DISC CUTTING SYSTEM IMPROVEMENTS

Tony Batchelor of Tam describes a disc cutting system that maximises analogue disc performance

In 1983, Ortofon of Denmark, made a commercial decision to cease manufacture of their own disc cutting system, comprising various models of head and the associated electronics. In August 1983, Tam took over stocks and designs for the system's electronic units and shifted production to the UK. Later, in March 1984, Ortofon handed cutting head manufacture over to Phonotech in Denmark and since then Tam and Phonotech have been consolidating design and marketing of the equipment, and researching both the commercial and technical aspects of the ex-Ortofon designs. As part of this consolidation, we have had to look to the future for analogue disc cutting, and these are our conclusions.

In all our collaborations with disc cutting facilities around the world, two inescapable conclusions emerge. Firstly, compact disc, or a successor, will eventually supplant the analogue disc for all but the veteran hi-fi enthusiast. Secondly, this will not be for some years, and in the meantime disc cutting facilities will need to maintain their competitive edge by improving quality, thus making further improvement in the pressing of the 'black vinyl' record possible.

Returning to the first of these points, various questions immediately come to mind. The most obvious, of course, is the most difficult to quantify: when will manufacture of the black vinyl record eventually cease to be a viable commercial proposition? Taking the easy way out, one could simply invent a convenient time, such as 'when 90% of all record sales are CD and only 10% black vinyl'. However, this is still rather vague and also totally ignores the expanding sales of records in areas of the world such as South America, Africa and the Indian sub-continent. In these areas, the technology of the CD is many years away. Generally then, the time scale we are talking about can stretch from five years to 25 years, and your guess is probably as good as mine.

Regarding the second point, many efforts are being made to improve the existing technology, witness the *Apollo* lacquer by Capitol and the recently introduced up-graded lacquer by Transco. Still other innovations are being added and extended, such as the increasing popularity of the disco single, which has led to increasing technical demands at all stages of the record manufacturing process. With the increasing awareness by plating and pressing plants that there are many improvements still to be made in product quality and with the continuing improvements being made in cartridge, tone-arm and turntable design. In the cutting equipment business we must look to our laurels. The recent introduction in several countries of the Neumann *DMM* system has answered part of the demand for continuing improvement at the disc cutting stage, but demands a total change of every part of the system, including the materials and other parts of later processes.

Therefore, bearing these points in mind, Phonotech and Tam have put together a package of improvements to the ex-Ortofon designs, and will shortly be showing the complete system. In general, we have found that the original Ortofon designs were more than adequate to handle the majority of cutting requirements and hence all the changes are fairly minor, and can be retrofitted to existing equipment.

System outline

Fig 1 shows a block diagram of the units that comprise the complete cutting system as far as the cutting head and cutting electronics are concerned. The cutting lathe itself, ie the mechanical part of a cutting facility, will generally be of either Neumann or Scully manufacture and both are completely compatible with our electronics. You may also meet the older Lyrec lathes or the Cybersonic lathe introduced a few years ago. Another part of a complete facility is of course the master reproducer. This may be of the standard reel-to-reel tape type, with preview head for lathe control; the same type but with digital delay to achieve the same result as two heads, or some form of digital tape machine, again with digital delay.

From the reproducer, the signals are processed by our first unit, the *CPS 852*. This unit takes the music signals and provides control of cutting level, equalisation and monitoring. Various other functions are also performed in this unit, such as keeping lathe control in step with cutting level and automatic control of the cutting power amplifiers in step with the lathe control systems.

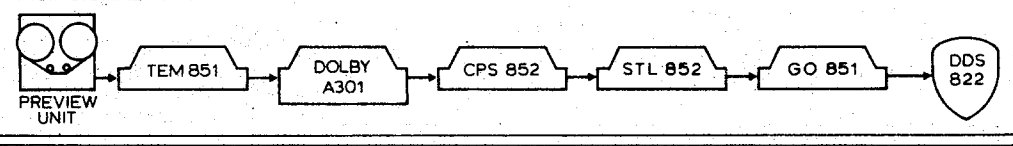
Inserted between the reproducer and the *CPS 852* is a new unit, the *TEM 851* but this is not in use for standard cutting procedure.

Following the *CPS 852*, is the *STL 852*. This unit performs two important functions, but for straight cutting, can be switched to bypass mode. In use, it is a dynamic treble limiter, or de-esser with threshold level, attack time and release time all being variable to suit the programme content. This characteristic protects the cutting head against high frequency (hence high energy) overload and ensures that the programme as cut, is playable by a cartridge on the finished pressing.

The last item in the electronics chain, is a pair of cutting amplifiers *GO 851*. Although basically a pair of power amplifiers supplying driving power to the stereo head, the amplifiers are specialised. Capable of 500 W RMS per channel, they can deliver enough energy to burn out a cutting head in less than a millisecond. Thus very effective protection circuits acting at high speed are an integral part of the design. Also necessary for the system, is accurate control of the RIAA equalisation curve, pick-up amplifiers for test and monitoring, and monitoring circuits working from the head feedback circuits. The feedback circuits give a signal for motional feedback control of the cutting head and continuous monitoring of the cutting stylus movement. This is like monitoring a tape recorder from the replay head, but with no delay as there is no physical separation.

Finally, the cutting head, type *DDS 822*, is a very small electro-mechanical unit, containing a powerful magnet system, two driving coils, two feedback coils, a stylus holder and an accurate lathe mounting. To give some idea of scale each driving coil is about 5 mm in diameter and must be able to dissipate 500 W of electrical energy on maximum (very short) peaks. To assist this, the head is normally filled with helium gas, as it conducts heat twice as fast as air can. The heat is transferred to the metal mass of the polepieces.

FIG.1 SIGNAL PATH



Design requirements

Our objective (at Tam and Phonotech) was set by ourselves to try to meet all the ▷

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requirements given to us over the past year or so by the various cutting facilities throughout the world, with whom we are in almost daily contact. In this we were helped by the fact that we run our own cutting facility, handling all types of programme material. We were helped, too, by consultation with Sean Davies, who has worldwide personal contact on an engineering and consultancy basis with cutting facilities and engineers. The prime objective was the design of one system that could handle any type of programme material and be capable of a higher specification than any current analogue disc replay units. Our existing designs met most of the limits set by these objectives but experience had shown that there were certain areas where we fell short of our targets. Three main areas were identified as needing improvement: cutting level and transient response; head life under continuous cutting of extreme programme material; protection of the cutting head in handling while setting-up and electronically cutting each affecting, and being affected, by the others.

Cutting level and transient response

By the nature of its design, the Ortofon type of head is capable of an extended frequency response, so much so, that it has been used to cut most of the quadrophonic catalogue throughout the world. It only needs replay speed to be cut by half, to achieve a flat response right up to the carrier frequencies required in this form of 'surround sound'. To achieve this, the design of the head and amplifiers is such that the frequency response is flat to beyond 25 kHz and the transient response is correspondingly fast. However, in order to achieve the cutting of the very high energy transients that much of today's music demands (eg heavy cymbal work and particularly synthesised music where high frequency energy content does not fall off with increasing frequency as in conventional acoustic based instruments) there is no way of avoiding the simple physical fact that such frequencies need very high electrical power to be fed to a cutting head. As some engineer pencilled in the margin of one of our technical manuals: High Power, High Heat, Smoke, Flames, Bang! We can, however, overcome this problem in a very simple way. If cutting is done at half-speed, then all frequencies are reduced by half and the power required for the same cutting level at the high frequencies is also reduced by one quarter. Or conversely, given the same equipment, half-speed cutting gives twice the energy when played back at normal speed and hence four times the level of conventional cutting when the record is played back. Absolutely ideal for short length sides at very high levels such as disco singles and modern synthesised instrumentation. Particularly so, of course, when the original is a digitally recorded master. In the Tam amplifiers, half-speed cutting has always been an available option, and in the new design it is included as standard for no extra cost. In practice, there are some problems with the response on tape machines playing back low frequencies at half-speed, and this is where the *TEM 851* unit comes in.

Cutter head protection

With the increasing demand for high level cuts, particularly at the bass end, the excursions of the mechanical system are greater than ever before. The new head (*DDS 822*) has a 50% increase in allowable excursion before the integral mechanical stops come into play. The increased strain, mainly metal fatigue, on the internal connecting wires has been greatly reduced by specially forming them along their supports. Internal clearances have been re-toleranced to ensure that the bridge spring links can stand up to the higher internal stresses. Helium cooling is now, of course, obligatory. Additionally, examination of the various safety circuits in the power amplifiers, has shown that under the new limit, the amplifiers themselves could produce unexpected severe transients that could shorten head life. This problem has now been eliminated.

The main safety circuit in the power amplifiers has already been mentioned in the previous section. The new high levels of which the head is capable have required changes to the electronics of which this item was just the first. All the basic circuits and controls were found to be more than capable of meeting the new requirements. Some refinements have been added to cope with the extra high frequency energy demands of synthesised instruments as well as the insistent bass rhythms of disco music. The main change has been in the way that the *STL 852* treble limiter is controlled from the programme content.

It has been found that under certain conditions, stress imposed on the bridge and stylus holding point while changing styli, has been exaggerated by the greater excursion allowable. Although this could be claimed to be a user problem, we preferred to tackle this ourselves by introducing a new fixture to aid stylus changing and thus prevent unnecessary stress. This will delay the possible onset of fatigue to give extended life under higher level cutting conditions.

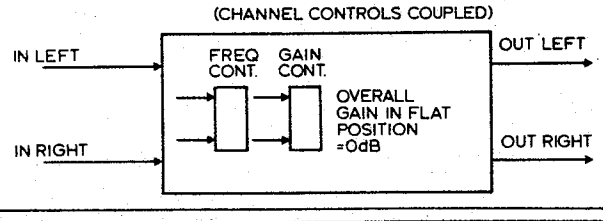
Technical details

The preview unit is a standard machine supplied by several well-known manufacturers. It can be a reel-to-reel with preview head, a reel-to-reel with digital delay, a digital (stationary or rotary head) with digital delay. In the second and third types, the digital delay is necessary to allow the initial signal to control the lathe pitch and depth parameters in advance of the programme being cut. The first type can be run at half-speed with the electronics appropriately switched to the correct time constants. Type two is similar to type one as long as the digital delay has an extended LF response, ie down to at least 10 Hz. (Incidentally, the old wives' tale that records cannot be cut with a response below, variously, 50 Hz or 30 Hz depending on the story teller, is totally untrue. All current equipment is usually flat down to 20 Hz.) Type three machines are not currently able to be run at half-speed and we would be interested in manufacturers' comments on the feasibility of design changes to enable this to be implemented.

Type one and two machines however, suffer from a normally unrecognised problem in half-speed playback: any analogue tape machine is a subtle blend of science, mathematics, manufacturing technology, compromise and art. Several compromises have to be made in the design of recording and playback heads, and of particular concerns here, are the dimensions of gaps and pole pieces. Too large or small in either respect will give trouble in the design. Thus compromises are made to ensure that playback on different machines will work to standard reference tapes and equalisation curves. However, if the effective dimensions are changed by playing back at half-speed, then, although the playback amplifiers time constants can be changed, the effective dimensions are now outside the design criteria. Particularly, there are wavelength and fringing effects which cause a major change in response at low frequencies. This change will vary depending on the machine (both manufacturer and wear being factors) and cannot readily be calculated in advance. We are not aware that any analogue tape machine manufacturer offers any modifications to cover this problem. The effect can generally be of the order of ±6 dB at 30 Hz (real-time). Such an effect is of course very noticeable and explains why listeners often complain that there is 'something wrong' with the bass of many masters cut at half-speed.

To take care of this problem, we have introduced the tape equalisation modifier *TEM 851* (**Fig 2**). This is a 1U rack mounting 2-channel device. It ▷

FIG. 2 TEM 851 TAPE EQ MODIFIER



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is intended to go into the programme chain before any noise reduction unit and consists of a coupled frequency selector and a coupled gain control. By reference to an appropriate test tape, an individual machine can have the wavelength effect compensated. The unit is switched to bypass mode for normal speed playing, and the switching can be coupled to other units so that monitoring in set-up conditions can be carried out at normal speed and EQ. It is advisable to have the tape machine switchable in and out of half-speed time constants as well as any noise reduction device, which must be after the *TEM* unit.

The unit is supplied in 2-channel configuration only, as just one is needed for a reel-to-reel with digital delay set-up. A type one set-up, ie with preview head, may also prove satisfactory if the lathe pitch and depth control is adequate under half-speed conditions. If not, a second unit, identical to the first, can be installed in the preview chain.

Dolby *A 301* units can have half-speed cards manually interchanged, or the necessary components can be piggy-backed for auto switching. For units using *Cat 22* cards, the *Cat 40* half-speed cards can be obtained from Dolby for manual interchange. Dolby cannot directly switch standard *Cat 22* cards into half-speed mode and they suggest the best way of handling the requirement for auto switching is to have four channels of playback only, relay switched to channels equipped with *Cat 22* or *Cat 40* cards. Dbx and Bel are possibly not suitable systems for half-speed playback, although Bel is actively looking into the necessary modifications.

Transfer consoles for disc-mastering are usually custom built by most standard console manufacturers or are standard units modified for disc mastering use. However, there are very few units in the world that can monitor while setting-up in standard mode and then switch all equalisation curves to half-frequency and Q for half-speed cutting. We have therefore taken an older Ortofon design *CPS 741*, and modified it to include auto switching of all cards. This unit, the *CPS 852* (see **Fig 3**), is a 3U rack-mounting unit which contains two by two channels of audio control for programme and preview. Within the chains, control is given of: low and high frequency gain; selectable mid-frequency and gain; treble and rumble filters; elliptical equalisation; cutting level; monitor and metering outputs with monitor gain control; stereo balance and width controls; automatic switching to and from cutting lathe and cutting amplifiers and switching for half-speed use. A tape copy facility is also provided.

To enable eventual playback of a pressing whose music content contains heavily stressed voice and some types of instruments, it is essential to be able to exercise some dynamic control over the treble frequencies, eg speech sibilance, so we have developed the stereo treble limiter *STL 852* (**Fig 4**). Many synthesiser tracks are also difficult to cut, purely due to the high energy levels needed. Although this latter problem is taken care of by half-speed cutting, the STL is still necessary in the programme chain so the cutting room can still cut at normal speed.

The STL has a second function which is equally important for both types of cutting. This is as part of the complex control of HF energy through the cutting amplifiers, to the cutting head, for protection of the head against overload. The STL design has been used previously to sense the head current at dynamically variable treble frequencies and, hence, maintain control of that current and energy dissipation. Although such a sensing system has been satisfactory in the past, mainly for the odd transient, the HF energy present all the way through much modern music, means that the delay between head current increase and control causes problems. Effectively, we are talking about a servo system. In a servo control loop, hunting can never be zero, otherwise there would be no control signal to sense. For the odd high current peak in a cutting head, this slight overshoot is tolerable. With high current peaks in the head throughout a whole record side, the cumulative effect on a cutting head leads to fatigue failure well before its design life.

The reconfigured STL is still a 1U rack mounting unit with the standard threshold, attack and release time controls, but now additional switching has been added to allow three control modes. Head current sensing control is still available but now a 'feed-forward' option has been added. This means that the programme source itself (from console or CPS) is used to control the limiting action. In the STL there is a 20μs delay between the input stage of the circuit and the circuit point at which limiting control is exercised. The limiting control voltage is delayed less than this amount, so limiting action in the feed-forward mode starts before the signal to be limited reaches the limiting circuit. There can, therefore, be no overshoot and peaks at the head are fully controlled. The feed-forward option has two different actions. The normal use includes an inverse RIAA filter to match the pre-emphasis applied in the cutting amplifiers, and this can be switched out to give a flat response when the unit is involved in making loop-bin masters where feed-forward is the norm.

The cutting amplifier *GO 851* (**Fig 5**) has needed little redesign. Two major features ▷

FIG.3 CPS 852 TRANSFER CONSOLE

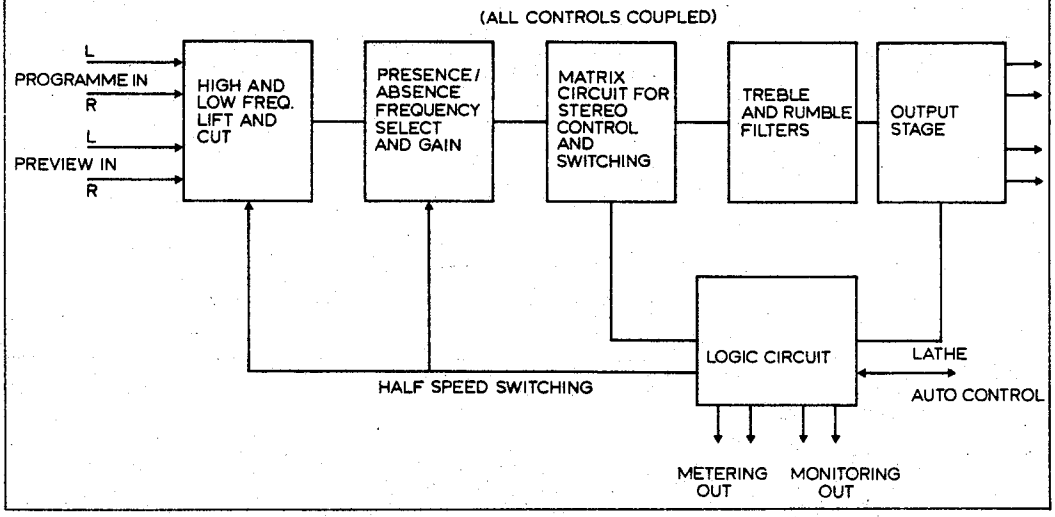
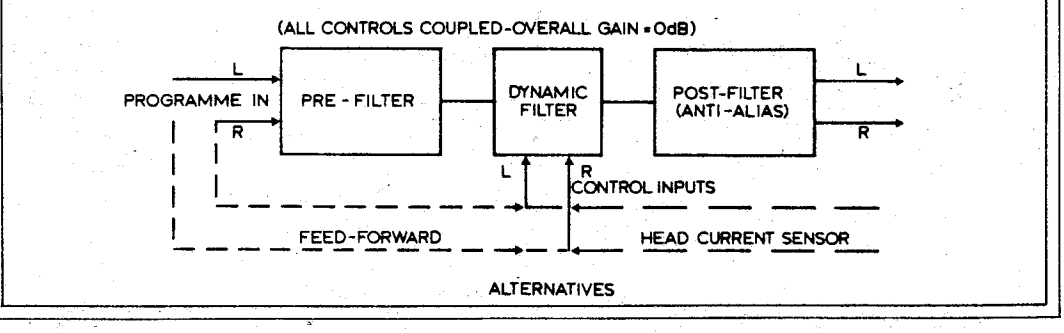


FIG.4 STL 852 STEREO TREBLE LIMITER



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are now included in new units for user convenience at no extra cost and a better circuit has been designed for the head protection part of the units.

All components are included for the half-speed option, and this is now part of the overall auto switching arrangement for the whole programme chain. Thus, test cuts and dry runs can be carried out at normal speed with full monitoring, including motional feedback monitoring, and then no changes are needed anywhere in the chain other than simply operating one switch to achieve half-speed cutting.

A second feature is related to monitoring overload conditions. These will inevitably occur and in the past, the cutting engineer has had no positive indication of the frequency of overloads—apart from head failure! Now two LEDs are provided, one for each channel, which respond whenever the internal overload limiting circuit comes into action. As overload depends on each cutting head's parameters, a visual indication directly on the cutting amplifiers provides an immediate indication to the cutting engineer of the effect of the programme material on the head.

In the final output stages of the amplifiers, head protection is achieved in two ways. Continuous current overload will cause the cutting head to rise in temperature and this is continuously sensed. At a set point, depending on head type, a high speed relay disconnects the head from the amplifier, until manually reset. Programme material disappears from the groove. For peaks, the protection is achieved at an earlier stage. Peak voltages are detected prior to the output stages and over-voltages switch clamping transistors while the peak lasts. The clamp was achieved by use of a pair of diodes, but this 'crow-bar' type of clamp meant that the action was very audible. This was manifested by, for example, a heavily plucked guitar note cut at high level sounding an additional click. More importantly, from the head protection point of view, the squarewave produced by diode action, introduced additional transient signals in a damaging part of the audio spectrum. The latest design of clamp no longer employs diodes so the limiting action is much softer and the squarewave transients do not appear.

Ortofon introduced its most important design of cutterhead in 1973, which was modified in 1982. Phonotech has now further modified the design to make the head, the *DDS 822* (see **Fig 6**), specifically suitable for the present demands made by cutting engineers.

Firstly, the head has had its maximum stylus excursion (limited by mechanical protective stops) increased from 106 microns to 170 microns in the 45° direction; this gives an extra 5 dB of level which is of particular value at low frequencies. Secondly, the earlier head had a frequency response only 2 dB down at 5 Hz and 25 kHz, essentially designed for quadrophonic, half-speed cutting. To give improved reserve and extended fatigue life, this response has now been changed to 2 dB down at 7 Hz and 23 kHz. This, of course, produces no audible difference and even further modification is possible before audible differences are noticed, such is the flexibility of the basic design.

Other changes have been made to extend life such as the method of forming and affixing the wires from drive coils and feedback coils. Experiments are continuing with respect to the magnetic field obtainable with different and newer materials, although the stability reserve is already more than adequate for the design.

Finally, it has been found that it is possible to stress the spring links connecting the drive coils to the stylus bridge when changing a stylus. This, it must be emphasised is not a problem under normal circumstances but with an inexperienced engineer it may happen. A new fixture has been designed which positively prevents such stress.

Conclusion

We shall be showing the complete system of units and head at APRS 85. Most of the changes in design specified are obtainable on a retrofit basis and we shall be making those available after a few months. We (Tam and Phonotech) believe that we have significantly extended the capability of analogue disc mastering, and look forward to several more years of servicing the industry, before the digits take over entirely.□

FIG. 5 GO 851 CUTTING AMPLIFIER

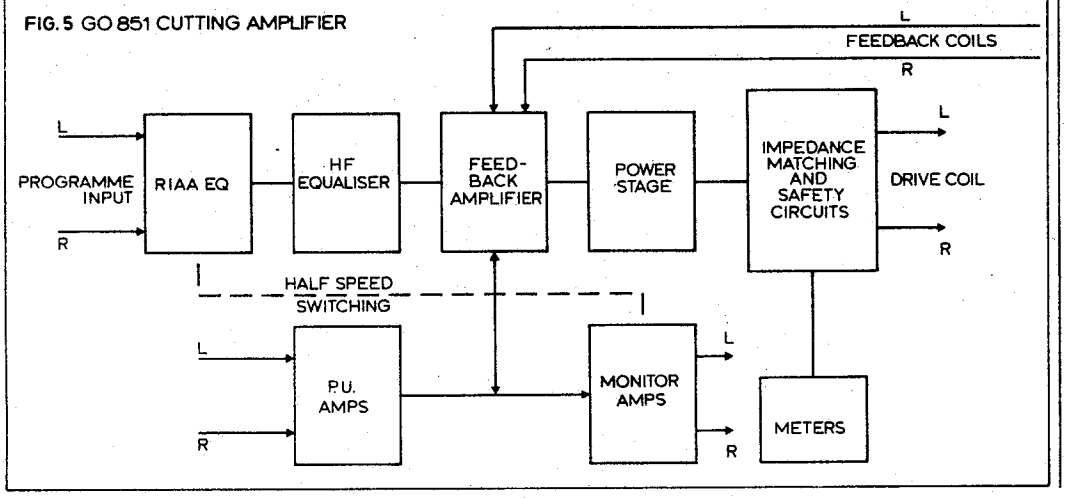
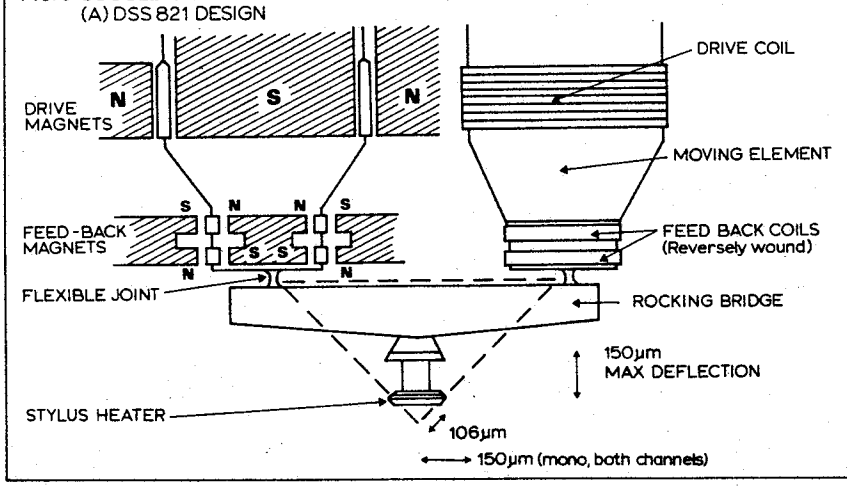
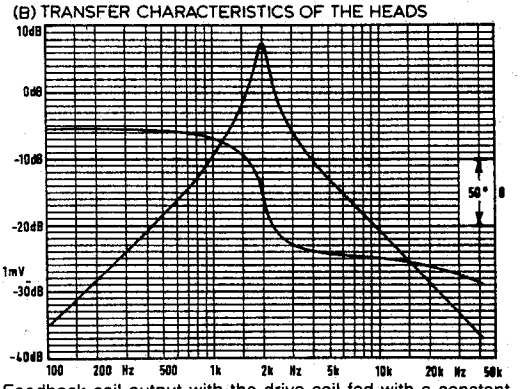


FIG. 6 DDS 822 CUTTER HEAD
(A) DSS 821 DESIGN



(B) TRANSFER CHARACTERISTICS OF THE HEADS



Feedback coil output with the drive coil fed with a constant current. The phase response curve shows the relation between drive current and feedback voltage. The phase changes sign through the resonance and in the high range, it turns into a straight slope representing the acoustical delay from drive coil to feedback coil.