The Digital Audio Word Clock
An Overview

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The digital audio clock, also expressed as Wordclock, Word Clock, Internal Clock, Clock or Master Clock, is a core determinant in the experience of audio, yet today, it is not often spoken about, considered or understood. Therefore, this month we review digital audio clocking in general terms, and from the perspective of industry leader MUTEC, using the term Word Clock. This complex technology can be explained in various forms, and given the diverse nature of our subscriber base, we have focussed on delivering a concise but hopefully compelling White Paper. The Word Clock is pivotal in other technology streams including video, which we will address in a future edition.

The Essential Role of the Word Clock Inside Devices

Every digital audio device features an internal clocking system from which, audio Word Clock rates are derived, needed to clock the audio processing and audio interface. However, such clocking systems vary markedly in terms of specifications and consequent performance outcomes. To digitize a continuous analogue audio signal, it must be sampled at precise and regularly repeating intervals. A Word Clock governs that timing interval, allowing the waveform to be re-constructed as an accurate analogue signal. The term Word Clock derives from the fact it clocks each audio sample (represented in data words), and is used entirely to keep a perfectly timed and constant bitrate to avoid timing errors that would compromise the accurate reconstruction of the analogue waveform. Should clock timing vary, audio samples may be captured or reconstructed at the wrong time, introducing distortion, hence the critical nature of Word Clock timing accuracy. The clock rate of the Word Clock used for the audio processing described, is standardly x256 or x512 higher as the Word Clock rate with which the audio input and output interfaces are finally exchanging the audio. Furthermore, the Word Clock provides other useful information, such as identifying each encoded audio channel in multi-channel systems. Formats that can use Word Clock include S/P-DIF, AES3, AES3id, ADAT, TDIF and MADI. For our purpose here, Word Clock and its function should not be confused with bit clock, clock-sync or timecode.

The Use of the Word Clock for External Clocking

External clocking of digital audio devices is standardly done by dedicated clock generators. They are based on one clock source, whose output signal is transformed into Word Clock frequencies and transferred to multiple outputs. The generated Word Clock frequencies are of basic clock rates for example; 44.1, 48 or 192kHz. One can distinguish between two applications of external clocking; clocking in pro audio and clocking in consumer, respectively for audiophile use. For pro audio, and although widely claimed to improve audio quality as well, the clocking in pro audio is mainly done to get digital audio devices synchronized in a studio environment to ensure problem-free exchange of digital audio data between them. Therefore, the stability of the clocking is essential, which is standardly achieved by the use of so-called Atomic or temperature-compensated clock oscillators (TCXO) installed in the clock generator. When it comes to audiophile set ups, external clocking of companion audio devices is done only to improve audio quality. For this purpose, the stability of the clock generator is not essential, but for the phase noise of the generated audio clocks. The phase noise is measured in frequency distances 1-, 10-, 100-, 1000Hz up to 1MHz to the respective carrier frequency of e.g. 44.1kHz. For audiophile sound improvement the distance area between 1-100Hz from the carrier frequency is most important and should be as low as possible.

Setting the Scene

By any measure, MUTEC have earned an enviable industry-wide reputation founded on research, uncompromised engineering practices and understanding the importance of operational simplicity. Therefore, we will consider word clock technology from the MUTEC experience and perspective, beginning with two recent R&D triumphs that produced a) definitive reference clock technology, and b) an enhanced USB environment.

Word Clock clocking technology can be found in all digital audio devices and systems usually involving a domain change, i.e. analogue to digital or digital to analogue, including DACs, CD Players, AD/DA Converters and Digital Audio Workstations et cetera. Today the MUTEC range is broad, diverse and categorized under many descriptors including; Clock Generator, Master Clock, 10MHz Reference Master Clock, Clock Distributor, Signal Distributor, Audio Re-Clocker, USB Interfaces, Audio Format Converter, Sampling Rate Converter, Video Sync Master Clock Generator, Video Routing Matrix and Distributor. Furthermore, MUTEC is highly favoured in both professional production and audiophile sectors.

Creating a Reference Masterpiece

The Word Clock has evolved significantly from the early days of digital audio electronics. Most current digital converters, master clocks and audio re-clockers perform acceptably when reproducing or processing digital audio, however they fall short in delivering optimum potential. MUTEC embraced the challenge to advance the state of the art and science by recruiting Germany's most renowned RF engineers to their R&D team, to enhance the performance of digital audio systems. The outcome, a 10MHz reference master clock of remarkable technical performance, consequently verified by a group of beta testers, named REF10, MUTECs first Empyreal Class product. It combines uncompromised engineering, the beauty of simplicity, and the utmost clock precision. The performance outcome is exemplified in REF10's ultra-low phase noise specification that directly impacts the experience of audio.

Debunking the "Atomic" Myth

MUTECs research has shown that the high clock stability of so-called "atomic clocks" based on a rubidium or cesium oscillator is limited to the long-term time domain. This long-term stability refers to the amount the absolute clock frequency (10 MHz or 10 million cycles per second, in this case) drifts over time. While this long-term stability may be useful for pro audio or telecommunication applications, it is essentially irrelevant for audiophile purposes. Ultimately, it is the timing from one sample to another as a digital audio stream transferred from one device to another that needs to be as precise as possible for ultimate sound quality outcomes. Fluctuations in short-term stability are measured as jitter or phase noise and are central to the critical performance of any digital audio device.

In contrast to these "atomic clocks" then, the REF10 is engineered around MUTECs handcrafted, oven-controlled oscillator (OCXO) produced in Germany. It uniquely combines the important features for both main applications; highest short-term clock stability for audiophile sound improvement and long-term clock stability for device synchronization in pro audio.

Power Supply and Voltage Considerations

Generally misunderstood is the importance of a well laid out main power supply, the foundation of all active electronic technology, whose quality will determine the performance capability and stability of a device. To meet the optimum requirement for the REF10, MUTEC designed a bespoke dual linear power supply based around a German made toroidal transformer. It provides a dedicated transformer winding for the sensitive OCXO that is completely isolated from the surrounding circuit. Networks of lowest-ESR (equivalent series resistance) capacitors made by Panasonic ensure best interference suppression for the supply voltages. Hereafter, sub-Hz optimized, lowest-noise voltage sources arranged in multiple stages independently supply every part of the circuit to avoid mutual interference. However, for the heart of the REF10, MUTECs handcrafted OCXO, the R&D team developed a dedicated power source whose remarkably low noise delivers outstanding oscillator performance. Unique ultra-low noise clock distribution and amplification circuits were then developed, which successfully transfer the oscillators reference signal to the REF10s 8 outputs with virtually no losses. Space limitations deny the opportunity of presenting all aspects of the REF10 development; however, we are sure you get the picture.

A New Benchmark for USB Audio

Universal Serial Bus (USB) interfaces are the preferred and most commonly used devices for digital audio transmission in a computer-based music environment, due the simplicity, reliability, set up speed and general ease of use. However, convenience can have a detrimental impact on audio quality in critical listening applications. Even the best D/A converters are not capable of reproducing and converting audio via USB at the highest level, which is why using digital audio inputs such as AES3 or S/PDIF deliver superior results and are generally preferred. This landscape presented another R&D mission for MUTEC, namely to research underlying principles and core problems with critical audio performance in the USB environment. Electromagnetic interference, particularly those caused by audio computers and IT devices, will induce noise and disturb audio transmission. To counteract these disturbances that damage the conversion process, MUTEC developed a new signal-isolating, asynchronous USB interface for the MC-3+ Smart Clock USB.

It has been designed as a dedicated building block with a power supply independent from the main board of the device. In addition, the USB interface is galvanically isolated from the other parts of the circuitry and employs its own ultra-low noise oscillators that are autonomous and isolated from the other processes. In combination with high-speed isolators MUTEC have achieved exceptional reduction of the impact of noise interference within the USB data stream, yielding a USB interface that is virtually immune to interference problems caused by PCs, laptops or music servers. Coincidentally, there are no limitations regarding the possible clock rates from music library playback, with the MC-3+USB supporting all rates up to high-speed USB and DSD streams up to 256.

All of these developments in combination with the subsequent re-clocking process, proprietary to MUTEC, leads to a significant acoustic improvement of connected digital audio devices, that usually manifests in increased width of the sound stage, more precise imaging, and with a more natural and linear representation of the recorded space and the instruments within it. The new benchmark in USB audio is realized.