INNOVATIVE MUSIC AUSTRALIA

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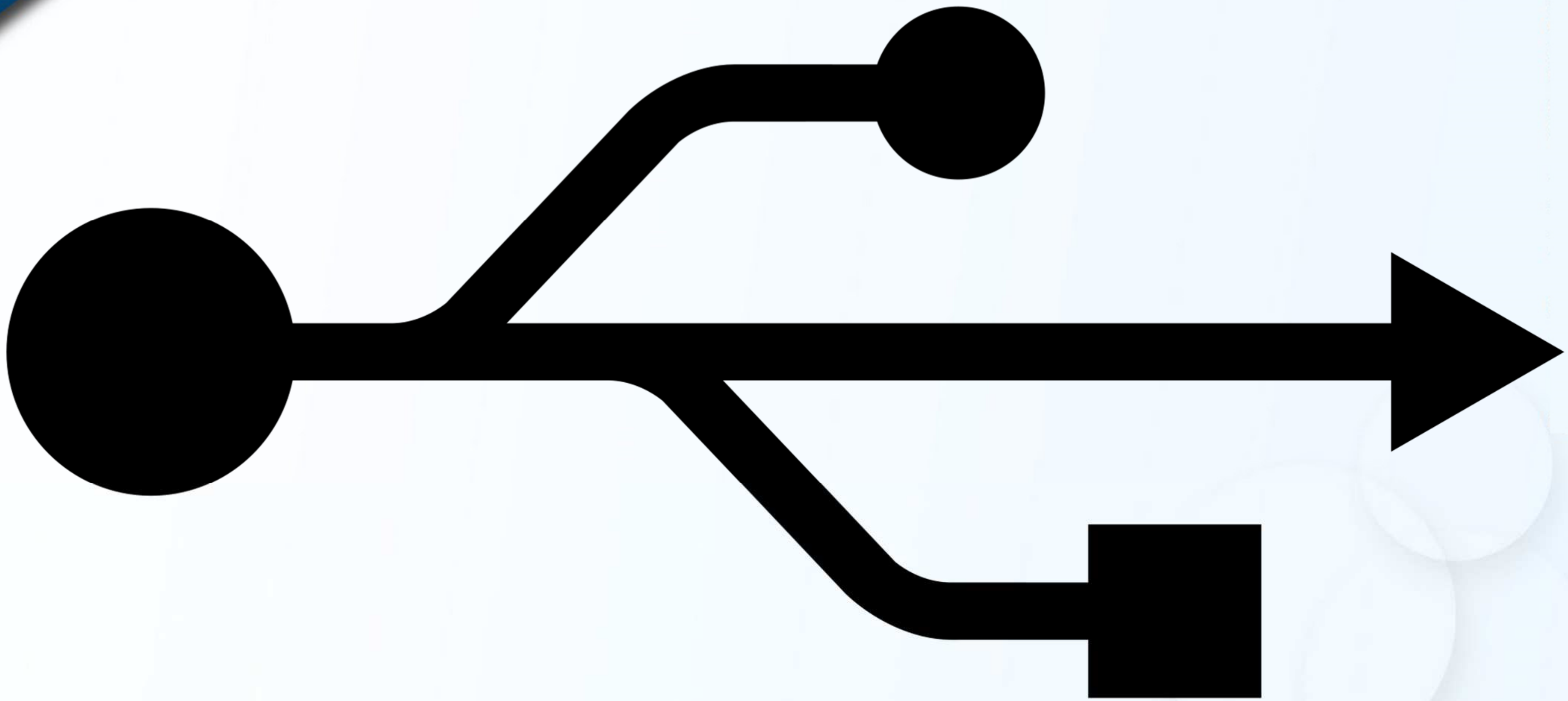
FORMAT WARS

After twenty years of struggling to contend with the emergence of many new formats manufacturers began to realise they had to adapt and embrance these new formats to Survive

USB



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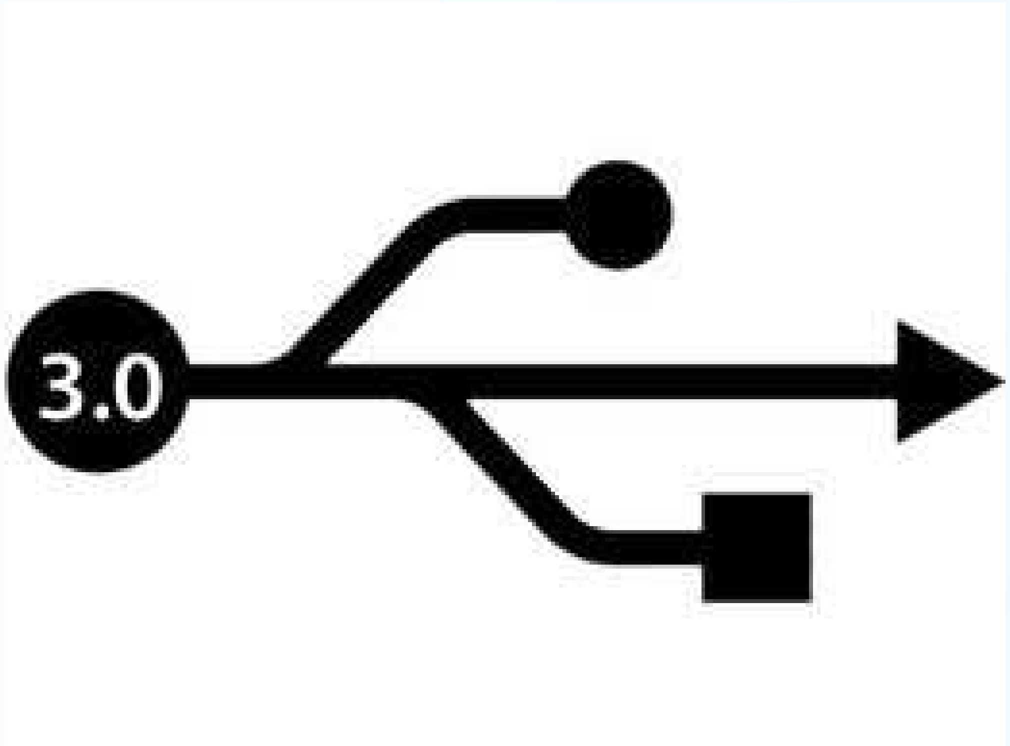
USB 2.0

USB-3



Thunderbolt

Firewire

The Question

Is it better to buy an audio interface that connects to my computer by USB, Firewire, Dante or Thunderbolt ?

And

Which will still be usable in five or 10 years' time?

It’s all about the bandwidth

Before we dive into the details, it’s worth noting some good news: despite various generations of USB, Firewire and Thunderbolt all being employed in current products, backwards compatibility is included as part of the latest standards. Most Firewire 400 devices can operate on Firewire 800 connections. With an adaptor, many can connect to a Thunderbolt port too. Similarly, most USB 1 and 2 devices function quite happily when connected to a USB 3 port.

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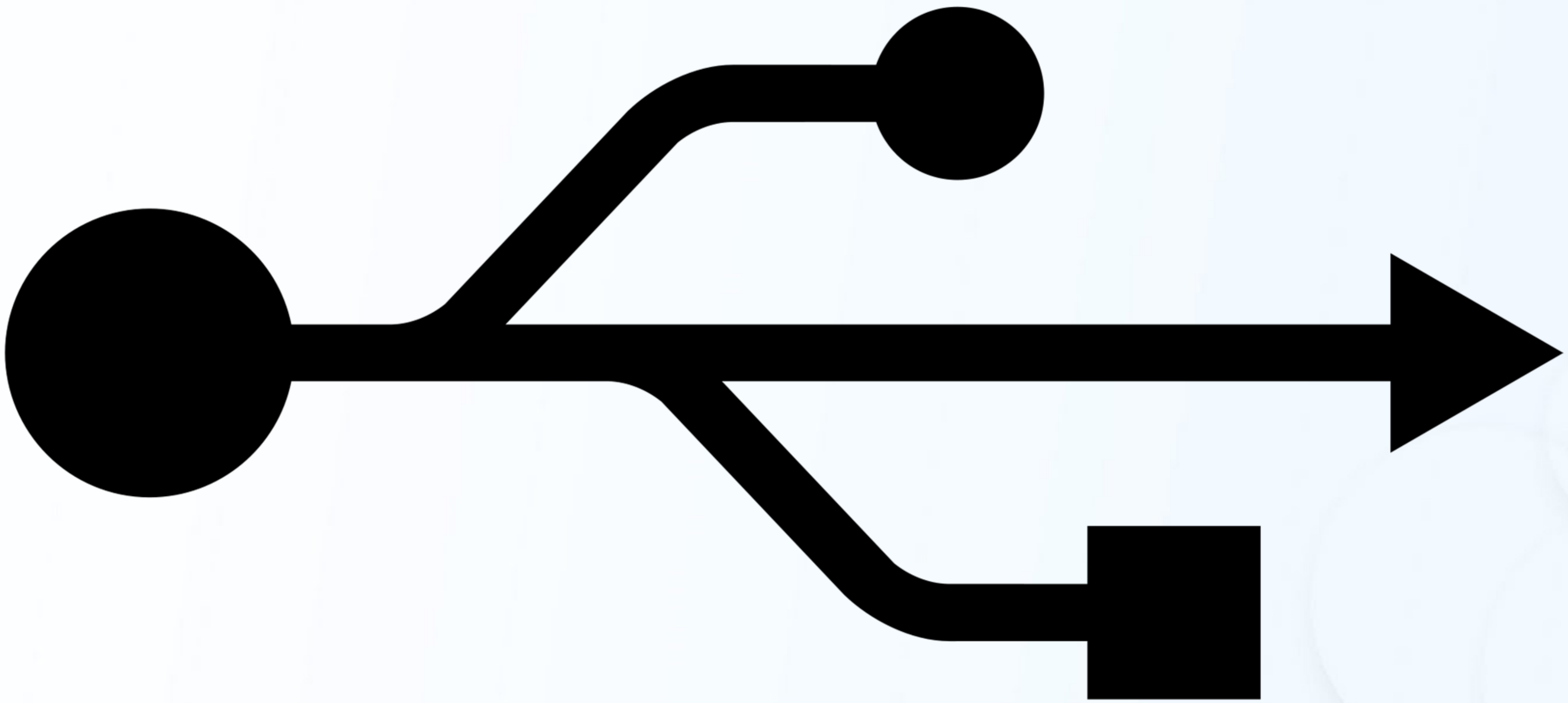
USB 1.0-12 Mbts



480 Mbts

USB 2.0

At the theoretical maximum USB 2 bandwidth, you'd be able to record just over 40 tracks of 24-bit, 96kHz audio, while halving the sample rate to 48kHz would give you 80 tracks.

Many manufacturers of USB 2 interfaces also cater for higher sample rates, including 96, 192 and 384 kHz, but these eat into the USB bandwidth: every time you double the sample rate, you double the amount of data.

In practice, manufacturers will tend either to offer fewer but higher quality (in terms of preamps, A-D and D-A conversion and so on) channels of I/O, or they simply to restrict the number of I/O which may be used at certain sample rates.

So, while it’s true to say the bandwidth of USB 2 does present limitations, it’s probably also fair to say that for most home-studio users these days they’re not all that limiting in practice.

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Firewire 400 Mbts

FireWire

Firewire (IEEE 1394) has never reached quite the same level of adoption on Windows PCs as on the Apple platform, and direct support on motherboards has tailed off almost completely in recent years, meaning that users of Firewire interfaces acquiring a new desktop machine have to fit a third-party card.

When it comes to bandwidth, the first-generation Firewire 400 standard (IEEE 1394a) is slightly worse (400Mbps) on paper than USB 2.

The second generation of Firewire (Firewire 800, or IEEE 1394b) has also been around for a number of years now. It offers twice the bandwidth of FW400 but we are now seeing a move away from this format to USB3

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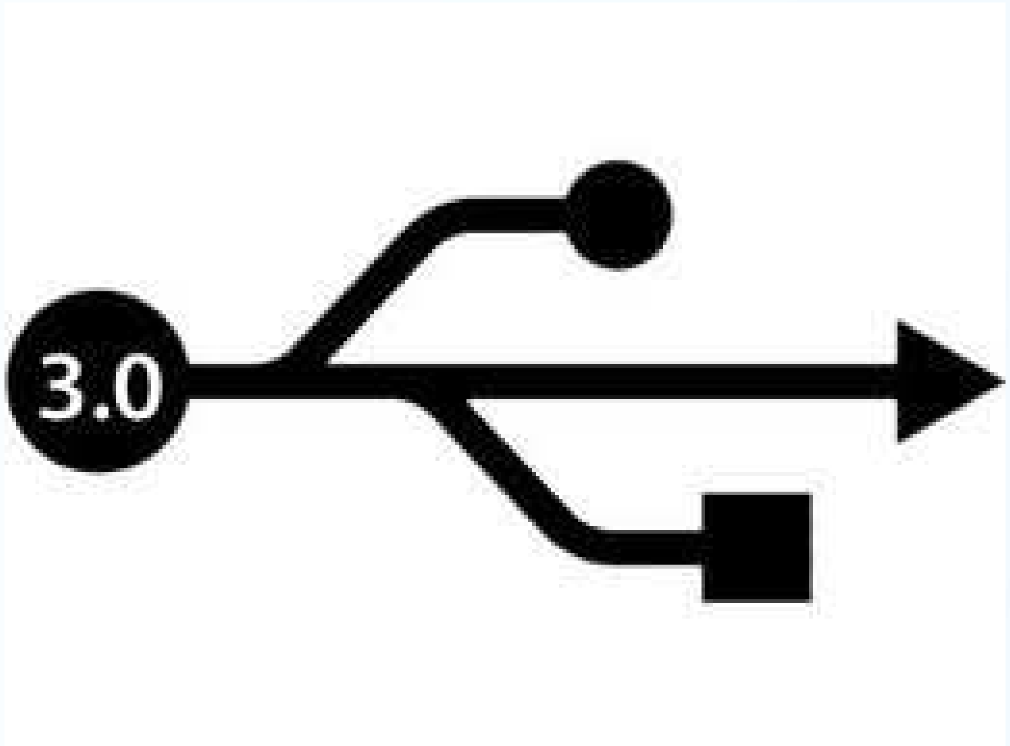
USB-3 5Gbts



According to the specifications, USB 3.0 can achieve an impressive 5Gbps but, just as with USB 2, this is reduced in real-world implementations. In practice, it tends to be closer to 3.2Gbps —that’s still over 10 times the bandwidth of USB 2.

Another potential benefit of USB 3 is that its ports can make more current available for bus-powered devices: 900mA, rather than the 500mA offered by USB 1 and USB 2. This should, in theory, allow manufacturers to develop better bus-powered interfaces, either with more facilities or more channels of the same. I say ‘in theory’ because most models haven’t yet taken full advantage of this extra power.

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USB 3 Compatibility Information

Fully compatible to **Intel's USB 3 implementation which - on current Windows and Mac** computers - is part of the chipset. USB 3 sockets that are connected via an internal cable(not directly soldered onto the motherboard) can cause transmission errors.

USB 3 Compatibility Information 2

Fully compatible to **AMD's USB 3 implementation. USB 3 sockets that are connected via an**internal cable (not directly soldered onto the motherboard) can cause transmission errors

USB 3 Compatibility Information 3

Compatible to **NEC / Renesas USB 3. Real-world performance and error-free operation** depending on the firmware version, driver version and the PCB layout of the respective extensioncard/motherboard.

USB 3 Compatibility Information 4

- Fully compatible to **Fresco USB 3 chip.**
- Fully compatible to **Via VL912, very often used in USB 3 hubs**
- **ASMedia - not compatible**
- **Etron EJ168A - not compatible**
- **Texas TUSB7340 - not compatible**
- **Via VL800/805 - not compatible**

Thunderbolt-2 10 Gbts

- Thunderbolt is actually external PCI Express with added Plug & Play.
- Unlike USB 2 and 3, Thunderbolt is under a very strict quality control and certification process.
- This rigid approach guarantees highest compatibility and functionality.

- Thunderbolt, on the face of it holds the most promise for audio applications. There are several interfaces that offer large numbers of high-quality I/O — some with on-board DSP processing
- There are more affordable units too, including those with few I/O. Why? Well, Thunderbolt offers the same benefits as Firewire did. Not only does that mean good low-latency performance, but also the ability to daisy-chain devices.

- In practice, that didn’t always work so well with Firewire, but that was largely because of the more limited bandwidth. There’s much more available with Thunderbolt, which could make Thunderbolt audio devices appealing given the relatively limited connectivity offered by most modern laptops: not only does it mean you don’t need an adaptor, but it could also free up USB ports for external drives, iLok dongles and so on.

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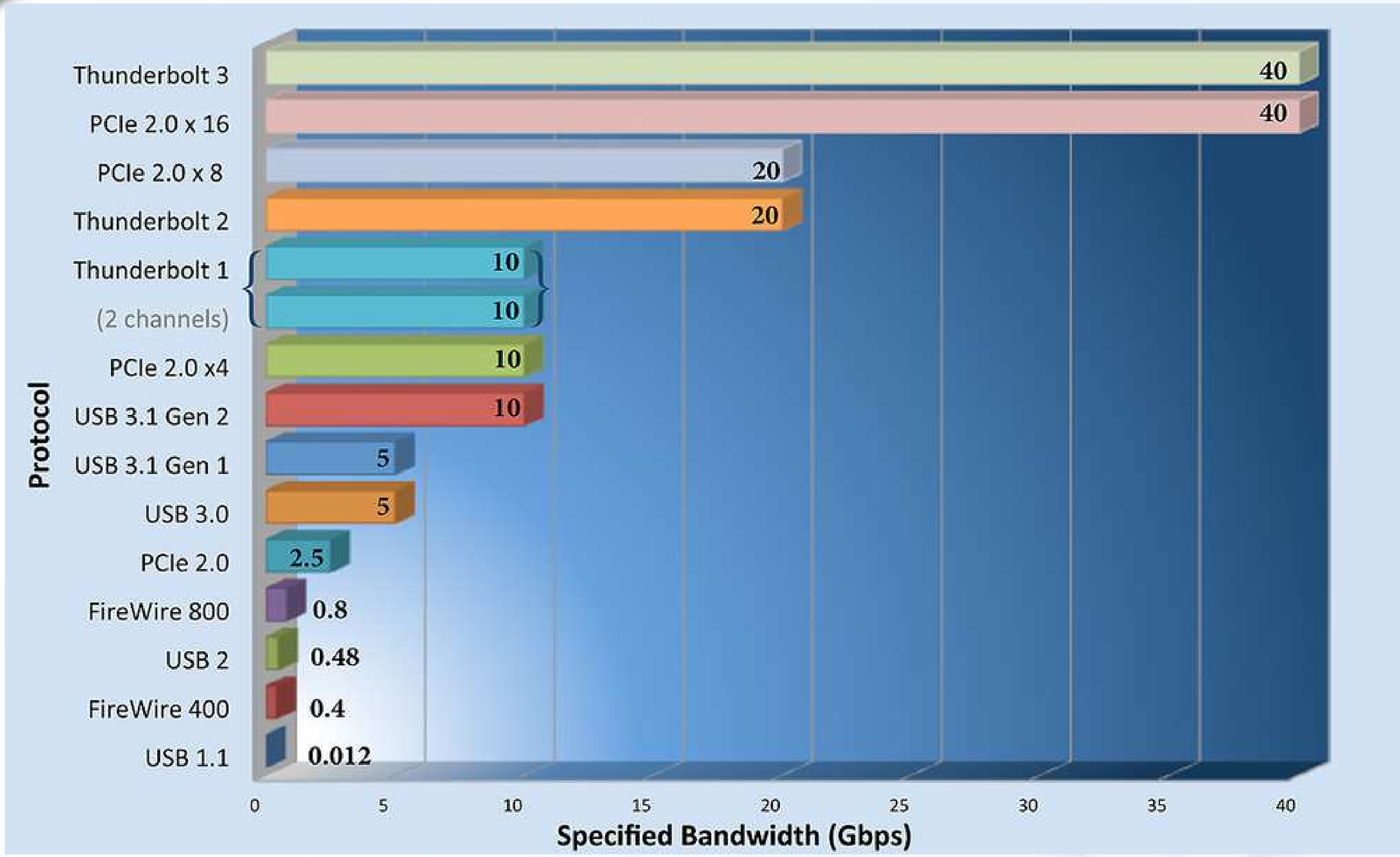
A Quick Bandwidth Review



Thunderbolt 3
40
PCIe 2.0 x 16
40
PCIe 2.0 x 8
20
Thunderbolt 2
20
Thunderbolt 1
(2 channels)
10
10
PCIe 2.0 x4
10
USB 3.1 Gen 2
10
USB 3.1 Gen 1
5
USB 3.0
5
PCIe 2.0
2.5
FireWire 800
0.8
USB 2
0.48
FireWire 400
0.4
USB 1.1
0.012
Protocol
0 5 10 15 20 25 30 35 40
Specified Bandwidth (Gbps)

What Really Makes the Difference in Audio Interfaces

Using an FPGA as both Mixer and a Virtual Controller Chip

- RME uses high powered FPGA chips from XILINX
- FPGA has many advantages over static EPROM chips
- User can flash upgrade new firmware for new features and bug fixes
- TotalMix processing and metering calculations are offloaded from CPU
- RME devices benefit greatly from FPGA use compared to off-the-shelf controllers

Driver Development

- Long history of rock solid drivers with fast update cycle for quick fixes
- Driver development is ongoing for all interfaces still in production
- Unified driver means fixes and changes are applied to all products in a range simultaneously

Steady Clock

- Originally developed to suppress high jitter, SteadyClock can handle any clock source.
- Hi-speed digital synthesizer operating at unsurpassed 200 MHz working directly on the FPGA
- Works on a single stage detection compared to the two-stage found in most clocks. Allowing it to sync with varispeed clocks quicker and more efficiently
- .
- SteadyClock has the ability to extract clock signal from any digital input, clean up the signal if necessary and make it available to all digital outputs.
- Makes external clock unnecessary in most circumstances.

Clock Types

Word Clock

- Equals the current sample rate (48 kHz etc.)
- Simple square wave
- Needs to be multiplied for further usage

Digital audio embedded clock

- Embedded in SPDIF/AES, ADAT and MADI
- Needs to be extracted from the complete data stream
- Usually in the range of 3 - 4 MHz
- Needs to be multiplied for further usage

Timing (Clock) Errors

Old Style Errors (Wow & Flutter)

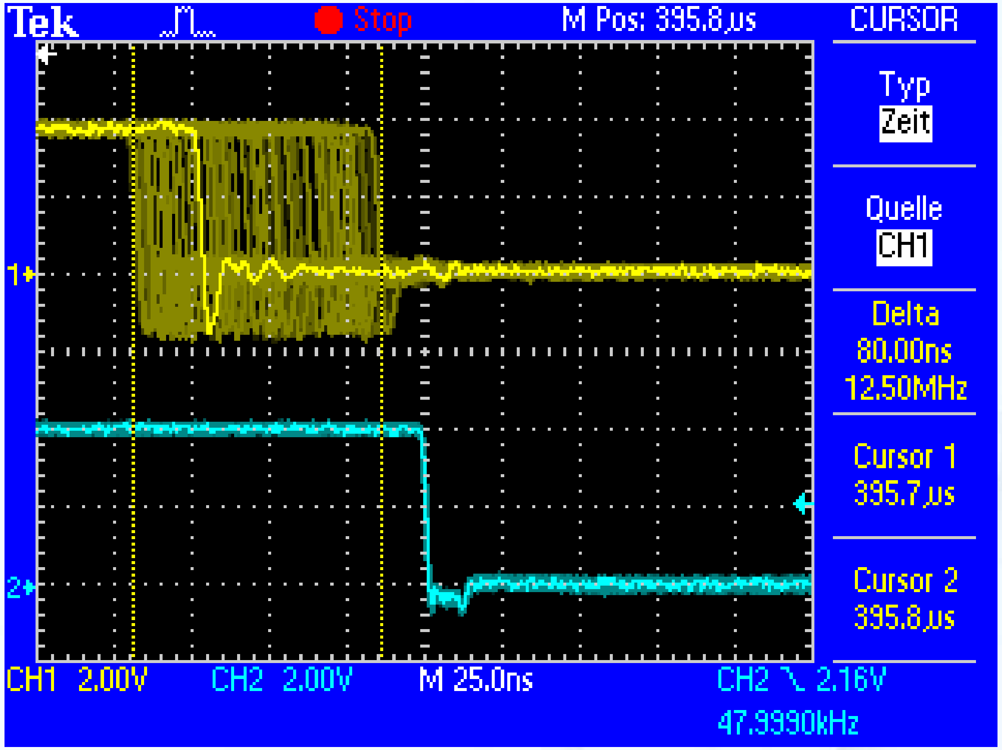
- **Wow: Slowly changing clock (LFO)**
- **Flutter: Fast changing clock (above 5 Hz)**
- **Fast Flutter: Frequency modulation (distortion)**

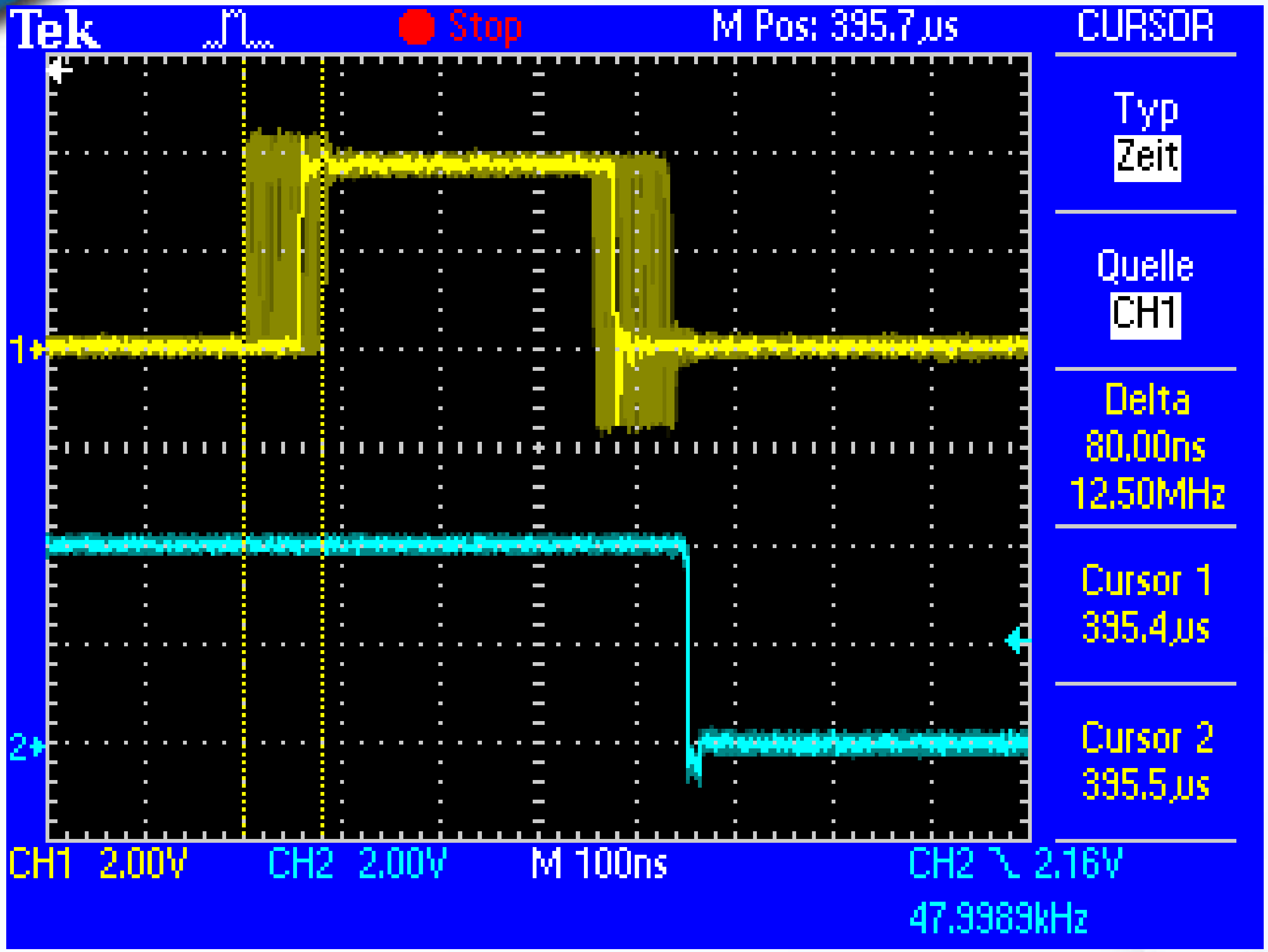
New digital errors

- **Absolute frequency error in ppm (< 20)**
- **Very slow temperature related drifts (< 20 ppm)**
- **Frequency modulation from DC to radio frequencies (RF)**
- **Frequency modulation is called ‘Jitter‘**

How to measure Jitter – DSO

- Move the triggerpoint to the left
- Lowest visible frequency = 1 / trigger offset
- DSO displays jitter as peak to peak in nanoseconds
- Use persistance mode to show all deviations

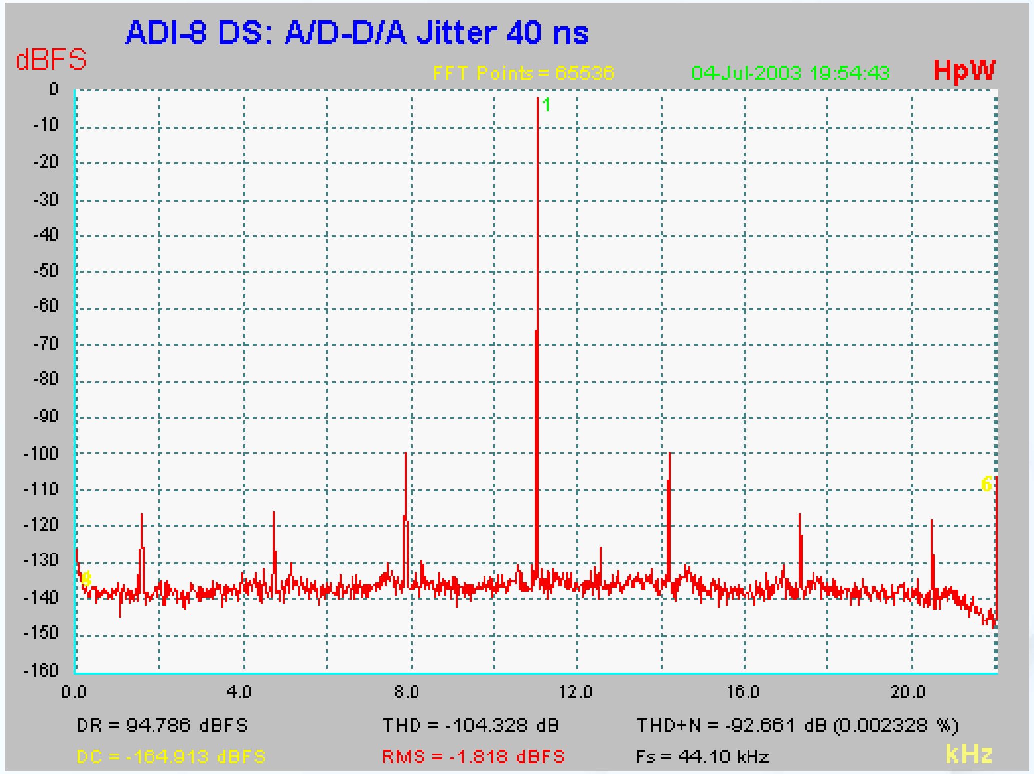


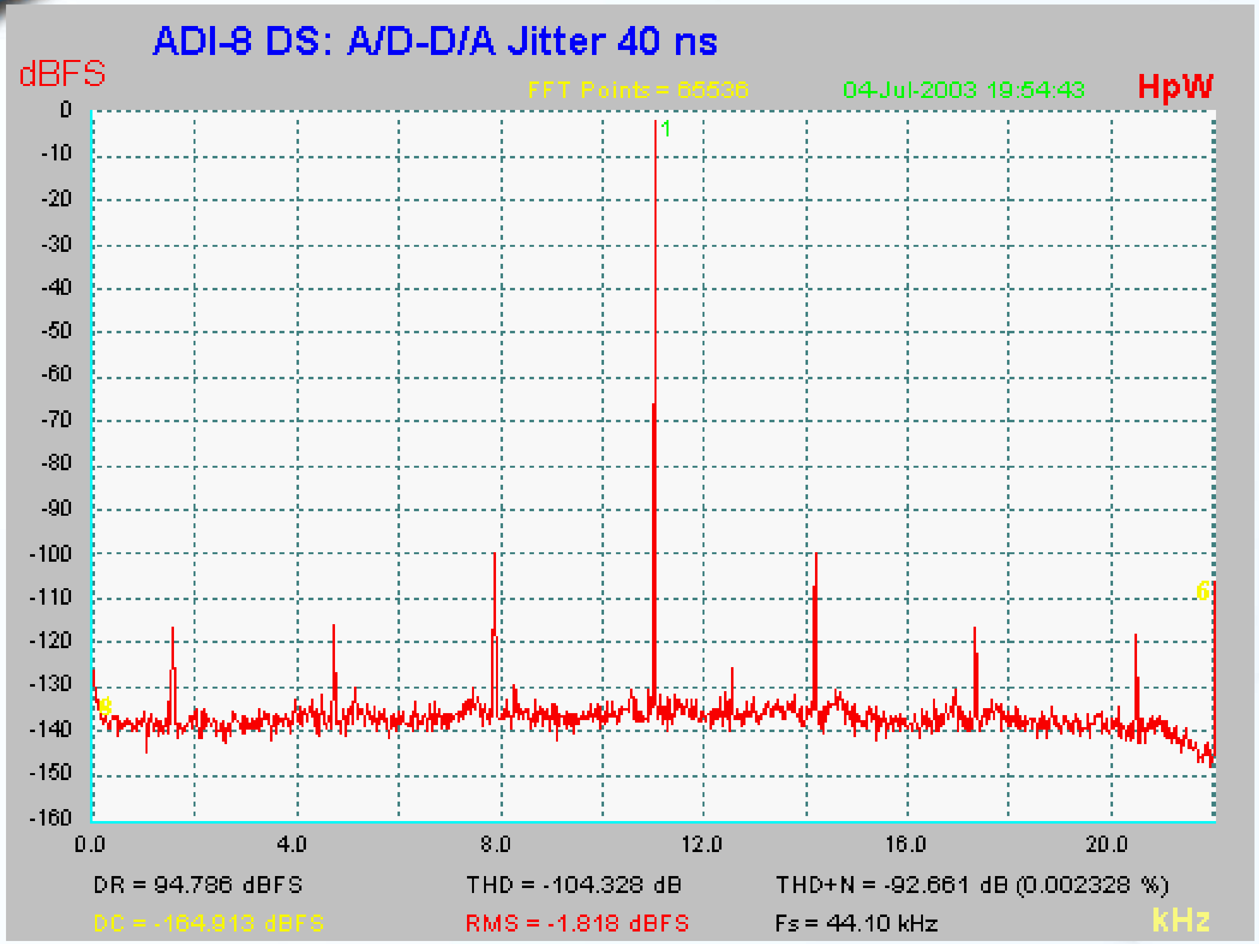


Tek
Stop
M Pos: 395.7 µs
CURSOR
Typ
Zeit
Quelle
CH1
Delta
80.00ns
12.50MHz
Cursor 1
395.4µs
Cursor 2
395.5µs
CH1 2.00V
CH2 2.00V
M 100ns
CH2 ⤥ 2.16V
47.9989kHz

How to measure Jitter – A to D Conversion

- Feed clean 10 kHz sine giving near 0 dBFS level
- Perform hi-resolution FFT of the digital output data
- Jitter is displayed as sidebands to the 10 kHz sine




ADI-8 DS: A/D-D/A Jitter 40 ns
dBFS
FFT Points = 65536
04-Jul-2003 19:54:43
HpW
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
0.0
4.0
8.0
12.0
16.0
20.0
DR = 94.786 dBFS
THD = -104.328 dB
THD+N = -92.661 dB (0.002328 %)
DC = -164.913 dBFS
RMS = -1.818 dBFS
Fs = 44.10 kHz
kHz

Methods to remove Jitter

Reclocking using a PLL

- The PLL (Phase Lock Loop) follows the incoming frequency
- A low-pass filter characteristic removes fast frequency changes
- Usual circuitry only removes RF-style jitter
- Jitter below 20 kHz stays unchanged

Techniques for audio-band low pass filters in a PLL

- Use of a VCXO instead of a standard quartz
- Use of ceramic filters instead of a standard quartz
- Use of digitally controlled frequency generation (DDS)

DDS – Direct Digital Synthesizer

Problems when using DDS in digital audio devices

- DDS jitters by design due to the limited clock resolution
- The measurement of the input frequency has limited accuracy
- Custom DDS chips are expensive and have limited speed
- Custom DDS chips need expensive and cumbersome filtering

DDS – Direct Digital Synthesizer

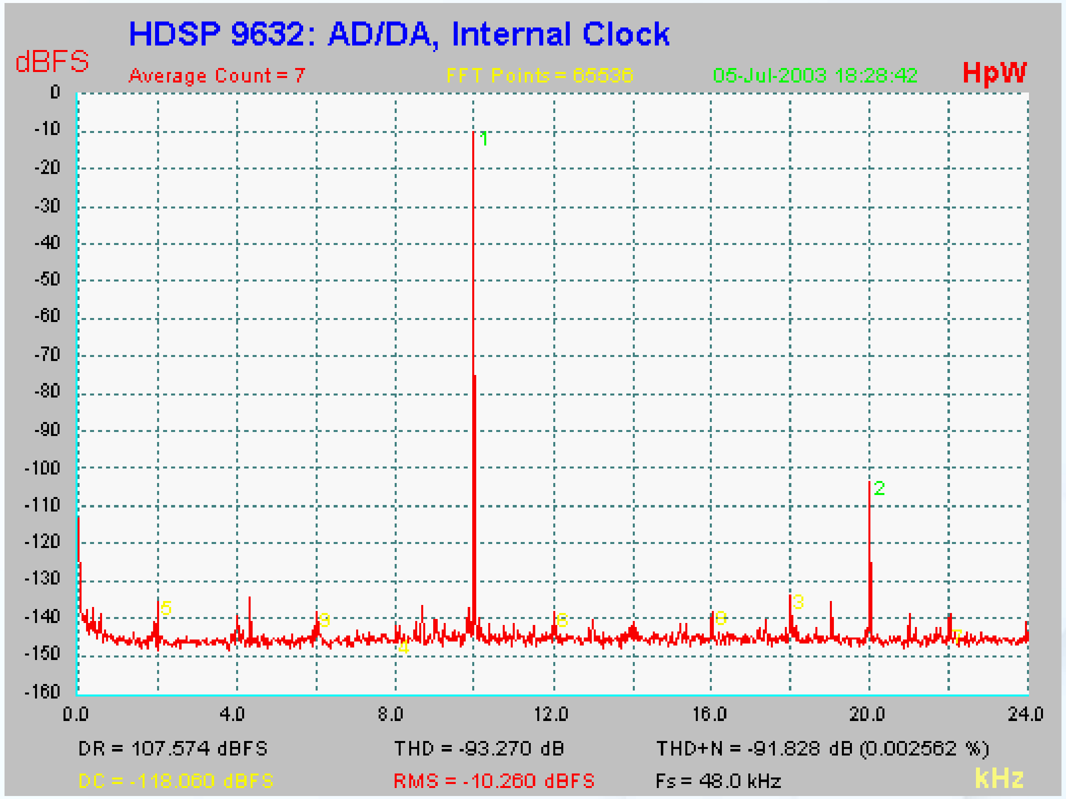
The RME solution - SteadyClock

- DDS performed directly within the FPGA
- Unrivaled accuracy when measuring the input frequency (100 MHz sampling)
- Digital averaging of 1024 input samples improves input frequency measurement and reduces audio band jitter
- Unrivaled speed of 200 MHz for the frequency synthesizer
- Completely digital PLL design
- Corner frequency 20 Hz, > 30 dB reduction at 2.4 kHz
- Analog hi-speed PLL removes all remaining DDS jitter

SteadyClock – how to guarantee best sound quality

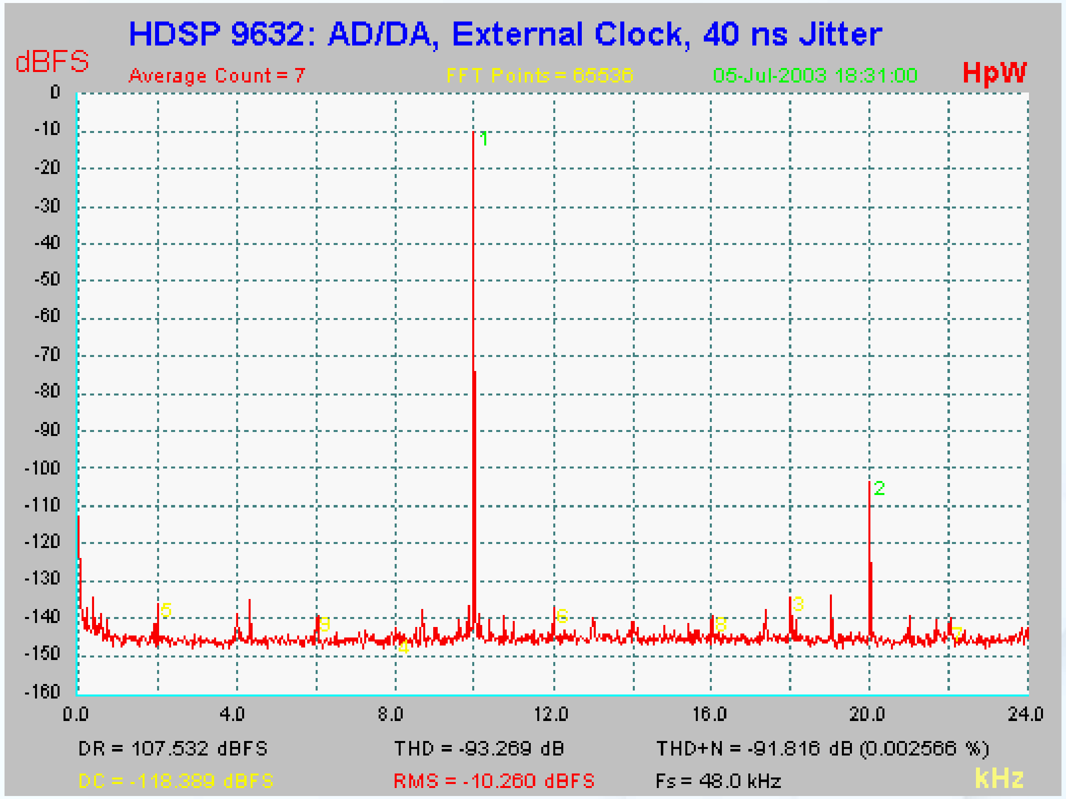
SteadyClock in the HDSP 9632

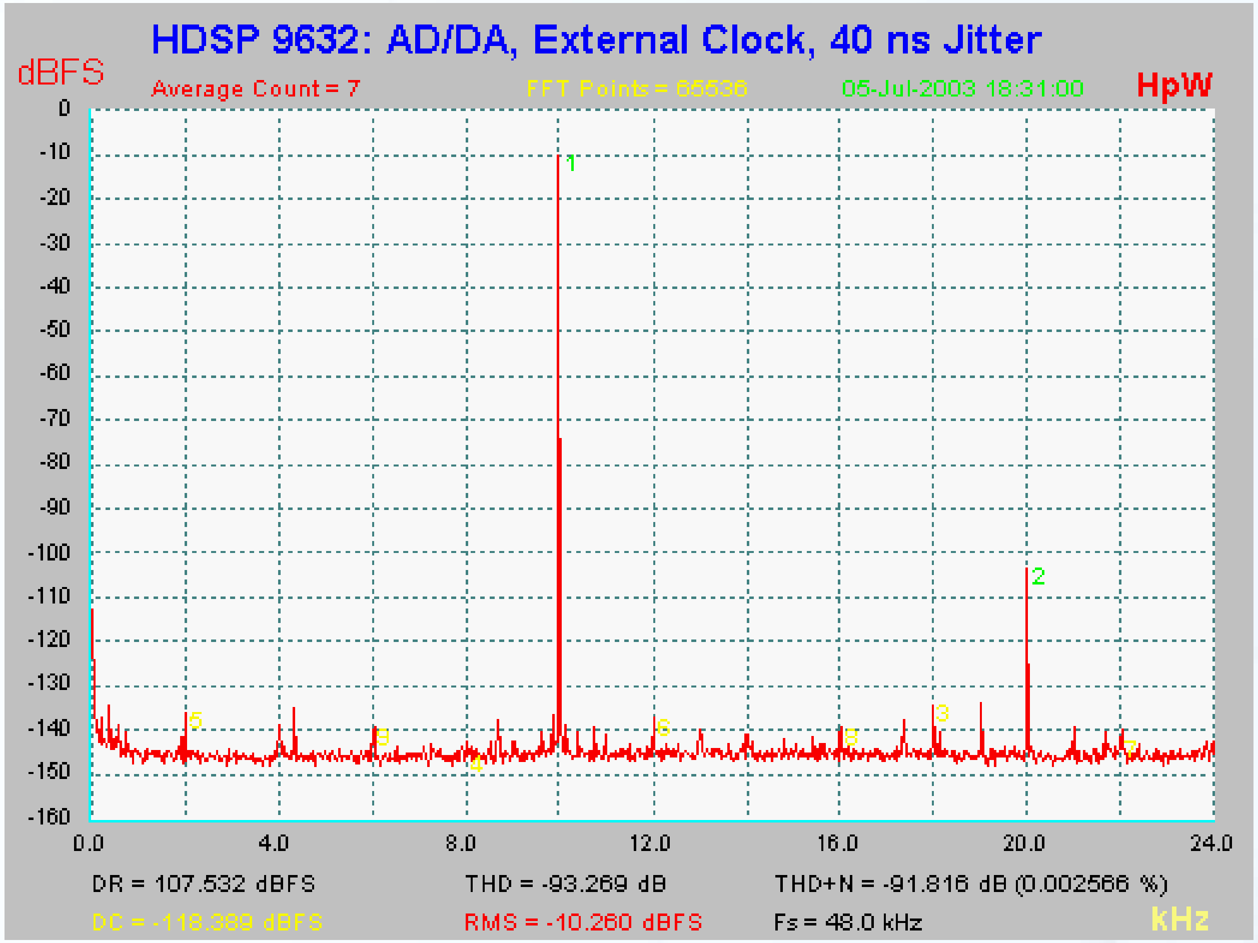
- **Feed clean 10 kHz sine giving near 0 dBFS level**
- **Internal clock jitter < 1 ns**
- **Perform hi-resolution FFT of the digital output data**
- **Jitter is displayed as sidebands to the 10 kHz sine**
- **No jitter artefacts visible**
- **Full SNR and THD as expected**



SteadyClock in the HDSP 9632

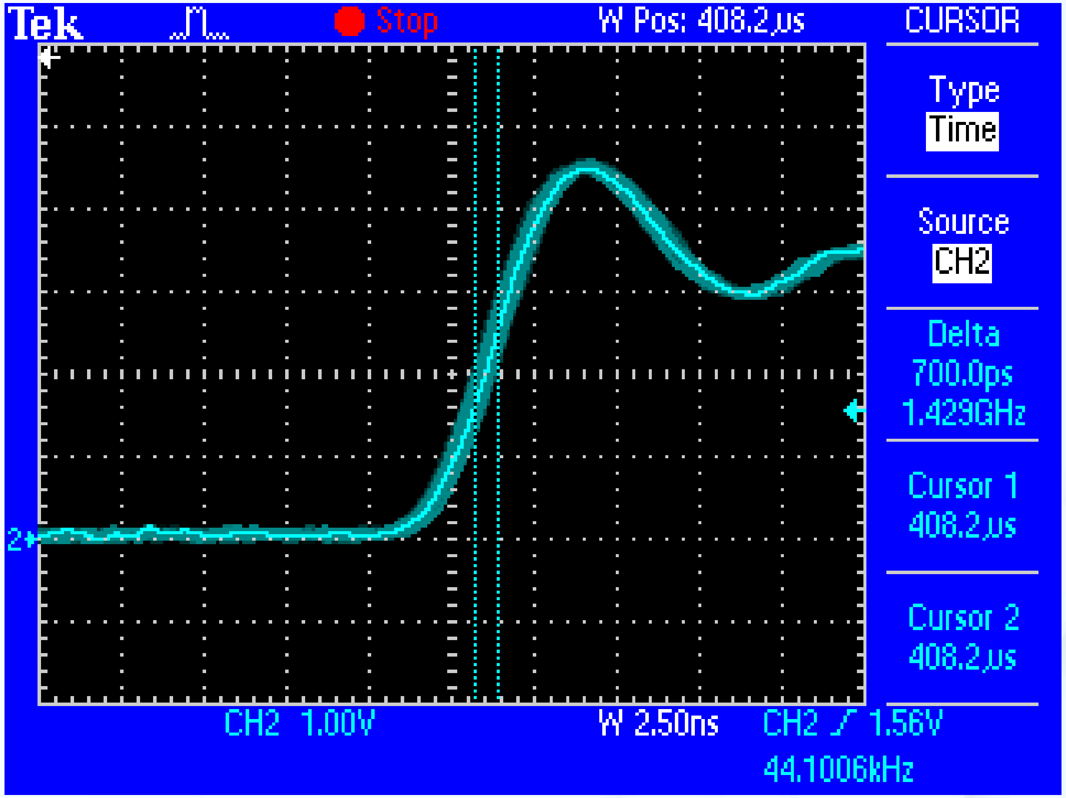
- **Feed clean 10 kHz sine giving near 0 dBFS level**
- **External clock jitter 40 ns**
- **Perform hi-resolution FFT of the digital output data**
- **Jitter is displayed as sidebands to the 10 kHz sine**
- **No jitter artefacts visible**
- **Full SNR and THD as with internal clock**




HDSP 9632: AD/DA, External Clock, 40 ns Jitter
dBFS
Average Count = 7
FFT Points = 65536
05-Jul-2003 18:31:00
HpW
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
0.0
4.0
8.0
12.0
16.0
20.0
24.0
DR = 107.532 dBFS
THD = -93.269 dB
THD+N = -91.816 dB (0.002566 %)
DC = -118.389 dBFS
RMS = -10.260 dBFS
Fs = 48.0 kHz
kHz

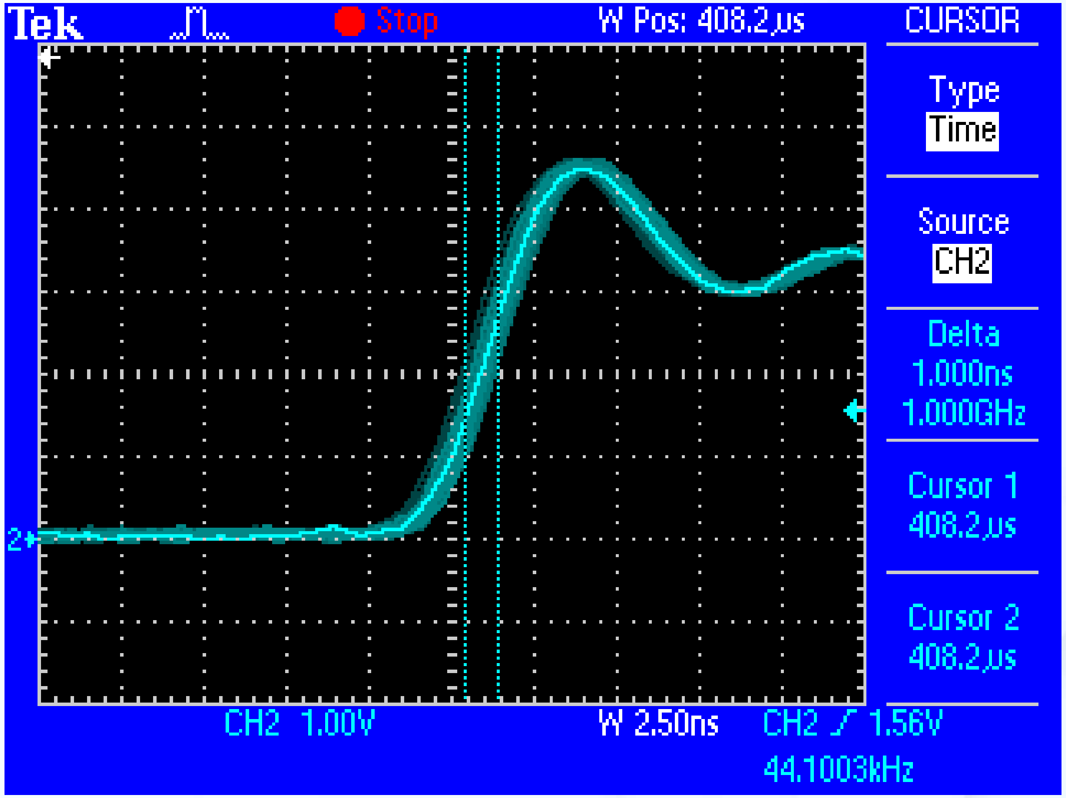
SteadyClock in the HDSP 9632

- **Move the trigger point 400 µs to the left**
- **Internal clock jitter < 1 ns**
- **Measured at word clock output**

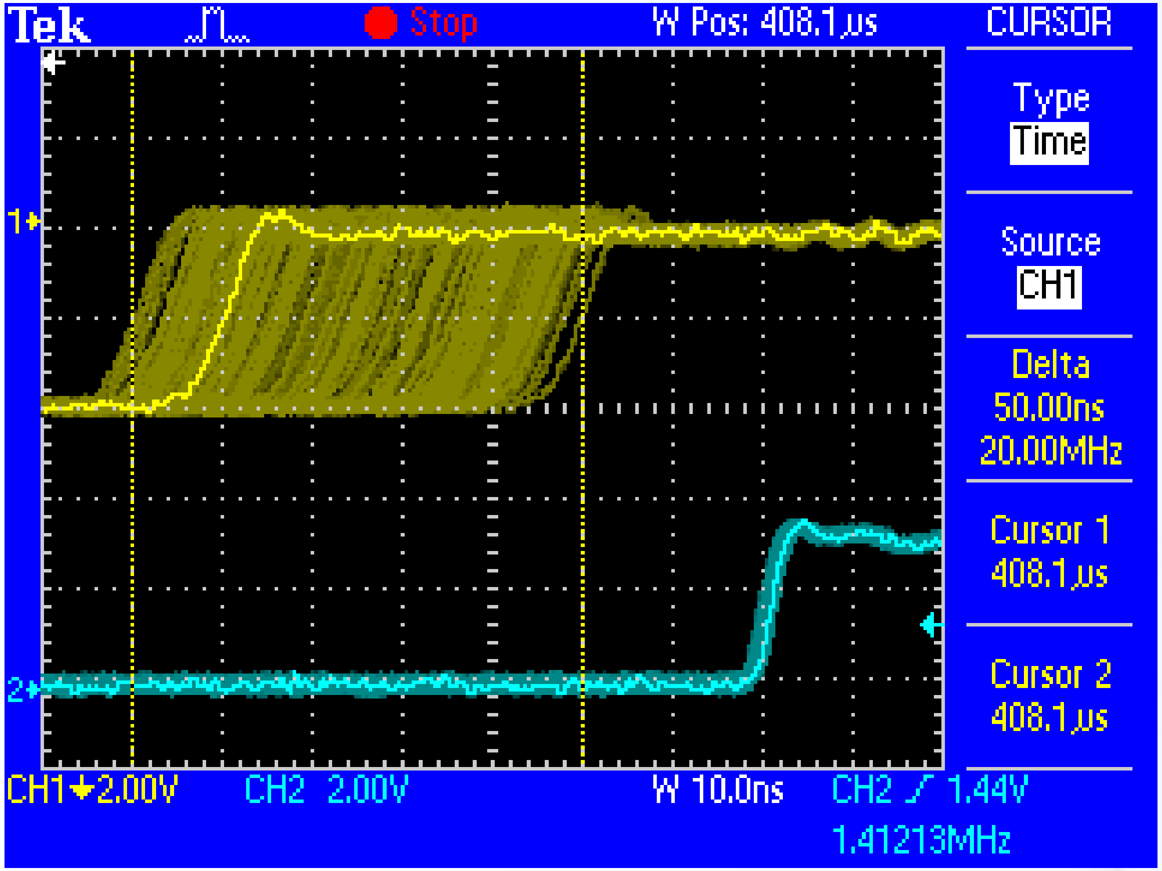


SteadyClock in the HDSP 9632

- Feed external clock jitter with 40 ns, modulation 2.4 kHz
- Clock jitter 1 ns
- Measured at word clock output



Comparison input signal to output signal



Summary

SteadyClock

- is a very cost-efficient solution
- outperforms other solutions based on special DDS chips
- effectively reduces clock jitter
- guarantees best AD/DA conversion = best sound
- locks fast and accurate as old-style analog PLL circuits
- can be controlled digitally
- generates any desired frequency / sample rate (< 1 Hz)

Thankyou

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