

MDR

M A S T E R I N G
D U P L I C A T I O N
R E P L I C A T I O N

IN DEPTH

New Mastering Formats

Sonic Solutions

Sony DA-5000

CEDAR AZ1

IN PRINCIPLE

Image Quality Control

Noise Shaping

PQ Encoding

IN THE STATES

Bernie Grundman Mastering

**STUDIO
SOUND**
AND BROADCAST ENGINEERING

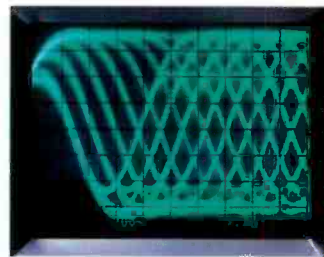
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R E P L I C A T I O N

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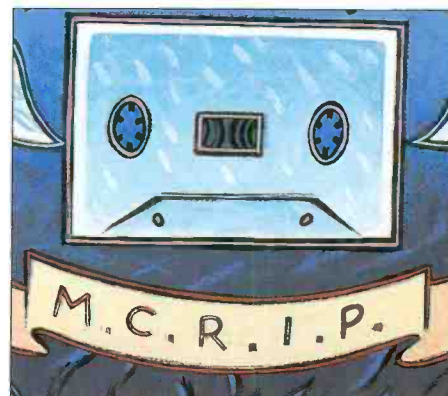
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The compact disc manufacturers

MDR

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DUPLICATION
REPLICATION

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AND BROADCAST ENGINEERING

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EDITORIAL

Between the lines

When *Studio Sound* generated its first *Mastering Duplication and Replication* supplement late last year, it did so in response to a number of factors.

Firstly, the advances currently being made in digital audio technology have brought the hardware considerations of studio recording and the mastering operation closer together than ever before. As more studios opt to use nonlinear (disk-based) recorders and editors, the ability to carry their own projects through to production of a complete premaster is becoming available to a section of the business that might, up until a handful of years ago, have been content to regard itself as exclusively involved in recording. On top of this there are a number of new media presently being considered for mastering purposes—some of which make the generation of complete masters a particularly worthwhile consideration for anyone already caught up in this mastering revolution.

Of course, new mastering media are not the only new media to consider. The arrival of Sony's MiniDisc and its Philips rival, Digital Compact Cassette have presented all areas of the mastering, duplication and replication industries with considerable food for thought. The outcome of this format war depends on a complex combination of big business politics and consumer preferences, and it is certain to have major ramifications for major copying houses across the world—no matter how the cards are finally played out. Long before that stage however, the considerations of preparing premasters for DCC, MD and CD are going to be concerning the 'expanded' operations above.

Secondly, there are the attitudes of the record companies who foot the bill for these services. In the days of vinyl and cassette, the major record companies had managed to establish a frustrating situation of differing standards. An artist signed to a US record company could expect their work to be mastered by facilities which regarded the mastering process as an artistic exercise in its own right—one capable of making or breaking a recording. And both artist and record company have been content to pay for it on this basis. Cross the Atlantic to Europe, however, and you can be assured of no such care. Instead, mastering is regarded at best as a 'necessary evil' and more likely as some kind of conspiracy on the part of the recording industry to extort money from the record companies.

Elsewhere in this supplement, CTS Mastering's Mike Brown accurately observes that mastering is actually the first stage of manufacture rather than the final stage of recording and goes on to say, 'Mastering has been and should continue to be a creative process undertaken in collaboration with producers and artists, not done remotely on their behalf.' Quite.

The changes in mastering-mastering requirements has offered the industry the opportunity to strike back. The inaugural issue of *MDR* highlighted London's Metropolis Mastering facility whose engineers were taking the opportunity of their opening to level the score with America.

These factors make clear the need for information. Certainly, a little knowledge is a dangerous thing—especially if the European recording industry is to convince its record company clientele that they have been negligent of the importance of the preparation and manufacture of their prime product. Hence *MDR*.

This title is not the first spawned by *Studio Sound*—as some of you will know, it is not even the first to address the mastering, duplication and replication industries. *MDR*, however does address new developments in a fast-evolving business. More than this, it attempts to identify an emerging face of this business and provide it with the assistance it needs to achieve its goals successfully, effectively and profitably.

If the response to the first issue is any guide, our reading of the situation has been good and our response to it well-pitched. I hope that this issue is as well received and welcome your response to it.

Tim Goodyer

NEW FACILITIES

Julian Mitchell reports from new and nearly new facilities from the world of mastering and manufacture

Town House mastering

The entire post-production operation at The Townhouse in London is being completely rebuilt to ultimately provide five state-of-the-art mastering suites, fully equipped for all aspects of both digital and analogue mastering work.

As well as continuing to offer lacquer and DMM disc cutting, all aspects of digital audio postproduction and CD mastering are being catered for, including 20-bit capability. Two Sonic Solutions hard disk digital editing workstations have been installed, along with Apogee and Prism A-D converters and new Marantz CDR machines.

The Town House post-production team is headed by Gay Marshall, with engineers Kevin Metcalfe, Gordon Vicary, Geoff Pesche and Jack Adams taking care of disc cutting and CD mastering. The digital rooms, staffed by Bunt Stafford-Clarke, Dave Bernez, Barry Woodward and Francis Arkwright, are also equipped for CD related work, with two recently added Sonic Solutions hard disk systems

with PQ encoding capabilities. U-Matic editing is catered for using Sony DAE3000 systems, and a range of digital domain signal processing is also available. Editing, copying, transfer and dubbing facilities for all commonly used analogue and digital mastering formats are also available.

Martin Bengé, head of EMI Studios commented, 'We currently have four rooms and so we are adding one. In effect though we are de-commissioning two of the existing four rooms and completely refurbishing them. We've added a new building on top of the Townhouse building, the Penthouse, and three rooms are being created in there.

'Mastering seems to be one area of the industry we've seen growth in through the recession, that and the post production side have been very strong for us. There are a number of reasons behind this growth. People are now recording in so many different locations and there are a lot of different formats around so when it comes to mastering there's much more to do now. The mastering engineers have often got a Herculean task to put all these different formats together. There's now more appreciation of what can be done in post production and increased awareness that mastering is not just a straight transfer, there are things you can do in post production that can really improve the end result.

'It's usually up to the producer of the record whether he wants just a flat transfer or wants any changes made. It's nearly always the case that changes will need to be made and creative input is wanted, that really is where the core of our business is. CD Plants are not set up to provide the level of creative expertise that is available in a studio environment, there is a different set of priorities really in a manufacturing plant, it's a numbers game really.'

The new rooms will be ready in July of this year but most of the equipment has already been installed in the other rooms to get them up and running. Except for the mastering consoles which are being designed and built in-house as a suitable alternative couldn't be found. Martin Bengé, 'There was nothing on the market that was suitable so we decided to build our own. Our consoles are going to be a combination of analogue and digital because so much of the work is still in the analogue domain.

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Proteq Magmedia

Proteq Magmedia is the first fully-integrated DCC manufacturing plant in the world and situated in the heart of Asia in Singapore. The company is a wholly-owned subsidiary of Goldtron Ltd, a public-listed holding company with a broad based electronics portfolio including cellular handphones and smart cards.

Proteq operates from a 40,000 sq ft plant which houses state-of-the-art DCC equipment. The process is fully automated and spans from the magnetic tape manufacturing right up to the final packaging of a DCC blank tape.

Magnetic coating, calendaring and slitting operations are executed in clean room environment to ensure that the pancakes are of the highest standard. Injection moulding of the DCC housings and boxes are carried out on the latest precision injection moulding machines.

Proteq have gone beyond the manufacturing specifications by making provisions for cleanroom facility for their assemble and loading sections. The housings are assembled into D-O shells on a sophisticated Japanese-designed assembling machine. Thereafter the shells are loaded with tape on automatic tape loaders which can be programmed to accurately wind the DCC tape into various customised lengths.

Proteq Magmedia can offer their D-O shells and pancakes to recording companies as well as their printing and packaging line to produce a complete OEM brand DCC to the final consumer. All these are carried

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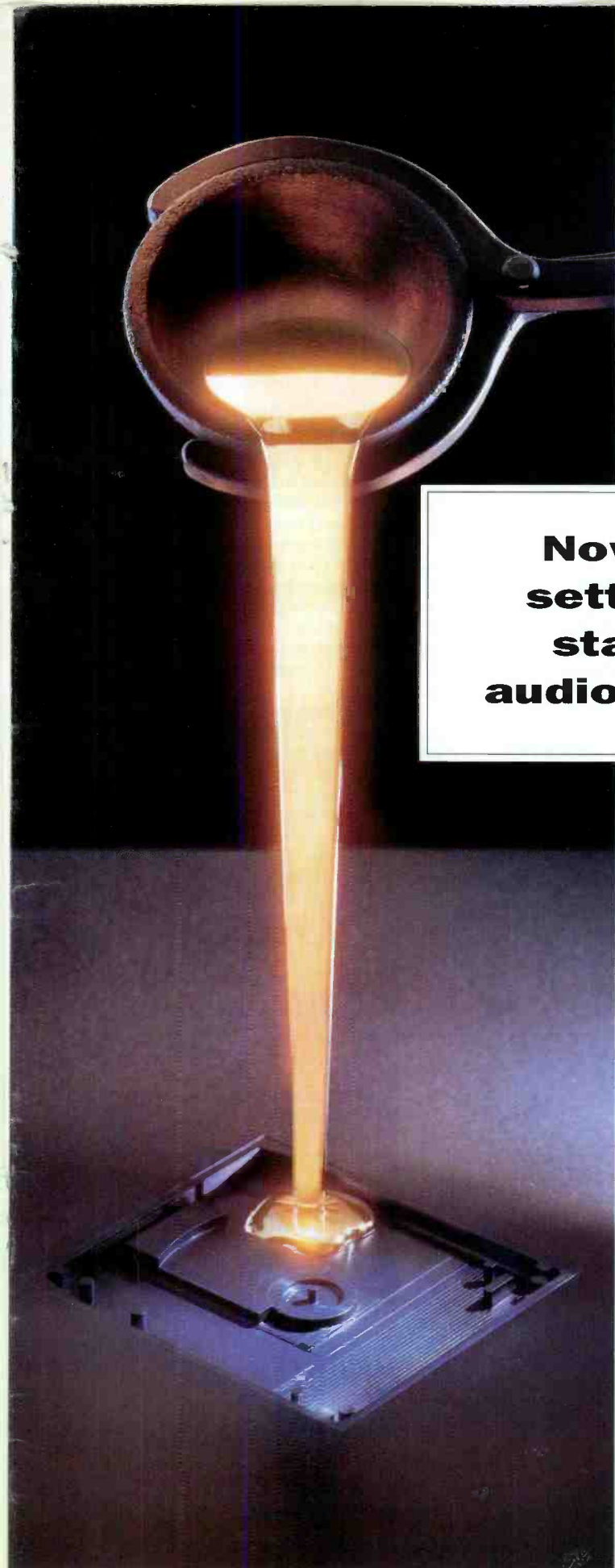
Profile Studio

Profile Studio is a mastering and audio for video production facility in Milan, Italy. Traditionally artists who made albums in Italy usually went abroad to master due to the lack of good enough studios. Profile is one of the first Italian mastering studio who can offer the professional standards artists need and in a year and a half a high proportion of the best selling Italian albums have been mastered here.

The heart of the studio is a four layer AMS *Logic 1* with an eight track *AudioFile*; monitors are DynaudioAcoustics *M3* and *PPM 1* (stereo and centre channel); all the amplifiers are Dynaudio *A1* and *A2*. Outboard includes Sony *PCM 7030*; Lexicon *300 x2*; Dolby *SEU 4* surround encoder and *SDU 4* decoder, Apple *Quadra 700*, and Kurzweil *K2000*. Profile is the first mastering facility in Italy licensed for production in Dolby *Surround*, and the the first project mastered in the studio with surround sound was the last CD of Jovanotti, the famous Italian rap singer.

The studio is looking to implement the new technologies that are now developing in the market such as 20-bit mastering, CD-I, CDV and the CD-ROM families.

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IMAGE CONSCIOUS

*Basler's
Dr Hans-Heiko
Müller discusses
the importance
of image
processing
technology in
raising the
quality of CD
production*

Within the expanding CD market, high-quality production is one of the keys to survival; another is a facility's ability to reduce production costs. It is not difficult to see the potential for conflict between the two issues. Both can, however, be made to contribute to an upgraded production process.

The key to aligning these considerations is to regard 'high-quality production' as a synonym for 'no low-quality production'—by assuring that no

low-quality CDs are produced, quality can be assured and money can be saved. One way of asserting this control is through new image processing technology. The area of quality assurance (QA) here is that of print—on CD packaging, CD printing. . . Basically, anywhere you can find printing ink.

Careful inspections have to be made within all the production stages of a CD and special effort should be taken to keep track of order numbers (inspecting the label and the packing of the CD) as this is an often underestimated area in which problems can arise. These inspections cannot increase the inherent quality of the CD programme, but can ensure that the customer is presented with a product of consistently high quality—how satisfactory is a perfectly replicated and packaged CD if the sleeve and disc do not match up?

The inspections to be performed to meet these demands are: reading and confirming the Ident code of the CD prior to printing, inspecting the printed label and evaluating any errors, reading and confirming the Ident code of the CD prior to packing, and inspecting the booklet and inlay at the packing stage.

Code reading

The main goal of the inspection is to save money by preventing unacceptable CD production. In addition, the inspection should (in the case of detected errors) help track down the source of the error.

It is obvious that a simple match-mismatch check of the Ident code can only help achieve the

first goal. The Ident code must actually be read if the error source is to be located. And the only practical method of reading of all types of code (alpha-numerical, barcode or mixtures of both) is through the use of image processing systems.

The desire to save money defines another requirement of Ident code reading, and that of any other inspection system: it must perform the inspection within the production cycle and must work with all existing applications. For Ident code inspection this requires the code to be read in either static (CD at rest) or dynamic (CD on the move) states.

A high-resolution monochrome CCD camera, sophisticated illumination and powerful software and hardware are the keys to fast and reliable code reading. This is most easily achieved with small inspection systems which can be equipped with a variety of communication links—Basler's *CD-IDCR* is a case in point. The performance of the *CD-IDCR* and its ability to assist in the prevention mistakes rather than just their detection has been proven in over 70 installations worldwide.

Disc inspection

Once again, installing label inspection equipment is all about saving money and increasing quality. High-quality production can be achieved only if unacceptable prints are detected and rejected; to save money, errors below the determined 'reject level' have to be detected, ensuring that action can be taken to prevent the production of unacceptable CDs. The installation of a system such as the *Label Inspection System* should, however, not require unnecessary expenditure on adapting the CD



compact disc

manufacturing system to accommodate it.

The design of such system demands the use of high-quality equipment as detection of defects as small as 0.1mm in diameter has to be performed in less than 0.5s. To meet these requirements a 3-chip colour CCD camera and special illumination must be used in the image-acquisition unit. Although a single-chip monochrome camera would be a cheaper option, a 3-chip colour CCD camera is necessary if colour labels are to be properly inspected. Also, a single-chip CCD has (as a maximum) one third of the resolution of a 3-chip camera and preventive error detection is almost impossible with the poorer resolution of the single-chip approach.

Software and hardware requirements are high too, as a production cycle of just 0.5s determines the time frame in which the image has to be recorded and a decision made regarding the acceptability of the item. Images as large as 768 x 576 pixels determine the amount of computation which must be performed to derive a satisfactory decision.

Paper inspection

The final production process takes place with the packaging of the CD. Involved at this stage are the booklet, inlay, jewel box and, of course, the CD

itself. Automated inspection systems suitable for use at this stage in the process were not available until recently. The visual random sample check still used gives rise to all kind of errors which result in high levels of wasted production. These are typically due to the time delay between detection of an error and halting the production. Additionally, anywhere in which personal judgment instead of well-defined, automated inspection parameters are applied usually give rise to further wastage. Presently, the *Basler Paperwork Inspection* system (PWI) is the only system on the market which can be used to eliminate these error sources.

To prevent that the customer unwrapping a CD box and finding something other than the CD identified on the packaging, the Ident code of the CD can be read with the *CD-IDCR* prior to packing. Even CDs with sleeves using identical prints but with different 'volume' numbers can be detected—something that it is not possible to guarantee with visual inspection.

In addition, the correct orientation of booklet and inlay within the box is ensured by using two high-definition monochrome CCD cameras. As the positioning of the paperwork in the jewel box is quite variable, it can be clearly seen that sophisticated image-processing software has to be used for error detection.

Experience in fields of image processing, optics and hardware shared among the 20 Basler development engineers has provided the market with a system that is performing well—even at this early stage. The first installations in Europe and USA running on Ilsemann packaging machines seems to satisfy the customers demands.

Conclusion

Saving money is the driving force behind the installation of any upgrade to a machine line. So if quality enhancement by through automated quality control systems is going to save the operator money, how long will it take before the investment pays off? Feedback from the 120 or so Basler installations, this period had proven to be about one year in most cases.

Providing high-quality CD production is no longer a matter of manpower and indeterminate levels of concentration. Today, an automated image processing system will do a better job. Having been sold the idea of 'perfect sound forever' by an overambitious record industry, the vast majority of CD purchasers are unwilling to accept anything but the highest quality. Upgrading the production process is the demand manufacturers must strive to meet. ■

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SONY DAE D5000

Patrick Stapley checks out the forthcoming DAE-D5000 editor intended to partner Sony's PCM-9000 20-bit M-O recorder

Sony took the opportunity of the recent Amsterdam AES show to demonstrate for the first time their DAE-D5000 digital editor, or rather 'Digital Mastering System' as they refer to it. Although the system was essentially still in prototype form, and is unlikely to be commercially available until late in the year, Sony reported that it attracted considerable professional interest.

The DAE-D5000's primary function is to interface with Sony's PCM-9000 magneto-optical disc recorder (see *MDR*, issue 1) to form a 2-channel workstation. This offers nonlinear editing, automated level control and crossfades, 4-band equalisation, full dynamic processing, and built-in EQ—in other words a fully integrated 20-bit CD premastering package designed to replace the various components needed for PCM-1630 premastering.

However, the DAE-D5000 does not turn its back on linear 16-bit editing, and will support tape-based copy editing using PCM-1630 and DAT sources. It will also interface to, and control, a CD player like the Sony CDP-3100.

Additionally, the system incorporates an internal hard disk and will interface with external hard disks to provide random access editing (more of which later).

As it stands, the PCM-9000 recorder is itself capable of certain basic editing functions using its detachable RM-D9000 control panel. It may also be interfaced to the DAE-3000 editor as a

player, although it will be restricted to 16-bit, 44.1kHz working. To maximise the full potential of the PCM-9000, it should ideally be used in conjunction with the DAE-D5000 which will allow up to 24-bit performance and an editing accuracy of one word.

Another significant advantage of using the DAE-D5000/PCM-9000 combination as opposed to a conventional hard-disk editor, is that there is no requirement to up and download program material, as it can be directly edited on the M-O disc (this, of course, presupposes that program originates on the format in the first place). However, depending on the kind of material being edited, it is likely that many users will feel more comfortable in keeping source discs separate to edited masters, and will prefer to record the edited data to a separate master disc. Also, if DSP functions such as equalisation and compression are to be used, audio will have to be processed through the DAE-D5000 and re-recorded.

An important consideration in designing the DAE-D5000 has been that it should be perceived as a follow on product from the discontinued DAE-3000. Sony wanted their third generation editor to retain strong links with its popular predecessors, even though it represents a radical departure in terms of its nonlinear capability and integrated facilities. Consequently, the DAE-D5000 user interface bears many similarities to the DAE-3000, and engineers familiar with this system should have little difficulty in finding their way around the new editor.

The system consists of two main components—an enlarged control console (605mm x 135mm x 465mm WHD) and a processor unit (424mm x 221mm x 440mm WHD). In addition to the console a separate QWERTY keyboard is provided which allows ISRC codes and characters to be input for PQ editing.

The console provides dedicated keys for all major functions, while eight soft keys interact with various pages of functions on the electro-luminescent display. Some functions that were previously controlled by soft keys on the DAE-3000—such as Edit Point Shift, Edit Point Set, and Crossfades—have been elevated in status, as a result of user requests, and appear as dedicated keys.

A conspicuous change to the controller's design is that the orange EL display is now an integral part of the console, being built into the sloped part of the control surface, rather than being a separate hinged unit. Sony have now included the option of a 14-inch colour computer graphics monitor for those preferring to work with a full-size screen display.

The controls are laid out like those of the DAE-3000, with transport keys positioned on the left, editing controls including the prominent Jog-Shuttle wheel in the middle, and the level and balance controls to the right. The EQ Editing controls are placed above the transport keys, and below a 3.5-inch floppy disk drive which is used for loading new software and for storing edit decision lists, PQ data, user setups and so on.



Sony's partner for the PCM-9000, DAE D5000

Also new are eight soft rotary controls positioned to the right of the display which control EQ and dynamics parameters by interacting with the screen. The console now has built-in 32 segment LED meters, rather than screen-based meters, and these include over indicators. At the base of the metering panel is a row of error status indicators.

There are three full length stereo faders, as opposed to just one on the *DAE-3000*. Although not moving, these VCA-style faders are dynamically automated and a display on the EL screen tracks their movement as well as confirming their true positions. The first two faders control the level of two edit sources, and the third acts as an overall stereo output master. By having individual control over two play sources, functions such as manual crossfades and mixing can be implemented.

Rotary Balance controls are provided for each stereo fader (0dB—3dB), and these double-up to provide an effects send and return facility. By pushing the knob while turning it, each control will function as a level control—the first two acting as stereo sends for respective faders, the last acting as a stereo return feeding directly into the master fader—thus allowing an effects unit such as a *Lexicon 480* to be directly digitally interfaced. In addition to this facility, a digital insert point is provided to connect external devices via AES-EBU.

On display

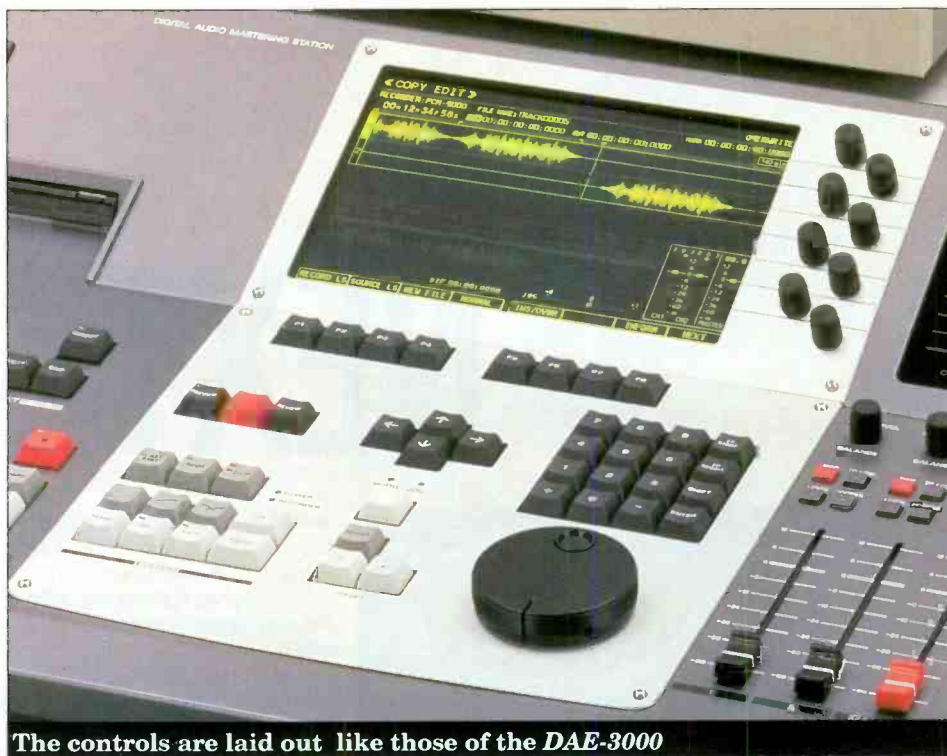
Audio is displayed on the main screen as three stereo waveforms which are controlled by the three faders. These 'zoomable' displays represent the three parts of the edit—the two upper waveforms (A and B) are the player sources while the bottom waveform is the recorder, or in nonlinear terms, the assembled EDL as it stands so far.

The nonlinear editing process has all the obvious benefits of speed and convenience associated with random access: locating audio and previewing edits is instant—there is no waiting for machines to locate and sync up; inserts can be made without having to re-copy large chunks of programme; and running orders can be changed in a matter of minutes. Also, the waveform display provides an alternative and intuitive method of visually marking edit points rather than relying purely on rock-and-rolling the audio.

The crossfade capability has been enhanced, and instead of offering just linear fades, the system now also incorporates cosine and exponential curves. Crossfades are variable between 1ms–999 ms and as mentioned can be performed manually while taking advantage of the system's dynamic automation.

Equalisation is split into four swept bands having an overall frequency range of 31Hz–17.4kHz (±15dB) with a generous overlap between bands. The High and Low bands are peak/shelf selectable, and all include three Q widths (0.7, 1.4, 2.5). Also included are variable high and low-frequency pass filters operating at 12dB per octave.

The dynamics section offers a limiter-compressor and expander-gate and like the equaliser has evolved from Sony's *SDP-1000 Effector* digital processing system. Although it is still too early to be specific, some form of graphic representation of EQ curves and gain reduction will be incorporated in the display and its possible these may be similar to the graphics



The controls are laid out like those of the *DAE-3000*

used in the *SDP 1000*. Both EQ and dynamics are supported by Snap Shot automation and settings can be freely copied from one area to another.

All processing in the *DAE-D5000* may be performed faster than real time, thus allowing edited and effected material to be down loaded

The waveform display provides an alternative and intuitive method of visually marking edit points rather than relying purely on rock-and-rolling the audio

via SCSI at double speed. However, Sony's Super Bit Mapping, which is a real time process, is not included within the system and the *K1203* unit will be required if this facility is to be used.

As mentioned, the system can edit directly on the source M-O disc and it is up to the user whether editing is carried out directly or transferred to a separate M-O disc. However, it is still possible to retain a source disk and produce a separate master by using just one *PCM-9000*. This has been achieved by incorporating a hard disc within the *DAE-D5000*

which will allow SCSI transfers to be made directly from the *PCM-9000*. Thus, by off-loading data at double speed, the player becomes free to re-record the edited data.

At the moment there is some uncertainty as to the exact size of the internal hard disk, but the system shown at the AES Show was equipped with storage for 20 minutes of stereo 20-bit audio. If this were to become the standard, then of course an additional *PCM-9000* or hard disk would be required to deal with programme material longer than 20 minutes—a total of six SCSI devices can be interfaced to the editor. The internal hard disk will also prove useful in storing audio from sources other than *PCM-9000*.

A criticism that has dogged the *PCM-9000* since its release last year, which equally applies to the *DAE-D5000*, is the cost of Sony's proprietary M-O discs. Currently priced at around £100 for an 30 minute disc (20-bit stereo), the media is extremely expensive compared to other formats and many mastering houses feel it will be impossible to justify this cost to their clients.

Conclusion

Although Sony do not expect the price of the discs to fall in the short term, they do point out that their re-usability has a significant benefit over other digital media, and in this respect the recycling of discs could actually make them more cost effective over time. It remains to be seen how the concept of erasable and re-usable media will be accepted by a mastering industry that has traditionally used virgin tape, and has historically preferred the archive to the bulk eraser. ■

UK: Sony Broadcast & Professional UK, The Heights, Brooklands, Weybridge, Surrey KT13 0XW. Tel: 0932 816000. Fax: 0932 817011.

US: Sony Corporation of America, 3 Paragon Drive, Montvale, NJ 07645-1735. Tel: 201 930 1000. Fax: 201 930 4752.

NEXT IN LINE

Currently celebrating their seventh birthday and building on the ongoing success of the Monoliner, ODME are offering the replication business a completely new equipment line. Tim Goodyer goes Dutch

Founded in 1987, the Netherlands-based Optical Disc Manufacturing Equipment company have been busy providing CD replication plant to the world—despite the economic depression of the last few years. From the pioneering engineering demonstrated in the *Monoliner* in-line replication system, ODME have come to the fore in the world

market for manufacturing systems handling CD-based products—CD-Audio CD-ROM, CD-I and Laserdisc.

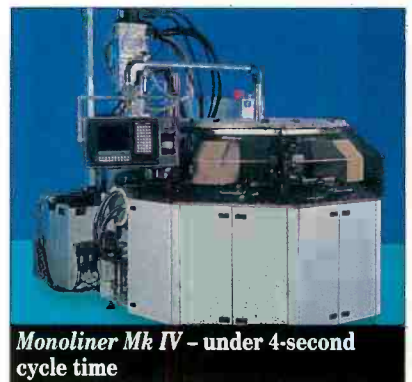
The adoption of a modular approach to their equipment is regarded by the company as one of their most important policies. It is an approach in which is reflected in every stage of the equipment handling both CD and Laserdisc manufacturing process and consequently, ODME are able to offer the replication industry both turnkey solutions and separate systems. ODME do not only see themselves as a manufacturer of systems and core products, however. Education and training are key elements in the company's perception of their service. In this way they offer support to CD manufacturers and potential CD manufacturers at every stage of their development.

In the challenging market presented by continuous development of the CD format, ODME claim to constantly be working on product and process developments and improvements, and as recently as last year, they introduced a completely new range of CD mastering and manufacturing units.

Gearing up

In the area of the premastering data conversion process, ODME recently introduced the *Media Conversion System (MCS)*, which handles the conversion of various input media into a standard output medium, such as the new Exabyte mastering format, ready to be used at mastering sites. Additionally, the *MCS* includes PQ editing, DDP editing, CD-ROM formatting of input data (in accordance with ISO 9660) technical audio editing and CD-R output.

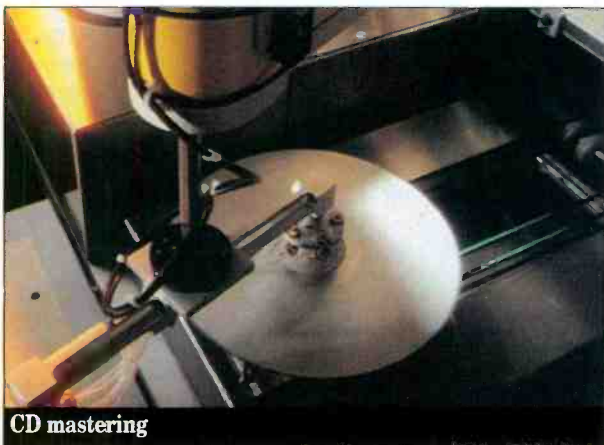
The *AMS 100* is the new in-line mastering and stamper making system which produces high-quality stampers as part of a fully automatic process. Within this one system ODME have successfully integrated the resist master preparation process, recording, developing, metallising and the stamper making process. The *AMS 100* has a built-in clean room and is intended to occupy minimal floor space. Menu-driven software allows for simple one-operator control, resulting in a fully automatic in-line process for all formats. This low-cost concept guarantees highly reproducible stampers which exceed all current quality requirements.



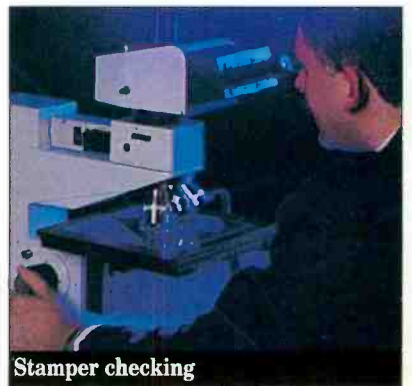
Monoliner Mk IV - under 4-second cycle time

In the replication field, there is now a fourth-generation *Monoliner*, the *Mk IV* which incorporates a vertical injection moulding machine to reduce its footprint. This newly developed moulding machine is equipped with a 'fast action' sliding mould which has two stamper positions, giving fully automated stamper changeover—and the consequent plant down time. The task may take as little as 30 seconds. This aspect of the *AMS 100's* performance is particularly significant in conjunction with the short runs typical of certain CD-Audio CD-ROM lines—when the equipment becomes considerably more economical than that involving longer changeover periods and resultant downtime.

Next to pad printing and screen printing, the latest development in ODME's CD printing equipment is the *Planprinter*. This is a compact 4-colour printing system, based on the use of UV-drying inks. This means that there are no problems with vapour emissions resulting from its operation, and as the water used is cleansed within the system, it can be recycled—as such the *Planprinter* can be ►



CD mastering



Stamper checking

**THE CLOSEST YOU'LL EVER GET TO
PERPETUAL MOTION: OTARI LOADERS, TMD DUPLICATION,
AUDIO DUPLICATION AND AUTOMATION SYSTEMS.**

When your loader or duplicator stops, you lose money. That's why many of our customers tell us that Otari sells the least expensive duplicating and loading equipment they can buy. They know that the real cost of loaders and duplicators must be measured over time, and includes interrupted production, rejects, customer returns and cost of repairs.



And now that Otari fields a full line of loading, duplicating and automation equipment, you can buy from one source. This way you'll know your system will all work together, and the hassle of dealing with several manufacturers is eliminated.

Otari audio and video loaders provide the ultimate in loading and automatic operation.

The new models **AL-631**, **AL-632** and **AL-662** provide standard audio cassette loading, and can be simply converted for the new DCC Digital Compact Cassette.



The new **AL-652** is a fully automatic R-DAT loader, with dual pancake supply.

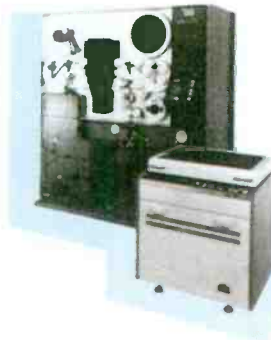
The new **DP-70** series audio twin slave duplicating system offers three duplication ratios including 80:1 and 128:1. The twin slave is digital master reproducer compatible. Up to 20 slaves can be connected to Otari's renowned binloop.



For video loading, the **T-301** and **T-320II** are VHS single & dual supply loaders with an optional fully automatic in- and outfeed system and loader central control.

The **T-812** is an 8 mm dual supply loader.

On request loading for D-1, D-2, Betacam, and U-Matic cassettes is available.

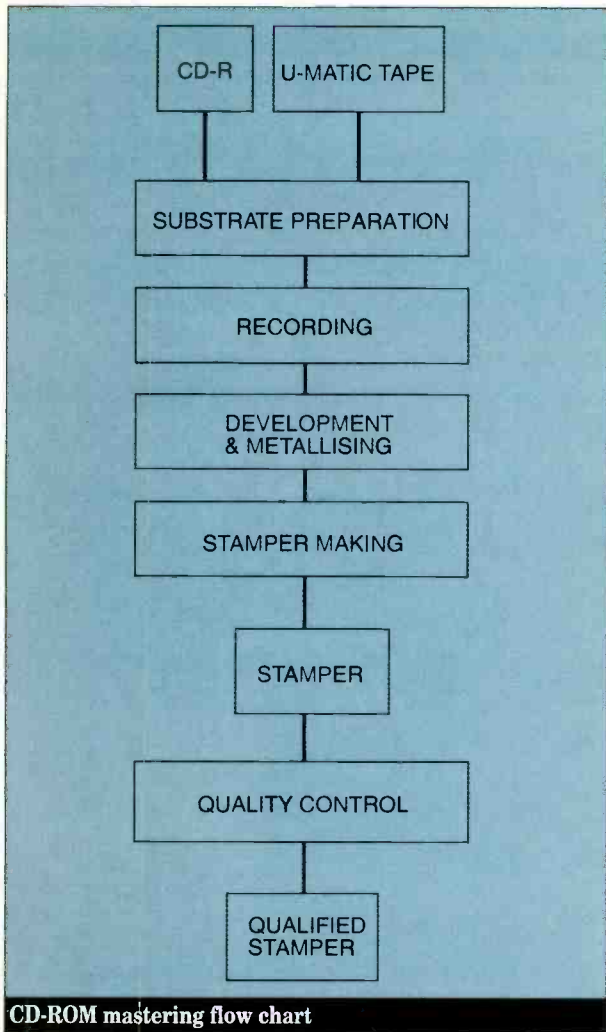


When it comes down to video duplicating, Otari's **TMD™** High Speed Video Duplicator is the acknowledged leader for demanding high volume operation. The **T-700** will produce an E-105 high quality copy every 26 seconds, and perform in PAL, SECAM, NTSC SP and EP with only one **MMR** Mirror Master Recorder.

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sequence, the test time of the *ODT* is less than two minutes. A version is also available for testing CD-R, focussing on the measurements of the recordable layer thickness.

The future

ODME can currently lay claim to being one of the first companies to offer mastering and stamper making for MiniDisc production. This conforms to Rainbow book standards for both



Inspecting a CD master

prerecorded and recordable MD and is the subject of a session the company is to present at the forthcoming Munich Replitech Show.

In order to properly serve a worldwide customer base, April 1st saw ODME expand their network of regional offices. The company is now represented worldwide by satellite companies in Hong Kong, Seoul, Taiwan, Singapore, Japan, Charlotte (USA) and San Jose (USA). Each satellite has its own service network, warehouse and customer back-up, directly linked with the head office, the R&D department and the production base. This arrangement makes it possible for ODME to provide the all-important

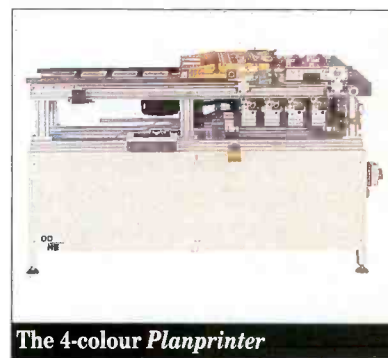
element of direct customer support from within the time zone of any ODME-equipped facility.

Most recently, ODME's Jacqueline van Huigavoort was able to report completion of a major contract with the American Uny Distribution Corporation (a division of the MCA Music Entertainment Group) to provide a turnkey manufacturing facility. The factory is to be sited in Tinckneyville, Illinois, and will house one *AMS 100* and seven *Monoliner Mk IVs* along with premastering and test equipment. The project includes the provision of all training and expertise, and delivery is set to begin in the second quarter of this year.

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US: ODME USA, 8000 Corporate Center Drive, Bldg 2, Suite 210, Charlotte, NC 28226. Tel: +1 704 542 5305. Fax: +1 704 542 5309

Asia: ODME Asia, 3F, No 9, Lane 99, Shih Pai Road Section 2, Taipei, Taiwan. Tel: +886 2 8208123. Fax: +886 2 8208280



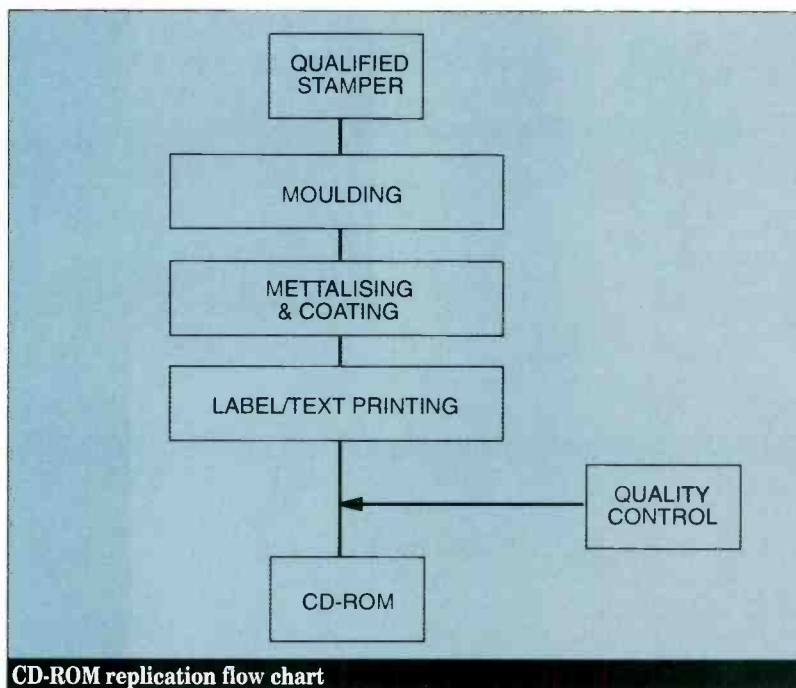
The 4-colour Planprinter

regarded as environmentally friendly. The *Planprinter* facilitates multi-colour text printing as well as full plain printing and negative printing, and it can be completely integrated into the *Monoliner Mk IV*. Consequently, it boasts all the advantages of the *Monoliner* replication line itself.

The value of such a printing arrangement is properly appreciated when the fact that 80% of music CD titles use just one or two-colour printing on the disc. CD-ROM titles, on the other hand, regularly use full, 4-colour printing. When used in conjunction with a fast changeover of stamper, this printing facility enables an operator to accommodate short-run CD-ROM titles within long-run audio projects without sacrificing equipment productivity.

To complete the new product lines and to meet with the high standards of quality currently expected of CD production, ODME have expanded their test equipment line—the *Q-liner ABC 200 DS* stamper and replication tester—to facilitate testing of all CD-formats (including CD-I and CD-ROM). The tester's double-speed drives make testing possible in ten-times real time. It also offers accurate correlation research between stamper and CD tests results. For optical tests on metallised and non-metallised optical discs, the new line incorporates the *Optical Disc Tester*.

When using its automatic test



Features include Continuous Play and no Pause facility



Optical Disc moulds from ICT Axxicon are so reliable that you can be sure of continuous production from day one. So reliable in fact, that every single mould installed is still in use today. They are simply the best optical disc moulds money can buy. The mould dictates the shape, quality and speed of production of discs.

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MASTERING HOLLYWOOD



All photos Elizabeth Annas

Bernie Grundman – ‘My role has to be in support of what my clients are attempting to achieve in their music.’

Will your mixes transfer satisfactorily to CD and vinyl? Are the sound balance and dynamics content up to snuff? Do they fit in with what the public are buying, or are they pushing the ‘credibility envelope’? James Douglas asks the questions

Often, it is the role of the mastering engineer to offer an objective assessment of our carefully-crafted work. If necessary, tactfully suggest that minor—and maybe not so minor—changes might be made will come from him or her. The line between suggestions and interference with our craft (all of us, after all, possess well-developed egos) is one that needs to be walked with care. You obviously have to respect the mastering engineer’s experience but, at the same time, acknowledge the fact that his or her opinions really are being expressed for your benefit. The secret is constructive criticism with a view to improving, if necessary, what you have already committed to tape.

One West Coast mastering engineer who has reached almost legendary proportions is Bernie Grundman. A 28-year veteran of the industry, Grundman and his crew enjoy an enviable reputation as objective assessors of master tapes, and individuals who possess the technical and artistic knowledge to enhance what we

have slaved long hours in the studio to achieve.

‘I like to look upon myself as the ‘Quality Controller’ for my clients,’ the affable engineer offers. ‘But my role has to be in support of what they are attempting to achieve in their music. Obviously, I refrain from making any comments about the performance but, because of the large number of tapes that come through this mastering facility, we get to hear a lot of material! We have developed what I consider to be an excellent sense of the current “musical genre,” if you like, and can make suggestions to a producer or artist about what might sound better.’

Industry veteran

Bernie Grundman got his start in 1965, while working in Phoenix as a second engineer-gofer. He relocated to Hollywood the following year, to work for Contemporary Records, a jazz label that operated its own in-house recording-mastering facility. As Grundman recalls, ‘Contemporary’s one-man studio meant that I had to handle everything from the

tracking session through to disc mastering. The label was best known for its direct-to-two-track jazz sessions—we had multitrack, but it wasn't used all that much—and so I concentrated more on the cutting and mastering side of the operation.

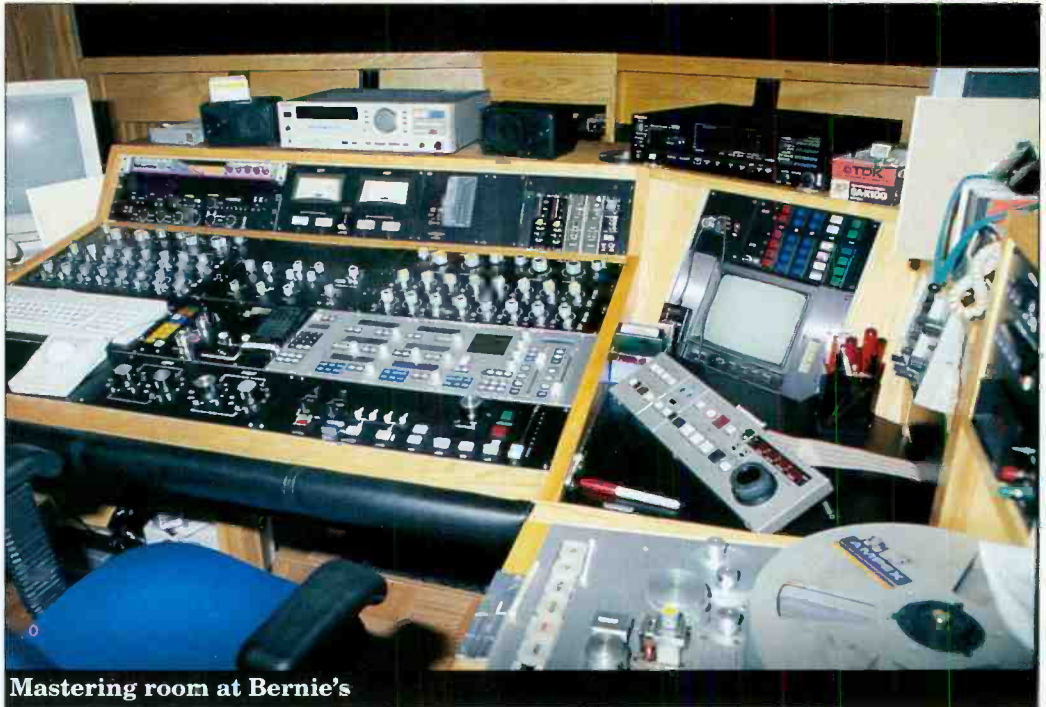
'Eventually, we began to offer mastering services to outside clients that were after the clean, straight-ahead sound we had on Contemporary. Through these mastering sessions for outside producers, which further stretched my talents, I met Herb Alpert—who was planning to set up his label [with partner Jerry Moss]—and people like Bruce Botnick, who was then a staff producer for Elektra Records.'

Having established himself as a *bona fide* mastering engineer, when in 1968 Herb and Moss set up A&M Records in the old Chaplain Lot on La Brea Avenue in the heart of Hollywood, Grundman was asked to head up the mastering side.

'The room was designed and equipped by Howard Holler,' he recalls, 'who had also been responsible for Contemporary. In fact, they looked pretty similar—why mess with success?'

During the next 15 years, A&M's facility expanded from a small operation to one with some 35 permanent staff members, including three mastering suites housed in a separate complex. 'That was a good move,' Grundman remembers, 'because it meant that we were self-contained and away from the traffic through the main studio areas. We had our own library and traffic department, which meant that we could be more efficient at what we did.'

In 1983, after 15 years with A&M, Grundman opened his own shop on Sunset Boulevard, just a couple of miles from A&M. 'When I decided to open this facility,' the engineer offers, 'I was firmly of the opinion that equipment selection was vital to any mastering operation. As everyone knows, tapes that are cut flat to a reference acetate or CD-R in various rooms will sound very different from one another. Every electronic component in the signal path is going to alter the final



Mastering room at Bernie's

sound we deliver to the vinyl or CD manufacturing plant.

'For me, Stage One was to develop a systems that wouldn't alter the original sound of their master, so that at least I would start out hearing what they had heard in the studio. Then I could maybe add additional processing to make it sound better or more effective. All equipment, to some extent or another, will cloud the sound; it is my job to anticipate those changes and modifications, and produce a sound that will carry the music to the consumer. But, of course, I cannot repair distortion that has been introduced during the recording or mixdown process.'

Today, Bernie Grundman Mastering comprises a trio of identical suites fully equipped to handle both analogue disc cutting (modified Scully lathes with *Compudisk 80* Mastering Computer) and digital CD mastering (Harmonia Mundi *BW102* console system, Sony *PCM-1630* and companion U-matic VCRs, plus

modified Panasonic *SV-3700* DAT machines). A fourth room serves as a Quality Control area, as well as handling PQ encoding for CD manufacture, and the preparation of recordable CDs using the facility's Yamaha CD-R system.

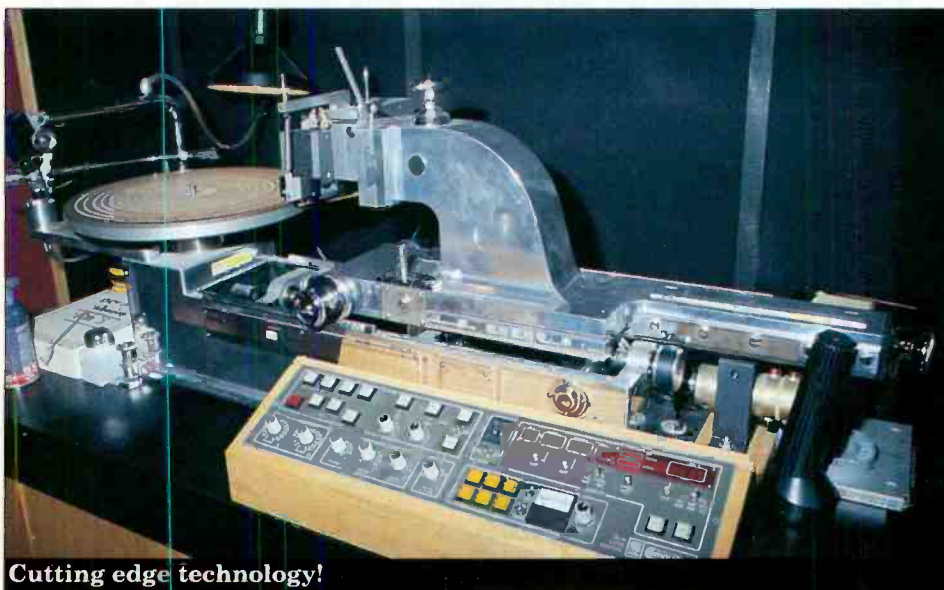
The majority of mastering, Grundman explains, is still from analogue masters. 'I would estimate that 65-70% involves quarter or half-inch masters, and 30-35% is from digital tapes—mainly on DAT, and occasional Mitsubishi *X-86HS* tapes.'

'These new analogue tape formulations—particularly 3M 996 and Ampex 499—with Dolby SR noise reduction, offer a remarkable signal-to-noise ratio. Also, analogue is much easier and faster to handle than digital.'

'I prefer it if the producer or engineer can attend the mastering session, because then I can offer alternatives, and let them hear for themselves exactly what I can do. As soon as the tape is laced up and the play button is pressed, I begin to size up the mix, and make judgments about what

might be needed — or whether it simply needs to be left alone.

'A great number of today's recordings are over-limited, which might result in a loud mix, but sounds very odd. By using a brick-wall limiter on the transients, the average level can be increased. But now the relationship between peak and mean levels has been dramatically upset, and the mix ends up sounding "disturbing" and uncomfortable. But there is nothing I can do about it, aside from suggesting that the tracks are remixed



Cutting edge technology!



The hotseat in the mastering suite

with a less savage peak-limiter setting.'

Accurate monitoring

'My main tools are years of experience, a good set of ears, and my monitor speakers. I spend a lot of time in here with these Tannoy's; I have got to know them very well indeed. They are never changed or modified without me knowing about it. I've listened to a great deal of material on these systems, and I can tell how a tape stacks up, in both objective terms, as well as subjectively whether it matches current musical tastes.'

Bernie Grundman's monitors in each mastering room comprise a set of highly customised Tannoy 2-way cabinets, driven by Crown DC-300 power amplifiers. 'They are not the DC-300A models,' he is quick to point out, 'which featured an integrated amp in the front end. The older, more rare 300s do not have any protective devices on the inputs nor outputs, and no coupling capacitors. Because of their DC coupling, the 300s offer outstanding transient response, and match to the Tannoys beautifully. The speakers use high-impedance tweeters, and AlNiCo woofers rather than the more recent ceramic magnets. I have found no finer combination of amplifier and speaker components. They are quite amazing!'

For analogue-to-digital conversions, and digital replay, Grundman relies exclusively on Apogee Electronics AD500 A-D converters and DA1000 D-A converters. Also available is the Apogee UV-22 Encoding System, which extract full 16-bit resolution from 20-bit master tapes, or the output from his AD500s.

On the subject of objective versus subjective assessments during the mastering stage, Grundman recounts an interesting session with Herb Alpert. 'During my days at A&M,' the engineer recalls, 'Herb asked me to master a new single. I made a couple of refs for him to take away, and then re-cut it to produce a more detailed and, what I considered to be, a better sounding mix. Herb compared the two, and preferred the original cut because he felt that its 'closed-down' and 'murky' sound—which I had attempted to eliminate during my second cut—was more in keeping with the feeling he was after. So, clarity isn't always what the producer is striving to achieve!'

Grundman also feels that he can help achieve a sense of consistency on a project that might involve more than one producer. 'Often each producer will have a different sound, not to mention the fact that the tracks might be mixed on different consoles at different studios. What I try and produce is a complete experience for the listener, by smoothing out the sonic differences and, with gentle EQ and level adjustments, making the tracks blend together more coherently—to establish a more pronounced sense of continuity on the project.'

Hard-disk editing

For editing, Grundman prefers to keep things simple. 'I recommend that a producer lets me assemble-edit the final U-matic masters needed for CD manufacturing, rather than use a hard-disc system,' he explains. 'Although such systems—like our Studer Editech Dyaxis

II—are very powerful, and let you do virtually impossible edits, I remain unconvinced that they do more to the sound than simply recording and playing back a sequence of incorruptible 16-bit numbers from the hard disk. I can hear definite artifacts and a narrowing of the stereo image after just one record-replay cycle. To me, the top end sounds buzzy and grainy.

'I'm not sure what's causing these problems, but it could be the system's convertors, or maybe the repeated copying and re-copying of data. But, there again, it's an effect that I can hear with DAT copies. Maybe it's caused by jitter at the digital interface? Although I haven't yet been able to measure the effect, my current advice to producers is: Don't use hard-disk editing systems unless you really have to. In most cases, DAT tapes can be transferred in the digital domain to the U-matic master without an editor.

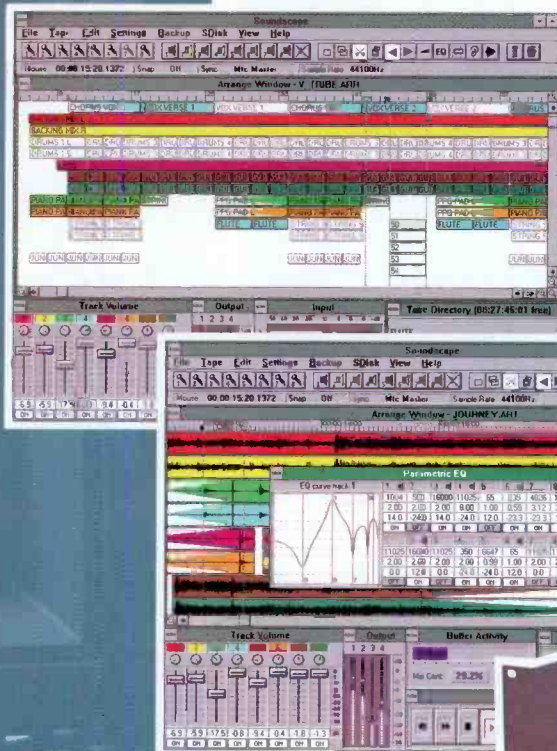
'Recent advances in studio processing and convertors mean that today's CDs sound almost as good as vinyl. Sure, you have to search for a good pressing—and looking after vinyl albums can be a real pain—but I consider CD to be a mass-produced, consumer item that offers good quality at a reasonable price. But, for results that match the master tape, you cannot yet beat vinyl.

'For CD quality control, our Yamaha CD-R system lets us prepare a good reference which, although it sounds slightly different from the factory product, is close enough for producers to listen to on their own home systems. CD-Rs also allow a mix to be auditioned against other compact disc releases in the same playback equipment, and at the same level—all of which can be useful for comparison ►

SOUNDSCAPE

MULTI-TRACK HARD DISK RECORDER

Soundscape is a high quality 16 bit digital audio recording and editing system, and is capable of expanding your studio with 8/16/24 or up to 128 tracks. The system can be used in a recording/composing environment and has extensive non-destructive audio editing facilities.



Operation is from an IBM PC™ or compatible and runs under Windows 3.1™. Software allows up to 64 virtual tracks to be recorded in stereo, edited (non-destructive) and digitally mixed down to four outputs. As the system is modular, several Soundscape units can be synchronised with full sample rate accuracy and used together giving up to a maximum of 32 inputs and 64 outputs.

If you are looking for a Hard Disk recorder/editor with "Open" architecture that can be totally integrated with any Windows™ sequencer or editing package, is random access to the disk, expandable beyond 8 tracks and offers full "chase lock" synchronisation to analog/video tape machines then the next stage of the digital revolution starts here.



2U 19" rackmounted unit.
Physical tracks: 8
Sampling rate: 22.050/32.0000/44.056/
44.100/47.952/48.000KHz
Data format: 16 bit linear
Signal processing: 24-bit internal N.L.
Data storage: IDE hard disk, fitted in the
rack unit (not supplied), size depends
upon recording time required, e.g.
250MB gives 47min 14sec total @
44.1KHz, 1GB gives 3hrs 9min
2nd internal IDE drive can be fitted
giving upwards of 3.4GB allowing 10hrs
42min recording time

A/D conversion: 16
bit sigma-delta 64 x oversampled
D/A conversion:
18 bit sigma-delta 64 x oversampled
Synchronisation: Master or Slave,
MTC with full chase lock, MIDI song
pos.pointer + clock
Analogue in: 2 x RCA/cinch,
unbalanced - 10dBv/+4dBv (2 tracks in)
Analogue out: 4 x RCA/cinch,
unbalanced + 4dBv (4 tracks out)
Digital in: 1 x RCA/cinch,
S/PDIF format (2 tracks in)
Digital out: 2 x RCA/cinch,
S/PDIF format (4 tracks out)
Input S/N Ratio: > 93dB un-weighted
Output S/N Ratio: > 113dB un-weighted
Wow and Flutter: Un-measurable
Pro-Audio Option: XLR balanced,
Analogue inputs and outputs,
AES/EBU Digital inputs
and outputs (XLR)

Host Interface: IBM-AT: parallel via PC
expansion plug-in card (ISA). Supports
2 x 4 track rack units.
MIDI: in, thru, out
Back-up medium: DAT-recorder
with digital i/o, or via the PC
(e.g. to a SCSI optical drive
or any logical PC drive)



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Quality control with Apple Mac

purposes.'

For Grundman, half-inch analogue represents possibly the 'ideal' mastering format. 'For me, analogue has a 'bigger' sound than DATs, which are being used a lot more these days. But with analogue masters, you have to know what you are doing. In many ways, analogue is a 'delicate' medium, and one that takes a great deal of experience to produce a good master. You need to learn how to compensate for certain losses that are inherent with analogue—such as the fact that the top-end response will gradually diminish over time, and that high-level transients will be dulled slightly.'

In terms of emergent technologies for mastering, Grundman has only limited experience with the new Sony *PCM-9000* magneto-optic recorder. 'But, from what I've seen and heard, the *PCM-9000* looks like a good format. U-matic tapes are pretty delicate, and can be easily damaged—the *DMR-4000* has an elaborate threading mechanism, which can easily damage the tape guides and cause edge damage. Also, uneven winds can mean that U-matic tapes are prone to damage during shipment.

'High-speed access will dramatically reduce wind times, although higher system costs will need to be passed on to the record labels. I estimate that if we installed a *PCM-9000* we would need to add between \$200 and \$250 to a session to cover the increased equipment and media costs. The major labels will be able to balance those costs against reduced storage space and lower shipping costs of M-O cartridges compared to bulky U-matic videotapes.

'Magneto-optic cartridges are also expected to offer a much longer shelf life than conventional tape. I have noticed that,

while working on re-issues the readouts on our *PCM-1630s* are showing higher error-rate values from tapes that have been in storage for maybe three to four years. While I don't hear any audible problems yet, we need to consider the re-recording of master tapes to a less fragile medium.'

What other technologies would the engineer like to see in the mastering suite? Grundman's response is immediate: 'A lower-cost glass master cutting system. I would like to experiment with in-house preparation of the glass master used to stamp CDs. Currently, we are always at least one generation away from the master tape. With a glass-master system I could go directly from an analogue or digital master, and compare the results from the normal technique of sending a U-matic or DAT master to the manufacturing plant, and having them cut the glass masters.



'Analogue has a bigger sound than DATs' - Bernie Grundman

'There may be no perceivable difference between the two, but I would like to find that out for myself. After all, a mastering engineer needs to be familiar with the limitations of analogue disc cutting, which involves us preparing the master here in our custom-designed lathes. I'm sure that I would learn a lot more about the limitations and opportunities of the CD mastering if I could be more involved in the preparation of the pressing master.' ■

Bernie Grundman Mastering, 6054 Sunset Boulevard, Hollywood, CA 90028, USA. Tel: +1 (213) 465 6264 Fax: +1 (213) 465 8367.

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Studer *A-80* (customised: 14-inch reels, discrete playback electronics)

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digital limiter-compressor, sampling frequency converter, (D-A for preview delay)
Apogee Electronics *AD500* A-D
Apogee Electronics *DA1000* D-A
Apogee Electronics *UV-22* Encoding System

PRODUCTION

Sony *BVU-800*;
Sony *BVU800DB*;
Sony *DMR-2000*;
Sony *DMR-4000*;
Sony *PCM-1630*;
Mitsubishi *X80*;
Mitsubishi *X86*;
Mitsubishi *X-86HS*;
Panasonic *SV-3700s* (modified);
Yamaha *K-2000s*;
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Ampex *ATR-102* 1/4- and 1/2-inch analogue decks, Modified Scully cutting lathe with *Compudisk 80*
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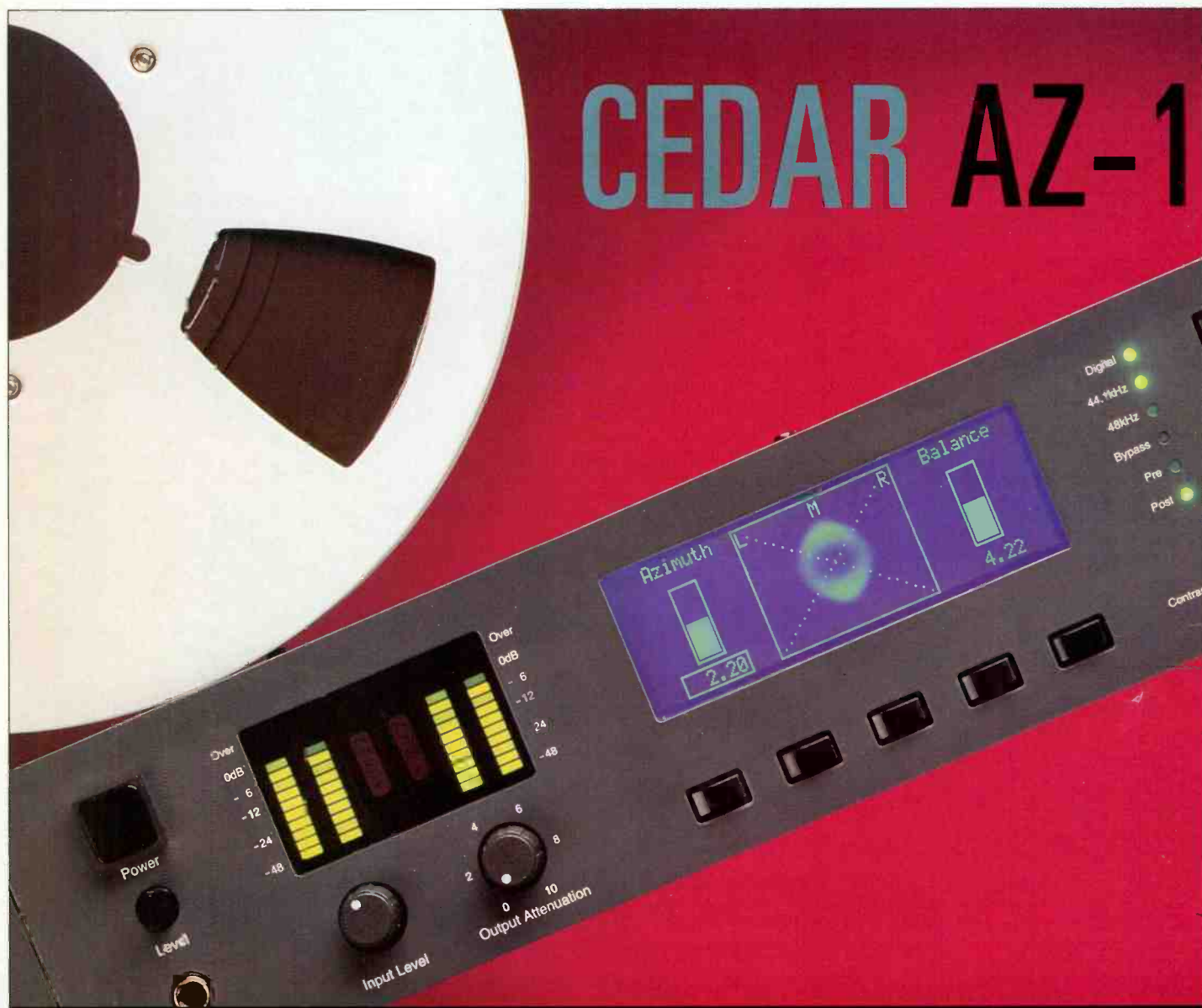
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The Reliable Source!

CEDAR AZ-1



Azimuth correction — as easy as AZ-1

Developing further units from their powerful computer-based system, CEDAR Audio have released a stand-alone azimuth corrector. Dave Foister gets things straight

It is a sobering thought that, in these digital days, there must be many perfectly competent audio people who do not know what azimuth is, never mind what sort of problems can be caused by its misalignment. The effects of incorrect azimuth—the angle between the vertical line of the gap in the head of an analogue tape machine and the direction of tape travel (which must be exactly 90° for proper operation) are nowadays almost exclusively the domain of the mastering or remastering specialist; they need only enter the consciousness of the rest of the industry where the lowly cassette is involved, and even then most prefer to throw up their hands and blame the medium rather than do anything about it.

The fact remains, however, that analogue tape is still in regular use, and that correct azimuth alignment is vital for it to perform

properly. The effects of its being misaligned are readily identifiable—a poorly-defined stereo soundstage, lack of presence of central images (bad news for vocalists), loss of HF (particularly in mono) and a general phasy, shifting muddiness. Since these phenomena are due to a more or less constant time offset between the two channels caused by the head, they are, perhaps, ideal fodder for correction using digital signal processing. Given this premise, it comes as no surprise that the first people to come up with a stand-alone unit for correcting azimuth errors are CEDAR Audio.

If one has access to the original master tape, of course, azimuth misadjustment is not a problem. Any suitable replay machine can have its repro head azimuth aligned to that of the originating record head using the original calibration tones; even if these are missing, a

close approximation can be achieved by ear, particularly by monitoring in mono, and the assistance of a phase meter or a vectorscope can make it simpler still.

The difficulties arise when an analogue original has been transcribed to another medium using misaligned equipment. Once a tape has been copied with incorrect azimuth (azimuth not matching that of the originating record head, whether 'correct' or not) then the problems become embedded in the new medium—be it another analogue tape, vinyl, or a digital format. Bring on the CEDAR AZ-1.

The AZ-1 joins the existing family of stand-alone CEDAR processors, the DC-1 DeClicker and CR-1 DeCrackler, which it resembles almost identically. The few visible differences arise because CEDAR have taken the opportunity of the new model to rethink some of the basics, notably the front panel construction, which now does a better job of keeping the DSP RF nasties inside the box, and the PCBs, which are now designed and sourced by new sub-contractors to meet CEDAR's ever more stringent demands.

The overall package remains very similar, with a full complement of analogue and digital I-Os and 40-bit internal architecture, with the familiar panel and set of in-out level controls and meters, four dedicated push-button switches, and the large central display with five soft keys underneath and continuous rotary encoder-data wheel.

These CEDAR boxes have also been notable for being extremely easy to operate, and this tradition too has been upheld in the AZ-1. There are only four pages on the display screen, two of which handle I-O configurations and MIDI control, so setting the unit up and making it do its job could hardly be simpler. In fact, having selected the required input format, the whole operation is controlled and monitored from one main screen.

Input options cover the usual selection of analogue (with choice of 44.1kHz or 48kHz sampling rates), SPDIF and AES-EBU, with the added refinement of using the analogue inputs with the digital output synchronised to an external SPDIF source. The analogue inputs are internally jumper-selectable as either fixed gain at nominal line level (giving a claimed range of 103dB) or variable via the front-panel control, while output level is handled by a digital output attenuator.

When the digital input is in use, the associated LED can be set to indicate one of four levels of error in the input data, ranging from a complete loss of usable signal to the slightest deviation from the relevant specification. This in itself is a useful diagnostic tool rarely found elsewhere—however professional the kit claims to be.

Operation

The main operation screen provides control and display of five central functions—accessed via the five soft keys and the main control wheel—and a sophisticated central display showing the end result in a particularly useful form. Two of the control functions are for basic setting up and checking of the unit's effects; one is a phase reverse of either or both of the channels, while the other gives an output signal which is normal stereo, summed mono (which can show in a more exaggerated way the problems present in the original signal and provide a clear indication of the efficacy of the process) or a mono difference

signal which can further point up subtle problems and make their solutions significantly easier to find.

There are then two main parameters for adjustment. One is the inter-channel balance in terms of straightforward amplitude; CEDAR have identified problems which can be caused by factors other than tape heads (errant RC networks in particular) which can include level imbalances as well as the time differences typical of out-of-whack azimuth. The other is the crucial function of correcting inter-channel time differences—to a resolution of 1/20 of a sample—which can be carried out manually but will generally be done automatically, hence the fifth soft key to switch between Manual and Auto.

In Auto mode the time compensation is glitchlessly adjusted 44 times per second in order to re-align the dominant common signals present on the two channels, within limits which are carefully defined to cover the range of errors likely to be caused by misaligned heads. Continuous monitoring and re-correction is necessary because even a correctly-aligned transport has difficulty maintaining constant

'There will, I imagine, be plenty of people who find it hard to appreciate the problems the AZ-1 sets out to solve. I am equally sure that there are a number of potential users who will see AZ-1 as a magic wand...'

perfect azimuth—try recording a stereo signal across tracks 1 and 24 of even the best analogue multitrack.

This combination of finding the best fit of the common signals and limiting the correction range should avoid the danger of the system misinterpreting deliberate timing differences, such as those produced by a spaced pair of omnis or a dummy head. CEDAR acknowledge the possibility of certain conditions fooling the software—a particular trial track had such a tight stereo ADT that the system thought it was an error, hence the manual over-ride.

The display screen carries bar-graph displays and numeric readouts for the current level and time offsets, but is dominated in the middle by a real-time graphic display of the stereo soundstage. This produces something akin to the kind of Lissajous figures familiar from vectorscopes and oscilloscopes configured in X-Y mode, but the result is rendered far more meaningful by having a logarithmic amplitude response, giving a more consistent, legible pattern. Obviously a centre mono signal gives a vertical straight line, left mono points North-West and right North-East, while out-of-phase mono gives a side-to-side straight line. Healthy normal stereo gives something between a circle and a vertically-elongated ellipse, usually with noticeable bunching of the signal, shown by a more dense pattern, at the top and bottom. An ellipse which is wider than it is tall suggests the existence of a problem since it means the side, or difference, signal is greater than the central

sum signal, and this is commonly the display produced by the phase errors inherent in faulty azimuth. Switching the unit into operation shows an immediate modification of the display's shape to the ideal, and this is reflected in the audible result.

This result can be quite remarkable. As already mentioned, and as old analogue hands will be only too aware, misaligned azimuth can produce an unpleasantly indistinct stereo image, with individual sources hard to localise and a general lack of clarity and focus, and these effects are made even worse by the all-too-common fluctuations in the inter-channel relationships as the tape weaves its erratic way across its misaligned path. The AZ-1 can immediately lock everything into place, providing a stable image, restoring the presence and perspective of the component sounds and keeping everything steady even when the extent of the underlying problem is continually varying. It even restores mono compatibility, which is always the first casualty of even the smallest azimuth error.

My own worst azimuth horror story involved a track I contributed to an album, the majority of which was recorded elsewhere. I still believe mine was recorded with a correct machine line-up, but when the record was cut the replay machine was lined up to the tones attached to the other tracks; these were sufficiently different from mine to leave my contribution sounding muffled and indistinct. It would have been unreasonable to expect the cutting engineer to have corrected this on the fly with nothing more than the big knurled knob on his repro head azimuth screw to help him, but the AZ-1 would have sorted it out on the spot, as I proved to myself by playing a dub of the finished album track—off vinyl—through it.

What it won't do is correct the problems created within each of the stereo tracks by a head with incorrect azimuth. Each track will suffer a degree of comb filtering and consequent HF loss caused by the angle of the head gap across the recorded flux patterns, and while this may be theoretically correctable it would require a knowledge or a calculation of the width of the track, the amount of azimuth error, the spacing between tracks and similar factors. What I heard, however, was enough to convince me that these problems are secondary to the time offsets the system does address, and that at least the comb filter effects generated across the two tracks were improved by the process, resulting in a real increase in HF information.

There will, I imagine, be plenty of people who find it hard to appreciate the problems the AZ-1 sets out to solve, still less why anyone would want to spend the AZ-1's asking price (which, once again, puts it squarely in the specialist bracket) to solve them. I am equally sure that there are a significant number of potential users who have fallen over these problems only too often, and who will see the AZ-1 as a magic wand they might once have thought impossible. ■

CEDAR Audio, 5 Glisson Road, Cambridge, CB1 2HA. UK. Tel: 0223 464117

UK: HHB Communications Ltd., 73-75 Scrubs Lane, London NW10 6QU. Tel: 081 960 2144. Fax: 081 960 1160.

USA: Independent Audio, 295 Forest Avenue, Suite 121, Portland, Maine 04101-2000. Tel: +1 207 773 2424. Fax: +1 207 773 2422

PQ EDITING

Anyone who has been involved with arranging the production of audio CDs will know that before a disc can be glass mastered, the master tape must be 'PQ'd'. But what exactly is PQ? Bill Foster sheds some light

Running alongside the main data track of a compact disc are eight data tracks—or 'words' to be more technically correct—which are designated by the letters P, Q, R, S, T, U, V and W. These eight tracks are known as the CD subcode.

The first two words contain all the timing and track information, along with various additional codes which identify whether a track contains data (CD-ROM) or audio, and in the latter case if the recording was made using pre-emphasis. On almost all CDs released, it is only these two words that are utilised; hence the term 'PQ code'. The P word identifies the pauses between each track, although this doesn't mean that there has to be an audible pause; the 'flag' is there in order that the CD player can identify the point where each track starts.

[It is perhaps worth noting here that the multi-session write-once CD format (Orange Book) does not use the P word. On CDs recorded to this standard—all discs made on the low cost write-once CD recorders—only the start time of a track is stored; the end of each track therefore being the start of the next one.]

The Q word carries flags which indicate the type of material contained by each track (audio, data video and so on), plus its copy prohibit and pre-emphasis status. The remaining Q data is divided into three modes: Mode 1 contains the Table of Contents, (the number of tracks and their start times); Mode 2 is the UPC-EAN barcode-catalogue number of the disc, and Mode 3 carries the International Standard Recording Codes (ISRCs).

Mode 1 is essential to enable a disc to be played and this information is generated by the PQ subcode editor as part of the premastering

process. Barcode numbers can also be inserted at this stage, but are more usually added later by the manufacturing plant. ISRC numbers are rarely supplied by the record company and so Mode 3 data almost invariably consists of zeros.

The PQ subcode editor is actually a computer that converts the track timing and status information—which has been input either by an engineer or directly from a digital editing system—into PQ code. All PQ codes are related to a 30 frame SMPTE time code recorded on the master tape, this having been generated by the digital recording system: for example, a Sony PCM-1630.

At the glass mastering stage the 30 frame time code is converted into CD time code. This runs at 75 frames per second and corresponds to the data block structure of the compact disc.

A major headache for CD premastering facilities, especially in the early years, was the failure of the Red Book to define the exact point before the start of a track where the laser should settle on the disc—the 'offset'. Because the output of the player is muted during the

search mode, and is only unmuted when starting to play, this offset must be slightly ahead of the start of audio. The unmuting parameters are laid down in the format, but in practice each machine has a differing 'unmute time', largely depending on the cost and quality of the player. In the early days only the CD manufacturers were able to add PQ code to the U-matic CD Master Tape. Most European plants standardised on a five or six SMPTE frame offset, but others had their own preferences as to the offset required, often based on their experiences with different players. Mastering facilities normally completed a cue sheet detailing the SMPTE time code reference for each cue point, and they frequently side stepped the offset issue by marking cue sheets with the *actual* start and finish times of each track, leaving it up to the plant to add their preferred offset. This resulted in a wide variation; anything from one and a half seconds to a couple of frames—the latter frequently resulting in clipped starts on the cheaper players. The situation has now settled down ▶

ISRC FR - Z03 - 92 - 00212

Country Code
FR = France
(two characters)

First Owner Code
Z03 = (Full name of
first owner (example:
Phonogram France)
three characters)

Year of recording Code
(two characters)

Designation Code
(five characters)

An ISRC code should always be preceded by ISRC - this is the structure

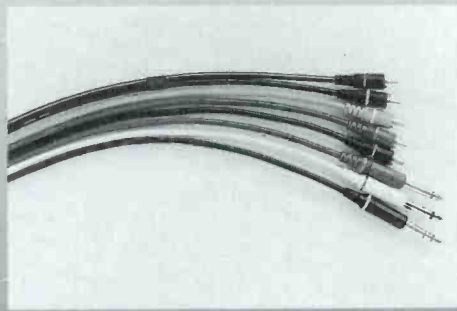
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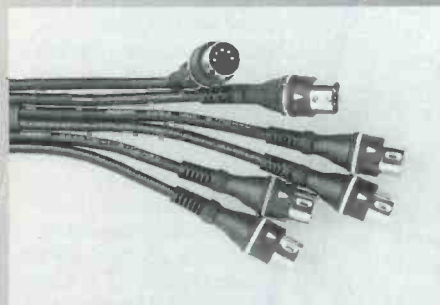
BANTAM PATCH CORDS



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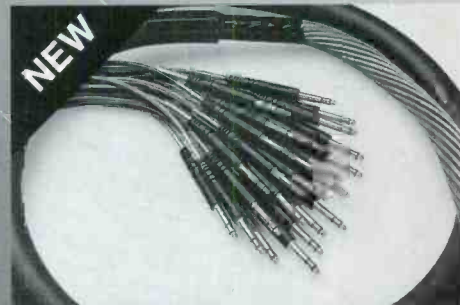
LONGFRAME PATCH CORDS



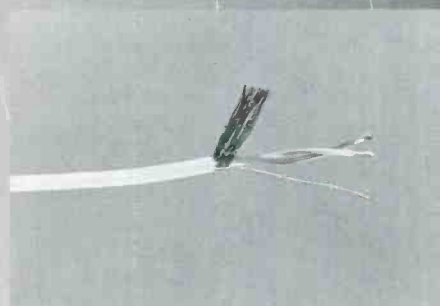
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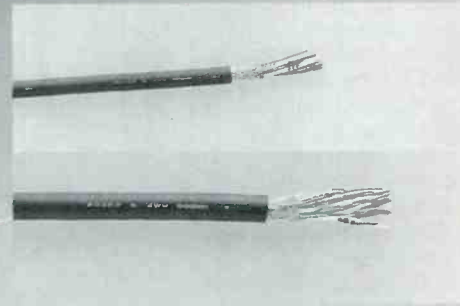
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somewhat, and almost all CD plants appear satisfied with an offset of between five and ten SMPTE frames—1/6th to 1/3rd of a second. This is with the exception of Track 1, which must always have an offset of one second. Similarly, pauses between tracks can be any length from zero upwards; even if a pause is of zero seconds duration it is still flagged in the subcode. This is how the player counts tracks. (The exception is the pause before Track 01 which the specification defines must be at least two seconds long.)

Another

preferable to hear it from the start. With CD programming this is not possible. There is only one cue point at a crossfade and so, when playing the album in other than standard sequence, you must either accept a sudden end to Track 2 or a sudden start to Track 3.

It will be

mentioned above are concerned, it's important that the producer and-or artist is involved at the PQ coding stage.

By and large, American mastering houses have chosen not to purchase PQ editors and continue to supply the CD plants with a PQ sheet for each CD Master Tape. Conversely, most European facilities have installed PQ editors and consider PQ coding to be an integral part of the mastering service.

Other codes

Where the R-W codes are used, they are normally generated separately and integrated at the final mastering stage. There are a number of potential uses for these six remaining subcode tracks and some of them have been defined in the Table of Contents. MIDI is one of the applications that has been used in the past (albeit infrequently), and apparently Philips are now considering whether to include the ITTS text mode (as used on DCC) as another option.

By far the most popular use for the R-W codes to date has been for graphics. The CD+Graphics (CD+G) or the new enhanced CD+Extended Graphics (CD+EG) formats are capable of delivering reasonable quality pictures on a television set when using a player fitted with a suitable decoder. The data rate from the six subcode tracks is far too slow for real-time video, but with a screen refresh rate of about 12 seconds it is possible to produce quite reasonable quality graphics and simple animations. Unlike CD-Digital Video and CD-I discs, CD+G discs are fully compatible a standard CD-Audio player.

Until now the principle use for CD+G has been Karaoke, although with the recently launched White Book CD-Digital Video format already catching on fast

in Japan it is likely that CD+G will soon begin to lose popularity.

The print-out

The example print-out shown in Fig.1 is taken from a classical CD and is typical of the mastering sheets produced by many PQ editors. Untypically perhaps, all the various boxes, including ISRC, have been completed in this example.

apparent from the above that in many instances PQ coding is an artistic operation rather than a purely mechanical process, and it is for this reason that many mastering houses have installed PQ editing equipment. Where albums such as those

FINESPLICE LONDON (081-564 7839)
 Date: 17-Apr-94 Page: 01/01 Mast.-Ident.: CD CAD 6087
 Title: Masterworks of Claudio Monteverdi
 Vol One
 St Mark Singers and Players
 Label: Greenhill
 Bar-Code No.: 9770144594017
 Set-Content:
 LP.-No.:
 Headroom (dB): 0 | DDD|xxx|xxx|xxx| Set-No.:
 Order Source: Greenhill Discs
 Planned Release Date: May 1994
 Initial Order: N/A
 Tape(s) from: Byrn Studios
 Mastering: BT
 Checking: TB
 PQ-Coding: JT
 ISRC-CODE and Pre-Emphasis
 Playing-RIT-Time
 MM SS FF T X P
 SMPTE-Ref. MM SS FF

Track T - X	Track or Index Content	ISRC-CODE and Pre-Emphasis	Playing-RIT-Time MM SS FF	T X P	SMPTE-Ref. MM SS FF
01-00	Pause				
01-01	Beatus Vir	GBHSS9400198 No Pre-Emph.	00 02 13 08 07 23	P T	01 56 17 01 59 00
02-00	1610 Vespers:				
02-01	-Nigra Sum	GBHSS9400232 No Pre-Emph.	00 04 08 07 12 15	P T	10 06 23 10 11 01
03-00	Pause				
03-01	-Ave Maria Stella	GBHSS9400233 No Pre-Emph.	00 05 14 10 59 01	P T	17 23 16 17 29 00
04-00	Pause				
04-01	Maas:				
04-01	-Kyrie				
04-02	-Gloria				
04-03	-Credo				
04-04	-Sanctus & Benedictus				
04-05	-Agnus Dei	GBHSS9400234 No Pre-Emph.	00 12 10 28 38 07	P T	28 28 01 28 40 11
05-00	Book VIII Madrigal:				
05-01	-Hor ch'el ciel...	GBHSS9300023 Pre-Emphasis	00 08 23 04 54 27	P T	03 30 28 32 11 09
06-00	Poppea:				
06-01	-Pur ti miro	GBHSS9400199 No Pre-Emph.	00 09 18 05 39 25	P T	09 39 12 38 19 23
6	1 Start LEAD-OUT: 2 Total Program : 3 4 5 6				

Remarks : SMPTE times include offset >= 6 frames
 TN01 offset = 1s.
 Rumble t'out TNO 1.
 Studio noises: 03.34; 35.45; 37.45 etc.; 44.21;
 58.19; 58.33; 62.39.
 Slight click at 23.34

problem, again inherent in the design of the CD format, is the inability of the system to accept what are known as 'negative cues'. In other words, one track cannot be programmed to start prior to the previous one finishing. This presents no real problem when playing a CD all the way through, but can cause difficulties when PQ coding continuous programme material, such as live concerts or concept albums where crossfades are present.

For example, if Tracks 2 and 3 crossfade into each other and you wish to play Track 2 on its own, you would probably want to hear it all the way to the end, even though Track 3 was beginning to become audible. Likewise, if you selected Track 3 it would be

ISRC CODE

The Q data provides for a 12-character alphanumeric code known as the International Standard Recording Code (ISRC). The designers of CD included this provision in order that each title could have a unique identifying number.

The 12 characters of the ISRC show the country of residence and the name of the recording's first owner, the year that the recording was first released and a unique number identifying that particular recording. In addition to providing these details of a track's origin, an ISRC can greatly simplify the time consuming job of airplay logging and royalty collection.

Unfortunately, giving each track an ISRC number was not made a mandatory requirement of the CD format, so only a handful of the thousands of CDs released since 1982 contain ISRC numbers (almost all of these being on Philips/Polygram-owned labels). However, Philips have made the inclusion of ISRCs obligatory for all DCC releases which may see a wider adoption of the codes as the number of titles available in this format increases.

Along with the timing data and the P and Q information, details of the title(s), artist(s), record label, mastering facility and any comments are stored for later display—although only the timings and P and Q data are written onto the compact disc.

Provision is also made to store the UPC-EAN (barcode) number on the CD, as well as the ISRC number of each track.

The Headroom figure indicates how far below zero level the programme peaks. (Well mastered tapes are normally recorded right up to maximum level of 0dBFS) The following boxes

give details about the recording process, as per the SPARS standard notation. In this instance, DDD indicates an all-digital recording (whether 2-track or multitrack), mixdown (if applicable) to digital 2-track and a digital CD master.

Each track (T)—of which there can be 99—is preceded by a pause (P). The pause is designated index (X) '00', and with the exception of Track 01 it can be any length from zero upwards. The start of the title is Index 01 and there can be any number of index points in each track, up to a maximum of 99. Indices are most frequently found on classical recordings; Track 04 on this example is divided in five indexed sections. Indexes are also used on many production music library discs, but they are not common on 'pop' releases—which is probably a good thing as a great many cheaper CD players have no provision to access index points.

Each track is individually flagged as to whether it has been recorded with pre-emphasis; this flag switches the de-emphasis circuit in the CD player's analogue output stage accordingly. Every track can have a different emphasis status (see Track 05), but switching cannot be done during a track. In addition (but not shown on this example), provision is made to enable/disable the copy prohibit function, and another flag indicates whether a particular track is audio or non-audio—CD-ROM, CD-I and so on. The latter flag is very important for mixed-mode discs.

The timings are in minutes, seconds and SMPTE frames (30 per second). The pause before Track 01 of approximately two seconds is inserted automatically by the PQ editor, but after this the timings must be typed in by the mastering engineer or, depending on the

system, the start and stop points can be located using a digital editor and then loaded in automatically. The left timing column shows individual track times, the right column is the progressive timing from the start of the tape. (It is industry practice to start the programme around two minutes into the tape in order to minimise the risk of digital errors.)

In the glass mastering process, some PQ editors run a program which controls the digital recorder to perform a premastering check. The editor plays five or 10 seconds either side of the start of a track, allowing the mastering engineer to verify that the cue point has been correctly positioned. The tape is then fast wound to check the end of that track and the start of the next—and so on.

The Remarks section is a text field. Most mastering facilities use this area to add comments regarding any quality defects such as clicks or tape noise, and to note the PQ offsets—although as five or six frames (30 frames-1 second for Track 01) is now considered by most to be the industry standard, this is not longer strictly necessary.

DCC and MiniDisc

The requirements for DCC and MiniDisc are the same as those for CD, although DCC, being a 2-sided medium, also needs a 'turnover cue'. This must consist of at least 12 SMPTE frames of digital zero at the point in the programme where the cassette is to reverse direction. At the premastering stage it is only necessary to indicate this point on the print-out or cue-sheet; the actual cue can then be inserted during mastering. ■

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MASTER STROKES

After dominating digital mastering for more than ten years, has Sony's PCM-1630 format finally had its day? Patrick Stapley poses the question to a number of key mastering houses

What then are the main advantages offered by the new generation of systems? To answer this it's probably easier to examine the criticisms that have been levelled at *PCM-1630*.

First of all *1630*—or *1610* as it first appeared—grew from a video format and many saw it as being 'dressed-up' to do the job rather than being a dedicated digital audio system. Being a linear format, access times are slow when compared with nonlinear media, and indeed other linear formats such as DAT. The system requires regular servicing if it is to be kept in a reliable condition, and this can often prove costly as many studios have discovered. Archiving problems have been experienced with early U-matic tapes, and although these are thought to have been largely eradicated with advances in tape formulation and better storage conditions, there still remains a degree of nervousness. Cloning has also come under fire, with some *1630* critics expressing their doubts over the system's ability to produce truly identical digital copies. It has to be said that these last two points may equally apply to the new formats once they have become more established and undergone the tests of time—although recent accelerated age tests performed on M-O (magneto-optical) discs give the format a life expectancy of over 90 years.

One big advantage that all three of the new formats have over *PCM-1630*, is their ability to replay and write data via SCSI at least double speed. This provides obvious benefits to suitably-

equipped CD plants where a significant increase in productivity can be realised. For this reason, it is considered likely that the plants themselves will be influential in deciding which formats are adopted by mastering houses.

One facility that has a considerable investment in *1630* is Abbey Road. With a total of 16 *PCM-1630* sets and six Sonic Solutions systems (soon to be expanded to eight), how does view the future?

'At the moment their isn't much incentive for us to change from *1630*,' says Chris Buchanan, Manager of Mastering Operations. 'We're investigating CD-R, and we've looked at the Sony *PCM-9000* which in our view would make a good 20-bit recording and archiving format, but it wouldn't be something we'd use for CD mastering bearing in mind the current price of the M-O discs.'

This view is shared by Crispin Murray, Technical Coordinator at London's newest mastering centre at Metropolis Studio; he believes that the *PCM-9000* should first be adopted as a remix format if it is to have a chance of replacing *PCM-1630*.

'I would love to see more people coming in here with 20-bit recordings for us to master from, but to use the *PCM-9000* purely for 16-bit mastering is like cracking a nut with a sledgehammer! Studios appear to view the *PCM-9000* as a mastering system, but the whole point is that they should be the one's supplying us with highest possible quality in the first place. There's no use us mastering 20-bit if all we're receiving is 16-bit DAT

The question of the *PCM-1630*'s future has increasingly been asked within mastering circles, fuelling intense debate and speculation as to the future direction of CD premastering and the adoption of new formats. With CD-R, Exabyte and the optically-based *PCM-9000* all vying for the *PCM-1630* crown, are we about to see the start of a new format reign, or will the industry become subservient to many different 'masters'?

As with all good debates, there are many conflicting and contrasting views; on the one hand 'futurists' like Crispin Murray (of London's Metropolis) believe *PCM-1630* to be 'well past its sell by date', and eagerly await its replacement, while 'loyalists' like John Dent from London's The Exchange are in no hurry to replace this 'reliable and well proven format.'

Irrespective of where allegiances lie, all are of the opinion that *1630* is on the way out, although most see its demise as being reasonably gradual—too many facilities have made too large an investment to allow the system to disappear overnight, and Sony paradoxically continue to sell the system even though they are trying to establish its successor.



Mastering on CD is now a real option

tapes.'

Chop Em Out are one of the few UK mastering studios to have actually used the *PCM-9000* for specific projects, and Director Avi Landenburg has been suitably impressed: 'It's a very, very nice machine and we think it's a superb format with a lot of future potential particularly once 20-bit becomes more widespread. M-O is a lot more reliable and slicker to operate than *1630*, the only problem with it is the price—not so much of the hardware, but of the media itself which at £100 a disc is prohibitive.'

Both Chop Em Out and Abbey Road, as mentioned, have Sonic Solutions systems; although Abbey Road are investigating Sonic's own PreMaster CD system that uses the Sony CD Writer, Landenburg is not interested.

'Firstly we're not in favour of a format that anybody can play in transit from the mastering house to the CD plant. Secondly, there's been some debate over the block error rate on CD-R that puts into question its ability to make good digital transfers; although I'm sure if you're using the right equipment at either end you probably won't run into problems, we're very reluctant to take that risk.'

There are also worries that manufactured CDs will find their way back to the plant as production masters, as Landenburg illustrates.

'You only have to imagine the scenario where a record company releasing back catalogue loses a master. What do they do? They nip out to the shops and buy the CD off the shelf and send it to the factory to be glass mastered. It's a pretty appalling thought, but not an unlikely one. I really can't see a lot of point with a purpose-built M-O format around to make recordable CDs. Hopefully the cost of M-O media will decrease which will make the system more attractive, but the other thing to bear in mind with the M-O disc is that it can be recorded over—if you make a mistake on a CD-R you have to throw the disc away.'

In contrast to Avi Landenburg's thoughts, CD-R's compatibility with domestic CD players is a factor that appeals to both Chris Buchanan and Crispin Murray.

'If you use two CD-R machines,' says Buchanan, 'you can run off a reference CD for the client at the same time as the premaster is being made. This would be exactly the same as the production CD and would give the client the opportunity to double-check the master on familiar equipment prior to it being glass mastered, which we think is a very attractive scheme.'

The danger, warns Murray, 'is that master and reference CD will get mixed-up, and instead of receiving a pristine master, the factory may end up with CD-R that's been taken home, covered in cigarette ash, coffee and God knows what else, given a quick polish with a Brillo pad, and left on a boiling hot radiator to dry!'

Another problem that Murray can see—although he believes the benefits of CD-R outweigh its disadvantages—is that if CD-Rs are sent to plants not properly equipped to deal with the format, there is the possibility (particularly with less reputable plants) that the disc will simply be dubbed-off to another format via a machine of unknown quality and perhaps not even digitally.

In this respect, Exabyte and *PCM-9000* are safer in that they require dedicated drives—as of course does *1630*. But the issue of what happens to premasters once they leave the mastering suite is causing concern among mastering engineers. Currently if a *1630* premaster is going to be used for high-speed mastering, the tape must first be transferred at the CD plant via an ODME (Optical



One of the first recordable CD players Marantz CR-1

Disc Manufacturing Equipment) console to the high speed medium. The worry is how cleanly have these transfers been performed, and what kind of effect is the high speed mastering itself having on the finished CD.

'We've actually been running some tests on CDs that have been mastered at Metropolis,' says Crispin Murray. 'Not only do some of them not sound the same, but they also look different when you compare waveforms on the *SADiE* hard disk editor. Now whether that's a direct result of double-speed mastering or not, I've no idea, but it does worry me that there are now additional processes that may affect the sound after it leaves the mastering suite. After all, it should be my job to produce the final audio stage in the production chain, not the factories.'

John Dent shares a similar concern.

'We had an occasion recently where a customer brought their CD back to us to compare it with the *1630* production master. The results were actually so bad that we got straight onto the factory to say that something had to be done about re-doing it. The worrying thing was that the factory were totally oblivious to the fact that they'd produced a really horrible sounding CD, and that element of quality control does concern me especially when there now appear to be more post mastering processes taking place.'

Richard Green, Technical Director For Manufacturing at EMI's Swindon-based CD Plant, feels there is little likelihood that preparation for double speed mastering will have any adverse effects. Nor does he believe that the high-speed process itself introduces any degradation.

'We have not experienced any problems and we've certainly not had any complaints from our customers which include a lot of companies other than EMI. We've also carried out electronic tests to compare the results of real time against double speed masters with regard to HF parameters and block error rates and they remain satisfactory.'

Speed of manufacturing appears to be a key issue and on that Chris Buchanan believes will play a significant part in establishing a new

format.

'Speed is definitely an important consideration, and I think what we'll find is that to a large extent factories will dictate formats. Whichever is the easiest for them to handle and the quickest to transfer is probably going to win. But there is the niggling worry that this could be at the expense of audio quality.'

'So much is based on price lately, and everybody seems to want things done cheaper and cheaper. A lot of factories are now offering PQ services free and glass mastering free with bulk orders; people are also sending in their raw DATs straight to the CD plants without any mastering stage at all, hoping that it will come out right—it's a big gamble but it's obviously a lot cheaper.'

John Dent agrees that the cost of manufacturing will play a crucial part in format acceptance, but sees the record companies having the ultimate say.

'What we find is that the nuts and bolts of CD manufacturing are decided by record company production people, and even if producers and engineers are aware of different ways of doing things, there is generally little communication between the two parties. At the end of the day all the record companies are interested in, is how quickly they can get their product out and how much it's going to cost them. It makes sense that if they are being offered reductions on certain formats and not others that they are going to start demanding their products are mastered to the formats that save them the most money.'

At present Exabyte DDP (Digital Data Protocol) seems to be the front runner as far as CD manufacturers are concerned. The system is already used for CD-ROM work, and is relatively cheap both in terms of drives and tape; it also has good error rate characteristics.

'All the major CD plants in the UK offer Exabyte,' confirms Richard Green, 'but the number of Exabyte tapes being sent direct from mastering facilities is minimal, I would say we receive less than 2% at the moment. Until we go public and say to all our customers that we can provide you with a price advantage if you supply us with Exabyte ►

direct, I don't see the situation really changing, and we won't be doing that until we've reached a comfort level with high speed mastering.'

Although double speed transfer is obviously advantageous to the manufacturers, does it offer any advantages to the mastering house? John Dent does not think so.

'One of the features of Sonic Solutions for instance is that you can dump data in the background while you continue working in the foreground. Now at the time we installed our system that seemed like a very good way of saving time and money, until we discovered that the software was not 199% reliable and some very strange things were happening to the sound. Consequently we abandoned background off-loading as studio policy, making it a rule that the engineer listens to the CD as intently as possible as it goes down to Umatic. So the thought of suddenly transferring something at double speed without being able to evaluate it is a fairly horrific thought, and the consequence would inevitably be a huge increase in rejects and the associated loss of time and money.'

Crispin Murray, while agreeing that Quality Checking production masters is extremely important, can see great potential for double-speed lay-back for archiving purposes.

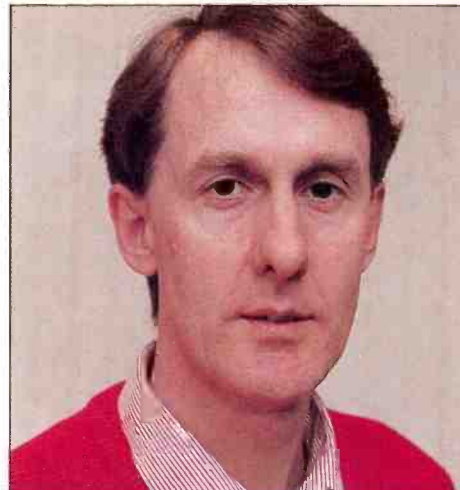
'Providing we know we can trust it, double speed 20-bit archiving or back-up would be really useful. At the moment most people balk at the price of archiving—for example a long album will currently end up on three reels of 1/4-inch X86, which is very expensive. If alternatively you could stick the whole thing on one five gigabyte Exabyte tape and take 40 minutes doing it rather than eighty, it would persuade a lot more people to archive their masters.'

Weighing up all the pros and cons, do any of the systems present themselves as clear winners to the mastering houses?

'No, I didn't think there's an obvious winner,' says Crispin Murray, 'but I would like to see CD-R in one form or another get a strong foothold. The sooner we can settle on a new format that allows direct mastering the better.'

'There's no clear picture of the way things are headed,' says Avi Landenburg, 'but my gut feeling is to go for the PCM-9000: its a well thought-out, dedicated audio format which would seem to be the natural successor to 1630. I think it will be a great pity, after having a standard format for so many years, if we lose the opportunity of replacing it with a good solid system.'

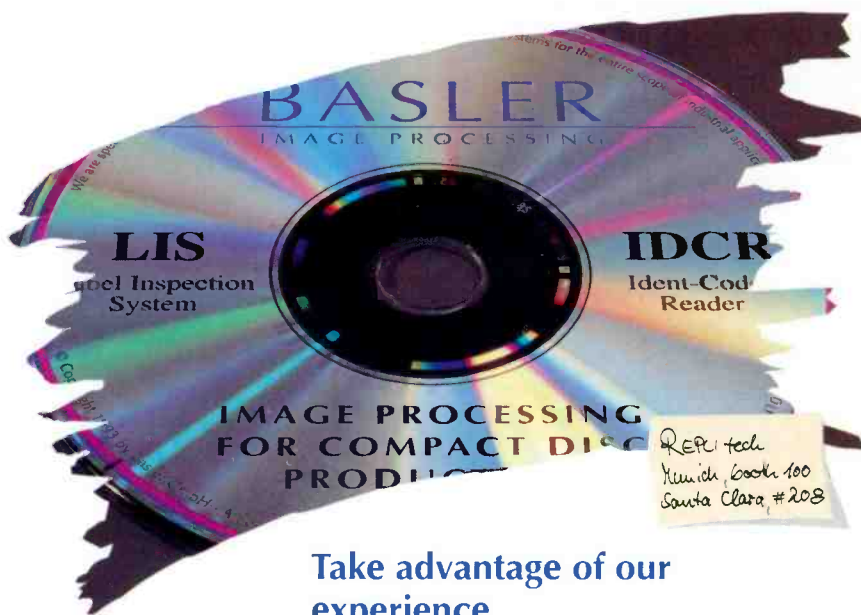
With a lack of any strong direction, it may be that 1630 will be around for much longer than people think. But the overriding feeling is that whatever does eventually take its place, should ideally be a single format that will be universally accepted as the new premastering standard. The prospect of 1630 giving way to a number of incompatible and competing systems has no appeal whatsoever; but if this is to be avoided, the mastering community really has to pull together and try and steer a common course. If the situation is ignored, the industry may very well find itself in the midst of a full-scale format war. ■



Two of the four protagonists, left to right Avi Landenburg, Chris Buchanan.

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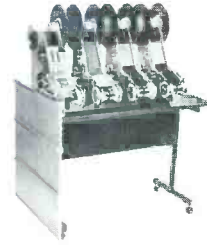
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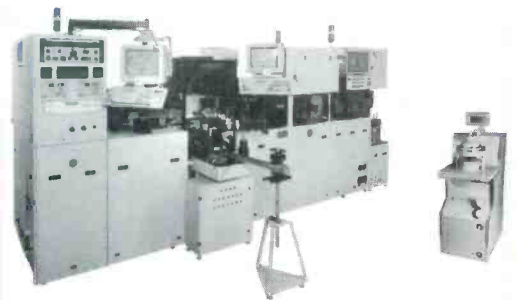
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THE SONIC SOLUTION

Patrick Stapley visits London's popular CopyMasters facility to discuss their experience using the Sonic Solutions hard disk system, and some of its developments

CopyMasters is now one of the UK's largest independent mastering houses. Since the demise of Tape One, who owned a substantial share in CopyMasters, the company has righted itself and gone from strength to strength, significantly raising its profile in the process.

Over the last couple of years, many improvements and additions have been made at the South West London

premises, including the installation of a Sonic Solutions system 18 months ago. Following the success of this first system, CopyMasters have recently purchased another to equip a second customer-attended editing suite.

The man responsible for the decisions is CopyMasters' Technical Director, Henry Edwards, who was one of the first people in the UK to see Sonic Solutions when it first arrived in 1988.

'Before CopyMasters, I was at CTS Studios in Wembley which were the first British studio to get a demonstration of Sonic Solutions. I seem to remember they had to work through the night to get the system actually operational, but nevertheless we were sufficiently impressed to buy one, and ever since I've been associated with it.'

Edwards joined CopyMasters just over two years ago and his first task was to re-design and re-equip the digital editing rooms.

'We looked briefly at other hard-disk systems, but at that time there was really no viable alternative for the sort of work we wanted to do. The major reason that I stuck with Sonics was because it was the one system that had

been specifically designed for mastering. Nearly all the others—up until *SADiE*—were designed for postproduction-type applications and had moved sideways into CD premastering. However, there are now a number of players in the field that are catching up extremely quickly, and *SADiE* in particular offer a very interesting product, that I think will present Sonics with some stiff competition, which is no bad thing.'

CopyMasters offer six rooms: two disc-cutting rooms, three editing rooms and a cassette-copying room. Ten operational staff are required to run these facilities and half are Sonic Solutions users. Although all have been trained on the system by Edwards himself, each has developed a unique operating style—as Edwards says, 'there are so many different operational approaches, that the flexibility is only really limited by the person driving it.'

But with so many options available isn't the system in danger of overwhelming the user, particularly when compared to CopyMasters' other editing system, the Sony *DAE-3000*?

'That's one of the big question marks, and it does take a lot longer for engineers to get used to Sonics than the



Sonic Solution's CD Printer set-up



Henry Edwards of Copymasters in London shows off his Sonic Solution

Sony DAE-3000. The learning curve is actually quite strange—to start with it's very slow and then, dependent on the engineer, there's a rapid acceleration period where everything starts falling into place. But it's also a continuous learning curve as far as I can see because the system contains so much and the software keeps changing.'

One of the aspects of Sonics that CopyMasters' engineers initially found hard to come to terms with, was controlling jog and scrub functions using a mouse rather than a wheel.

'Everyone had been used to performing the function with a wheel, and the prospect of using a mouse seemed far from intuitive. However, people have got used to it, but what we have also found is that all our engineers are now tending to edit with their eyes rather than their ears, and are using the waveform displays to visually mark edit points rather than rock-and-rolling the audio. Of course, this is incredibly accurate as the waveforms can be viewed all the way down to individual samples.'

CopyMasters still have three DAE-3000 editors that are in daily use, and although Edwards can see them running in parallel with Sonics for some time to come, he believes their life is inevitably limited by his clients' preferences.

'There is no doubt that Sonic Solutions has become the standard disk-based mastering system, and we get more and more enquiries from potential clients to check if we have it. The majority of client attended work we do now is on Sonics, very few book in to use the 3000 so we've moved them into other areas where they're used mainly for compilation work.'

'Once people have worked with a Sonics system and realised the kind of flexibility it offers, I don't think they really want to go back to working on a 3000. One of the things that really

appeals to our customers is the ability to try out loads of different ideas and then very simply return to the first one they thought of. Of course this is possible on the 3000 but it's very time consuming.

'Actual editing within the Sonics is so much quicker because everything is instant access—you don't have to spool through a pile of 1630 tapes to find the source material. Also the crossfade capability is stunning compared with the 3000, and again you can instantly listen to the results—if you change a fade on the 3000 you have to press PREVIEW and wait for the tapes to shuttle back. So from the client's point of view, the whole

People are learning that digital EQ is always going to be different to a lesser or greater degree from analogue

operation appears a lot slicker and much faster.'

Savings

Although the time-saving aspects of nonlinear editors are widely discussed, are they actually achievable? A common

criticism of hard-disk editors is that although they undoubtedly save time through instant access, they require extra time initially to upload audio. In practice, how do the overall operating times vary between nonlinear disk-based editing and linear tape-based editing?

'In practical terms there's actually very little difference between the two. You can, of course, background load with Sonics if you want to, although most of the time we find it's extremely useful to listen through to the material as it's loaded so we can get an idea of what needs to be done—this is something you'd do irrespective of which system you were using. Equally when it comes to downloading audio, we'll frequently be running a listening copy at the same time, and if we're working with the 3000, the tape still has to be verified after it's been edited.'

The use of EQ is one of the mastering engineer's fundamental skills, and many reputations have been built on it. The engineers at CopyMasters have all grown up with analogue EQ of various kinds, so how have they adjusted to using the Sonic EQ?

'Variably,' Edwards exclaims. 'I think people are learning that digital EQ is always going to be different to a lesser or greater degree from analogue and it's a matter of adapting to it—again it's all part of the overall learning curve. Most of the time our engineers manage to achieve the results they're after using the internal EQ, but occasionally, if they really want a particular sound which they can't recreate digitally, they'll use an analogue unit—but it's not something we like doing.'

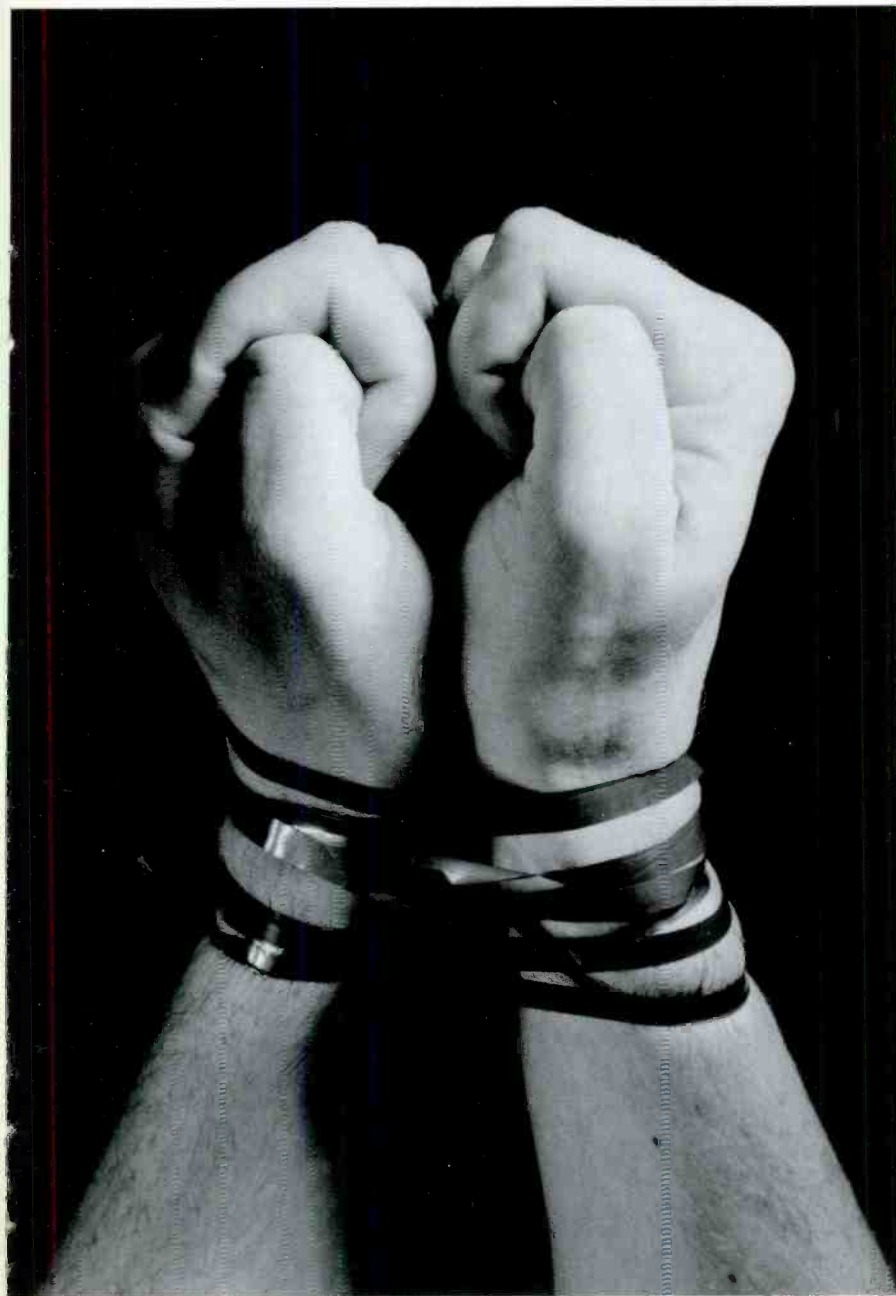
'Generally speaking people are far more concerned these days about trying to keep things in the digital domain and avoid converting to analogue. Both our Sonic systems are equipped with sampling rate converters so we can accept digital on whatever source material arrives.'

'The whole area of transferring digital is becoming far more complex; digital used to be treated like analogue—things were plugged together any old way without worrying about clocks and so on. Fortunately people are growing out of that and a lot more care is being taken. Also we've grown out of this complacent attitude that "digital is perfect"—you only have to look back to the days of early digital processors when that was a popular statement to realise that digital was actually abysmal.'

So what of 20-bit? This is obviously one of the biggest advantages Sonic Solutions has over the DAE-3000, but how many of CopyMasters clients supply 20-bit masters?

'Very few,' Edwards reveals. 'I would say less than one percent at the moment. We're just starting in that area and we've been waiting for the cross licensing agreement between Sony and Sonics to allow Super Bit Mapping to be incorporated within the system. This agreement has now been finalised and we ►

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should be installing SBM very shortly.

'In the absence of a 20-bit master, the best format as far as I'm concerned for improved resolution is well recorded 1/2-inch SR, and I wish more people would use it rather than always going to DAT. There's going to come a time in the future when we look back and find everything is limited to 16-bit DAT, and I think people will really regret that. At least with 1/2-inch SR we'll be able to benefit from new technologies as they inevitably come along, such as the 20-bit Compact Disc.'

A format CopyMasters are keeping an eye on is the Prism AD-1.

'The Prism system appears to be gaining a lot of popularity, and the DRE (Dynamic Range Enhanced) DAT does seem to work. Again we've had very few pass through here but its a system we're looking at seriously. However, it still has to be viewed as something of a compromise, being enhanced 16-bit rather than full 20-bit.

'The main problem at the moment is the format that masters will end up on, and that area is becoming very grey with the various options that are available. We tend to think Exabyte DDP will be the format people are most likely to go with because it seems to be what the factories like. Sonics are currently working on software that will permit double-speed DDP transfer as well as allowing it to be read back into the system.'

Another appeal of the Sonic Solutions system is the fact that it offers a fully integrated system with no need for periphery boxes, but with so many features available, are there some facilities that don't often get used?

'We don't use dynamic automation that much; when we do it's usually for capturing manual fades. The snapshot automation on the other hand is used extensively for changing parameters between tracks. Dynamic signal processing I would say is the weakest part of the system, and currently has a few limitations which means that we only use it quite basically; Sonics are well aware of these limitations and will be updating the software at some point. Another change that's imminent is to the way the EQ is presented—at the moment it's a bit old fashioned compared with the other waveform display of the frequency response which the engineer will be able to manipulate directly.'

Sonic's *NoNoise* is an option that a number of mastering houses have taken up allowing them to offer specialist restoration and recovery work, but CopyMasters felt that the expense didn't warrant the addition of the facility.

'I think we probably came to the market a little bit late because there were already plenty of people offering *NoNoise*. You really have to weigh up the investment against returns, and

with the full *NoNoise* system costing nearly £20K, we didn't really feel we could justify it.'

Another option is PQ editing, and although CopyMasters have installed it they don't actually use it. Instead they continue to use the Philips system, as Henry Edwards explains.

'There are still some question marks about the Sonic's PQ editor as far as we're concerned. Although I know it works perfectly well because an awful lot of people use it, we're currently not using it for two reasons. Firstly there's no verification facility on the PQ burst which is something we like to do, and secondly there's up to a 2-frame discrepancy between the Sonic's and Philips' PQ editors.

'We discovered this irregularity by running PQ from the Sonics through the Philips in Check mode and found the two didn't tally. It's something we've informed Sonics about and they're investigating at the moment, but whether it's a real error or simply an error in the way numbers are presented on the screen, I don't know. However, until it's been resolved and we can also verify code, we'll stick with the Philips system. It's actually a shame because PQ'ing in the Sonics is much quicker as the machine automatically enters all the start and end marks for you, assuming of course there are individual tracks

with black in between them.'

CopyMasters' second Sonic Solutions editing room will have officially opened a few weeks before you read this, but already Edwards is looking to the future and the installation of further systems. Even though he believes there are now viable, cheaper alternatives to Sonic Solutions, he feels that installing another manufacturer's system with a different user interface would be extremely confusing. The solution apparently still lies with Sonics.

'Eventually we'll replace all our 3000 editors with Sonics, and I can see the time rapidly arriving where we use network facilities to allow different people to do different parts of a job—by having a central pool of storage, one person could be EQ'ing material while someone else edits it at another terminal. This type of shared operation is quite feasible now using SonicNet, and personally I think it's the way things will go.' ■

Sonic Solutions, 1891 East Francisco Blvd, San Rafael, CA 94901. Tel: +1 415 485 4800. Fax: +1 415 485 4877

UK: Sonic Solutions, PO Box 1714 Bournemouth BH1 4ZA. Tel: +44 202 399 033

Europe: Sonic Solutions, Brugwachter 19, 3034 KD Rotterdam, The Netherlands. Tel: +31 10 4147354.

LATEST SONIC SOLUTION SOFTWARE

SonicCinema

The SonicCinema MPEG Video-CD premastering system prepares video-audio programs for release on Video-CD. This add-on option to the Sonic System allows for the ability to encode audio and video data streams in MPEG-1 format in real-time, the tools to sequence MPEG clips in Video-CD format, and the ability to record the resulting MPEG data onto recordable compact discs at high speed.

Compact discs produced with SonicCinema adhere to the new Video-CD standard which was promulgated by Sony, Philips, Matsushita, JVC and others in June 1993. In mid- to late-1994, industry experts expect the arrival of Video-CD players as well as inexpensive adaptors for existing CD audio players equipped with digital outs.

SonicCinema builds on the Macintosh-based Sonic System by adding a video acquisition board capable of inputting component or digitak video, an encoding board for real time MPEG-1 encoding of video, and an MPEG decoder for video and audio playback.

Sonic's SSP-3 card performs real time MPEG-1 encoding of audio. A Sonic MediaNet card, which allows high-speed data handling over a network, is also included. SonicCinema includes a suite of software to permit capture and

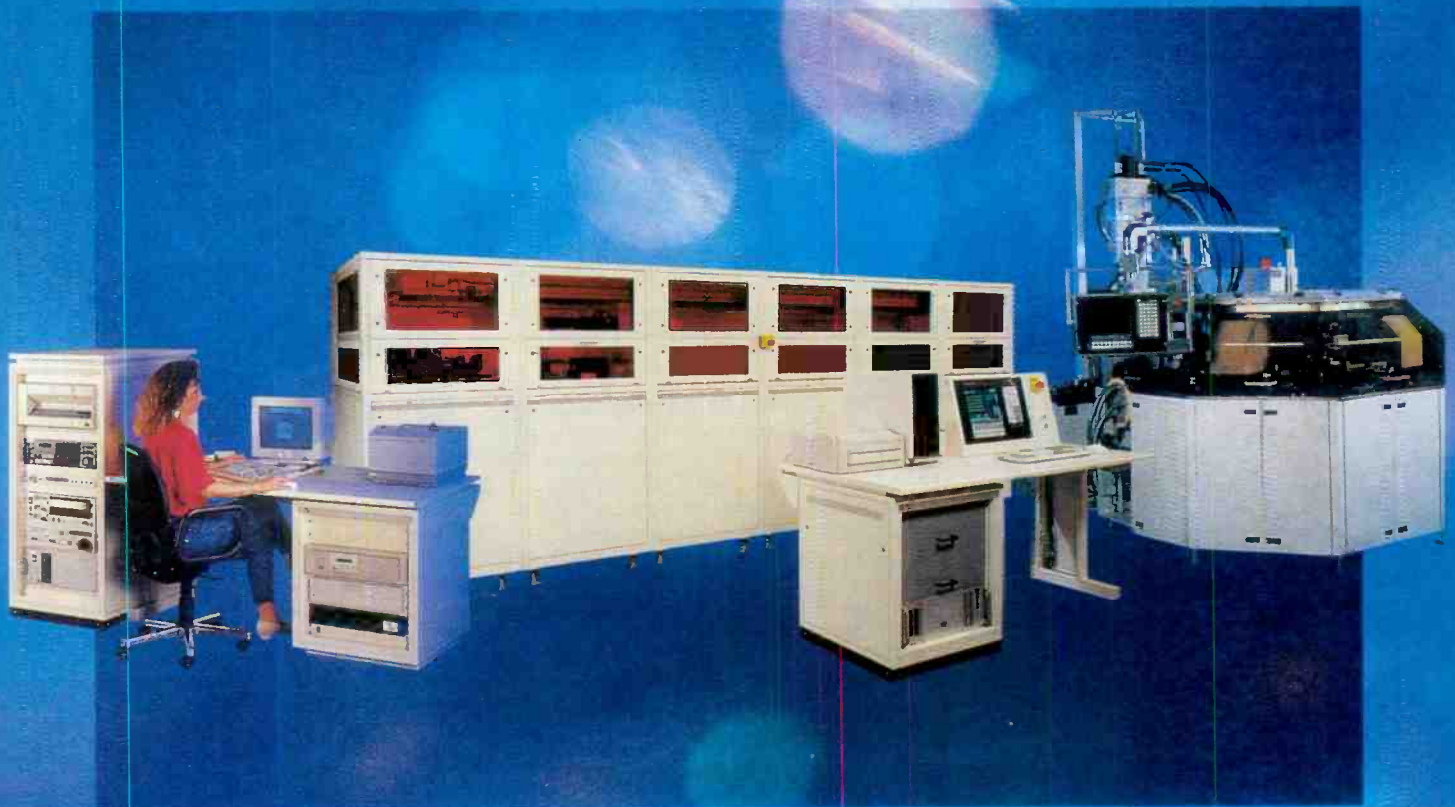
interleaving of the encoded audio and video streams, arrangement of the encoded data into sequenced clips, and insertion of Video-CD random access 'entry points' as well as traditional track start and track end marks.

Vice President for sales Kirk Paulsen commented at the launch of the new software at NAB 94, 'SonicCinema will be extremely useful to record label companies who wish to produce music videos on disc, as well as mastering houses helping film production companies master films and video for distribution on CD. Video post production houses can use SonicCinema to prepare convenient approval copies of works in progress, not to mention the many industrial and training applications for which the new format is very well suited.'

MediaNet developments

At NAB Sonic introduced a number of enhancements to MediaNet including ATM MediaNet - Users can now use Asynchronous Transfer Mode environments to support overall network bandwidths in excess of 1Gb per second. NFS MediaNet - MediaNet v.2.0 will incorporate direct support for Sun's Networked File System permitting networking between Macintoshes and UNIX workstations.

The ODME CD-manufacturing system



- * Media Conversion System - MCS
- * Automatic Mastering and Stamper making system - Masterliner AMS 100
- * CD-Replication System - Monoliner® MK IV
- * Test equipment - Q-Liner ABC 200 DS and Q-Liner ODT

The strength of a modular approach

ODME is the worldwide market leader in the field of manufacturing systems for CD-Audio, CD-ROM and Laser Discs. Their supply programme includes premastering, mastering, electroforming (stamper making), replication, printing, packaging and quality control.

In offices in Eindhoven, Veldhoven (both in the Netherlands), Charlotte (USA) and Taipei (Taiwan). ODME is constantly working on product improvement and intensive customer support. The focus of ODME's company strategy is total commitment to customer relations and their market needs.

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ODME USA 8300 Corp. Center Drive Charlotte NC 28226 USA Phone: +704 542-5305 Fax: +704 542-5309

REPLItech Show Preview

Bill Foster presents a roundup of exhibitors at the Munich Replitech Show

A **Accurite Technologies:** Floppy disk drive test and alignment tools. Alignment and reference diskettes, diagnostic diskettes and software. New options for the *Drive Probe* Advanced Edition Tester. **Adivan High Tech:** No information available. **Adtec Audio Video Produkte:** Range of audio and video splicing tapes for both manufacturing and studio applications. V-0 cassettes, R-DAT cassettes in lengths from ten to 120 minutes, and CD-Rs for CD-Audio and CD-ROM in 63 and 74-minute versions. **Aerosonic:** New *CDQ1000* CD Test System with up to eight or 16-drive capacity. Twin PC handles fully automatic test cycle. New range of PC control and logging software, including VPTEST for the *Video Pancake Tester*. **Alpha-Tech Moulding:** Video box and custom plastic packaging. High quality blank video cassettes from JIP, Alpha-Tech's European distributor. **Amtec:** Suppliers of video tapes, V-0s and cases. **Apex Machine Company:** Audio and video on-cassette printers. Picture CD printing machines. **Applied Innovation America:** No information available. **Audio Development:** QC equipment for compact discs. **Automatic Inspection Devices:** Optical disc inspection equipment for compact disc and optical storage media manufacturers. Showing *SL100* table-top single drive CD analyser for Red, Yellow and Green book discs.

B **Balzars:** Showing the *CDI 905* metalliser with reduced cycle time of better than 1.8 seconds and the new generation *SDS 100* M-O Production System for both 2.5-inch and 3.5-inch formats. Orders can be placed for Balzers' 1994 catalogue, due in May. **BASF Magnetics:** New video duplication tapes. *VT19 SPRS*, specially designed for Shuttle Sprinters and available in SHG and HG grades. Also, *VT16TMD* 7,250m super long pancake, which uses BASF's revolutionary concept in thin tapes. **Basler Image Processing:** Improved optic for the *CD-Identcode Reader*.

Shown in conjunction with *Label Inspection System* and new system for paperwork inspection, *PWI*, which will ensure correct match and positioning of booklet and inlay. **Bronway:** No information available.

C **Central Research Laboratories:** *AQAID* audio tape duplication quality control system including software and PC plug-in card. Tests frequency response, azimuth and speed errors. **C.E.D.A.:** No information available. **Copymaster International:** No information available.

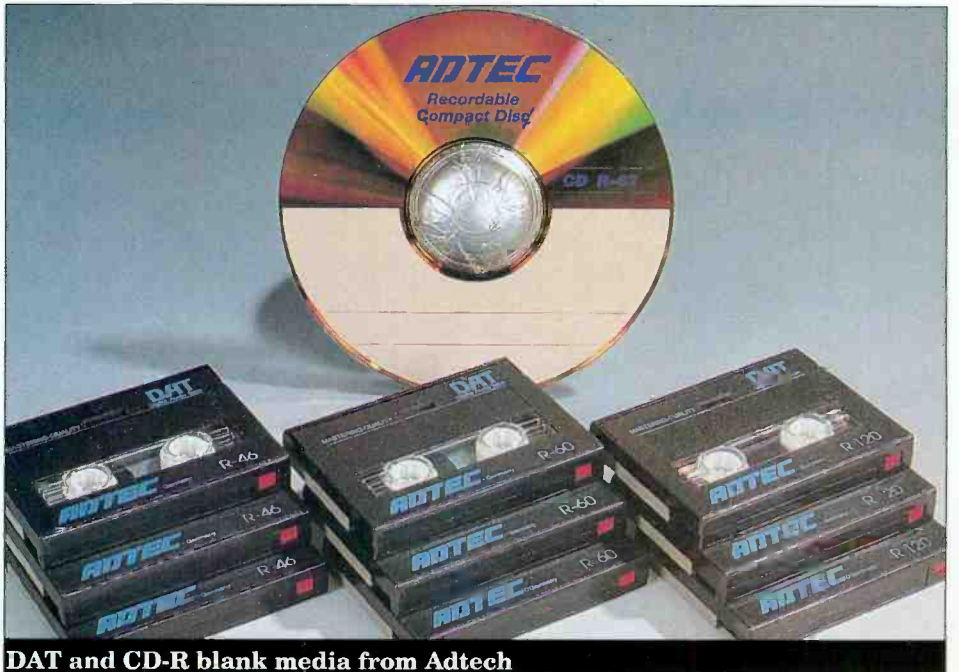
D **Data Disc Systems:** CD and MiniDisc manufacturing equipment. **Datapulse Technology:** No information available. **dBm:** A complete service for the audio duplicator and CD replicator, from total systems to spare parts. Exclusively representing Gauss, ElectroSound, CST, Emerald Technology, Magnefax, World Cassette and Nobler Technologies. **Del Mar Avionics:** Manufacturers of *FireTrac* CD Mastering System, a lower cost alternative to conventional glass mastering. Uses a preprocessed polycarbonate substrate to produce masters in the CD-Audio, CD-ROM and CD-I formats. **deVille Integrated:** Worldwide agents for EAM automated assembly and packaging systems. **Dwight Cavendish Developments:** Video duplication systems.



Mastering - the BASF way

E **Ecofina:** Computer software duplication. **Emerald Technology:** Audio cassette packaging equipment. **First Light Technology:** Manufacturers and distributors of CD replication equipment.

G **Galic Maus Ventures:** Higher output conversions of Krauss Maffei CD moulds to run sub-6 second cycle times and eliminate Remac robot



DAT and CD-R blank media from Adtec

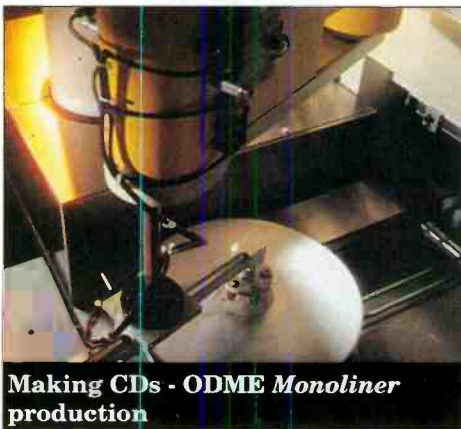
arms. **General Magnetics:** Range of C-zeros, audio and CD boxes and audio magnetic pancakes. Premastering and glass mastering services, CD-Audio and CD-ROM, 3.5-inch micro floppy disks and DCC. **Global Zero:** V-O shells. **GTS Fabrications:** Audio and video cassettes and cases, including a wide range of coloured and transparent C-0s and cases. DCC D-0s

H **Hamatech:** STEAG MicroTech model *HCD-90S*, the world's fastest CD lacquer coater with a 1.8s cycle time per disc. **Heino Ilsemann:** Information on the company's range of packaging machines for audio and video cassettes, as well as CD packaging and handling equipment. **Hollingsworth & Vose:** Introducing *Hovoliner*, new generation of embossed floppy disk liner (1500 series), and *Hovowipe* cleaning tape featuring low lint, thickness uniformity, precise slitting and anti-static properties.

IJK **ICT Axxicon:** Single and multicavity moulds ranging from 64mm to 300mm.

Integral Vision: No information available. **JVC Professional Products:** Range of VHS and S-VHS duplication recorders (3-in-1 and 2-in-1), plus the *BR-7020* VHS duplicator with PC-based auto QC system. **Koch Digitaldisc:** New Time Base Error Analyser Board for the *CDCS-4* which allows measurement of jitter and effect length deviation to the latest Philips specification. Also the *CDCS-4/SA* stamper adaptor which ensures both protection and flatness of the stamper. **Kodak:** CD-R discs.

LSK Data Systems: Disk duplication systems and in-line label printers. **Machines Dubuit:** Two to six colour screen printing machines for CD. **Magnetic & Memory Technology:** Introducing *DLB 3000* digital 'loop bin' with memory up to C-150 and three duplication ratios; 32/64/128:1. Interfaces to any make of slave recorder. New *VCBU 900* VHS boxing machine automatically adjusts to case size and operates up to 900 pieces per hour. Also featured are products from Everhard Automation and Robdale Ltd. **Media Service**



Making CDs - ODME Monoliner production



Datadisc systems at Replitech

International: No information available. **Miri:** Video cassette packaging machines. **Multi Media Masters & Machinery:** Mastering, engineering and project management services. Range of CD replication machines including new *MCL 5000* for CD-R production and *MCL 8000* for recordable MiniDisc.

N **Netstal Machinery:** Moulding subsystems for 64, 80, 120, 130, 200 and 300mm optical and M-O discs. Product range includes injection moulding machine, mould, take-out device and mould temperature control unit. **Nobler Technologies:** New *NTG170* Galvanic Electroplating System offers precision to within 5 microns. Each plating cell is equipped with its own reservoir tank. Unique 'carry case' design permits Glass, Father and Mother changeover in less than 30 seconds.

OP **ODME:** CD and Laserdisc premastering, mastering, replication and test equipment. **Optical Disc Corporation:** Glass mastering equipment for CD-Audio, CD-ROM and Video CD. **Otari Deutschland:** New additions to the TMD video duplication range; the *Mini-Pro* TMD production code system; a redesigned 1/2-inch audio master tape recorder; new bidirectional QC machine and double pancake loaders for VHS, audio cassette and DAT. **Pilkington Micronics:** Manufacturer of all types of glass mastering discs, to any specification for any mastering system. **Pilz:** CD manufacturing. Double jewel box.

R **Rimage Europe:** No information available. **RMV-Rheinmetall Machine Vision:** CD inspection systems. **Robi-Systemtechnik:** Showing the *Robi Rondo-Line*, the latest RobiSystem CD replication line designed for flexibility and versatility. Capable of producing

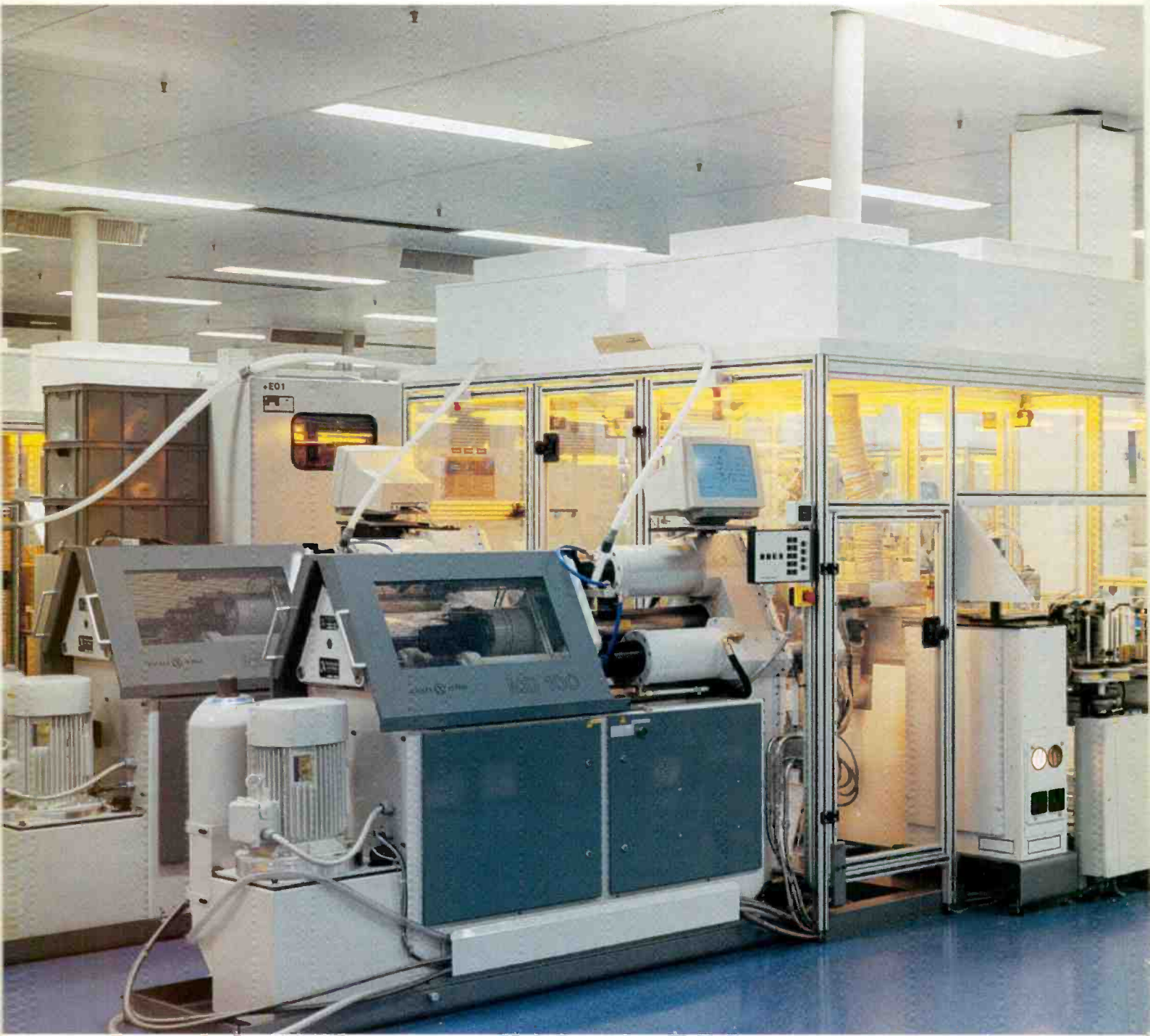
up to 1200 discs per hour.

S **Sacma Plast:** Automatic packing machine for video boxes which can handle 2000 pieces per hour. Machine opens box, inserts sleeve, advertising literature and cassette, and closes box. Sacma also manufacture a complete range of video boxes. **Sentinel:** No information available. **Sunkyoung Magnetic Europe:** Range of chrome, cobalt and ferric audio duplicating tape.

T **Tapematic:** New Mini Series of loaders for audio, and 8mm and VHS-C video. First showing of the *Re-Loader*, which recycles loaded VHS cassettes by removing unwanted tape before loading new program. Featured duplication systems include *SAM* and the Dupcentre analogue bin/2-slave combination. **Teca-Print:** Multiple screen and pad printing systems. **Tomei/Quali Source:** C-0s, V-0s, pancakes, preloaded audio and video cassettes, cassette boxes, CD jewel boxes and floppy disks. **Trace:** Floppy disk duplication, printing, labelling and collating systems. **Truminco of California:** Supplier of video heads and spare parts; video tapes, pancakes and V-0s.

VW **Verity Systems:** Range of degaussers including the new *V870* and *V862C* diskette-cassette conveyor systems, the *V8000* high volume boxed diskette conveyor eraser, and the manual operation *V91M* and *V93* high and low power units for all types of media. **Webcom Communications:** No information available. **Werner Kamman Maschinenfabrik:** Screen and offset CD printing machines. ■

Replitech International, Sheraton Munich Hotel & Towers and the Arabella Hotel, Munich, Germany. April 12th-14th.



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MASTERING MATTERS

Mike Brown discusses how the premastering process is being changed by advances in technology, and offers a personal view of its perceived value

The compact disc has been with us for more than ten years now, and has become the primary music carrier in most countries—yet little more is actually known and understood about the process of digital premastering than is known about disc cutting. Worse, the perceived value of this crucial stage of the recording process is being eroded and undermined, partly by a lack of understanding but also by financial pressures.

Although little is really understood about disc cutting it is, at least, recognised as a critical stage of record production. These days, digital postproduction can be attempted by anyone with a few thousand pounds to spend on a computer system—and as CD manufacturers strive to make their service more attractive in an increasingly competitive market, some offer premastering at a cost which is either nominal or 'built-in' to their pressing price structure (a lost leader). In order to compete, studios and independent postproduction houses have been forced to keep their prices down to the point at which mastering is one of the cheapest processes in the chain. This may afford clients some short-term benefit, but how will this extra 'competition' effect the industry in the long term?

One of the main effects is that such an approach blurs the understanding of the mastering process, giving the impression that it is the first stage of the manufacturing rather than the final stage of recording. The creative input provided by a skilled and experienced mastering engineer, accepted and welcomed when the final product was on vinyl, can now be virtually bypassed on the way to CD or cassette. The

assumption is that once something is recorded digitally (usually on DAT) it's more-or-less perfect and just needs copying and sending to the factory.

The service

If digital premastering is still so vital, exactly what can it offer? It is perhaps best summed up as experience, skill and a sympathetic understanding, although if I had a to write a job description I'd have to include many different qualities: not just a good pair of ears but a certain amount of experience, intuition and common sense along with skills in communication, psychoacoustics, psychology, diplomacy, advertising, PR, electronics, mechanics, and plumbing (anyone who's ever seen a Neumann cutting lathe will understand). Most of the time the job is 20% technology and 80% psychology. The question which usually needs asking is, 'I can hear what is on the tape, but is this actually what is wanted?'

Ideally, mastering should simply be a matter of transcription, a 'flat' transfer of the original tape, maybe with minor tweaks in levels and the addition of any information required to suit the ensuring production process. No-one is happier than the mastering engineer when this ideal is achieved, after all, the best time to EQ a mix is during the mix! If everything is satisfactory, then the mastering engineer simply acts in his quality control capacity to provide that final reassurance that everything is fine.

Vinyl discs are quite different—a different medium with its own peculiar properties. The problem regularly faced by cutting engineers is that sound which can be recorded easily on tape can be difficult to cut on lacquer without changing the overall sound; the skill comes in doing this in such a way as to detract from the mix as little as possible (maybe even enhancing it). This may occasionally produce some consternation but if handled well the client, producer, artist or engineer can quickly be made aware of the problem and given an acetate to approve. This type of problem is usually the most obvious and easy to deal with. The sad fact is, however, that in the bold new digital age the ideal of the flat transfer is still achieved

surprisingly rarely.

The reality is that many of the recordings which arrive in the mastering room are less than perfect and will benefit from some kind of tweak before going into production—even if it's just 'top and tailing', assisting fades and cleaning up gaps. In many cases these tweaks may be quite small, but this is not always the case; I've lost count of the number of tapes I've been sent which have been labelled 'Production Master' but would certainly cause problems if I sat back and did nothing to them but transfer than to *PCM-1630* U-matic and add PQ codes.

We should examine the reasons why mastering often has to be such a creative rather than technical process.

There are any number of reasons why things may not have gone according to plan at earlier stages of the recording, or maybe things have gone as planned but the plans themselves have now changed. An album may have been mixed over a period of weeks or months and perhaps the tracks don't quite match up with each other as well as they might. Often, these days contemporary music is recorded and mixed using fairly basic equipment and may not have been heard through anything other than a pair of *NS10s* or headphones, so playing the mix through the mastering room monitors can sometimes come as a revelation to the independent artist or producer. Even if something is mixed in a well-equipped studio, the engineer or producer may well prefer to leave the question of overall compression of limiting to the mastering engineer—a course of action which the writer feels has much to commend it, as the compression can then be tailored more meaningfully according to the release format and the songs final position in the running order, which may not have been known when the track was mixed. Last, but by no means least, there is the question of the inevitable quest for loudness. 'I want this record to sound really loud. . .'

The increasing use of DAT has brought its own peculiar set of problems. When DAT was first introduced, the only inexpensive way to edit material recorded on DAT was to copy it carefully to an analogue machine. Naturally this state of affairs couldn't last for long, and

now digital editing workstations are in use in many small studios and homes. Power to the people. But beware; a little computing power is a dangerous thing. If you are using such a system, take care with your work—check it carefully and don't assume that digits are digits are digits, and that everything will automatically sound right. In the last year or so we have uncovered a couple of examples of digital editing systems affecting the quality of recordings. In these cases recordings had simply been edited—with no other sound processing or level change applied—yet when compared with the source tapes the quality had been demonstrably changed.

Aside from technical problems there are other, more commercial, questions to consider. If a project involves a great deal of music editing there may be some advantage in using an 'off-line' digital editing system but if not there may be little point in using one just to sequence or compile your material. If you do this, sort out all the levels and gaps and print out your timings while you're still working off-line and without time code. Your carefully-derived timings are useless for PQ coding purposes and at worst you may have degraded your recording unnecessarily.

These are some of the more technical problems which a mastering engineer can help with but what about creativity?

In terms of quality control, a mastering engineer brings a fresh pair of ears to a project. Consequently, he or she may be able to help make more objective judgments and decisions about the recording. Apart from EQ and compression, there are other crucial decisions to be made, whether the project is a new album by a prestige artist, a re-issue or a compilation album. For a start, the engineer should establish that (s)he is working from the right tape. Past experience of remastering has shown that working from the best tape is better than working with a poor tape and the best EQ. Basic things such as relative levels between songs and the pauses between them are an important part of the feel and pace of an album. Can you cross-fade the titles? If so, where should you put the PQ access point? Which mix of a song works best?

When it comes down to it, different clients have different expectations of their mastering engineer. Consequently, different kinds of relationship are built up—in some cases a passive approach is most appropriate, while in others the creative abilities of the engineer are appreciated. The importance of a firm relationship with a mastering facility should not be overlooked.

Once standards and working practices are established, any deviation from the pattern can be identified and queried at once. A single phone call to a record company can save a great deal of expense and heartache.



Mike Brown and Sonic Solutions editor at CTS

Value judgments

Ten years ago—when CD was launched—the sound quality of most early releases was undeniably astounding. This was, to a large extent, because everyone involved was keen to impress—not just recording engineers, but mastering engineers too. Ten years on, the novelty has worn off and much of the industry is driven by a different motivating factor: money. Like a great many other sectors of industry, the music business is now acutely aware of the cost of everything. It is not, however, necessarily aware of its value.

CTS have begun regularly to receive enquiries from clients who have been asked by factories to have tapes copied or transferred onto DAT, so that the DAT 'copy' can be sent to the factory for glass mastering. This is the clearest possible indication of how little value is placed on the mastering process, and how little factories understand or consider it. This attitude is often also passed on the factories' client.

What all this amounts to is that some clients call a factory first, as opposed to calling a mastering facility. As a result, the factories are saying, 'yes, send your tape to us—we can do it all'. In some cases, the job is then subcontracted to a specialist mastering house, but by then at least two things have already happened. Firstly, the mastering process has become 'invisible' to the client and secondly, the chain of communication between the mastering house and the original client has become tortuous.

The willingness of manufacturing plants to undertake premastering is born partly of a desire to maintain a

competitive edge, and partly because it may be more convenient for them to have full control over the process. This means that full artistic control is taken away from those who should be exercising it. Mastering has been—and should continue to be—a studio process, creative if necessary, undertaken in collaboration with producers and artists, not done remotely on their behalf.

Studio engineers have amassed years of experience in dealing with every kind of music, every kind of tape and problem which may occur. Factories now claiming to offer this level of service simply do not have the skills, and are seriously misleading clients into undervaluing the mastering process. By comparison with other related industries, European recording in general—and mastering in particular—are clearly under priced and have been so for some time. This being the case, where is the money for further investment and modernisation to come from?

I feel that the time has come for those who specialise in premastering to set out their position and defend it by ensuring that clients are aware of the implications it carries. The answer to the problem—as with many problems these days—lies in education. I hope this article sheds light on this small but significant part of the industry which is in danger of losing its identity as technology continues to develop. ■

Mike Brown is head of the mastering facility at the CTS Studio complex in Wembley, England.

NOISE SHAPING IN CD MASTERING

Now in its second decade and still going strong, the compact disc is producing better sound quality than ever— thanks to techniques such as noise shaping. John Watkinson looks at the technology and what it can offer

As a PCM audio device, the compact disc itself doesn't have a sound quality as it is just a precision frisbee covered in binary numbers. If the error correction system in the player is working within its capacity, then the numbers coming out of the player's logic are the same as the ones which existed on the tape which drove the cutter. The whole CD cutting, pressing and playing process is then transparent.

In fact the perceived sound quality when listening to a CD is determined by the D-A converters in (or driven by) the CD player, and by the recording and production processes, including the A-D converters used. Early CD mastering equipment and CD players had fairly mediocre converters, but CD got the blame for it. This makes as much sense as blaming a floppy disk for the quality of this article.

Converter technology has advanced by leaps and bounds, fuelled by the demand for CD players, and new technologies have resulted in near transparent quality without excessive cost.

When CD was launched, the performance of its 16-bit PCM audio format was way ahead of the analogue technology of the day, and equal to the professional digital equipment of the day. Traditionally, professional audio equipment always possessed higher quality than the format used for final delivery to the consumer in order to allow for losses due to dubbing, mixdown and so on. The lack of converters of more than 16 bits meant that this 'quality headroom' was absent in CD production

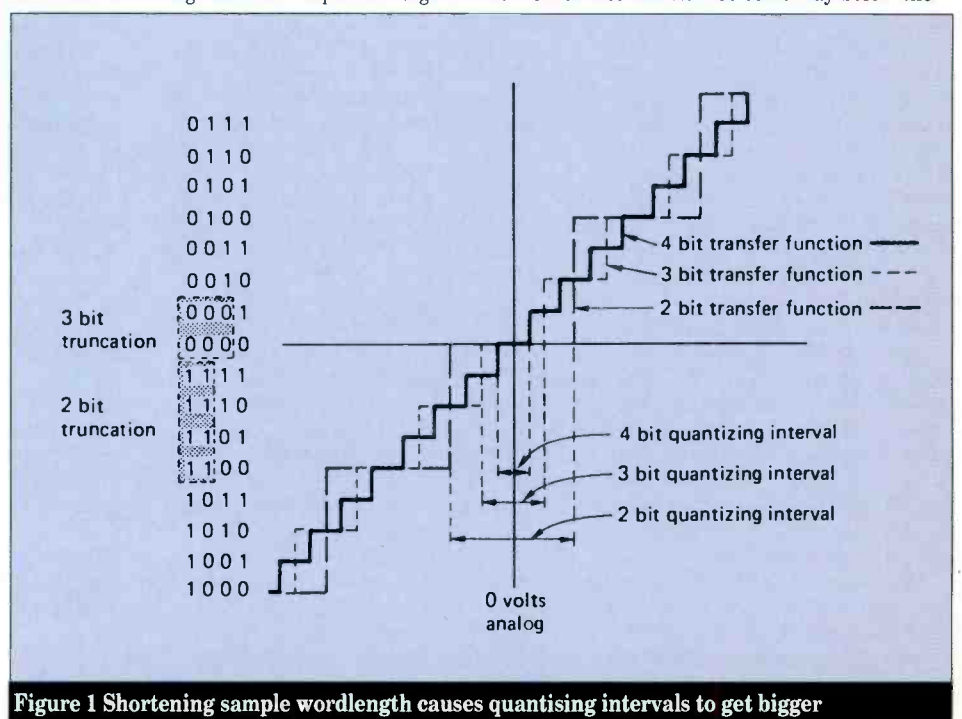
equipment. CDs made from analogue source tapes and mixed in the analogue domain (AAD discs) would employ 16-bit converters at the mastering recorder, and these matched the CD format well. The problem was that the analogue source tapes

were a quality bottleneck and it was desirable to use digital source tapes and digital

mixdown (DDD discs). This was impossible until converters of 18 or 20-bit word length were available for the source recorders as without them there would be no 'quality headroom' for the production process.

Early A-D converters were surprisingly nonlinear at low signal levels. This was due to a combination of lack of component accuracy and lack of appropriate dither. Dither is essential to linearise a quantiser and one approach is to use the dither to convert quantising error into a broadband 'white' noise giving the system a constant signal to noise ratio at all frequencies. In this approach an ideal 16-bit PCM system has a S/N ratio of about 92dB.

When longer word length converters are used during the production process, the existing 16-bit CD mastering recorder needs to be connected to the output of a system with greater word length. The words need to be shortened in some way by removing low order bits. Even if the original conversion was correctly dithered, the random element in the low-order bits will now be some way below the



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end of the intended word. If the word is truncated by discarding the unwanted low-order bits or rounded to the nearest integer the linearising effect of the original dither will be lost.

Shortening the word length of a sample reduces the number of quantising intervals available without changing the signal amplitude. As Fig.1 shows, the quantising intervals become larger and the original signal is requantised with the new interval structure. This will introduce requantising distortion having the same characteristics as quantising distortion in an A-D converter. It then is obvious that when shortening the word length of a 20-bit converter to 16 bits, the four low-order bits must be removed in a way that displays the same overall quantising structure as if the original converter had been only of 16-bit word length and correctly dithered. It will be seen from Fig.1 that truncation cannot be used because it does not meet the above requirement but results in signal dependent offsets because it always rounds in the same direction. Proper numerical rounding is essential in audio applications because it accurately simulates analogue quantising to the

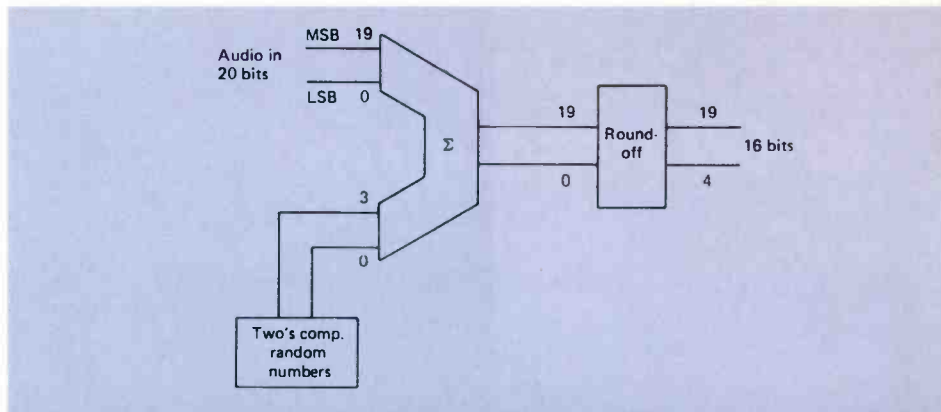


Figure 2 Simple digital dithering system reduces wordlength without distortion

new interval size.

Unfortunately the 20-bit converter will have a dither amplitude appropriate to quantising intervals 1/16th the size of a 16-bit unit and so in practice the word length of samples must be shortened in such a way that the requantising error is converted to noise rather than distortion. One technique which meets this requirement is to use digital dithering prior to rounding. This is directly equivalent to the analogue dithering in an A-D converter.

Digital dither is a pseudo-random sequence of numbers. If it is required to simulate analogue dither then it is obvious that the noise must be bipolar so that it can have an average voltage of zero. Two's complement coding must be used for the dither values as it is for the audio samples.

Fig.2 shows a simple digital dithering system (without noise shaping) for shortening sample word length. The output of a two's complement pseudo-random sequence generator of appropriate word length is added to input samples prior to rounding. The most significant of the bits to be discarded is examined in order to determine whether the bits to be removed sum to more or less than half a quantising interval. The dithered sample is either rounded down (where the unwanted bits are simply discarded) or rounded up (where the unwanted bits are discarded but one is added to the value of the new short word). The rounding process is

no longer deterministic because of the added dither which provides a linearising random component.

An ideal implementation of the above wide-band digital dither approach results in a CD having a constant S/N ratio at all frequencies. The S/N ratio is essentially the same as if an ideal 16-bit converter had been used in the first place. In practice a better result is obtained because converters never actually have the resolution which their word length permits. Thus a good 16-bit converter usually has around 15-bit performance. Following this argument it can be seen that a CD made by properly digital dithering a nominal 20-bit converter output (actual performance 18-bit) would actually be better than if a real 16-bit converter had been used.

The noise floor of a wide-band dithered PCM system is flat, whereas the noise sensitivity of human hearing is not. The well known Fletcher Munson curves show that as sound pressure level falls the frequency response of the ear is reduced dramatically at both ends of the spectrum. The result is that audibility of noise is increased in the midrange or speech frequencies. As a consequence a subjective improvement in S/N ratio can be obtained by 'noise shaping' or altering the spectrum of the requantising noise so that it is concentrated at high and low frequencies and not in the sensitive midrange. The noise power remains the same, and communications theory tells that it must, but the subjective result is an improvement 'In band' noise shaping is a special case of noise shaping where oversampling is not used. Noise shaping dates from the work of Cutler in the 1950s. It is a feedback technique applicable to quantisers and requantisers in which the quantising process of the current sample is modified in some way by the quantising error of the previous sample. When used in an A-D converter, part of the noise shaping circuitry will be analogue. As the feedback loop is placed around an A-D converter it must contain a D-A. When used in converters, noise shaping is primarily an implementation technology. It allows processes which are conveniently available in integrated circuits to be put to use in audio conversion. Once integrated

circuits can be employed, complexity ceases to be a drawback and low-cost mass production is possible. When used with requantising, noise shaping is an entirely digital process. It will be found in this form in oversampling D-A converters and in CD mastering.

The term noise shaping is idiomatic and in ▶

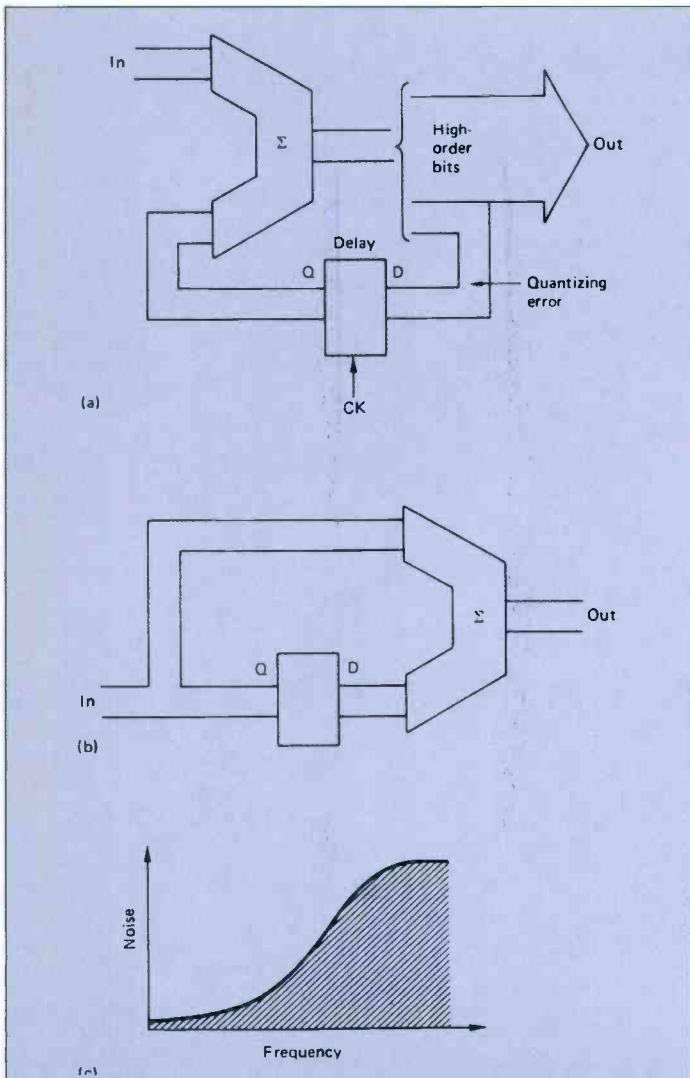
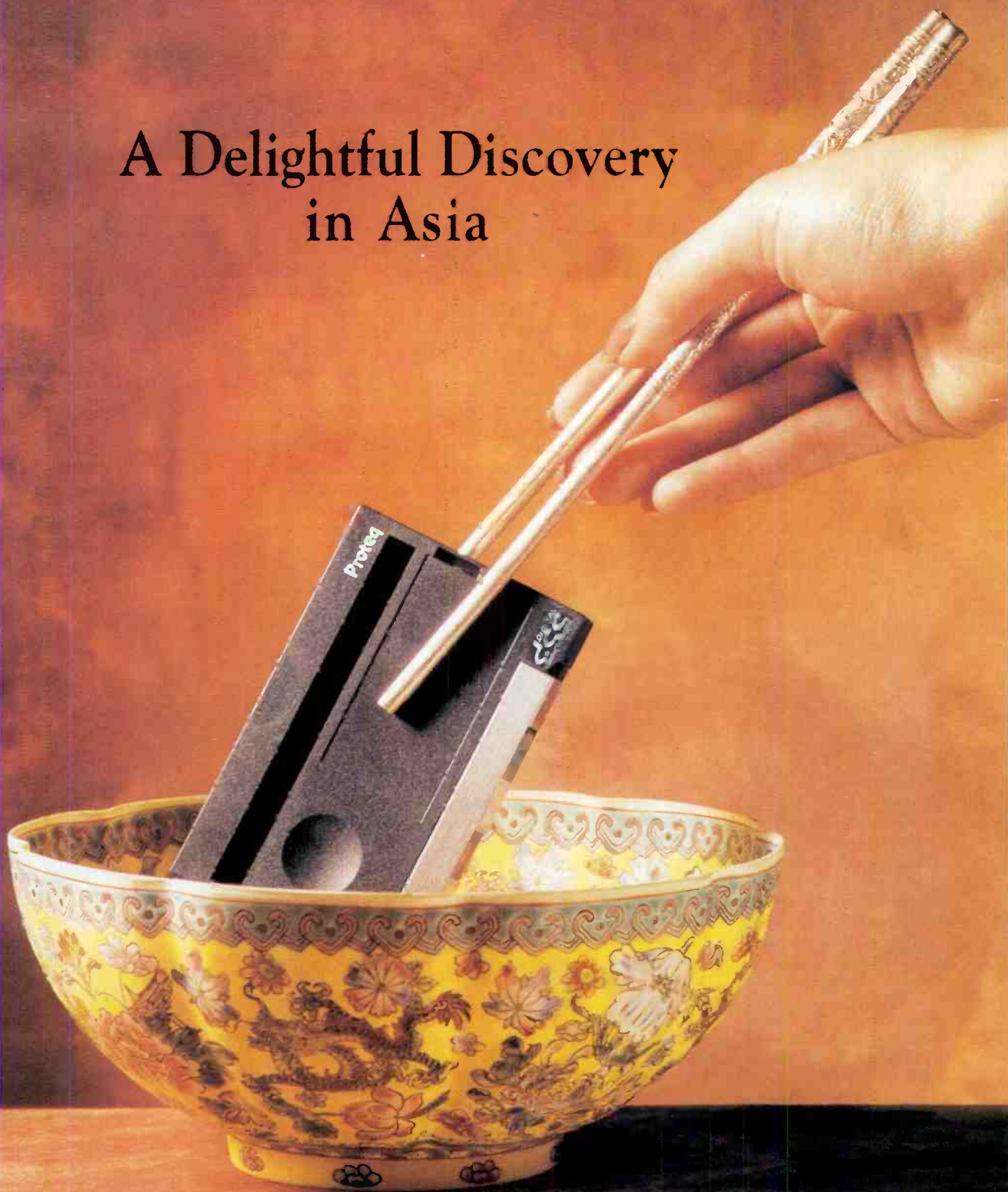


Figure 3 (a) A simple requantizer which feeds back the quantizing error to reduce the error of subsequent samples. The one-sample delay causes the quantizing error to see the equivalent circuit shown in (b) which results in a sinusoidal quantizing error spectrum shown in (c)

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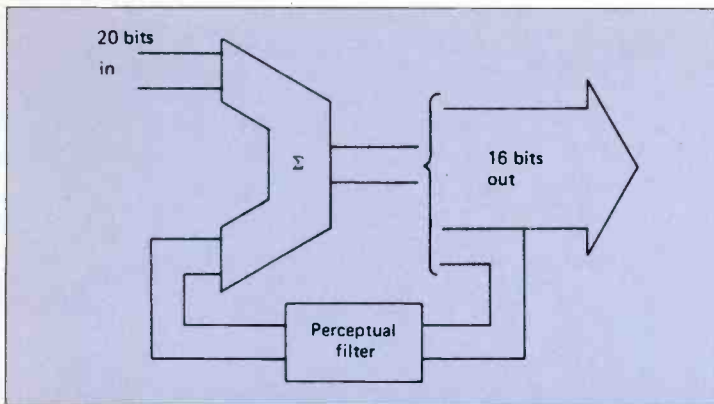


Figure 5 Noise shaping is applied by feeding back the quantizing error through a filter whose response is based on the human threshold of hearing

some respects unsatisfactory because not all devices which are called noise shapers produce true noise. The caution required when treating quantising error as noise is also relevant in this context. Whilst 'quantising-error-spectrum shaping' is a bit of a mouthful, it is useful to keep in mind that noise shaping means just that in order to avoid some of the pitfalls. Some noise shaper architectures do not produce a signal decorrelated quantising error and need to be dithered.

Fig.3 shows a requantiser using a simple form of noise shaping by way of introduction to the process. The low-order bits which are lost in requantising are the quantising error. If the value of these bits is added to the next sample before it is requantised, the quantising error will be reduced. The process is somewhat like the use of negative feedback in an operational amplifier except that it is not instantaneous, but encounters a one sample delay. With a constant input, the mean or average quantising error will be zero over a number of samples, achieving one of the goals of additive dither.

The more rapidly the input changes, the greater the effect of the delay and the less effective the error feedback will be. Fig.3b shows the equivalent circuit seen by the quantising error, which is created at the requantiser and subtracted from itself one sample period later. As a result the quantising error spectrum is not uniform, but has the shape of a raised sine wave shown at Fig.3c, hence the term noise shaping. The noise is very small at DC and rises with frequency, peaking at the Nyquist frequency (half the sampling rate) at a level determined by the size of the quantising step. If used with oversampling, the noise peak can be moved outside the audio band. However, for CD mastering, the sampling rate of 44.1kHz must be used and so the only possibility is to distribute noise within the audio band. This requires a more complex feedback approach.

Fig.4 shows noise shaping applied to a digitally dithered requantiser. Such a device is suitable for making a 16-bit CD master from a 20-bit recording format. The input to the dithered requantiser is subtracted from the output to give the error due to requantising. This error is filtered (and inevitably delayed) before being subtracted from the system input. The filter is called a perceptual filter because its frequency response is determined by a knowledge of the human threshold of hearing.

Fig.5 shows that in simple terms, the filter is

designed to shape or weight the requantising noise so that its spectrum matches the frequency response of human hearing at low level. In practice the filter is not designed to be the exact inverse of the perceptual weighting curve because this would cause extreme noise levels at the ends of the band. Instead the perceptual curve is levelled off such that it cannot fall more

than around 40dB below the peak.

Psychoacoustically optimal noise shaping can offer the equivalent of nearly 3 bits of increased dynamic range when compared with optimal spectrally flat dither. Enhanced compact discs recorded using these techniques are now available under a variety of trade names. For example Sony use the term Super Bit Mapping to describe their requantiser and Deutsche Grammophon use the technique in their 4D Audio Recording System. Although all systems rely on the same basic principles. However individual implementations differ widely in the exact nature of the perceptual filter used. As a result the perceived quality of the finished CD will vary. The technique is still in its infancy and it is not inconceivable that there may be some audible artifacts lurking.

There are some potential areas in which care must be exercised. In the majority of studies of the effect of masking only monophonic sound is considered. When all sounds appear to emanate from the same point masking between those sounds must be at its most effective. In stereo it is possible for an artifact to be generated which appears to be separated spatially from the sounds which are meant to mask it. It is possible that under these conditions the masking would not work so well and the actual

audibility of the artifact could be greater than imagined.

Another consideration is that the threshold of hearing is a function of an absolute sound pressure level. The waveform from a CD cannot produce a constant SPL because of the presence of the volume control. The effect of the noise shaping is only optimal if the CD is played at such a level that the noise floor from the loudspeakers falls below the threshold of hearing of the listener. Listening at high levels could result in the high and low-frequency noise becoming audible. This could easily happen if the signal level on the CD is not using the full dynamic range available. Thus it is important that CDs are fully modulated during the mastering process: excessive headroom is undesirable.

One last concern is that few CD players will be able to extract the full performance from the noise shaped discs. In real CD players, the 16-bit converters seldom have 16-bit performance. Unequal step size and the effects of clock jitter produce a noise floor which is not necessarily ideal. However, playing a noise shaped CD on such a converter requires it to have 18 or 19-bit linearity, which it may not have. It is possible that in some cases the shaped noise floor on the CD may simply fall below the converter noise of the player so that the improvement is not obtained. Good quality D-As using oversampling and one-bit technology should, however be capable of delivering the noise shaped performance, provided attention is paid to clock jitter. ■

John Watkinson is an independent consultant in digital audio, video and data technology and is the author of seven books on the subject, including *The Art of Digital Audio*, acclaimed as the definitive work on the subject. He is a Fellow of the Audio Engineering Society and is listed in *Who's Who in the World*. He regularly presents papers at conventions of learned societies and has presented training courses for studios, broadcasters and facilities around the world and is currently writing a book on digital video recorders.

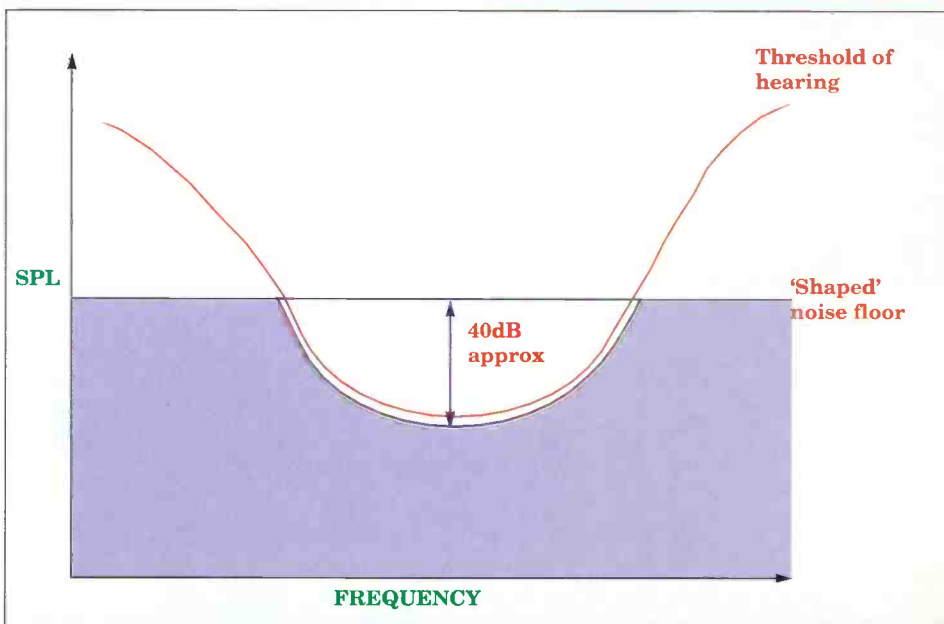


Figure 5 The noise is filtered to match the threshold of hearing except at the ends of the audible band where the noise level is limited

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The latest pronouncements from the various areas of the world's major record companies suggest—only suggest—that the compact cassette format is being phased out. Nobody has come right out and told the public what everybody inside the record industry already knows. But it is clear to those inside the industry that those in power have long since decided upon a *de facto* 'final solution' for the publicly popular cassette.

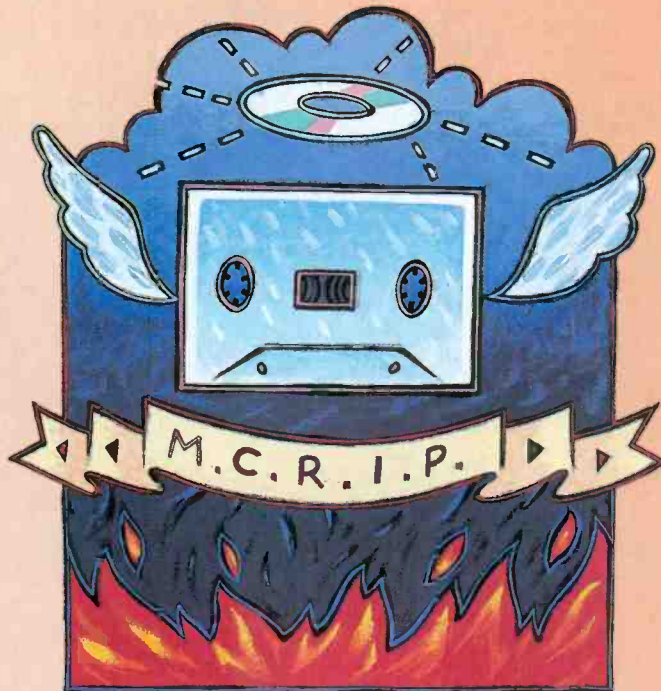
The number of cassette releases made available, the quantity of product and the distribution of the product have all subtly changed direction over the last several years. Certain record retailers have dropped the cassette from certain locations and many others have scaled down their commitment to the format to concentrate on higher profit SKUs (stock control units) such as CDs, blank media, laser discs, video games, VHS movies, recording accessories and so on. It is difficult today to find a music retail chain or independent retailer who has not in some way modified their floor space *vis-a-vis* the cassette.

The industries' recent distaste for this format has its roots in several arguments. The first concerns in-store theft. Said one record store owner, 'cassettes either have to be locked into an unwieldy frame or else they are the first thing to walk out of the store. Size really is an issue—personally I believe that one of the reasons the record industry shit-canned DAT as a release format was its size. Anyway, it's getting worse for the cassette.'

The second issue is that of quality. The first thing that comes to mind with this topic is the painful and to many still, untimely death of the vinyl LP. The death of the LP saw cooling cycles shortened, stamper life extended despite the obvious and damaging wear to the 'daughter', cheap reprocessed vinyl began to make its way into the plastic 'biscuit', coated paper album liners were dropped leaving cardboard fibres trapped in the cooling vinyl and tight shrink wrap became the norm. All to save a penny or two in production costs.

The same thing has always plagued the cassette. Quality of duplication has been more variable than that of, say, the compact disc with its Red Book standards. And to be absolutely honest, no other release medium for music has so many real variables present in the replication process whether by bin playback for tape 'pancake' load of C-zeros or by multiple cassette recorders loaded with C-60s.

Thirdly, and a much less discussed topic, is the industry distaste for the public's supposed enthusiasm for illicit home copying on cassettes. It is always difficult to comprehend the public posture of the RIAA (Record Industry Association of America) and the IFPI (International Federation of Phonograph Industries) against cassette copying in light of all of the cassette



Compact cassette:

hardware, software, and blank media sold for that purpose in virtually every record outlet in the Western world today—not to mention the East. The record retail community has become the number one source for both CD 'masters' and blank cassette media; as well as an extensive range of cassette recorder head cleaning kits and cassettes, patch cables of virtually every connector, and pin configuration, recording how-to manuals, switch boxes to place the recorder in home systems lacking tape outputs. And in some retail record locations even a selection of stereo cassette recorders.

And we are not just talking about the so-called electronic superstores which have become so popular in the US and elsewhere in the last five years and which, by definition, carry everything necessary to record including the source disks—we are talking about virtually every record store in America. It is a curious fact that some industry analysts suggest that record retail income figures for cassette copying paraphernalia may account for as much as 20% of all income in some stores.

Fourth, and also sub-rosa is the possibility that the cassette is a threat to industry sales as the last release media to lack digital coding capable of tripping the SCMS chips in digital recorders. Since they are analogue technology, cassettes can be copied over and over.

If this is the case, and my take on the cassette issue is still admittedly a tad fuzzy, there is the equally fascinating matter of the threat to the whole digital release camp posed by the current and potential success of Dolby S. Since it is a domestic variation of the Dolby SR system used for about half of all albums made during the last ten years, it's real and perceived quality has increasingly caught consumer attention. That would certainly constitute a threat to the record companies perceived new digital order sufficient enough to justify the subtle 'euthanasia' of the cassette format—if one was a believer in

conspiracy theories.

A curious corollary to all of this is the fact that the cassette has absolutely no value with the record companies' current Bete Noire—the used record store. The question of potential damage to the prerecorded tape is so strong and there is so little opportunity for a visual inspection of the tape, the cassette just doesn't get resold in a major way, if at all.

Which brings us to the fifth factor. Profitability for the cassette is just about half, give or take a few points, that provided by the CD for the record labels, distributors and music retailers. Need I say more?

All of this leads us to the question of the cassettes' supposed replacement format. And with the cassette replacement question comes the plight of the duplicator being asked to invest in a new equipment format with new technologies and expensive learning curves. Last and certainly far from least, we must face the question of whether the public will accept the slow strangulation of the cassette. It is important to remember that the trade in LP records new and used, turntables, cartridges, preamps and associated LP paraphernalia is still remarkably brisk considering the format's virtual disappearance from regular record retail channels—nearly ten years after the LP's suffocation began. Add the fact that LP had neither a recording capability nor an installed automotive and 'lifestyle portable' (read Walkman) player base, and the public's posture towards the analogue cassette becomes quite clear: 'thank you'.

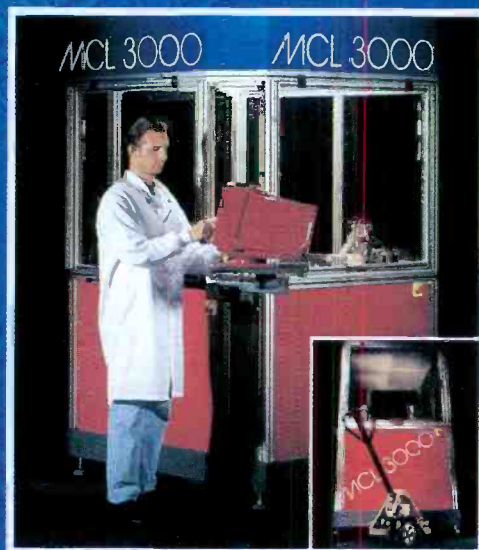
The answer to the first question posed has become sullied by the public's response to both MD and DCC. The weak response after more than a year of exposure underlines the vulnerability of the new formats to an early death! But, if the backers of the new systems really wanted to ensure success and replace the analogue cassette, they would have flooded the record stores with tens of thousands of prerecorded music titles in the new formats.

As to the replicators, and the cost of investment in the new system aside, the ability to guarantee that the MD and DCC systems will survive and prosper in the recorded music marketplace and justify the investment in new replicating facilities is a 'hard' call to make.

The bottom line, then, is whether the public surrender the analogue cassette. A recent study suggests that the answer is no. An astonishing 84% of those surveyed (2,100 respondents), indicated that it was considered an ideal format for 'lifestyle' music listening. Curiously, most indicated that the only thing they would surrender their cassettes for would be 'music on a chip.' And for all those in the record industry and who did not make it to the recent ITA meetings in Arizona, this is exactly what AT&T and others intend to do.

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