Technical and Application Differences Between CMOS, DSP-Based, and Passive Relay Audio Switchers

For Professional Broadcast, Production, and Sound Applications

Subject: Technical comparison of CMOS, DSP-based, and passive relay audio switching technologies for professional broadcast, production, and sound applications (analog, AES3, and FM composite/MPX).

Executive Summary

Modern broadcast, production, and sound-reinforcement environments demand reliable, high-performance audio switching to maintain signal integrity across analog, digital (AES3), and composite baseband paths. Historically, switching has centered around two technologies: **active CMOS-based switching and passive relay-based switching**. However, as digital signal processing has become central to modern audio workflows, **DSP-based audio switching** has emerged as a powerful third category, enabling routing, switching, and signal manipulation within the digital domain.

Broadcast Devices, Inc. (BDI) offers a full spectrum of professional audio switchers, including active CMOS, DSP-based, and passive relay architectures. This paper compares these technologies, referencing BDI's GPM-300, ATB-300, DAB-300, RAS-200 Series, PAS-200, and 8/16 Audio Switcher products. It covers analog, AES3 digital, and composite baseband applications, highlighting technical distinctions, best-fit scenarios, and integration strategies.

Signal Classes and Practical Bandwidth / Timing Constraints

Analog Audio (balanced/unbalanced)

Analog program audio is commonly evaluated from 20 Hz to 20 kHz, but switching devices and routing layouts must also be stable above the audio band, as parasitics and frequency-dependent crosstalk can increase with frequency and become operationally relevant. In solid-state switching, "bandwidth" alone is not a complete predictor; isolation and crosstalk frequently degrade with frequency.

AES3 Digital Audio (AES/EBU)

AES3 is a standard for exchanging professional digital audio signals between devices, carrying two channels of PCM audio, along with embedded clocking and channel status information. Common professional physical layers include balanced 110-ohm twisted pair with XLR connectors. Facility-wide synchronization practices are addressed in AES11, which provides a systematic approach to synchronizing digital audio signals and discusses timing-uncertainty considerations in studio operations.

MPX FM Baseband Composite audio

FM stereo MPX combines mono (L+R), a 19 kHz pilot, and a stereo difference (L–R) signal modulated on a 38 kHz subcarrier; RDS/RBDS commonly uses a 57 kHz subcarrier. These components define why MPX switching must maintain wideband linearity and amplitude/phase integrity into the 53 kHz region and beyond.

Passive Relay Audio Switchers

Overview

Passive relay switchers use electromechanical relays to route signals, providing a true passive path with no active circuitry in the signal chain. This ensures maximum transparency and reliability, especially for critical broadcast paths.

BDI Product References

- **RAS-200 Series**: RAS-208 (8 stereo), RAS-216 (16 monaural); relay switching for analog/AES3; hermetically sealed relays; customizable naming; remote control; redundant power supplies; ideal for remote source selection, automation, EAS.
- **PAS-200**: Programmable A/B switcher for 16 pairs; relay-based; hermetically sealed relays; customizable groups; remote control; redundant power supplies; ideal for transmitter site emergency, public safety, theater sound, backup console, EAS.
- **8/16 Audio Switcher**: 8/16-8 (8 A/B to 8 outputs), 8/16-16 (16 A/B to 16 outputs); hermetically sealed relays; emergency backup, monitor selection, router bypass, console switchover; optional redundant power supplies.

What passive relay switching is

Passive relay switching uses electromechanical contacts to connect/disconnect paths, offering near-zero processing latency and a “direct” signal path. However, relay behavior includes contact bounce and switching time effects that must be managed for glitch-free program transitions.

Why relays remain common in professional broadcast and sound: Transparent pass-through for analog, AES3 (steady state), and control lines

Relay contacts can pass signals “without modification” and are often chosen for bypass and redundancy patterns.

BDI implementation: RAS-200 Series Audio Switchers accept analog and AES3 digital audio signals or control signals without modification, and there is no active circuitry in the signal path. **BDI implementation:** PAS-200 Audio Switchers analog and AES3 (non-synchronous) and low-voltage DC control signals without active circuitry in the signal path. **BDI implementation:** Hermetically sealed relays, to combat contamination and reduce contact wear, and a passive signal path for analog, AES3 (non-synchronous), and DC control signals. Emergency bypass and multipair changeover patterns

Passive A/B switching is a standard design pattern for bypassing single points of failure and switching multiple pairs simultaneously.

Advantages

- True passive signal path: zero insertion loss, maximum transparency
- Supports analog, AES3 digital, and control signals without modification
- Fail-safe operation: relays can default to a preset state on power loss
- High reliability and EMI immunity
- Ideal for air-chain, STL, EAS, and emergency switching

Limitations

- Larger physical size compared to CMOS switchers
- Mechanical relay wear (though rated for millions of cycles)
- Slower switching speed (milliseconds vs. microseconds)
- Audible clicking (not an issue in rack-mount installations)

DSP-Based Audio Switchers

Overview

DSP switchers process audio in the digital domain, enabling flexible routing, mixing, and seamless switching.

What DSP switching is

A DSP-based switcher typically terminates and conditions incoming signals, performs switching/routing decisions within a controlled processing and timing environment, and then reconstructs outputs in the required format. This makes DSP systems well-suited to multi-format routing, controlled transitions, and digital timing management—but it also introduces design considerations around latency, clocking, and conversion behavior.

Why DSP switching is used in broadcast-grade systems

Digital timing robustness: SRC and synchronous switching

Digital audio switching problems often manifest as clicks/pops, loss of lock, or timing-related artifacts when signals cross clock domains or switch at arbitrary points. AES11 explicitly frames synchronization as a systematic engineering requirement for digital audio systems. Jitter theory references highlight how timing variation can be meaningfully analyzed and how interface timing matters in practice.

BDI implementation: The DAB-300 Dual Path Audio Switcher provides Sample Rate Conversion on every AES3 input with 24-bit resolution throughout and Synchronous AES3 switching for silent, glitch-free audio transitions. **BDI implementation:** The ATB-300 Audio Switcher and GPM-300 Matrix Audio Switcher both support active frame rate conversion on AES3 inputs, accepting 8–96 kHz and outputting 32/44.1/48 kHz (user-definable).

Multi-format routing and conversion (analog ↔ AES3, composite ↔ digital)

DSP platforms can be engineered as “format-aware switchers,” combining routing, conversion, and consistent output formatting.

BDI implementation: Both ATB-300 Audio Switcher and the GPM-300 Matrix Audio Switcher platforms accept AES3 I/O, analog L/R I/O, composite baseband I/O, and hybrid versions, and they provide format conversion in addition to switching functions (including composite baseband to AES3). **BDI implementation:** The DAB-300 Dual Path Audio Switcher analog to AES3, AES3 to analog, and composite baseband to AES3.

Rule-based switching for continuity: silence detection, auto-revert, priority logic

Broadcast switching often requires automation that reacts to silence or source loss.

BDI implementation: The ATB-300 Audio Switcher priority list and an algorithm that constantly monitors all inputs for fast selection of an active source. The GPM-300 Matrix Audio Switcher also includes this capability.

DSP switching limitations (and the practical engineering response)

Latency

Any A/D, buffering/processing, and D/A chain introduces delay. Operationally, latency matters for live monitoring, IFB, and tight audio/video alignment. General audio engineering references explain how buffering and sample rate relate to latency behavior. Clocking discipline still matters

Even with SRC and synchronous switching, facilities benefit from disciplined synchronization practices. AES11 addresses timing uncertainty and synchronization practices used in studio operations. Composite MPX integrity requires wideband and linear behavior

Because MPX contains pilot/subcarrier structures, the switching/conversion chain must maintain wideband behavior and avoid nonlinear distortion that could generate unwanted spectral products.

BDI implementation: The Audio Toolbox common features across the models ATB-300 / GPM-300 / DAB-300 include **sample rate conversion on AES3 inputs**, and **composite models convert composite to AES3**. **BDI implementation:** ATB-300, GPM-300, and DAB-300 specifications include composite baseband operation at **3.5 Vpp for 100% modulation**, with response specified from **10 Hz to 53 kHz.**

Advantages

- Fully digital signal integrity
- Highly flexible routing, crossfades, level management
- Integrated processing (EQ, SRC, delay, dynamics)
- Glitch-free, phase-coherent switching
- Ideal for production, networked audio, live sound

Limitations

- Requires A/D and D/A conversion for analog sources
- Latency depends on DSP buffer
- Not inherently fail-safe without relays
- Not suitable for composite/MPX signals (>50 kHz bandwidth)

CMOS Audio Switchers

Note Regarding CMOS Audio Switching in BDI's implementation: BDI composite-capable Audio Toolbox configurations explicitly support composite-baseband I/O and specify the baseband frequency response up to 53 kHz. The BDI Toolbox Audio Switchers (GPM-300, ATB-300, and DAB-300) models that include composite baseband audio inputs and outputs employ CMOS switching for the composite inputs, as required by the bandwidth limitations of the DSP Engine. CMOS switching is used only for composite baseband channels. The analog and AES3 audio is processed and switched through the DSP Engine.

- **GPM-300-9 and -10**: 8x8 matrix switcher for analog, AES3, and composite baseband
- **ATB-300-9 and -10**: 8-channel switcher, distribution amplifier for analog, AES3, and composite baseband
- **DAB-300-4, -5, and -6**: 4-channel dual path multi-format switcher with analog, AES3, and composite baseband

Overview of CMOS Audio Switchers

Active CMOS switchers use semiconductor analog-switch ICs to route audio signals. These are often found in high-density, feature-rich products like the GPM-300, ATB-300, and DAB-300. These versatile switchers are available in 4x4, 8x4, and 8x8 configurations. Each model has versions available for analog balanced stereo audio, AES3 digital audio, and composite baseband signals, and they include audio format conversion capability for additional signal-switching and distribution flexibility. All incorporate features such as synchronous "glitch-free" AES3 digital audio switching, silence sensors to activate alarms and automatic switching to maintain on-air content, and input and output gain controls.

What CMOS "analog switches" are

A conventional CMOS analog switch uses parallel n-MOS and p-MOS devices to create a bidirectional path under logic control. Key parameters include R_ON and its flatness, leakage, charge injection, off-isolation, and crosstalk.

Core limitations in professional audio use: Charge injection and switching spikes (click/pop)

When solid-state switches change state, parasitic capacitances and coupling can inject charge into the signal path. The stored charge on parasitic capacitances can create audible transients when reconnecting a signal path.

Composite MPX and "solid-state stage" design cautions

MPX is wideband and structured (pilot/subcarriers), which makes it particularly sensitive to wideband crosstalk and switching transients. FM stereo and RDS descriptions show subcarriers at 19 kHz, 38 kHz, and 57 kHz, reinforcing the need for wideband integrity.

Advantages

- High channel density and compact design
- Fast, silent switching suitable for automation
- Flexible routing and integration with control systems
- Ideal for monitor switching, cue routing, and non-critical paths

Limitations

- Finite on-resistance, limited headroom
- Not ideal for wideband composite or unconditioned AES3 unless specifically designed
- Requires continuous power; may not be fail-safe

Comparison Table

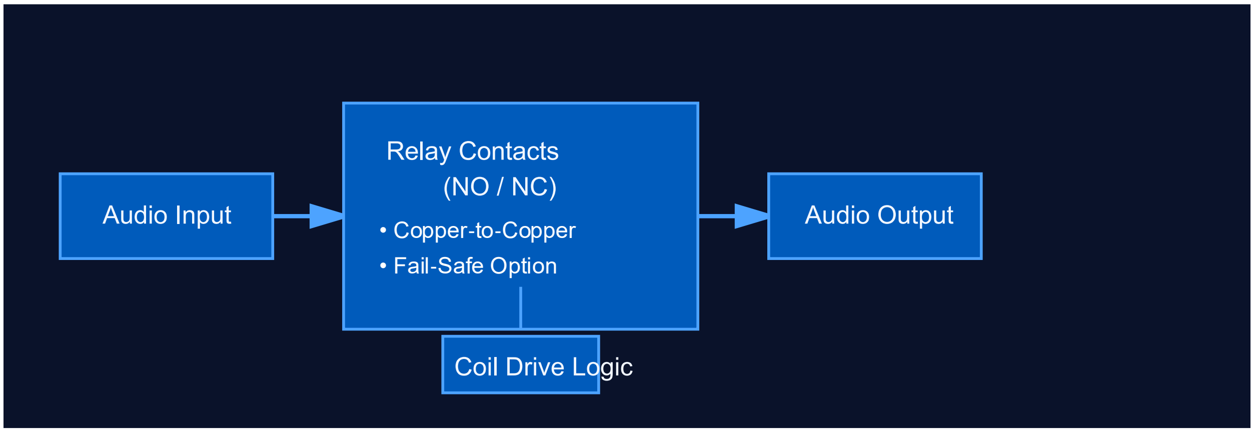
Feature	DSP (GPM-300, ATB-300, DAB-300)	Relay (RAS-200, PAS-200, 8/16)	CMOS (GPM-300, ATB-300, DAB-300 Configurations with Composite Audio)
Signal Path	Digital domain	Passive hardwire	Active analog for Composite Audio paths only (DSP switching used for all other signal types)
Latency	Low/moderate	0	Near 0
Transparency	Excellent (digital)	Excellent	Moderate
AES3 Integrity	Perfect (in DSP)	Perfect	May distort
Composite MPX	Not suitable	Excellent	Poor
Control Flexibility	Very high	Medium	High
Fail-safe	Limited (unless relays are used)	Excellent	Limited
Channel Density	Very high	Low/medium	High
Noise/Click	Silent	Audible	Silent
Processing	Extensive	None	None

Application Guidance

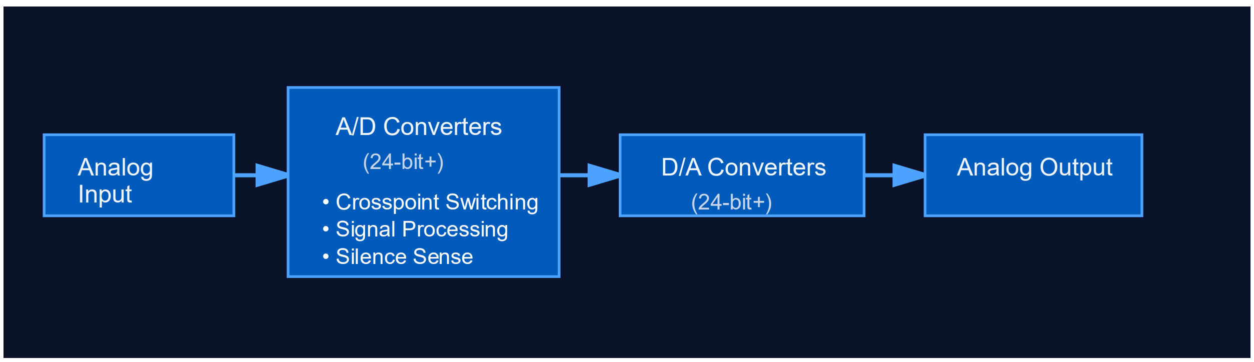
Scenario	Recommended BDI Product(s)	Technology	Rationale
Air-chain switching	RAS-200, PAS-200, 8/16	Relay	Transparency, fail-safe
Emergency backup	8/16, PAS-200	Relay	Reliable, multi-pair
Studio monitor/cue	ATB-300, GPM-300	CMOS/DSP	Fast, flexible
Automation/satellite	RAS-200, PAS-200	Relay	Programmable, robust
Composite baseband	GPM-300, ATB-300, DAB-300, RAS-200	Relay/hybrid	Wideband transparency
AES3 routing	DAB-300, RAS-200, PAS-200, 8/16	Relay/hybrid	Bitstream integrity
High-density matrix	GPM-300	CMOS/DSP	Compact, automated
Production/post	ATB-300, GPM-300	DSP	Flexible, seamless

Diagrams

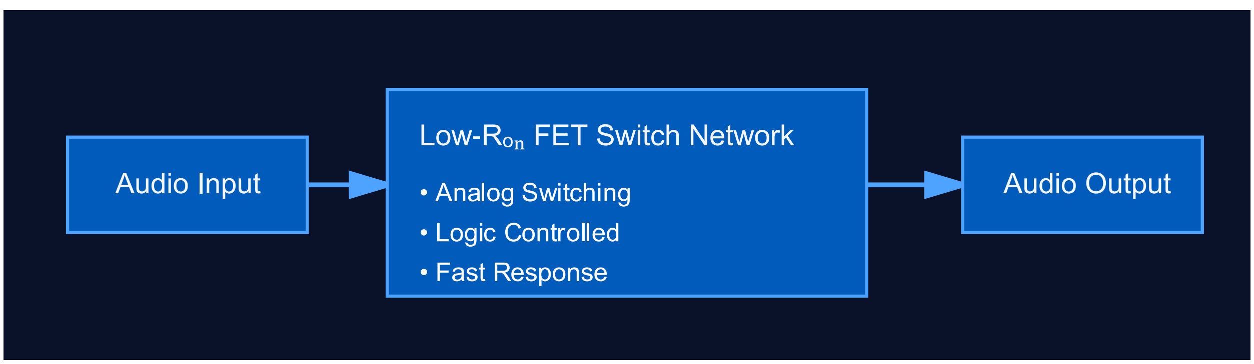
Relay Switcher Architecture



DSP Switcher Architecture



CMOS Switcher Architecture



Technical Comparison

Signal Path and Fidelity

Passive Relay Switching

- Pure analog copper-to-copper connection
- No active components in path → lowest possible distortion and noise
- Ideal for FM composite, DC-coupled audio, and high-level balanced signals

DSP Switching

- Digital domain introduces A/D and D/A conversions
- Dynamic range up to 110–118 dB, depending on converters
- Processing allows enhancement or correction of signal integrity

CMOS Switching

- Analog path but includes MOSFET on-resistance (2–20 Ω typical)
- Capacitance and charge injection must be managed for low distortion
- Suitable for composite FM signals if specified switches meet bandwidth requirements

Reliability and Lifecycle

Passive Relay Switching

- Mechanical relays are finite-life components
- Life cycle typically 1–5 million operations
- Excellent for fail-safe conditions (relays can default to a bypass state)

DSP Switching

- No mechanical wear
- Requires stable power and firmware
- Long operational life with minimal maintenance

CMOS Switching

- Semiconductor reliability is high
- Performance degrades only with extreme ESD or overvoltage
- Requires clean power and RFI mitigation

Latency and Switching Speed

Passive Relay Switching

- 5–10 ms typical
- May produce audible artifacts if switching active program material

DSP Switching

- A/D + processing latency typically 0.25–1.5 ms

- Logical switching is instantaneous
- Suitable for live broadcast when latency budget allows

CMOS Switching

- Nanosecond-to-microsecond switching
- No additional latency

Resilience and Fail-Safe Behavior

Passive Relay Switching

- Can be wired in **fail-safe** configuration (default connection when de-energized)
- Ideal for emergency audio paths in broadcast plants

DSP Switching

- Can perform intelligent failover using silence sense or error detection
- Not inherently fail-safe—requires power to pass audio

CMOS Switching

- Also requires power; no passive bypass
- Failure typically results in an open or shorted switch element

Recommended Applications

Broadcast Radio (AM/FM/HD)

Relay-Based (RAS-200, PAS-200, 8/16)

- Best for MPX/composite routing where absolute transparency is required
- Essential in fail-safe transmitter chains
- Ideal for “always-on” emergency switching

DSP Switchers (GPM-300, ATB-300, DAB-300)

- Excellent for composite audio backup chains
- Ideal for silence-sense driven switching and remote control
- Good for multi-input monitoring or EAS automation

CMOS Composite Switching (in GPM-300, ATB-300, DAB-300 DSP models)

- Fast switching for FM composite signals
- Compact routing with minimal added noise
- Not suitable for extremely high-level or DC-coupled feeds

Television Broadcasting

Relay-Based (RAS-200, PAS-200, 8/16)

- Typically used for analog reference audio, IFB backup paths, or silent hard-bypass systems

DSP Switchers (GPM-300, ATB-300, DAB-300)

- Superior where embedding, de-embedding, loudness control, or monitoring integration is needed
- Reliable for multichannel program ingest and automation systems

Production Audio and Sound Reinforcement

Relay-Based (RAS-200, PAS-200, 8/16)

- Useful when absolute analog purity is required in mastering or archival environments

DSP Switchers (GPM-300, ATB-300, DAB-300)

- Preferred for matrixing, routing, leveling, presets, and remote control
- Supports integration with processing blocks (EQ, limiting, routing)

Best Practices for System Designers

1. **Match switching technology to the signal type**
   - DSP is excellent for processing-heavy workflows
   - Relays are superior for pure analog, high-voltage, or fail-safe routing
   - CMOS is suitable for compact, fast analog switching when levels are controlled
2. **Consider fail-safe requirements**
   - Relay-based designs offer physical bypass
   - DSP and CMOS should be paired with UPS protection
3. **Evaluate long-term lifecycle costs**
   - DSP: long life, no mechanical wear
   - Relay: plan for periodic relay replacement in heavy-duty applications
4. **Manage RF and grounding**
   - CMOS circuits require careful shielding
   - Relay circuits can generate small transients—add snubbers if needed
   - DSP requires well-designed power/noise management to preserve noise floor
5. **Account for *latency* in live workflows**
   - DSP adds small but real delay; avoid in zero-latency cueing paths
   - CMOS and relay paths are effectively latency-free

Advantages and Disadvantages: BDI Implementations

BDI Passive Relay Models (RAS-200, PAS-200, 8/16)

Advantages

- Pure analog path
- Excellent for composite MPX and high-fidelity applications
- True fail-safe operation
- No DSP latency or conversion artifacts

Disadvantages

- Mechanical wear (minimized with robust hermetically sealed relays)
- Slower switching
- Potential for audible switching noise

BDI DSP/CMOS Models (GPM-300, ATB-300, DAB-300)

Advantages

- Intelligent monitoring and auto-switching
- Supports processing and conditioning
- Fast, repeatable switching
- Integrated CMOS switches provide compact composite routing

Disadvantages

- Dependent on power and firmware
- Slight latency due to DSP conversion
- CMOS switching may introduce minor insertion loss or bandwidth limits

Conclusion

The choice between DSP, CMOS, and relay-based audio switching depends on signal requirements, operational context, and reliability needs. BDI's product lineup allows system designers to precisely match technology to application:

- **DSP/CMOS models** excel in intelligent routing, processing, and automation-driven workflows.
- **Relay-based models** provide unmatched analog transparency and fail-safe reliability.

For modern broadcast operations, the most robust facilities commonly deploy **a hybrid approach**, using DSP switchers for primary routing and relay switchers for critical emergency bypass or composite signal paths.