Design Analysis of 800m^2 Studio 4K Systems (Postprint)

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Abstract

The 4K studio system plays a crucial role in IP-based video, audio, intercom, synchronization, and control systems. Taking the design of a 4K system for an 800 m^2 studio as an example, this paper explores the associated project construction objectives, system design solutions, system scalability, and integration requirements.

Full Text

Preamble

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Design and Analysis of a 4K System for an 800 m^2 Studio

Abstract: The 4K studio system plays a crucial role in IP-based video, audio, intercom, synchronization, and control systems. This paper examines the project construction objectives, system design scheme, system scalability, and integration requirements for an 800 m^2 studio 4K system.

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1. Project Construction Objectives

The project aims to establish an ultra-high-definition live broadcast studio system with IP equipment as the core for signal transmission, switching, and scheduling. By fully leveraging IP network characteristics to achieve IP-based transmission and signal exchange for video, intercom, and control systems, the project will create a model with demonstrative and guiding significance for future ultra-high-definition live broadcast studio systems.

Upon completion, the project should achieve four primary objectives. First, it should provide a complete technical platform for ultra-high-definition television production. Second, it should construct a highly reliable broadcast system with IP switches at its core for signal exchange, enabling IP-based transmission, switching, and scheduling of video, audio, intercom, synchronization, and control systems. Third, it should employ advanced IP technologies and equipment to implement SDN design concepts, allowing system scheduling and configuration functions to be planned and defined through software. Fourth, it should accommodate future technological developments and growing business demands.

2. System Design Scheme Description

This project comprises the following systems: video system, synchronization system, clock system, control system, and monitoring system.

2.1 Video System

The studio is designed with a conventional configuration of eight 4K standard-channel ultra-high-definition cameras. To ensure compatibility with multiple interface standards, the system reserves ten channels for external signals, including: 3G-SDI signals conforming to SMPTE ST 425-5 standard; HD and UHD IP video data based on SMPTE 2110-20; UHD IP data using TICO compression based on SMPTE 2022-6; UHD 3G-SDI signals using TICO compression; HD-SDI signals conforming to GY/T157-2000 standard; and 12G-SDI UHD video signals based on SMPTE ST 2082-1.

2.2 Video Production Workflow

Given the equipment employed in this studio, the flexible multi-zone production requirements, IP-based video stream signal exchange, compatibility with various current UHDTV formats, and the fundamental need to simultaneously produce both 4K and HD signals, the video production workflow is designed as follows. The video system utilizes four IP matrix core switches (COTS), with the main core switches consisting of two units in a cascaded 64-port 100G configuration. The production switcher offers processing capacity for 40 inputs and 12 outputs of 4K signals, configured with a 36-channel direct-cut main panel and a 28-channel direct-cut satellite panel. The associated core video matrix is 64$×$64, with inputs accommodating HDR and SDR camera signal access, monitoring signals before and after external signals enter the HDRC, V/K signals from character generators, replay signals from ultra-high-speed cameras, various output signals from the production switcher, and the system' s four TX outputs and CLN outputs for both UHD 4K and HD signals. The system is configured with two sets of ultra-high-definition online packaging systems, with expansion capacity reserved for two additional sets [1].

2.3 Emergency Backup

The emergency handling approach for IP core matrix systems differs fundamentally from that of traditional studios. In conventional HD systems, emergency backup primarily relies on matrix-based switcher backup, implemented through two-way or multi-way selection boards or through coordinated switching between switcher and matrix signals. In this system design, signals are switched through the IP core matrix, converted to 4$×3*GUHDsignalsviaIPG*, *andthenembeddedwithaudiobeforebeingdistributedbya*4×$3G video distributor. The UHD signals are sent via video cables to 3G-SDI matrix inputs, emergency UHD outputs, and HDRC for emergency 4K down-conversion, with the resulting HD signals also returned to the SDI matrix. Simultaneously, emergency UHD signals are converted back to IP video streams via IPG for IP matrix scheduling, and are also sent to TICO IPG boards, which transmit TICO IP video streams via 25G fiber to the external interface switch.

3. Synchronization System

Synchronization is the most fundamental and stringent requirement in video environments. Every device in the system must be synchronized to ensure normal production and transmission, and to correctly reproduce video images and audio information. In both analog and digital environments, all video reference signals are locked to a common reference signal provided by a master sync generator to achieve overall synchronization. In video environments mixing various signal sources, all signals must be synchronized; otherwise, image rolling, jitter, tearing, or incorrect color reproduction will occur.

The 4K IP system synchronization should support analog BB signals, tri-level signals, Word Clock signals, and PTP network precision synchronization signals. The BB synchronization signal consists of primary and backup sync generators with an automatic switcher, whose outputs are distributed to provide sync signals for all equipment. Unlike traditional baseband systems, IP-based systems incorporate PTP synchronization within the video network.

PTP (Precision Time Protocol) network synchronization is a protocol for time and frequency synchronization of standard Ethernet terminal devices. Networks applying the PTP protocol are called PTP domains. A network may contain multiple PTP domains, each being an independent PTP clock synchronization system with only one clock source. All devices within a domain synchronize to this clock source based on a network master-slave timing protocol, wherein all devices in the network can be synchronized by PTP. PTP domain nodes synchronize clocks according to a specific master-slave relationship. The master-slave relationship is relative: nodes synchronizing clocks are called slave nodes, while nodes publishing clocks are called master nodes. A single device may simultaneously synchronize its clock from an upper-level node while publishing clock to lower-level nodes [2].

The synchronization system design includes sync signal generators and distribution to subsystems, requiring unified synchronization design within each subsystem. Except for PTP synchronization devices based on PTP networks, other equipment primarily uses analog BB as the sync signal source. If individual devices in a subsystem require sync signals other than analog BB (such as digital BB, tri-level, or digital audio word clock), these are generated within the respective subsystem. To ensure synchronization system security, all equipment and links employ primary-backup redundancy. Analog BB sync signal transmission uses video cables exclusively.

4.1 Overview

The clock system in this scheme primarily provides unified clock signals. Clock information serves as the sole time reference for coordinated unified operation across all station systems. The system features high stability, reliability, and accuracy, with necessary redundant design in core equipment to ensure security and reliability. The entire system enables convenient adjustment and expansion, allowing flexible interface additions when required. System clock signals comply with EBU international timecode standards and can also output RS-232/RS-422 signals.

4.2 Design Scheme

This scheme configures one GPS satellite automatic time-calibration master clock and one EBU(LTC) automatic timecode switcher, enabling clock switching between satellite clock and sync system clock outputs. The output clock signals are distributed to provide timecode for monitoring and recording equipment. Production area clocks respectively serve the director area, secondary production area, technical area, and audio area displays.

5.1 Overview

The intercom system handles signal communication between the scheduling system and various workstations, cameras, and cascaded systems. Equipment selection, system design safety, and design scale and configuration fully consider IP networking. The system architecture employs an intercom matrix + switch + IP intercom panel approach. During program production, configurations can be reassigned and workstation functions can be changed, with suitable intercom panels or other intercom nodes conveniently accessible at any workstation. All extended intercom panels and wireless relay stations can be extended to the field via fiber and network cables. Interoperability with the audio system is achieved through AES67-standard IP audio signals, with backup design enabling emergency intercom switching between the director and all cameras within an extremely short time.

5.2 Design Scheme

In accordance with intercom system requirements and IP trends, all intercom panels within the system adopt IP connections, enabling long-distance extension of intercom panels via IP and IP-based cascading between systems of the same brand with at least 32 channels of cascade paths. The system facilitates communication between the main production area, secondary production area, technical area, audio area, and multimedia area workstations, as well as between each work area and camera operators, field directors, lighting, sound, and presenters. It supports free communication modes from point-to-point or point-to-multipoint, with design-expandable GPIO functions and external intercom access methods and output interfaces including IP, two-wire, four-wire, telephone, and wireless. The system can access wireless relay stations and handheld walkie-talkies to meet field production communication needs for video, audio, field directors, and wireless cameras [3].

The system employs a 160$×$160 intercom matrix equipped with 36 IP intercom panels. All panel communications within the system are IP-based, with panels freely configurable for communication definitions with other areas according to program format. All signal connections between the intercom system and audio system are implemented via AES67 network routing. All camera communications are completed through four-wire communication on AIO boards, with both ENG and PROD from 28 cameras simultaneously accessing the matrix four-wire and configured with different groups to meet communication requirements during dual-system switching. The system is equipped with telephone couplers for communication between intercom and telephone routing, and with walkie-talkie stations and handheld walkie-talkies connected to the system via four-wire, with GPI functions enabling PTT trigger signal transmission from walkie-talkie base stations. The flexible use of walkie-talkies also serves as a backup for the intercom system.

5.3 System Scalability

The system offers strong scalability. The matrix can be expanded up to 288$×$288, with multiple input/output channels still available for allocation. In terms of monitors, both technical and director areas can accommodate additional signal inputs. The control system employs centralized system control, integrating IP matrix scheduling, SDI matrix scheduling, TALLY display, and source name following for comprehensive control, making the system more flexible and enabling free expansion.

6. System Integration Requirements

System integration primarily utilizes video/audio patch panels, video/audio cables and connectors, fiber optics, and optical modules. As this system is a 4K IP UHD and HD compatible system, integration must strictly follow system integration specifications to achieve optimal signal transmission quality with minimal signal loss. Necessary equipment protection ensures system construction quality, product appearance integrity, and sophisticated craftsmanship.

An ultra-high-definition live broadcast studio system with IP equipment as the core for signal transmission, switching, and scheduling can better meet future development needs. In system design and integration, relevant personnel must provide guarantees for system scalability.

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