MADI

20 years old and feeling fit

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AES10

AES Recommended Practice for Digital Audio Engineering — Serial Multichannel Audio Digital Interface (MADI)

was published by the AES in 1991
What is a standard?

A standard is: an agreed specification
What is its purpose

A useful standard is not abstract
There must be positive benefit
There must be some value
C.540 OLD PHILHARMONIC

C.523.3 BRITISH STANDARD

C.522 NEW PHILHARMONIC

C.517.3 CONTINENTAL
Example 1

A = 440 Hz

ISO R16: 1955

International musical compatibility
Example 2

Simple connectors
Worldwide application
Example 3

Well established in different territories
Example 4

Universal application
A Good Book

“Information Rules”
A Strategic Guide to the Network Economy
Shapiro & Varian
1999
Harvard Business School Press
Core or Edge?
Example 5

Camera lens
Proprietary interface
Retain control
Lock-in opportunity
Example 6

Computer motherboard
Proprietary core
Standard interfaces at edge
Example 7

IEC 61883, IEEE 1394, FireWire
USB: trade association standard
ISO/IEC 8877, RJ45, Cat5
MADI story covers 35 years

- Digital pioneers saw opportunities
- They couldn’t realise these opportunities in isolation
- Real systems needed equipment from different manufacturers to work together
- Digital audio needed standards
Digital Audio Pioneers

Early pioneers focussed on parts of an overall system.

Customers were happy to see the technology, but many wanted to see complete functional systems before investing.
Stockham’s Soundstream

- Sampling frequencies of 37.5, 42.5, later 50 kHz Fs
- Computer editing
- Bilateral arrangements with other recorder manufacturers to provide editing
Many wanted digital audio

3M, Ampex, BBC, Decca, Denon, JVC, Matsushita, Mitsubishi, NHK, Nippon Columbia, PBS, Philips, Polygram, Sony, Teac, Telarc,
Denon

Figure 1. Denon engineer Takeaki Anazawa standing next to the original Denon DN-023R digital recorder. Source: Audio Magazine.
Some chose a standards

- Co-ordinated by the AES
- Chaired by Jay McKnight
- Included representatives of SPTE, EIA, NAB
Sampling frequency

AES5-1984

$F_s$ of 48 kHz recommended
(will lock to all known film & video pictures)

44.1 kHz acknowledged for CD
(locks to small subset of film & video pictures)
PCM coding

Linear pulse-code modulation - easy and clean way to preserve audio samples

2’s complement notation - makes life simple for handling waveforms symmetrically with a mid-scale zero
Digital interface

2-channel interface widely required

- Audio content not controversial
- Channel status data problematic
- AES and EBU standardized professional version (AES3)
- IEC standardized consumer version
  - IEC 60958-3, (aka: S/PDIF)
AES3 frame format
**AES3 subframe format**

<table>
<thead>
<tr>
<th>Preamble</th>
<th>LSB</th>
<th>24-bit audio sample word</th>
<th>MSB</th>
<th>V</th>
<th>U</th>
<th>C</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
<td>4</td>
<td>27</td>
<td>28</td>
<td>31</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a)

- **V** validity bit
- **U** user data bit
- **C** channel status bit
- **P** parity bit

**AUX** auxiliary sample bits

<table>
<thead>
<tr>
<th>Preamble</th>
<th>AUX</th>
<th>LSB</th>
<th>20-bit audio sample word</th>
<th>MSB</th>
<th>V</th>
<th>U</th>
<th>C</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
<td>4</td>
<td>7</td>
<td>8</td>
<td>27</td>
<td>28</td>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>

(b)
Channel coding

Bi-phase mark coding - DC-free signal
AES3 physical

Line driver

Interconnecting cable

Line receiver

Driving Network

Termination and Isolation Network

$Z_S = 110 \, \Omega$

$Z_C = 110 \, \Omega$

$Z_L = 110 \, \Omega$
Multi-channel audio?
For connecting digital consoles and multitrack tape machines

- Need >48 audio channels
- 48 kHz sampling frequency, or higher
- Expect high data rate
Neve DTC (Tape One)
Sony
PCM3324
Mitsubishi
X86
SSL 01

Integrated digital mixer with hard disk recording and editing

Launched February 1988
MADI Group

Neve

Solid State Logic

Sony

Mitsubishi

*Developed multichannel interface with intent to standardize through AES*
AES10

MADI became first draft of AES10 at AES Paris Convention, in March 1988

AES10 published in 1991
MADI block diagram
MADI channel data format

Unencoded channel data bits

Audio data bit 27 = MSB

AES3 block start
AES3 subframe A/B
ON/OFF (MADI channel active)
MADI subframe zero

AES3P
AES3C
AES3U
AES3V
MADI specs

125 Mb/s serial link, using NRZI coding

56 channels at 48 kHz, including +/- 12% varispeed range

96 kHz support, reduced channel count

Tiny latency - 1 sample
## Sync coding

<table>
<thead>
<tr>
<th></th>
<th>Channel 0</th>
<th>Channel 1</th>
<th>Sync</th>
<th>Sync</th>
<th>Channel 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of frame</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Channel $N$</td>
<td>Sync</td>
<td>Channel $N + 1$</td>
<td>Sync</td>
<td>Sync</td>
<td>Channel $N + 2$</td>
</tr>
<tr>
<td>Channel 54</td>
<td>Channel 55</td>
<td>Sync</td>
<td>Sync</td>
<td>Sync</td>
<td>Channel 0 (next frame)</td>
</tr>
</tbody>
</table>

End of frame
MADI physical
TAXI chips

Intended to be implemented using a dedicated TAXI chip set from AMD

• Standard was written using knowledge from pre-production samples
• Production quantities were late arriving
• Discontinued in 1999
Early implementors
MADI group made slow progress
Broadcast applications were faster - (eg) routing switchers
Oh No! No TAXI chips!

Some concern among some manufacturers

Others simply implemented AES10 using FPGAs
Modern silicon is fast

Modern Ethernet PHY chips routinely out-perform the older TAXI chips.

The rest of MADI can be programmed into (eg) FPGAs.

Now many implementors...
Modern MADI
Coax or fibre data link, point-to-point
24-bit linear PCM audio
64 channels at 48 kHz; 32 channels at 96 kHz
Near realtime - 1 sample latency
Open standard - no competitor issues
Easy & cheap to implement
AES10 - MADI implementors

www.aes.org/publications/

AES3-2009: AES standard for digital audio engineering - Serial transmission format for two-channel linearly represented digital audio data. Parts 1 to 4.

AES-2id-2006: AES information document for digital audio engineering - Guidelines for the use of the AES3 interface

AES5-2008: AES recommended practice for professional digital audio - Preferred sampling frequencies for applications employing pulse-code modulation (revision of AES5-1997)


AES-10id-2005 (r2011): AES information document for digital audio engineering - Engineering guidelines for the multichannel audio digital interface, AES10 (MADI)
ITU-R

ITU-R BS.647-2 A digital audio interface for broadcasting studios

ITU-R BS.1873 (2010-03) "Serial multichannel audio digital interface for broadcasting studios" limited to 48 kHz sampling frequency
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