CHART RECORDERS EVOLVE INTO DATA MANAGEMENT SYSTEMS

Grant M. Smith, Marketing Manager
Western Graphtec, Inc.

ABSTRACT

A synopsis of the very recent evolution of telemetry chart recorders from "closed" chart paper output devices to powerful "open" Data Management Systems. A Data Management System (DMS) is defined as one which incorporates a video screen for waveform preview and monitoring, direct connection of hard or optical disk via SCSI for real-time data archiving, and DR11 digital interfacing. The DMS concept of providing real-time waveform monitoring independent of hard copy recording is discussed, as well as the capabilities of the hard copy recorder.

The realities of budget shortfalls makes wholesale system upgrades to eliminate DAC's entirely difficult at best. These concerns—and a potential remedy: a DMS which accepts any mix of analog and digital waveforms—are reviewed.

Objectives: How DMS's can be integrated with existing telemetry systems, encompass the functionality of conventional recorders and add new capabilities, with an emphasis on how data can be digitally pre-formatted in real-time, simplifying—or even eliminating—post-mission reduction and analysis. A demonstration of how a video display allows real-time trace viewing—a major weakness of conventional thermal array recorders.

INTRODUCTION

Chart recorders have been getting more and more capable over the past several years, due primarily to the introduction of thermal array printing technology, which eliminated pens and most other moving parts, and introduced new functionalities, such as computer interfacing, direct digital input, line and graphics printing, X–Y plotting, recording in engineering units, and data capture in memory.

However, due to the small viewing delay caused by the printhead itself, thermal array recorders have been found lacking in applications where direct observation of the waveforms in real-time is a requirement, and even the smallest delays cannot be tolerated.

Attempts at adding a row of LED's above the chart exit are well-intentioned but do not satisfy telemeterists who must make go/no go decisions based largely on real-time data. Also, thermal array recorders have not been particularly easy to integrate with other test and measurement equipment, and generally require custom software to take full advantage of their computer interfaces.

As a result of these limitations and concerns many telemeterists have been forced to abandon recorders altogether in favor of PC-based acquisition systems which provide analysis and archiving to disk. Those who have been unable to do without real-time hard copies have continued to use stylus or thermal array recorders and data acquisition systems in parallel, an expensive and cumbersome arrangement.

To address the needs of these disenfranchised flight test professionals, a whole new type of instrument has been developed: the Data Management System (see Figure 1). The heart of the Data Management System (DMS) is a powerful 32-channel thermal array recorder with 330,322 dot per square inch resolution on a 15.3" wide chart. It uses a single printhead which eliminates the unprintable gap down the center of the chart of dual-printhead systems, and allows waveforms to be expanded up to the full chart width.

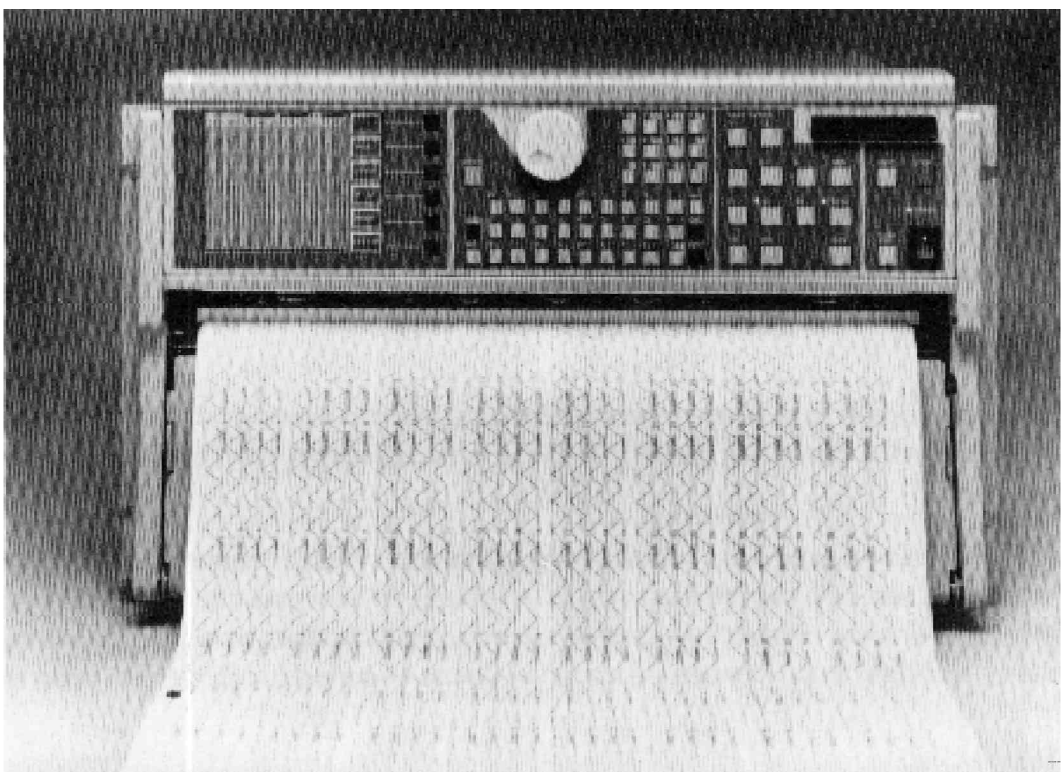

Figure 1. 32-channel Data Management System

The DMS offers a large number of input channels: up to 32 analog or digital waveforms (in any combination). Each input channel has an associated event marker and line of alphanumeric text. Event markers and text may appear simultaneously. Incoming waveforms may be analog or digitized in any combination. The DMS has 12 expansion slots on the rear panel for accepting up to eight 4-channel analog input cards, one 32-channel high speed digitized input card, and IRIG translator card, a SCSI interface card, and an RS-170A video output card. A thirteenth slot is always filled with a standard interface card containing RS-232C (or RS-422A) and GPIB (IEEE-488). If their data is not high speed, users may input up to 32 12-bit digitized waveforms via GPIB. The total number of channels that may appear at any one time is 32, although they can be of any combination of sources.

VIDEO MONITORING

To address the real-time waveform viewing issue, incoming data may be monitored on a built-in front panel video display (see Figure 2). This video monitor has its own set of scroll rate and channel selection controls, allowing it to be operated independently of the chart presentation. Users have found that it is most useful to display just a few channels of particular interest on the display, since displaying all 32 is confusing and generally not necessary anyway. This video image can also be output to an external video monitor for remote viewing. This has been found to be especially useful in flight test control room applications, where the same data needs to be viewed at several locations at once, or where a larger monitor is required. Besides the familiar "squiggly line" presentation, waveforms can be displayed in bar graph form if desired.

Figure 2. Built-in Video Display

SCSI INTERFACING AND DATA STREAMING

An integral SCSI (Small Computer Systems Interface) port allows direct connection of a hard disk or other mass-storage device. Much like a data acquisition system, incoming waveforms are digitized and streamed to disk at a selectable rate. Unlike PC-based systems, however, a high-resolution real-time chart can be printed continuously, with up to 32 waveform channels of any size on the chart. Telemeterists have already discovered the value of allowing the DMS to stream or archive data to disk, since it writes a comprehensive header containing all set-up and recording parameters with the data. Days, months or years later, files can be read back from disk in precisely the same fashion in which they originally appeared, including the interchannel annotation, scaling, offset, engineering units, and so on. Of course, these parameters may also be changed during playback if desired.

SYSTEM ARCHITECURE

Figure 3. illustrates the architecture of the DMS. Of particular note is the level of independence that this architecture permits. We have already described how the video display may be operated independently of the chart output. In addition, data may be sent to memory “in the background,” i.e., without interrupting the real-time recording in any way, even if a different sample rate has been chosen. In the same fashion, data may be streamed to disk via SCSI, and the video display echoed to an external monitor without affecting any other operation of the system.

CUSTOM CHART PRESENTATIONS

Telemeterists require the standard chart presentation of eight 40 mm wide channels for a variety of good reasons. In many cases, calibrated scales—either Gerber or home made—are placed against the recorded charts in order to make comparisons or measurements. Some thermal array recorders have been introduced which do not have 40 mm wide channels—they are slightly larger or smaller, presenting analysis problems of all sorts. Even when they can emulate the familiar “eight 40 mm channels” and several other fixed modes—including overlapped waveforms—most thermal array recorders but do not allow custom chart presentations to be defined.

The DMS is the first device of its kind to allow the user to define any combination of channel order, size, grid patterns, and the location of event markers and annotation. Custom charts are designed graphically on the video screen, or via host PC. Once created, any number of custom charts can be stored internally, onto hard disk, or to RAM cards. Set-ups include every recording parameter, including interchannel annotation, gain, offset, and so on.

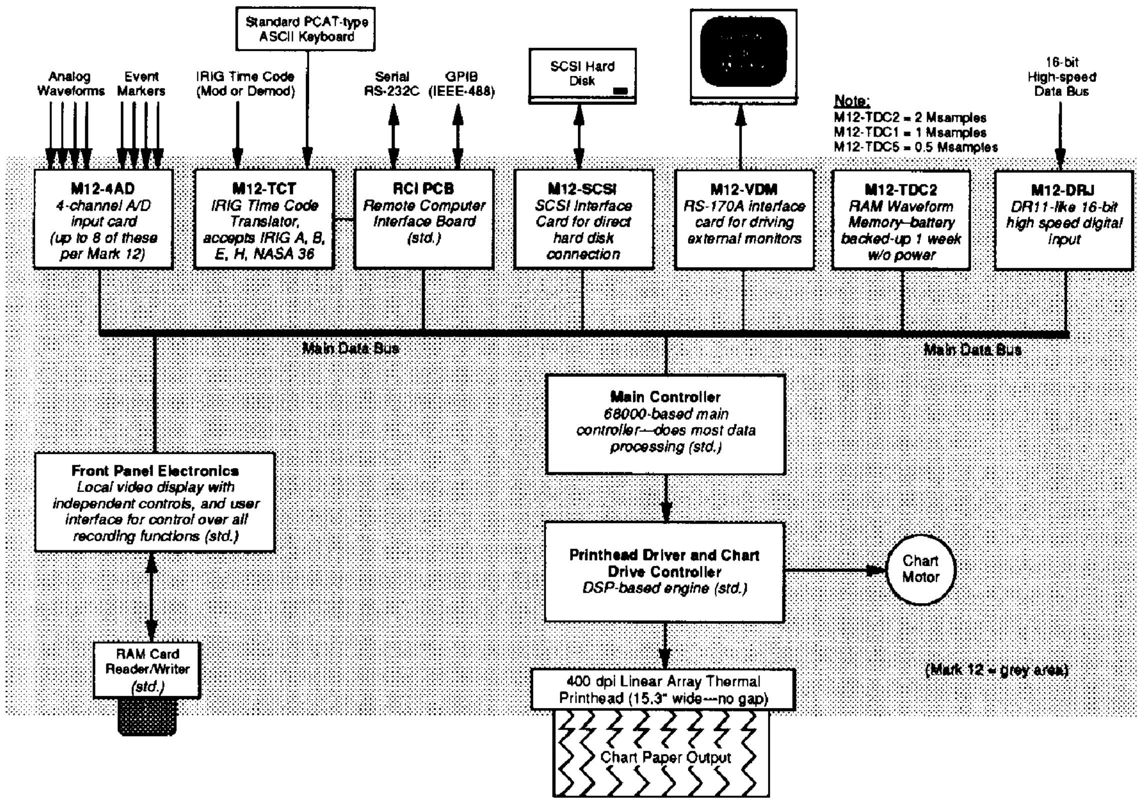

Figure 3 Data Management System Block Diagram

Text entry is facilitated by a complete set of alphanumeric keys is located on the front panel. In addition, users may plug a standard AT-style PC keyboard directly into the DMS, making the process much faster and easier. Since the typed text appears instantly on the video screen in its entirety, text entry is fast and foolproof.

MEMORY ORGANIZATION

One of the most powerful features of thermal array recorders is their ability to capture incoming waveforms in RAM memory for subsequent replay and analysis. This is even more important with thermal array recorders, since their real-time chart speeds are currently limited to 500 mm/sec. This is only about 20 inches per second, paltry compared to the 160 inches per second speed of some light beam oscillographs (LBO's). Capturing data in memory and replaying it on a longer time base allows high effective chart speeds to be emulated. Obvious limitations include the maximum sample rate, quantization, memory size, memory organization, and the sheer time required to replay the data out of memory. In addition, although some thermal array recorders can acquire data without interrupting the real-time chart recording, they cannot replay it without doing so.

Data Management Systems have improved each of these parameters over typical specifications, providing a 200 kHz sample rate per channel, 16 bit quantization, a 2 million sample RAM, and the ability to play data out at a variety of higher and lower rates. Most important, however, is their ability to mix real-time recording with data being replayed from memory. Typically, users set up a set of conditions whereby the DMS will continuously cycle incoming waveforms through RAM while making a real-time chart recording. When a trigger condition is met the data are frozen according to the pre-trigger percentage previously chosen, then output at a preselected rate on a portion of the chart which along with the proper time scale references. This allows users to capture and replay data that meets programmed trigger conditions without interrupting the real-time recording.

Memory organization has been improved over conventional recorders, most of which must overwrite the entire buffer when a new acquisition is performed. A DMS allows multiple acquisitions to be stacked—one on top of the other—until the memory is full. Additionally, memory can be divided freely among any or all channels—there is no preset amount of memory that must be used per channel. The user can call up a directory of what's in memory onto the video monitor, similar to typing the familiar `<DIR>` command on DOS PC. In fact, files are stored in a very DOS-like manner. Each file has a name like `<CAPTURE1.TDA>`. Configuration files use the `<*.CFG>` extension. Files are also shown by size, and time/date captured.

If a hard disk is attached to the SCSI port, it is treated much like an extension of the internal RAM, and the above kind of file management is also employed, making record retrieval simple and intuitive.

THE DMS—A VIABLE REPLACEMENT FOR LBO'S

Thermal array recorders may never achieve the real time chart speed capabilities of LBO's, which range higher than 100 inches per second (>2500 mm/sec!). Telemeterists using LBO's have been eager to "trade up" to the computer-era capabilities of thermal array recorders. Another important consideration is the high cost of photosensitive chart paper. Despite frequent predictions regarding the imminent demise of LBO's, however, they continue to attract repeat sales. This is because although conventional thermal array recorders can capture small segments of time in memory for replay at very high effective chart speeds, there is no way to preview the data, or record continuously. Also, no thermal array recorders have offered several important DMS breakthroughs:

- 32 Channels
- 20 kHz bandwidth
- 15" wide chart—no gap
- Video Monitoring
- Real-time streaming to disk

DATA ANALYSIS & ARCHIVING

Once acquired in RAM/hard disk, waveforms can be previewed on the video screen to facilitate editing, analysis, and playback. It is generally useful to view the entire record at once, then "Zooming in" on the area(s) of interest. Cursors are used to selected the zoom locations, and also provide an easy way to calculate delta-T and delta-V. Mathematical operations can be performed on any or all waveforms, including averaging, integration, differentiation, RMS conversion, filtering, AC/DC coupling, and even FFT's (Fast Fourier Transforms). The cursors are used here to select the portion of the record for these operations. Records can be edited right on the screen, saving disk space and reducing calculation time. Once analysed, waveform data is available for permanent archiving to disk (or any SCSI device), hard copy recording, or both.

HIGH SPEED DIGITAL INPUT

Telemeterists are increasingly interested in inputting data in digital format directly—skipping the usual Digital-to-Analog Converters (DAC's) and eliminating their expense, calibration time and ongoing maintenance, and freeing up some badly needed rack space. This makes sense, after all, the DMS is a digital instrument already—why convert digitized waveforms back to analog just to send them to a recorder that digitizes them again? Not only is this wasteful, but it increases the potential for conversion and truncation errors. A single plug-in card adapts the DMS to most high-speed 16-bit telemetry data buses, as typified by the DR11 system by a prominent manufacturer. In fact, the DMS is directly compatible with this data bus, and can keep up with its aggregate throughput of 500 kHz, picking off any 32 channels and event markers for printing on the chart. The channels are selectable either locally or via RS-232C/GPIB interfaces.

COMPUTER INTERFACING/GPIB WAVEFORM INPUT

All this may sound like a PC is not required at all by the DMS. This is true, but does not mean that a PC cannot add value to the system. Both IEEE-488 (GPIB) and RS-232C interfaces are built into the system for just this purpose.

Up to 32 waveforms may be input via GPIB at rates up to 400 Hz per channel. Users may elect to have the DMS print data points synchronous with their data stream, or asynchronously, as required. Many users have chosen to input waveform data via GPIB, simultaneously controlling the system via RS-232C—and the front panel controls are still available for local use if needed. This kind of multiple access brings unprecedented power and convenience to operators who would otherwise be forced to adapt some very expensive equipment to make up for the limitations of comparatively inexpensive equipment. This imbalance has been long overdue for correction.

PASSWORD ACCESS CONTROL/HANDLING CLASSIFIED DATA

Of equal importance to providing increased access to functions is the programmable restriction of access. This particularly true in uncontrolled environments, where systems are set up by engineers but attended by less experience operators, or where classified data is processed. The DMS allows any combination of functions to be locked out by a main user, who may assign tiered password access to the system for multiple users. The benefits here are obvious, and far superior to simplistic "all of nothing" approaches to security.

Recorders used in classified applications must have their memories overwritten according to standard classified data handling procedures at some interval, often daily. This has the unfortunate side effect of wiping out all of the annotation and set-ups held in internal RAM. Users may download complete set-ups—including annotation—onto RAM card before purging their system's memory, locking up this RAM card in an overnight safe just as they would a classified floppy disk. Next day, simply plug in the RAM card reload the set-ups and annotation instantly.

400 DPI PRINTHEAD FOR RELIABILITY, AND...

We have seen how a single, continuous printhead makes recordings across the entire 15" wide chart without a gap or drop-out in data. The printhead itself is a 400 dpi model which has every two dots electrically tied together as if they were one. This results in the industry standard printing resolution of 200 dpi across the printhead, but provides for two important features:

- 100% dot redundancy
- Potential for future increase to 400 dpi resolution

The potential for actually implementing each dot individually, while perhaps intriguing from a marketing perspective, pales in significance compared to the reliability benefits which may be realized by telemeterists today. 100% dot redundancy reduces bu half the negative effect on performance of the failure of any single dot Figure 4 illustrates the reduced loss of data resulting from losing one large dot versus losing one smaller one in the 400 dpi scheme:

SUMMARY

The Data Management System combines the best features of conventional thermal array recorders with those of PC-based data acquisition systems. It puts busy telemeterists back in charge of their data—letting them manage it better and more effectively. The result is a whole new kind of instrument, one which offers high-speed. high-resolution, customizable

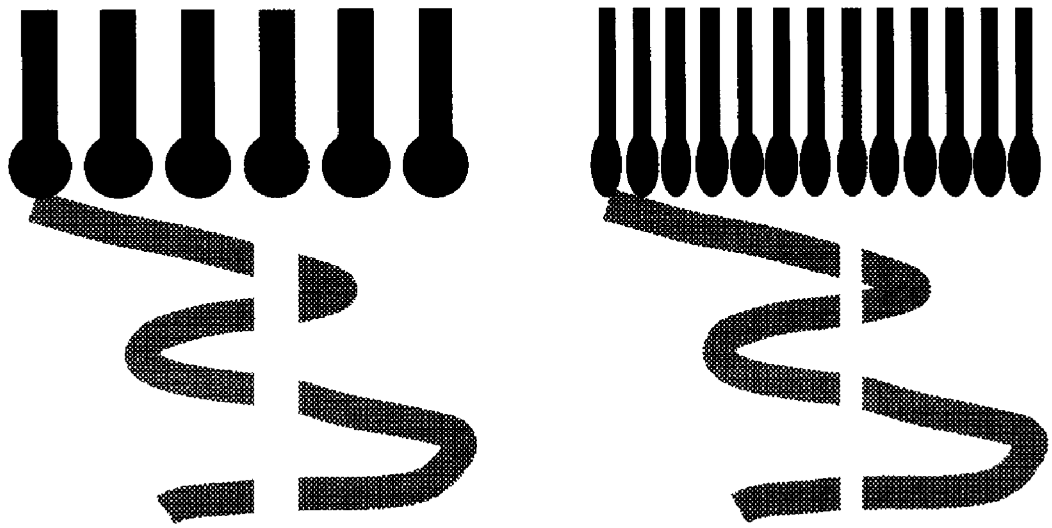

Figure 4. 100% Dot Redundancy Scheme

real-time hard copy recordings, video monitoring, continuous streaming of data to hard disk, advanced memory organization features, and powerful post-mission analysis capabilities. The data management, analysis and hard copy platform of the '90's.

Key Words: Data Management Systems, Chart Recorders, Data Recording, Telemetry Recording