Achieving 24-bit Resolution with TASCAM's New-Generation DTRS® Format Recorders / Reproducers

TASCAM
a whole world of recording

Introduction.

The DTRS® 16-bit format was originally seen by many people as an interim technology to bridge the gap from analog tape-based linear recording to the emerging 16-bit random access systems. For many audio professionals, tape has a physical appeal and known quality parameters that helped ease the transition from analog to digital. The DTRS format in particular had several redeeming qualities that set it apart from other digital tape formats of the day. These included the small physical size of the Hi-8mm cassette, the 108 minute (1 hr. 48 min) recording time available on a standard tape, a rapid response transport mechanism, and the ease of interfacing DTRS machines into a wide variety of production and post production environments.

As technology evolved, we began to see the emergence of 20-bit and 24-bit systems, both in the tape and non-linear areas of audio recording. It has taken several years for the industry to refine and ultimately embrace the new higher bit rates, and agree on what are now recognized as the “standard formats” for recording and production arenas. These include the 24-bit 44.1/48 kHz, and 24-bit 96 kHz standards, with the ultimate record quality being that of 24-bit 192 kHz for DVD music mastering.

As more disk-based recording and editing systems that supported these higher bit and sample rates became available, several problems began to emerge. The first of these issues was the cost of multi-track disk-based recorders that had high-resolution capabilities. Secondly, storage requirements began to increase. A 24-bit/96 kHz recording, for example, occupies twice the storage capacity of a 24-bit/48 kHz recording. Hence, acquisition and archiving became important issues.

While a few manufacturers built tape-based systems at the 20-bit level, few supported 24-bit word lengths or the higher 96/192 kHz sample rates - at least at a price point that could be afforded by the average musician or recording facility. Recognizing this situation, TASCAM engineers began the long, arduous task of developing a next-generation DTRS recorder capable of integrating into the contemporary 24-bit recording environment.

Development History.

In 1996, upon completion of the DA-38 Digital Multi-track Recorder, TASCAM engineers determined the time was right to develop a 24-bit DTRS machine that could carry the popular format forward into the emerging high-resolution recording era. Upon conclusion of numerous studies and evaluations, TASCAM R&D had reached consensus that it was technically feasible to incorporate 24-bit capability into the DTRS format while maintaining backward compatibility with the existing installed user base of 16-bit machines.

While TASCAM continued development of its final 16-bit DTRS recorder (the DA-98 Digital Multi-track), it also diverted a number of engineers to begin work on a 24-bit, high-resolution DTRS machine - recognizing that 24-bit record capability would be the core technology for numerous future products. In July of 1999, the engineers succeeded at producing what would ultimately be the TASCAM DA-78HR 24-bit Digital Multi-track Recorder.

Looking Into the Technology.

TASCAM’s recent introduction of its DA-78HR Digital Multi-track Recorder ushered in a new era in tape-based, linear digital audio recording. With 24-bit digital audio rapidly becoming the new standard for music, audio post and multimedia production, the ability to capture 24-bit word lengths to Hi-8mm tape without increasing tape or head rotation speed is no small achievement.

Compared to the first-generation 16-bit DTRS recorders such as the DA-88, which was followed by the DA-38 and DA-98, capturing 24-bit digital audio data to Hi-8mm posed significant challenges for the company. Since a 24-bit word has 1.5 times the density of a 16-bit word, where would all this additional data be stored? As DTRS has become the de facto standard in many recording and audio post facilities throughout the world, engineers have come to rely upon the I hr. 48 min. record time (with a standard 120 tape) characteristic of the format.

In addressing the issue of how to capture all this additional data to tape, TASCAM engineers examined the

available options. The 4 possible methods included:

1. Increase tape speed and head rotation speed 1.5 times
2. Increase head rotation speed 1.5 times, but with reduced track width
3. Employ bit splitting technology
4. Engineer a new solution

By briefly examining each option, we can better get an understanding of the significance of the DA-78HR's technological merits.

Increase tape and head rotation speed 1.5 times.

The easiest and, perhaps, most obvious method for fitting all the extra data onto the tape would be to increase both tape and head rotation speed 1.5 times, or 150%. This approach makes it fairly easy to store significantly more data with each full rotation of the drum. Unfortunately, this is not a particularly good solution to the problem.

The principle drawback to this method lies in the fact that the increased tape speed would reduce the available record time substantially. Aside from being a robust and highly transportable format, a major attraction for audio engineers has been the long record time available with DTRS recorders. Whether it be the live recording of a concert or an 8-track mix stem for the television movie of the week, the DTRS format is recognized for its ability to handle long format recording tasks. If TASCAM were to suddenly reduce the amount of available record time-ne, this would seriously erode the DTRS advantage for such recording operations.

Increase head rotation speed 1.5 times, but with reduced track width.

Since increased tape speed and the resultant reduced available record time was not a good solution, why not increase the head speed, but print the data in such a way that the track width occupied less space on tape?

By reducing track width (let's remember, we're talking microns to begin with), ATF (Auto Track Finding) compatibility with first-generation machines would be impaired and users would typically encounter an increase in the machine's error rate. ATF has proven itself to be the most advanced tape-to-head control system available as it embeds timing information into the tape's subcode area during the helical scan and eliminates tracking errors during playback and record. The success of ATF's ability to ensure perfect tape exchanges between different machines has been another key ingredient in the format's success. Hence, reducing track width was ruled out.

Similarly, the increased rotation speed of the recording heads would likely reduce the life expectancy of the associated parts. In commercial facilities where these recorders frequently run for days at a time, this was deemed unacceptable. If the recorder were to require greater maintenance and be subject to more down time, there is little benefit derived from this method of capturing 24-bit data.

Employ bit splitting technology.

Bit splitting technology has proven itself to be a valuable and highly effective method for capturing the vast amount of data associated with 24-bit digital audio. Bit splitting is a technology made popular by Apogee Electronics as a means of archiving 24-bit audio data. If, for example, you wish to store a 24-bit, 44.1 kHz 2-track mix; bit splitting technology would typically utilize 4 tracks of a DA-88 and print the left channel's first 16 bits to track 1 while placing the remaining 8 least significant bits (LSB) onto track 2. The right channel would then be stored in similar fashion on tracks 3 and 4.

Obviously, bit splitting technology (while quite beneficial in the right circumstances) was not the answer as it reduces the number of available tracks for recording. As the DTRS format is associated with eight tracks, reducing that number would not have been a popular decision with audio professionals.

Engineer a new solution.

After exhausting the alternate methods of storing 24-bit digital audio data to tape, TASCAM engineers made the decision in October of 1997 to develop a new chip that would enable them to address the challenges of capturing this data while retaining the advantages of long record time and a robust, reliable transport mechanism. The result is known as the Application Specific Integrated Circuit (ASIC).

In order to gain an appreciation for how all this information is stored, we need to backtrack to the 16-bit domain and examine what happens to all those 1s and 0s that constitute a digital data stream. The first generation DTRS machines have their roots in DAT technology, which employs what is known as an 8-10 Modulation Principle. By reducing the number of 1s and 0s in the following example, we will be able to more easily understand the complexities that confronted TASCAM's DA-78HR engineering team.

Imagine that the incoming digital audio data has just 3-bits per word. Each "word" in Column #1 (from top to bottom) represents the incoming data.

Column #1		Column #2	
000		0101	
001		0110	
010	⟹	0111	8-10
011	(expands)	0101	Modulation Principle
100		1011	
101		1110	
111		1111	

When this digital information is stored in linear fashion, it begins to look somewhat like the following: 000001010, etc. Since each 0 represents no data, the recorder's operating system must somehow track all this information while simultaneously being able to distinguish not only the 1s and 0s, but also each individual word, as it represents a portion of the total sound the machine is expected to reproduce. The excessive number of 0s at the head of the data stream serves to make matters quite complex.

In order to address this issue, DAT technology employs the 8-10 Modulation Principle as a means of "expanding" the data into a more manageable structure. After being processed with 8-10 modulation, the incoming data stream assumes the appearance as shown in Column #2. Note that each word now has, at most, one 0 at its beginning. When stored in linear fashion, this new structure makes the data stream much more manageable for the recorder's operating system.

If we were to place all those 1s and 0s to represent a full 16-bit word, you call now begin to appreciate the complexity of storing and retrieving all this data. As the DTRS format employs eight tracks as opposed to DAT's two, multiply this by 4 and matters become even more challenging.

Now that we have an understanding of how the DTRS 16-bit recorders store all the incoming data, imagine having to capture not a 16-bit word length, but a 24-bit word. Suddenly, we need to address 1.5 times, or 150%, more data than in the first generation machines.

The ASIC IC - optimized for 24-bit DTRS.

With each 24-bit word occupying 1.5 times the density of a 16-bit word, the incoming data stream can be overwhelming. Hence, a new and more efficient modulation process was needed. For this task, TASCAM engineers opted to incorporate 1-7 RLL (Run Length Limited) Code to modulate the incoming data into a structure that the operating system could accommodate.

RRL- Code is the same modulation process used in Magneto Optical (MO) and HDD (Hard Disk Drive) storage technologies. While this modulation process is universal to random access media, the TASCAM DA-78HR represents the first time this technology has ever been incorporated into a tape-based, linear audio recorder. The new ASIC IC goes significantly beyond the 150% performance increase necessary to support 24-bit digital audio. In actuality, this chip increases performance 166% over and above the 8-1 0 Modulation Principle as employed in 16-bit digital audio storage.

In order to maintain backward compatibility with first-generation DTRS recorders, the new ASIC IC also incorporates 8-10 Modulation Code as part of its instruction set. While the original 8-1 0 Modulation Code was a conventional integrated circuit that is found in essentially all 16-bit DAT recorders, this code has also undergone significant enhancements. As a result, TASCAM engineers have been able to increase the performance characteristics of the DA-78HR even when it is not operating in High Resolution Mode. When playing back tapes made on first-generation DTRS machines, the new DA-78HR is yet a “cut above” the capabilities of the recorder the tape was originally made with.

How did we arrive at a 166% performance gain?

While 24-bit digital audio data has a density 1.5 times greater than 16-bit digital audio, TASCAM engineers wanted to improve upon the recorder’s error correction capability. As a result, the ASIC found in the DA-78HR has a significantly improved error correction algorithm as part of its instruction set. The result is a powerful second-generation, 24-bit capable DTRS digital audio recorder with increased error correction performance.

While this improved error correction code does not occupy the entire 16% performance boost over tile required 150% necessary to process 24-bit digital audio, it does, nonetheless, occupy a substantial percentage of that number. The remaining performance gain can be attributed to improvements in the accompanying circuits that process tape read and write operations.

Summary

During the course of the past several years, the DTRS format has proven itself to be a tremendously versatile performer throughout leading studios the world over. In addition to being a highly respected format for music and other audio recording tasks, DTRS tapes have become the most common transfer medium throughout the audio post production community - thanks to their reliable performance, rapid transport mechanism and the inexpensive cost of media.

At a time when every business is looking for the greatest return on its investment, the cost of storage media cannot be overlooked. Even though removable media exists for off-loading projects from a Digital Audio Workstation (DAW), tape continues to be the most cost-effective choice available. As a result, the 24-bit DTRS format makes a compelling case both as a dedicated recording tool and as an archival/transfer medium.

In terms of its audio resolution, the TASCAM DA-78HR places the DTRS format on an equal footing with the multitude of 24-bit random access systems so popular in audio production today. Mix stems for film and television are routinely recorded to DTRS and shuttled between recording facilities from one DAW to another. Many production companies and recording studios actually specify the DTRS format for delivery of materials. With the second-generation DTRS recorders such as the DA-78HR and forthcoming models, TASCAM has provided the right tool for the job by ensuring full compatibility with other 24-bit digital audio recording and editing equipment.