Static		
Gateway :	0.0.0.0		
Static Routes +			
✘ IP Address :	192.168.0.0	Net Mask :	255.255.0.0
Gateway :	192.168.2.1		
DNS <input type="checkbox"/> Enable DNS			

IP Address: Inserting a ‘0’ indicates that all hosts within that subnet should follow that static route. All hosts on the same subnet of a given interface are ALWAYS contacted directly. In the example above, the static route contacts the specified gateway when contacting any address beginning with 192.168 that’s outside the 192.168.1.0 subnet.

Net Mask: This sets the mask for the static route. Any 0 in the IP Address field will need the corresponding 0 in the Netmask. Else, this entry follows the standards of subnet masking.

Gateway: Sets the gateway for the hosts within this Static Route. Using Static Routes in this and other similar network configurations will result in much more robust communication between the Q-SYS devices.

Miscellaneous Topics

Switch Requirements (Layer 2 or Layer 3)

- Managed switch
 - » Meaning it features a web or command-line configuration interface to allow configuration of QoS and other Q-LAN requirements
- Non-blocking
 - » Gigabit switch with bandwidth meeting or exceeding gigabit “wire speed” (or higher) on all ports simultaneously
 - » Gigabit ports on switches featuring predominantly Fast Ethernet ports are not acceptable.
- DiffServ Quality of Service
 - » Alternate DiffServ terminology: TOS, DSCP, Layer 3 QoS.
 - » If a switch’s data sheet only mentions COS and/or 802.1p and none of the alternate DiffServ terminology, it is cannot be used for Q-LAN.
- Packet forwarding delay of less than or equal to 15 microseconds
- No Jumbo Frames on any Q-LAN paths or uplinks (must be able to disable jumbo packet support)
- Some Q-SYS products support Media Endpoint Discovery (LLDP-MED)
 - » Not necessary for normal operation but LLDP-MED is required if the customer wishes to use the Q-SYS ‘Dynamic Pairing’ function in LLDP mode.
- Minimum of 40kB of Egress Queue Memory per switch port including any uplink ports which carry Q-LAN traffic. Sometimes referred to as Packet Buffer Memory.

Bandwidth Usage

- Bandwidth equation
 - » $\text{Mbps} = (1.77 \times \text{total stream count}) + (1.54 \times \text{total channel count})$.
 - » Streams are unicast, so incoming and outgoing bandwidth at each device is calculated separately.
- Dual redundant network configurations will produce the bandwidth shown above on both Core Q-LAN ports (LAN A and LAN B).
- Automatic Core bandwidth calculations are available on the “Check Design” screen, which is found under the File menu in Q-SYS Designer software.
- Core-to-Core redundant housekeeping data can be up to 10 Mbps when a Q-SYS System is being polled by a third-party control system such as AMX or Crestron.

Remote Connectivity and Firewall setup

It is possible to remotely connect to a Q-SYS Core over the Internet; this is particularly useful when providing service or support to projects remote from your office. In order to do so, a network connection between the Local and Remote networks must be established using VPN Tunnel technologies such as SSL, PPTP, L2TP/IPSec, OpenVPN, IKEv2, SSTP, etc.



Once a network route (VPN Tunnel) has been established then you may need to “Allow” the following ports in any hardware/software firewall:

- TCP 80 – Supervisory Functions
- TCP 1700 – Control Messaging
- UDP 6504 – Discovery

In addition to the firewall ports shown above, the PC must be able to exchange ICMP (ping) echo messages with the Core.

Note: ICMP messages may need to be “Allowed” on the firewall too.

Note: Q-LAN protocols are not compatible with NAT or PAT gateways (a.k.a. Port Forwarding) because those types of routers function by replacing the Layer 3 IP header addresses, which negatively affects the validity of the Layer 4 payload data. These routers cannot rewrite the Layer 4 payloads as the packets pass through to match the newly assigned Layer 3 IP header which means the Q-LAN packets are essentially corrupted.

A remote VPN connection functions properly because the remote user is provided access to the local IP address range used on the destination network. In this case, packets never have their Layer 3 IP headers modified from end-to-end. In other words, these local IP packets are “tunneled” to your remote machine.

Mesh or Cloud Networks

It is possible to route Q-LAN across a cloud network (such as MPLS or VPLS) as long as the following requirement is in place.

“Dynamic hashing” which determines specific pathways taken to traverse the mesh network must be configured to remain persistent (i.e. not dynamic). A typical dynamic mesh network continually prioritizes routes or paths based upon load-balancing across all available links. However, the convergence time for dynamically induced path changes is disruptive to the strict timing requirements of Q-LAN and one-chance nature of UDP. The disadvantages of traversing a non-deterministic and dynamically routed network can be overcome by setting switches to maintain persistent hashes for all Q-SYS device IP addresses. Examples of vendor-specific persistent path terminology are:

- Cisco: MPLS Static Labels
- Juniper: Static Label Switched Paths for MPLS (LSPs), etc.

Q-SYS Qualified Switch Program

QSC tests gigabit network switches which (according to the manufacturer data sheet) meet the minimum requirements listed above and have been pre-approved by QSC for testing. A representative switch model of at least 20 ports is typically required to approve an entire generational switch series (PoE capability is not important as the internal switch chipset will almost always be identical in both PoE and non-PoE models).

Typically, switch models tested by QSC are considered “Edge” or “Access” switches. QSC does not perform tests on Core or Distribution class switches because those are almost always running a vastly different configuration (featuring mostly 10 or 40Gb uplinks) than an Edge switch would be running.

Q-LAN can pass from Edge to Distribution to Core to Distribution to Edge as long as the requirements listed in this document are in place across all involved switches and/or routers.

Note: The most important aspects to keep in mind for large-scale networks are end-to-end cumulative packet latency (<333μs) and QoS prioritization throughout all hops.

QSC Qualified network switches have achieved the following while passing 512 x 512 audio channels between Q-SYS devices;

- No late or missing packets over an extended period (typically 48-72 hours)
- QoS Test: Maximum allowable interference latency (40μs) is not exceeded when large amounts of Layer 2 multicast data are injected onto another switch port.
 - » The QoS engine should 'Tail-Drop' the majority of these packets to allow high-priority Q-LAN packets to continue uninterrupted.
- Backplane Test: Up to 10 two-port VLANs are created with STP and/or Loop Detection disabled. The same 512x512 data is then looped through each VLAN. This test:
 - » Verifies the switch backplane can handle far more than gigabit bandwidth
 - » Simulates cumulative latency resulting from multiple switch hops

Switches which pass these tests, are listed on the QSC website as Q-SYS Qualified Switches. An accompanying Setup Guide details how to configure the switch or switch series with the recommended Q-LAN settings via either the built-in CLI or Web Interface.

Any switch tested, which does not pass the tests above, is listed as Disqualified and should not be used or considered for Q-SYS projects.



Support

Should you have any questions or need additional assistance, please contact your local QSC representative or QSC's sales department.

Alternatively, if your request is related to an active project experiencing network related issues then please contact Q-SYS Technical Support using the details below:

Q-SYS Technical Support

Monday to Friday 6am – 5pm Pacific Coast Time

- Tel: 800-772-2834 (U.S. only)
- Tel: +1 (714) 957-7150 (global)

Q-SYS 24/7 Technical Support: EMERGENCY-ONLY

After-Hours and Weekend Support

- Tel: +1-888-252-4836 (U.S./Canada)
- Tel: +1-949-791-7722 (global)
 - » After hours calls are guaranteed a 30-minute response time from a Q-SYS Support Team member for a Q-SYS Emergency ONLY!

Email:

- qsysupport@qsc.com
 - » Immediate email response not guaranteed
 - » For URGENT issues use the phone numbers above

Q-SYS Designer Software Version v4.0 and earlier

This appendix collects information regarding protocols and port numbers used in previous generations of Q-LAN and Q-SYS firmware. It is separated from the main body of the document to avoid confusion with the currently used protocols and ports utilized in the 4.x and higher versions of Q-SYS.

Q-LAN Protocol Suite

Note: Q-SYS systems running Q-SYS v3.3 or lower are not capable of transmitting or receiving Q-LAN audio with another Q-SYS system running v4.0 or higher.

Sample Clock Distribution v1.0 to v3.3

- IEEE 1588-2002 Precision Time Protocol (PTPv1) used for synchronization
- UDP on Ports 319 and 320 (same as PTPv2)
- 224.0.1.129 ~ 224.0.1.132 – registered to NIST/IEEE

Audio Streams

v1.0 to v2.3

- UDP Source Ports 6511 through 6766 (as needed)

v3.0 to v3.0.293

- UDP Source Ports 7535 & 7536 (only)

v3.0.311 to v3.3.45

- UDP Source Ports 6516 & 6517 (only)

Discovery

v1.0 to v2.0

- Bonjour/mDNS
 - » Q-SYS v2.0 utilizes both Bonjour and Q-SYS Discovery Protocol (QDP) for backward and forward compatibility

V2.0 to present

- QDP

