DEVELOPING A RECORDER FOR HARSH ENVIRONMENTS UTILISING THE VLDS FORMAT

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Overview

The VLDS half-inch helical scan tape format has been in use since 1986 and is registered under the IRIG 106 standard. A family of products has been produced by Metrum and others to permit cost effective data collection and storage. Customer requirements suggested a need to cope with harsh environment data collection while maintaining full compatibility with the VLDS and IRIG 106 format.

The vast majority of helical scan recorders need only to perform in a domestic or office environment. Some, however, need to have characteristics which permit them to operate in more demanding situations where moderate vibration and temperature excursions will be seen. This latter requirement may be met using Japanese donor transports and modifying or customising the packaging. But what if the requirement is really harsh? A fighter aircraft, an unmanned air-vehicle, a fast patrol boat or an all-terrain vehicle for example. For this class of application, beyond

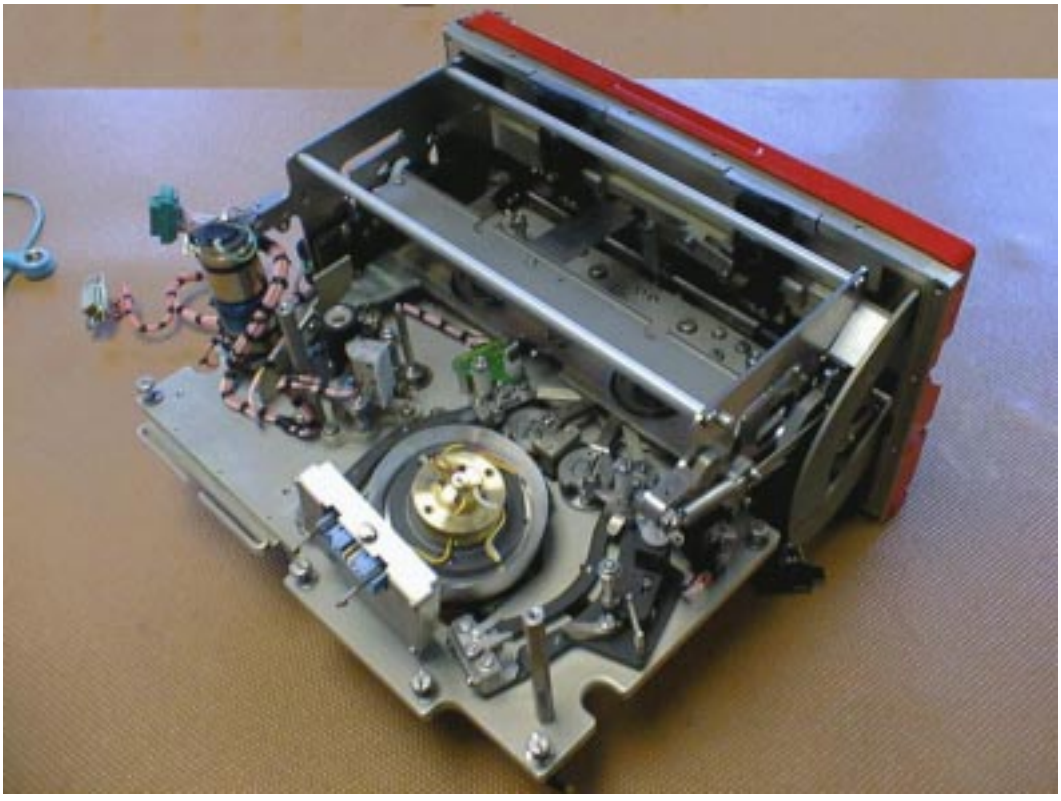

Fig 1. Metrum 32HE

the original design concepts for helical scan technology, a special 'designed for purpose' machine is needed.

This paper describes the design processes and trade-offs that go to develop a digital cassette recorder which will operate in some of the harshest environments likely to be encountered. All of this while maintaining fully compatibility with the IRIG 106 (VLDS) tape format. Clearly, it is desirable to meet all of these requirements within a target product cost; in this case Metrum aimed to be able to sell the completed Harsh Environment (HE) machine at a small premium over the laboratory machines with which it would be format compatible. The results of format testing across a broad range of environments demonstrate that all of the design requirements have been met.

About Harsh Environments

The term 'harsh environments' needs to be defined in this context. It is assumed that all of the specifications on data rate, bit error rate, total capacity etc. are specified to be identical to a laboratory machine but must be met under the fully envelope of the environment. That environment may contain excursions beyond laboratory conditions on the following parameters: Temperature, Vibration, Altitude, Angular acceleration, Power supplies, Mounting requirements, Ingress of sand and dust, Ingress of water, contamination by fluids, contamination and

ingress of salt & fog, Media protection and Mean time to repair.

All of these requirements need to be met within a framework of high reliability and long product life. It is important to note that the customers of such recorders are likely to have high installation costs and will thus wish to have long product life with 10 or 20 years spares support creating a need for full configuration management. A combination of the environmental, performance and reliability requirements cannot be met by modifying a donor transport for a number of reasons. Central to these is the need to address the tape transport and tape path parameters and servo systems and to have these fully modelled for the harsh environment. Failure to take such steps will result in compromises to the requirement and using components outside of their design specifications. Metrum have taken a 'ground up' approach by basing their tape transport on a well proven harsh environment design developed originally for analogue recording in fast jets.

Design Solutions

A few of the design considerations are discussed with their design considerations.

Temperature

The temperature performance of a harsh environment recorder is defined by the need to protect the media and ensure it operates within its specified design limits. The VLDS format uses certified S-VHS tape which exhibits temperature limitations below about + 5 °C and above around + 65 °C. At low temperature the tape becomes brittle, at high temperature it suffers memory loss and, as temperature increases, becomes sticky and can deposit oxide on the heads and upper cylinder. It is thus necessary to protect the media from the effects of high and low temperature.

At low temperatures the standard approach is to insert heaters to raise the internal temperature. This requires careful design attention. The tape path needs to be heated in a consistent manner; one large heater would give differential heating and create undesirable temperature gradients which would distort the written track. Such distortion could give replay and crossplay problems. The solution is to model the impact and strategically place distributed heater elements. Such heaters need to be fully controlled and able to be powered from a separate power rail to allow start-up without full system power applied.
High temperatures have a much greater impact on the design of harsh environment helical scan recorders. They require an holistic view of the entire enclosure and all sources of heat generation. Techniques need to be devised to limit the effects of the ambient environment on the media. Metrum's solution to this problem is to create a separate compartment for the tape, its cassette and all of the helical scan components. This compartment is surrounded by a 'cold wall' which isolates the tape transport from the remainder of the heat generating components.

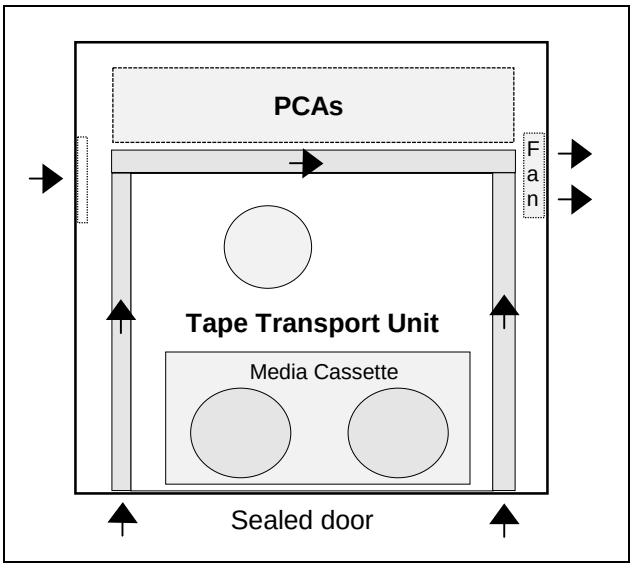

Figure 2 Schematic of the cold wall concept

Key: ' → ' indicates air flow and direction

A temperature controlled fan moves air around the cold wall thus removing the heat from the tape transport module and attempting to keep it as near to ambient as possible. A diagram of the principle involved is shown in figure 2. A further critical design aim is to keep the power dissipated within the tape area as low as possible. Power dissipated in motors, motor drivers and head preamplifiers need to be kept to an absolute minimum.

By taking special care with all of these parameters, the Metrum 32HE is able to operate at ambient temperatures between -20°C and + 55°C without tape damage.

Vibration

Vibration levels of 9 or 10 G's in any axis places real demands on the tape path mechanics and servo systems. It is commonly believed that mounting on anti-vibration mounts (AV mounts) is a solution. This is not necessarily true. AV mounts will attenuate some of the frequencies present but will always transmit energy at others. As the frequency and energy of the vibration can vary from application to application there is a need to have a fully modelled system which can be used to simulate the transmitted vibration forces. If particular attention is played to basic system resonances, and a stiff deck assembly is designed, resistance to vibration will be 'designed in'. It is not just the baseplate that matters; the cassette mounting, tape spool handling, helical scanner, capstan and tape guides all need special attention. Tape tension control and correct tape handling are essential to maintain head to tape contact in these conditions and are addressed later.

Angular Acceleration

Angular acceleration specified in degrees per second per second is a tough requirement to meet. The effect on the transport is to attempt to disturb the close coupling of the servo systems necessary for accurate tape location and helical track position and accuracy. The solution is to have extremely high performance servo systems with high bandwidths and reserve power. The 32HE uses a fully controlled digital signal processor (DSP) servo which locks together the two spool motors, the capstan and the scanner such that they can remain in tight control when subjected to high angular rotation. High tolerance motors and feedback components are specified to ensure complete control over the life of the product.

Altitude

For airborne applications, altitude has a performance and design impact. The unit may need to operate at altitudes of 50,000 feet where the air is thin. Key design parameters are to ensure the tape transport remains as sealed as possible to maintain the air for an air bearing around the scanner and airflow for printed card assembly (PCA) cooling. Sealing a compartment is also a criteria for the prevention of foreign body ingress and the solution here is to ensure gasketing is of adequate quality and specification. Gasket choice is also a factor in meeting the EMC/EMI specification.

Power supplies

While not a particular challenge, power supplies are needed to condition the available power input and convert it to the internal supplies required. 100-230 VAC, 40-60 Hz supplies are rarely available and where they are their regulation may be suspect. Size, weight and efficiency are paramount as is adherence to EMC requirements.. Metrum's design goal was to incorporate the power supply into the unit to reduce integration costs and provide a 'one box' solution. This has been achieved by the use of an efficient switched mode PSU.

Mounting requirements

While some harsh environments will accept a 19 inch rack mounting scheme, many will be so severe or space limited such that a 19 inch rack would be inappropriate. Mounting in any orientation except upside down and with AV mounts positioned either at the top or the bottom of the unit yields flexibility for a wide range of applications. The earlier cautionary notes on AV mounts and their selection are relevant to the mounting scheme.

Protection, externally and internally, from Contaminants

For this requirement a sealed unit is required. The door and any removable panels need to be sealed with appropriate gaskets. Figure 2 showed the use of a cold wall for air circulation which allows contaminants to pass through the unit without touching critical components It must be remembered that requirements will be placed on the ease of removal of the media cassette, that is without special tools, and the mean time to repair. These will compromise the ideal sealing schemes.

Surface finishes must be designed to tolerate the various fluid contaminates found in harsh environments. These may range from aircraft hydraulic fluids to salt in seaborne applications and natural acids found in oil exploration applications. Contaminant types will normally be incorporated in the requirement specification and most customers require proof of qualified testing in the final recorder configuration.

Media protection

The steps outlined above will ensure the protection of the media when inserted in the recorder. There are, however, additional requirements such as dew point control and tape dynamics. Dew point control is handled by inhibiting tape lacing and using the heaters to control humidities outside of the media's specified range. Tape dynamics are the media specification parameters which must not be exceeded while lacing or moving the tape in record or playback. This is particularly important in incremental applications where the tape is operated in stop start modes. The Metrum solution is to use precision tape control servos with profiled algorithms to ensure the tape is not stretched or otherwise damaged. Tape tension is controlled at all times by this system.

Mean time to repair

The commonly specified mean time to repair (MTTR) to module level is 25 minutes. This is a 'start to finish' time and includes diagnosis, panel removal, repair or replacement and re-test. Such requirements place conditions on built in test (BIT) and constrain designs such that access is required to all major parts. Clearly higher reliability reduces repair occurrences and must be the overriding goal of any harsh environment design. Routine maintenance must be kept to a minimum. The use of teflon loaded guides and sealed bearings, for example, remove the need to lubricate and reduce contamination potential.

VLDS & IRIG 106 Tape Formats

Metrum introduced the VLDS standard in 1986 and almost 2000 units have been shipped to various applications world-wide. The format is defined under IRIG 106. There are two tape footprints specified; a 'B' format for laboratory environments and an 'E' format for harsh environments. Within these two footprints two possible densities are possible on the helical tracks; 50 Kbits per linear inch and 100 Kbits per linear inch. The Metrum 32HE writes IRIG 106 'E' footprint at 100 Kbits per linear inch.
The 'E' format allows a track to be written which is each track at exactly twice the 'B' spacing. Thus when operating under severe environments a considerable margin on track straightness is

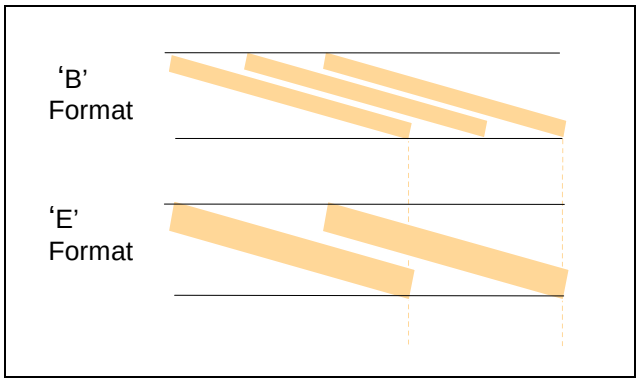

Figure 3 IRIG 106 tape footprints

81 percent wider than the 'B' format, but with permissible before crossplay is affected. The presence of a guard band increases the off-track read performance. Track pitch for the 'B' format is specified at 40.4 microns with a track width of 32 microns. For 'E' formats as used in the 32HE product the figures are 80.8 and 58 microns respectively. Figure 3 shows a schematic representation of these formats.

Product Realisation

Figure 3 Metrum 32HE Tape Transport Unit
The Metrum 32HE is a 'designed for purpose' helical scan direct digital recorder. Its performance is qualified over a range of harsh environments and it is fully compatible with other recorders writing or reading IRIG 106 'E' format at 100 Kbits per linear inch. A data transfer rate of zero to 32 Mbps is achieved by the incorporation of a 64 MByte solid state buffer. The design incorporates all of the 'design for environment' concepts outlined above.

The tape transport unit (TTU) is a derivation of a succession of designs which have flown on fast jets and commercial aircraft. One of the most surprising facts about the tape transport unit is that it is fully removable as a module and has only one quarter the parts count of a typical Japanese VHS transport. This greatly reduces repair times and increases reliability. It further reduces the interacting resonances and vibration impacting parameters. The TTU is shown in figure 4

To ensure crossplay compatibility with IRIG 106 and existing deployed VLDS products, the electronics for the data channel is a repackaged version of the Metrum 64 PCAs. The form factor and rigidity of the cards is changed to fit the outline and environment. Additional ASICs

Fig 4 32HE TTU

implementation was included to reduce the size and increase the reliability. In all other respects the design of the data channel, its Reed-Solomon encoding and other attributes enjoy the pedigree of the large number of deployed Metrum VLDS products. The entire recorder/reproducer, as shown in figure 1, is contained within one 1500 cu inch box and has space for a personality card which could hold a multiplexer or some other data conditioner.

The results from qualification testing show the unit to meet all of its design parameters. As an example the performance the track straightness of a track written while the 32HE was undergoing vibration to MIL-E-5400T Fig. 2 Curve IIIa levels was within ± 4 microns (the track width is 58 microns!). This demonstrates the ample margins available for crossplay compliance.

From the results obtained it is possible to model the performance that would be obtained by writing IRIG 106 'B' format on a harsh environment recorder. This would yield 64 Mbps and 27.5 GBytes of storage on each S-VHS cassette and looks entirely feasible.

7) Conclusions

The design of a recorder for harsh environments is not a task for the faint hearted. By combining good design practice, a knowledge of harsh environments and many years of tape recorder experience, Metrum have been able to produce

an advanced machine capable of exceptional performance under harsh environments. The design goals have been met and the costs targets give a machine at a small premium to the laboratory product.

It has not been possible in the briefness of this paper to cover all of the necessary design approaches or results. For further information contact Metrum sales offices world-wide. The author may be contacted via e-mail at “manyoaks@easynet.co.uk”.