

CRT GEOMETRY TEST PATTERN

CRT GEOMETRY TEST PATTERN IS AN ESSENTIAL TOOL USED TO CALIBRATE AND ADJUST CATHODE RAY TUBE (CRT) DISPLAYS FOR OPTIMAL VISUAL PERFORMANCE. THESE TEST PATTERNS HELP IN DIAGNOSING AND CORRECTING VARIOUS GEOMETRIC DISTORTIONS INHERENT TO CRT TECHNOLOGY, SUCH AS PINCUSHION, BARREL, AND TRAPEZOIDAL DISTORTIONS, ENSURING THE DISPLAYED IMAGE MAINTAINS ACCURATE PROPORTIONS AND ALIGNMENT. UNDERSTANDING HOW TO USE A CRT GEOMETRY TEST PATTERN EFFECTIVELY IS CRUCIAL FOR TECHNICIANS, VINTAGE ELECTRONICS ENTHUSIASTS, AND ANYONE INVOLVED IN CRT MAINTENANCE OR RESTORATION. THIS ARTICLE EXPLORES THE PURPOSE OF CRT GEOMETRY TEST PATTERNS, THEIR COMMON TYPES, THE SPECIFIC GEOMETRIC ISSUES THEY ADDRESS, AND BEST PRACTICES FOR UTILIZING THEM TO ACHIEVE PRECISE SCREEN CALIBRATION. ADDITIONALLY, IT COVERS THE HISTORICAL CONTEXT AND RELEVANCE OF THESE PATTERNS IN MODERN DISPLAY TECHNOLOGY. THE FOLLOWING SECTIONS PROVIDE A DETAILED OVERVIEW AND PRACTICAL GUIDANCE RELATED TO CRT GEOMETRY TEST PATTERNS.

- UNDERSTANDING CRT GEOMETRY TEST PATTERNS
- COMMON GEOMETRIC DISTORTIONS IN CRT DISPLAYS
- TYPES OF CRT GEOMETRY TEST PATTERNS
- USING CRT GEOMETRY TEST PATTERNS FOR CALIBRATION
- HISTORICAL AND MODERN RELEVANCE OF CRT TEST PATTERNS

UNDERSTANDING CRT GEOMETRY TEST PATTERNS

A CRT GEOMETRY TEST PATTERN IS A SPECIALLY DESIGNED IMAGE OR SET OF IMAGES USED TO EVALUATE AND ADJUST THE GEOMETRIC PROPERTIES OF A CATHODE RAY TUBE DISPLAY. CRTs, UNLIKE MODERN FLAT-PANEL DISPLAYS, USE AN ELECTRON BEAM TO ILLUMINATE PHOSPHORS ON THE SCREEN, WHICH CAN BE AFFECTED BY MAGNETIC FIELDS, COMPONENT AGING, AND DESIGN LIMITATIONS. THESE FACTORS OFTEN RESULT IN GEOMETRIC DISTORTIONS THAT DEGRADE IMAGE QUALITY.

THE TEST PATTERNS PROVIDE VISUAL REFERENCES SUCH AS GRIDS, CIRCLES, LINES, AND SHAPES THAT ALLOW USERS TO IDENTIFY MISALIGNMENTS AND DISTORTIONS. BY DISPLAYING THESE PATTERNS, TECHNICIANS CAN ADJUST THE CRT'S INTERNAL CONTROLS OR EXTERNAL SETTINGS TO CORRECT GEOMETRY ISSUES. PROPER USE OF THESE PATTERNS ENSURES THE PICTURE IS NOT ONLY CENTERED BUT ALSO FREE FROM WARPING, STRETCHING, OR COMPRESSION.

PURPOSE AND IMPORTANCE

THE PRIMARY PURPOSE OF CRT GEOMETRY TEST PATTERNS IS TO SERVE AS A DIAGNOSTIC AND CALIBRATION TOOL. ACCURATE GEOMETRY IS CRITICAL FOR APPLICATIONS REQUIRING PRECISE IMAGE REPRODUCTION, INCLUDING BROADCAST MONITORS, VIDEO PRODUCTION, AND GAMING. MISALIGNED GEOMETRY CAN LEAD TO INACCURATE COLOR RENDERING, IMAGE DISTORTION, AND USER DISCOMFORT.

USING THESE TEST PATTERNS REGULARLY EXTENDS THE LIFE AND USABILITY OF CRT DISPLAYS BY MAINTAINING IMAGE INTEGRITY. THEY ALSO HELP IN TROUBLESHOOTING HARDWARE PROBLEMS RELATED TO DEFLECTION COILS, YOKE ADJUSTMENTS, OR INTERNAL CIRCUITRY.

COMMON GEOMETRIC DISTORTIONS IN CRT DISPLAYS

UNDERSTANDING THE TYPES OF GEOMETRIC DISTORTIONS THAT CRT GEOMETRY TEST PATTERNS DETECT IS ESSENTIAL FOR EFFECTIVE CALIBRATION. CRTs ARE PRONE TO SEVERAL CHARACTERISTIC DISTORTIONS DUE TO THEIR ANALOG NATURE AND ELECTRON BEAM DEFLECTION MECHANISMS.

PINCUSHION DISTORTION

PINCUSHION DISTORTION CAUSES THE EDGES OF THE IMAGE TO BOW INWARD, RESULTING IN A CONCAVE APPEARANCE ON THE SIDES OF THE DISPLAY. THIS HAPPENS WHEN THE HORIZONTAL DEFLECTION IS NOT LINEAR, OFTEN DUE TO MAGNETIC INTERFERENCE OR IMPROPER YOKE ALIGNMENT.

BARREL DISTORTION

BARREL DISTORTION IS THE OPPOSITE OF PINCUSHION, WHERE THE IMAGE EDGES BOW OUTWARD, CREATING A CONVEX SHAPE. THIS CAN BE CAUSED BY INCORRECT DEFLECTION COIL CURRENTS OR AGING COMPONENTS AFFECTING THE ELECTRON BEAM PATH.

TRAPEZOIDAL DISTORTION

ALSO KNOWN AS KEYSTONE DISTORTION, TRAPEZOIDAL DISTORTION OCCURS WHEN THE IMAGE APPEARS AS A TRAPEZOID RATHER THAN A RECTANGLE. THIS IS TYPICALLY DUE TO MISALIGNED DEFLECTION COILS OR IMPROPER SCREEN POSITIONING RELATIVE TO THE ELECTRON GUN.

OTHER DISTORTIONS

- DIAGONAL DISTORTION – WHERE THE IMAGE CORNERS ARE UNEVENLY STRETCHED OR COMPRESSED.
- PIN-CUSHION OR BARREL EFFECTS COMBINED WITH VERTICAL OR HORIZONTAL STRETCHING.
- CONVERGENCE ERRORS, WHERE COLOR COMPONENTS FAIL TO ALIGN PROPERLY.

TYPES OF CRT GEOMETRY TEST PATTERNS

VARIOUS CRT GEOMETRY TEST PATTERNS HAVE BEEN DEVELOPED TO ADDRESS DIFFERENT ASPECTS OF DISPLAY CALIBRATION. EACH PATTERN SERVES A SPECIFIC DIAGNOSTIC PURPOSE, PROVIDING VISUAL CUES TO DETECT AND CORRECT DISTORTIONS.

GRID PATTERNS

GRID PATTERNS CONSIST OF EVENLY SPACED HORIZONTAL AND VERTICAL LINES FORMING SQUARES OR RECTANGLES. THEY ALLOW THE USER TO DETECT BENDING, STRETCHING, OR COMPRESSION OF THE DISPLAY AREA. MISALIGNED GRIDS CLEARLY REVEAL PINCUSHION OR BARREL DISTORTIONS.

CIRCLE AND ELLIPSE PATTERNS

THESE PATTERNS USE CONCENTRIC CIRCLES OR ELLIPSES TO HELP IDENTIFY GEOMETRIC INACCURACIES. ANY DEVIATION FROM PERFECT CIRCULAR SHAPES INDICATES DISTORTION, MAKING IT EASIER TO PINPOINT AREAS REQUIRING ADJUSTMENT.

CROSSHATCH PATTERNS

CROSSHATCH PATTERNS COMBINE LINES RUNNING DIAGONALLY AND ORTHOGONALLY ACROSS THE SCREEN, PROVIDING A COMPREHENSIVE REFERENCE FOR BOTH VERTICAL AND HORIZONTAL GEOMETRY. THIS PATTERN FACILITATES FINE-TUNING OF TRAPEZOIDAL AND DIAGONAL DISTORTIONS.

CONVERGENCE AND COLOR ALIGNMENT PATTERNS

ALTHOUGH PRIMARILY FOCUSED ON COLOR ALIGNMENT, THESE PATTERNS ALSO ASSIST IN GEOMETRY CALIBRATION BY HIGHLIGHTING HOW THE RED, GREEN, AND BLUE ELECTRON BEAMS CONVERGE ON THE PHOSPHOR SCREEN. MISALIGNMENT CAN CAUSE COLOR FRINGING AND GEOMETRIC INACCURACIES.

COMPOSITE GEOMETRY PATTERNS

SOME TEST PATTERNS COMBINE MULTIPLE ELEMENTS SUCH AS GRIDS, CIRCLES, AND COLOR BARS, PROVIDING A HOLISTIC TOOL FOR COMPREHENSIVE CALIBRATION OF GEOMETRY, CONVERGENCE, AND COLOR FIDELITY.

USING CRT GEOMETRY TEST PATTERNS FOR CALIBRATION

PROPER USE OF CRT GEOMETRY TEST PATTERNS INVOLVES A SYSTEMATIC APPROACH TO DIAGNOSE AND CORRECT GEOMETRIC DISTORTIONS. CALIBRATION REQUIRES SPECIFIC EQUIPMENT AND AN UNDERSTANDING OF CRT INTERNAL CONTROLS.

PREPARATION AND SETUP

BEFORE CALIBRATION, THE CRT SHOULD BE WARMED UP FOR AT LEAST 15 TO 30 MINUTES TO REACH STABLE OPERATING CONDITIONS. THE DISPLAY SHOULD BE SET TO THE NATIVE RESOLUTION AND STANDARD REFRESH RATE TO ENSURE ACCURACY.

DISPLAYING THE TEST PATTERN

THE SELECTED CRT GEOMETRY TEST PATTERN IS DISPLAYED FULLSCREEN, IDEALLY FROM A RELIABLE SIGNAL SOURCE SUCH AS A TEST PATTERN GENERATOR OR A DEDICATED CALIBRATION DEVICE. THE PATTERN SHOULD BE STABLE AND FREE FROM FLICKER.

ADJUSTING GEOMETRY CONTROLS

THE CRT TYPICALLY INCLUDES INTERNAL AND EXTERNAL ADJUSTMENTS FOR GEOMETRY, INCLUDING:

- **HORIZONTAL AND VERTICAL SIZE:** CONTROLS THE WIDTH AND HEIGHT OF THE IMAGE.
- **HORIZONTAL AND VERTICAL LINEARITY:** ENSURES UNIFORM SCALING ACROSS THE SCREEN.
- **PINCUSHION AND BARREL DISTORTION CONTROLS:** CORRECTS EDGE BENDING.
- **TRAPEZOID (KEystone) CONTROL:** ADJUSTS THE SHAPE OF THE IMAGE CORNERS.
- **ROTATION AND CENTERING:** ALIGNS THE IMAGE PROPERLY ON THE SCREEN.

USING THE VISUAL CUES FROM THE TEST PATTERN, THE TECHNICIAN ADJUSTS THESE CONTROLS ITERATIVELY UNTIL THE IMAGE APPEARS GEOMETRICALLY CORRECT. CIRCLES SHOULD BE ROUND, GRIDS PERFECTLY SQUARE, AND LINES STRAIGHT WITHOUT BENDING.

VERIFICATION AND FINE-TUNING

AFTER INITIAL ADJUSTMENTS, IT IS IMPORTANT TO VERIFY THE RESULTS BY SWITCHING BETWEEN DIFFERENT TEST PATTERNS AND REAL-WORLD IMAGES. THIS ENSURES THE GEOMETRY SETTINGS HOLD UNDER VARIOUS CONDITIONS AND CONTENT TYPES.

HISTORICAL AND MODERN RELEVANCE OF CRT TEST PATTERNS

CRT GEOMETRY TEST PATTERNS HAVE PLAYED A VITAL ROLE SINCE THE EARLY DAYS OF TELEVISION AND COMPUTER DISPLAYS. THEY WERE ESSENTIAL FOR BROADCAST STATIONS, VIDEO PRODUCTION FACILITIES, AND CONSUMERS TO MAINTAIN DISPLAY QUALITY DURING THE CRT ERA.

HISTORICAL USAGE

IN THE MID TO LATE 20TH CENTURY, CRT DISPLAYS WERE THE DOMINANT TECHNOLOGY FOR TELEVISIONS AND MONITORS. GEOMETRY TEST PATTERNS WERE COMMONLY INCLUDED IN BROADCAST SIGNALS OR AVAILABLE ON SPECIALIZED CALIBRATION TAPES AND DISCS. SKILLED TECHNICIANS RELIED ON THESE PATTERNS TO ENSURE CONSISTENT IMAGE QUALITY ACROSS DEVICES AND BROADCASTS.

MODERN CONTEXT

WHILE CRT TECHNOLOGY HAS LARGELY BEEN REPLACED BY LCD, LED, AND OLED DISPLAYS, CRTs REMAIN IN USE IN SPECIFIC FIELDS SUCH AS RETRO GAMING, PROFESSIONAL VIDEO MASTERING, AND CERTAIN SCIENTIFIC APPLICATIONS. FOR THESE USERS, CRT GEOMETRY TEST PATTERNS REMAIN INDISPENSABLE TOOLS FOR MAINTAINING DISPLAY FIDELITY.

ADDITIONALLY, THE CONCEPT OF GEOMETRY CALIBRATION AND TEST PATTERNS HAS INFLUENCED MODERN DISPLAY CALIBRATION TECHNIQUES. UNDERSTANDING CRT GEOMETRY TEST PATTERNS PROVIDES FOUNDATIONAL KNOWLEDGE APPLICABLE TO NEWER TECHNOLOGIES, ALTHOUGH THE SPECIFICS OF DISTORTION AND CALIBRATION VARY.

FREQUENTLY ASKED QUESTIONS

WHAT IS A CRT GEOMETRY TEST PATTERN?

A CRT GEOMETRY TEST PATTERN IS A VISUAL TEST IMAGE DISPLAYED ON CATHODE RAY TUBE (CRT) MONITORS TO HELP USERS ADJUST AND CALIBRATE THE SCREEN'S GEOMETRY, INCLUDING ASPECTS LIKE LINEARITY, CONVERGENCE, AND ASPECT RATIO.

WHY IS A GEOMETRY TEST PATTERN IMPORTANT FOR CRT DISPLAYS?

GEOMETRY TEST PATTERNS ARE IMPORTANT BECAUSE CRT DISPLAYS CAN SUFFER FROM DISTORTION SUCH AS PINCUSHION, BARREL, AND TRAPEZOIDAL SHAPES. THESE PATTERNS HELP IDENTIFY AND CORRECT THESE DISTORTIONS TO ENSURE ACCURATE IMAGE RENDERING.

WHAT ELEMENTS ARE TYPICALLY INCLUDED IN A CRT GEOMETRY TEST PATTERN?

TYPICAL ELEMENTS INCLUDE GRIDS, CONCENTRIC CIRCLES, CROSSHAIRS, AND ALIGNMENT MARKS THAT ALLOW USERS TO CHECK FOR LINEARITY, CONVERGENCE, AND ASPECT RATIO ISSUES ON CRT SCREENS.

HOW DO YOU USE A CRT GEOMETRY TEST PATTERN FOR SCREEN CALIBRATION?

TO USE THE PATTERN, DISPLAY IT ON THE CRT SCREEN AND ADJUST THE MONITOR'S GEOMETRY CONTROLS (SUCH AS SIZE, LINEARITY, PINCUSHION, TRAPEZOID, AND ROTATION) UNTIL THE SHAPES IN THE PATTERN APPEAR UNIFORM AND UNDISTORTED.

CAN CRT GEOMETRY TEST PATTERNS BE USED ON MODERN DISPLAYS?

WHILE PRIMARILY DESIGNED FOR CRTs, SOME GEOMETRY TEST PATTERNS CAN BE USED ON MODERN DISPLAYS FOR ALIGNMENT AND CALIBRATION, BUT MODERN LCDs AND OLEDs USUALLY REQUIRE DIFFERENT CALIBRATION TOOLS AND SOFTWARE.

WHERE CAN I FIND CRT GEOMETRY TEST PATTERNS?

CRT GEOMETRY TEST PATTERNS CAN BE FOUND ONLINE ON WEBSITES DEDICATED TO VINTAGE COMPUTING, MONITOR CALIBRATION, AND VIDEO SIGNAL TESTING, OR THEY CAN BE GENERATED USING SPECIALIZED CALIBRATION SOFTWARE.

WHAT COMMON ISSUES CAN CRT GEOMETRY TEST PATTERNS HELP DIAGNOSE?

THEY HELP DIAGNOSE ISSUES SUCH AS SCREEN DISTORTION, MISALIGNMENT, CONVERGENCE ERRORS, IMPROPER ASPECT RATIO, AND FOCUS PROBLEMS ON CRT MONITORS.

ADDITIONAL RESOURCES

1. *UNDERSTANDING CRT GEOMETRY: FUNDAMENTALS AND APPLICATIONS*

THIS BOOK PROVIDES A COMPREHENSIVE OVERVIEW OF CRT GEOMETRY PRINCIPLES, FOCUSING ON THE FUNDAMENTAL CONCEPTS THAT GOVERN TEST PATTERNS. IT EXPLORES THE RELATIONSHIP BETWEEN ELECTRON BEAM DEFLECTION AND SCREEN GEOMETRY, OFFERING PRACTICAL INSIGHTS FOR TECHNICIANS AND ENGINEERS. DETAILED ILLUSTRATIONS AND EXAMPLES HELP READERS GRASP THE INTRICACIES OF CRT CALIBRATION AND TROUBLESHOOTING.

2. *CRT TEST PATTERNS: DESIGN AND DIAGNOSTIC TECHNIQUES*

A SPECIALIZED GUIDE ON THE CREATION AND INTERPRETATION OF CRT TEST PATTERNS, THIS BOOK DELVES INTO THE VARIOUS GEOMETRIC PATTERNS USED TO ASSESS AND CORRECT DISPLAY DISTORTIONS. IT COVERS COMMON ISSUES SUCH AS PINCUSHION, BARREL DISTORTION, AND CONVERGENCE ERRORS. READERS WILL FIND STEP-BY-STEP PROCEDURES FOR DESIGNING EFFECTIVE TEST PATTERNS AND USING THEM TO MAINTAIN OPTIMAL CRT PERFORMANCE.

3. *PRACTICAL GUIDE TO CRT GEOMETRY CALIBRATION*

FOCUSED ON HANDS-ON CALIBRATION TECHNIQUES, THIS BOOK WALKS READERS THROUGH THE PROCESS OF ADJUSTING CRT GEOMETRY USING TEST PATTERNS. IT INCLUDES CASE STUDIES AND TROUBLESHOOTING TIPS TO ADDRESS TYPICAL GEOMETRIC ANOMALIES. THE CLEAR, PRACTICAL APPROACH MAKES IT AN ESSENTIAL RESOURCE FOR SERVICE TECHNICIANS WORKING WITH ANALOG DISPLAYS.

4. *THE SCIENCE OF CRT DISPLAY GEOMETRY*

OFFERING AN IN-DEPTH SCIENTIFIC EXPLORATION, THIS TITLE EXPLAINS THE PHYSICS BEHIND CRT GEOMETRY AND HOW TEST PATTERNS REFLECT UNDERLYING DISPLAY CHARACTERISTICS. IT DISCUSSES ELECTRON BEAM BEHAVIOR, MAGNETIC DEFLECTION, AND THE IMPACT OF COMPONENT TOLERANCES ON IMAGE GEOMETRY. ADVANCED MATHEMATICAL MODELS AND SIMULATIONS ARE PROVIDED TO ENHANCE UNDERSTANDING.

5. *ADVANCED CRT GEOMETRY CORRECTION METHODS*

THIS BOOK TARGETS PROFESSIONALS SEEKING ADVANCED SOLUTIONS FOR CRT GEOMETRY ISSUES, HIGHLIGHTING MODERN CORRECTION TECHNIQUES AND TECHNOLOGIES. IT COVERS DIGITAL CORRECTION METHODS, ADAPTIVE ALGORITHMS, AND THE INTEGRATION OF TEST PATTERNS IN AUTOMATED CALIBRATION SYSTEMS. THE CONTENT IS TECHNICAL, SUITABLE FOR ENGINEERS AND RESEARCHERS IN THE FIELD.

6. *VISUALIZING CRT GEOMETRY: TEST PATTERNS AND IMAGE DISTORTION*

EXPLORING THE VISUAL ASPECTS OF CRT GEOMETRY, THIS BOOK EMPHASIZES THE ROLE OF TEST PATTERNS IN IDENTIFYING AND CORRECTING IMAGE DISTORTION. IT PRESENTS A VARIETY OF PATTERN DESIGNS AND EXPLAINS THEIR DIAGNOSTIC VALUE. THE BOOK ALSO DISCUSSES HOW HUMAN PERCEPTION INTERACTS WITH GEOMETRIC DISTORTIONS ON CRT SCREENS.

7. *CRT GEOMETRY FOR BROADCAST AND VIDEO PROFESSIONALS*

TAILORED FOR BROADCAST ENGINEERS AND VIDEO TECHNICIANS, THIS BOOK ADDRESSES CRT GEOMETRY CHALLENGES IN PROFESSIONAL VIDEO ENVIRONMENTS. IT COVERS STANDARD TEST PATTERNS USED IN THE INDUSTRY AND BEST PRACTICES FOR MAINTAINING GEOMETRY ACCURACY IN STUDIO MONITORS. PRACTICAL ADVICE ON ROUTINE CHECKS AND ADJUSTMENTS IS A KEY FEATURE.

8. *HISTORY AND EVOLUTION OF CRT TEST PATTERNS*

THIS HISTORICAL OVERVIEW TRACES THE DEVELOPMENT OF CRT TEST PATTERNS FROM THE EARLY DAYS OF TELEVISION TO MODERN APPLICATIONS. IT HIGHLIGHTS SIGNIFICANT MILESTONES AND TECHNOLOGICAL ADVANCEMENTS THAT SHAPED TEST PATTERN DESIGN. THE BOOK ALSO EXAMINES THE INFLUENCE OF CRT GEOMETRY STANDARDS ON DISPLAY QUALITY OVER TIME.

9. *TROUBLESHOOTING CRT GEOMETRY WITH TEST PATTERNS*

A PROBLEM-SOLVING MANUAL, THIS BOOK EQUIPS READERS WITH STRATEGIES TO DIAGNOSE AND FIX COMMON CRT GEOMETRY PROBLEMS USING TEST PATTERNS. IT INCLUDES DETAILED DESCRIPTIONS OF DISTORTION TYPES, THEIR CAUSES, AND CORRECTIVE PROCEDURES. THE PRACTICAL FOCUS MAKES IT IDEAL FOR REPAIR TECHNICIANS AND HOBBYISTS WORKING WITH VINTAGE CRT DISPLAYS.

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project, it presents the reader with the importance of the user's needs and various aspects of the human computer interface (HCI). It further treats technical aspects of VR, hardware and software implementations, and details on the sensory and psycho-sensory interfaces. Providing various concepts and technologies, including mathematics and modelling techniques, it allows the reader to formalize, conceptualize and construct a virtual reality project from original thought to application. This book is intended for engineers, computer scientists and computer game developers working on various VR applications. It can further serve as an educational tool in Virtual Reality courses for senior graduate and postgraduate students.

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professional guide, designed as a standard point of reference for engineers, whether you are from an audio, video, computer or communications background. Without assuming any background and starting from first principles, the four core technologies of image reproduction, sound reproduction, data processing and communications are described. Covering everything from digital fundamentals to conversion methods, sound and image technologies, compression techniques, digital coding principles, storage devices and the latest communications systems, the book shows how these technologies operate together and the necessary conversions that take place between them. Acronyms and buzzwords are introduced only after their purpose has been described in plain English - as the book serves to give a reliable grasp of the fundamentals. The criteria involved in determining image and sound quality are based on a thorough treatment of the human senses, a unique description of how motion portrayal works in managing systems. John Watkinson is an international consultant in audio video and data recording. He is a Fellow of the AES, a member of the British Computer Society and a chartered information systems practitioner. He presents lectures, seminars, conference papers and training courses worldwide and writes for many industry magazines. His other books for Focal Press are widely acknowledged as standard reference works and industry 'bibles'. John is author of MPEG2, The Art of Digital Video and the Art of Digital Audio, An Introduction to Digital Video, An Introduction to Digital Audio, The Art of Sound Reproduction, Television Fundamentals, Co-author of The Digital Interface Handbook and Contributor to The Loudspeaker and Headphone Handbook.

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