What is Jitter?

Jitter is a kind of vibration - and the thing that vibrates is the time an event happens, that you expect to happen at a specific time.

So, if you have a girlfriend that you expect to see every day after work at 7.00pm you know, what jitter is: Sometimes she comes at 6.30, sometimes at 7.23 and sometimes maybe the next day. The time of arrival of your girlfriend then jitters.

If you then observe these irregularities in arrival time over a longer period, you will learn more about the kind of jitter.

The latest arrival time minus the earliest arrival time during the observed period of time is called the "peak to peak jitter amplitude".

The "jitter-amplitude" is the expected time minus the time of arrival. So jitter-amplitude can have positive (early) or negative (late) values.

You can build the average over a larger number of jitter-amplitues, if you want to know the time your girlfriend may most likely arrive. Then you may see, if the distribution of the arrival-times is completely random (random jitter) or depends on other events (correlated jitter).

Correlated jitter is, when you know that on Thursday she comes later, because she has to look after her mother.

If you got it to this point, you are already an expert concerning jitter.

What is Clock Jitter?

In digital audio, we deal with the transmission of digital signals:

> Music is read as binary numbers from a CD or a DAT tape and then these numbers are transferred to the DA-converter, that restores the music as an analog waveform.
>
> A reference clock signal is transmitted to an AD converter, that converts analog waveforms into digital numbers for a digital recording.

Digital signals are always transmitted together-with, or referring-to a clock signal. Some digital transmission formats like S/PDIF(by Tomi Engdahl) or AES/EBU(crystal an22.pdf) carry clock and data in one signal.

A digital clock signal is a square-wave with a "fixed" frequency and amplitude and, desirably a 50% duty cycle.

The transitions of a clock signal (when the square wave goes from low to high level or from hi to lo) contain the timing information.

If the distance between 2 or 3 subsequent transitions is not equal over the time, we have a jittered clock. And if you take it seriously, there is no such thing as a jitter-free clock! (There is no such thing like a girl friend that always arrives at 1/1000 sec. precision).

Now, that you know the basics of clock-jitter, we will switch to the professionals:

Joe Adler (of Vectron International, a manufacturer of frequency control products) defines clock-jitter like this:

"Short-term variations of the significant instants of a digital signal from their ideal positions in time" **Βλέπε jitter_1.pdf**

In his article, Adler also speaks on jitter measurement techniques and how jitter performance is specified.

What generates the jitter?

Precision is a delicate thing - the more precise, the more vulnerable.

And as we will see later, a very high degree of clock precision is needed in digital audio, since our ears and their post-processors seem to be of such excellent quality, that very accurate measurement instruments are needed, in order to find the underlying causes of differences in sonic perception.

Digital audio equipment is timed by crystal clocks.

As Mike Story (of dCS Ltd, a manufacturer of audio equipment) states:

"Crystal based clocks (XCO´s, VCXO´s) generally have the lowest jitter - but they still have some."

and

"There are other sources of jitter inside equipment that may contribute substantially more than the VCXO." **Βλέπε jitter_2.pdf**

These "other sources of jitter" are mainly power supply fluctuations "causing variations in logic level switch points" respectively - variations in switch timing.

With this statement, Story has put his finger on one of the key aspects of our todays audio related jitter problems.

What happens inside a CD player?

If power supply noise will cause timing variations in logic level switches, what will happen in a disc player (CD, DVD, DSD) or in a MiniDisc player or in DAT machines?

A simple CD player has multiple motors or actuators and associated control loops, in order to perform disc reading:

There are f.e. the spindle motor that turns the CD, the sledge motor that performs axial tracking, and actuators for focus and radial tracking.

Each of these motors / actuators will add a portion of noise to the power supply of the player and this noise will affect accurate switch timing.

So, each of the motors /actuators adds jitter to the digital audio signal and each adds a different kind of jitter (different in frequency, amplitude, waveform) and will affect audio reproduction in different ways.

And this fact gives you the answers to a lot of questions that are hot topics among audiophiles and recording engineers:

- Why do different clamps on a top loading CD transport lead to different hearing results?
- Why do some manufacturers of CD-transports use belt drives?
- Why does a CD-R sound different, although bit-identical?
- Why do different CD-transports sound different?
- Why do some manufacturer use stray light inside the CD-player?
- Why do products that "demagnetize etc..." the CD seem to work?
- Why do different recording media sound different although they are all digital?

The answer to these questions is mainly:

Clock jitter due to power supply noise.

Therefore some CD-players or -transports are very expensive, because they treat clock jitter at the source. These components have a very stable and clean power supply, or multiple supplies, precise clocking circuits and costly mechanical construction.

As we will see later, we can have comparable performance for much less financial effort.

But how can we be sure, that the above "Why´s" can all be explained with jitter? This is discussed later in "How does jitter sound".

Let us first take a look at:

The sources of jitter

In his article "Jitter: Specifiation and Assessment in digital audio equipment" **Βλέπε jitter_3.pdf.** Julian Dunn (of Nanophon, an engineering company that specialises in digital audio) differentiates between "interface jitter" and "sampling jitter".

Interface jitter is then further divided into "transmitter jitter" (fe. the jitter that comes out of our CD transport / -player) and "line induced jitter".

The latter comes into action, if we connect the digital output of our CD-player to an external DA-converter. This is a transmission of a digital signal and it will add jitter to our signal whether we use a coaxial cable TOSLINK or SToptical interfaces.

Funny enough, all these interfaces behave different and add different kinds of jitter (different in jitter amplitude, waveform, frequency distribution, correlation).

So now you have the answer to the following questions:

- Why do different digital interfaces sound different, although they carry exactly the same information?
- Why do different cable lenghts sound different?
- Why do some coaxial cables of the same lenght but different manufacturers sound different?

This is line induced jitter.

Sampling jitter

In an audio reproduction chain we can try to attenuate the jitter in our signal prior to DA conversion by means, discussed later in "How can we get rid of it".

But what can we do, if the jitter is already on our recording.

Well, unfortunately nothing, but make a new jitter-free recording.

This is a sad story and i can understand those of you, who stick to their turntables and play vinyl, because the CD-recording does not sound.

What happens to a digital recording in the presence of clock jitter? You take the right samples at the wrong time. This is not correctable later on.

Transmitter jitter and line-induced jitter are keywords that also apply for digital recording chains:

A master device, that generates the clock for an AD converter will have a certain amount of transmitter jitter. The clock signal is transmitted from the master device to the AD converter via a digital transmission line and line-induced jitter will be added. This jittered signal will then be the timing reference of the AD converter and determines the sample points. Internal circuitry of the AD converter attenuates the jitter from the external clock input prior to conversion but it cannot remove all jitter.

The rule of thumb for the recording engineer is:

The less jitter at the clock input of the AD converter, the better the recording quality, and vice versa.

Bob Katz (of Digital Domain, a manufacturer of audio equipment) states:

"The A to D Converter is one of the most critical digital audio components susceptible to jitter, particularly converters putting out long word lengths (e.g. 20-bits)."

With low budget equipment it is sometimes better to use the internal timing reference of the AD converter. Then there would be no interface jitter between an external clock reference and the converter. This is possible if only one converter device is used and only one take is necessary. If you want to add tracks later on, you have to synchronize the ADs to the tracks that you have already recorded and then you need the external reference clock.

In high quality recording studios, a high precision reference clock (typically oven controlled) is used to synchronize the AD converters. If we have such a good clock, we have very few transmitter jitter. But this clock signal has to be distributed via digital transmission lines, so we have to cope with line induced jitter.

That was the jitter overview. I tried to put it all into a context. The articles of the various experts contain detailed information. If you feel that i am wrong with this or that, please email me.

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