CHAPTER 8

Technical Problems Related to Cutting

During cutting of the lacquer original there are several mechanical problems which must be solved, but which will not be further described here. There are for instance problems of

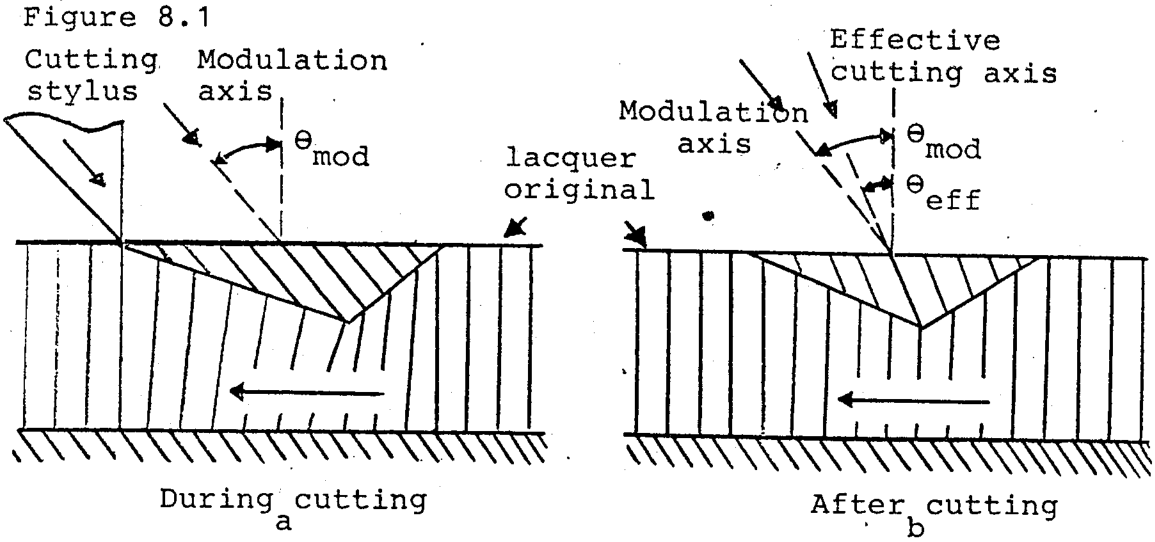
- achieving recordings without any wow and flutter
- ensuring an exact, absolute rotational velocity
- obtaining correctly positioned stylus tracking in the lacquer
- adjusting the position of the cutting stylus in relation to the lacquer
- removing the swarf without influencing the movements of the stylus, etc.

On the other hand, great importance is attached to the surface noise which determines the obtainable dynamic range, equalizing systems and recording characteristics, as well as the vertical cutting angle. These relations will be further described in the following sections.

8.1 The Vertical Cutting Angle

An angular difference between the vertical modulation axes and the movement of the pick-up stylus causes both harmonic distortion as well as intermodulation. This state of things has involved a standardisation of the vertical tracking angle at $20^\circ \pm 5^\circ$ (before 1972: "about 15°"). One would now expect that the cutting stylus would also move in a plane forming an angle of 20° with the vertical plane. This, however, is not the case because of the elastic properties of the lacquer material, the effect of which is that the cut signal does not exactly correspond to the movement of the cutting stylus (the spring-back effect). Further, it must be noted that, under certain circumstances, the cutting stylus may have a springy impact, so that the effective modulation direction does not correspond to the geometric one. These conditions are difficult to calculate, but the effect of the elastic quality of the lacquer material is illustrated in figure 8.1. The state of stress in the lacquer during cutting is shown in figure 8.1 a, in that the cutting stylus is assumed to move at an angle of Θ with the vertical plane. Owing to the elastic quality of the material, this will yield to the cutting stylus and be compressed in front of the stylus. This effect increases in proportion to the cutting depth. After the cutting, the material will try to return to a neutral state of stress, as shown in figure 8.1 b, which corresponds to the effective cutting angle of Θ_{eff} being smaller than the geometric value Θ_{mod}.

Figure 8.1



Similarly, in figure 8.2 is shown the impact of a springy cutting stylus as it appears in a WESTREX 3C or 3D cutterhead. This cutterhead provides a geometric cutting angle of $\Theta = 23^o$, which angle is provided by the pivot point of the cutting stylus holder above the record, whereas the moving coil system is in fact moving vertically. The axis of modulation deriving from the flexible stylus is said to be approximately $\Theta_{mod} = 15^o$ for this system, and the total impact of the two effects should result in an effective cutting angle of $\Theta_{eff} = 8^o$. However, recent studies show a value of $\Theta_{eff} = 8^o$ for the same cutting equipment, which indicates that the elasticity of the lacquer corresponds to a reduction of the geometrical cutting angle of approx. 7 - 8^o. It must be assumed, however, that this effect depends on the composition and temperature of the lacquer, the speed of the material past the cutting stylus and the temperature of the cutting stylus, so that it is not possible to give an accurate value. Similarly, the impact of the compliance of the cutting stylus will depend on the length of the stylus and the design of the holder. As an example, for the company's cutterheads Ortofon indicates a total spring-back effect of 10^o distributed with 5^o on the flexion of the cutting stylus and the elasticity of the lacquer, respectively. Therefore, the geometric cutting angle must be about 30^o for these cutterheads against approx. 35^o for the WESTREX 3D cutterheads in order to obtain an effective cutting angle of 20^o.

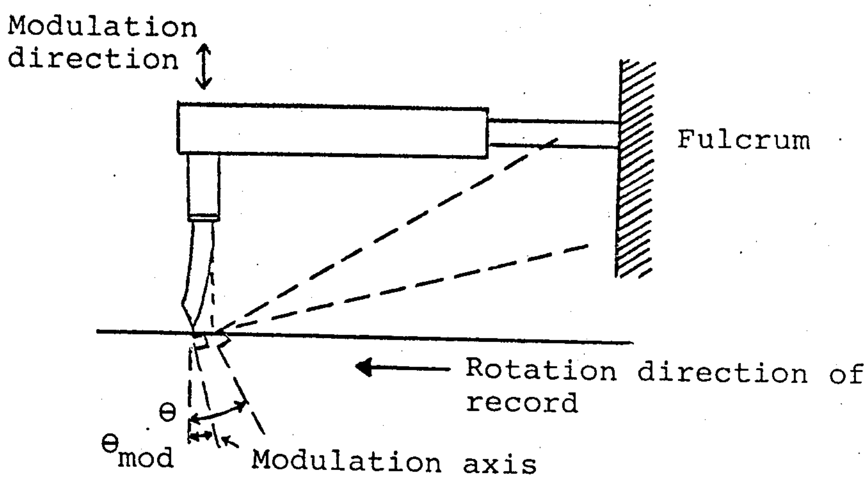


Figure 8.2

8.2 Random Noise and Dynamic Range

Random noise beyond the noise which may already be present in the signal, arises during the cutting process and the record production. Primarily, the random noise derives from groove walls which are not absolutely smooth. In chapter 7 it was mentioned that the cutting stylus had to be provided with specially polished facets to ensure a smooth groove. From tests it appears that the lacquer original will show surface noise which is highest at low groove velocities (the innermost grooves), cf. table 8.1. If the cutting stylus is heated, however, a

Table 8.1

Diameter	With Heat dB	Without Heat dB
12"	-68.5	-67.0
10"	-69.0	-66.0
8"	-69.5	-63.5
6"	-69.5	-60.0
5"	-70.0	-57.0
4"	-70.0	-53.0

Table showing surface noise measured by means of 200 Hz HP filter. Reference level corresponds to cutting velocity of 5.5 cm/s at 1 kHz (RMS).

smoother section will be obtained, and the surface noise will be correspondingly lower. This particularly applies to low groove velocities. The table shows the improvement in random noise when a heated cutting stylus is used. The heating of the stylus is provided for by passing a current through a wire wound round the cutting stylus. The relative spectral noise caused by the use of a cold and a hot cutting stylus, respectively, appears from the

Figure 8.3
Lacquer Master Noise Using Cold Cutting Stylus

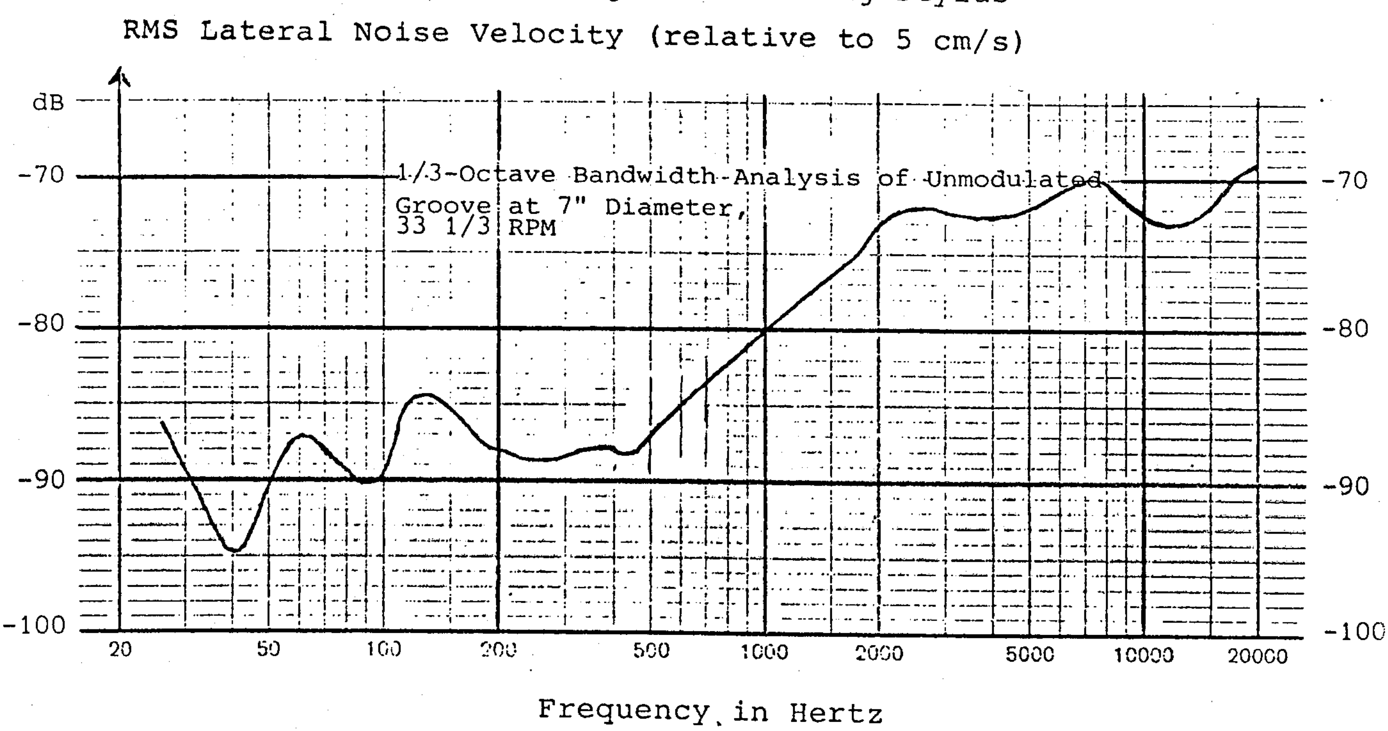


Figure 8.4
Lacquer Master Noise Using Heated Stylus

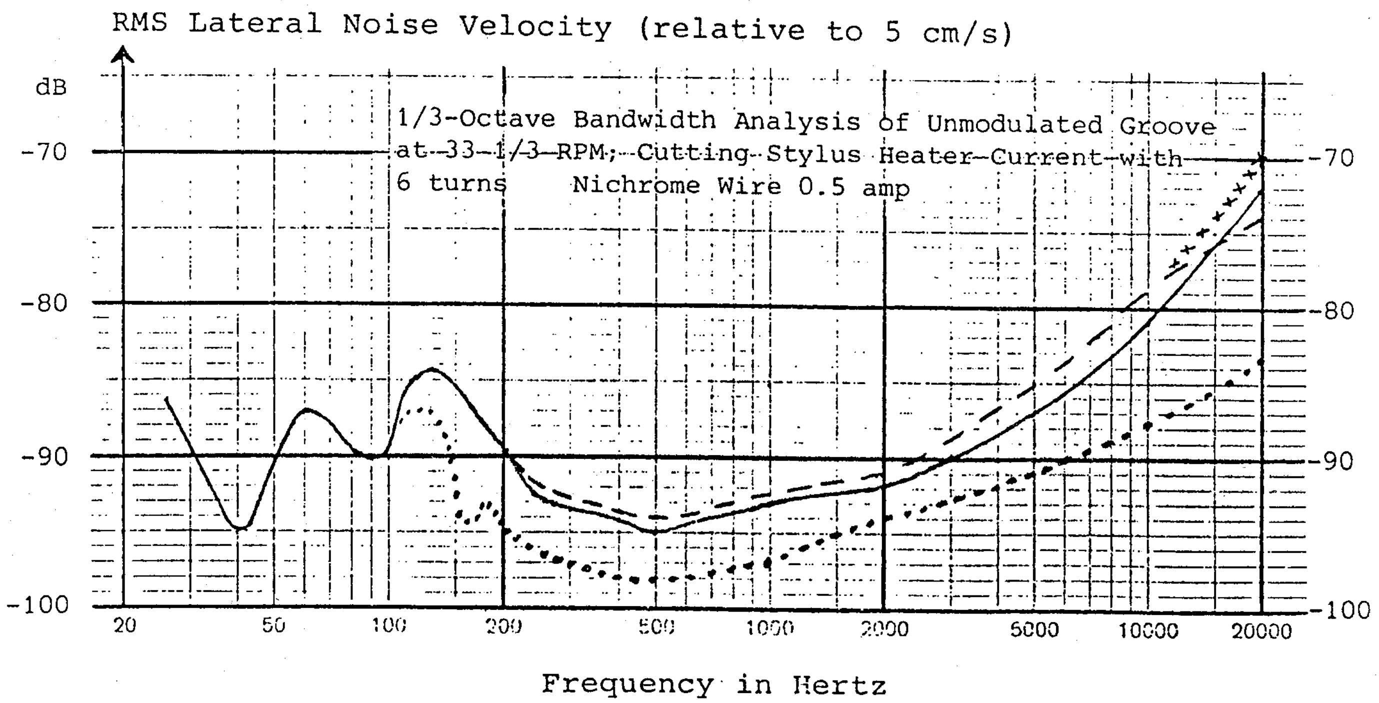
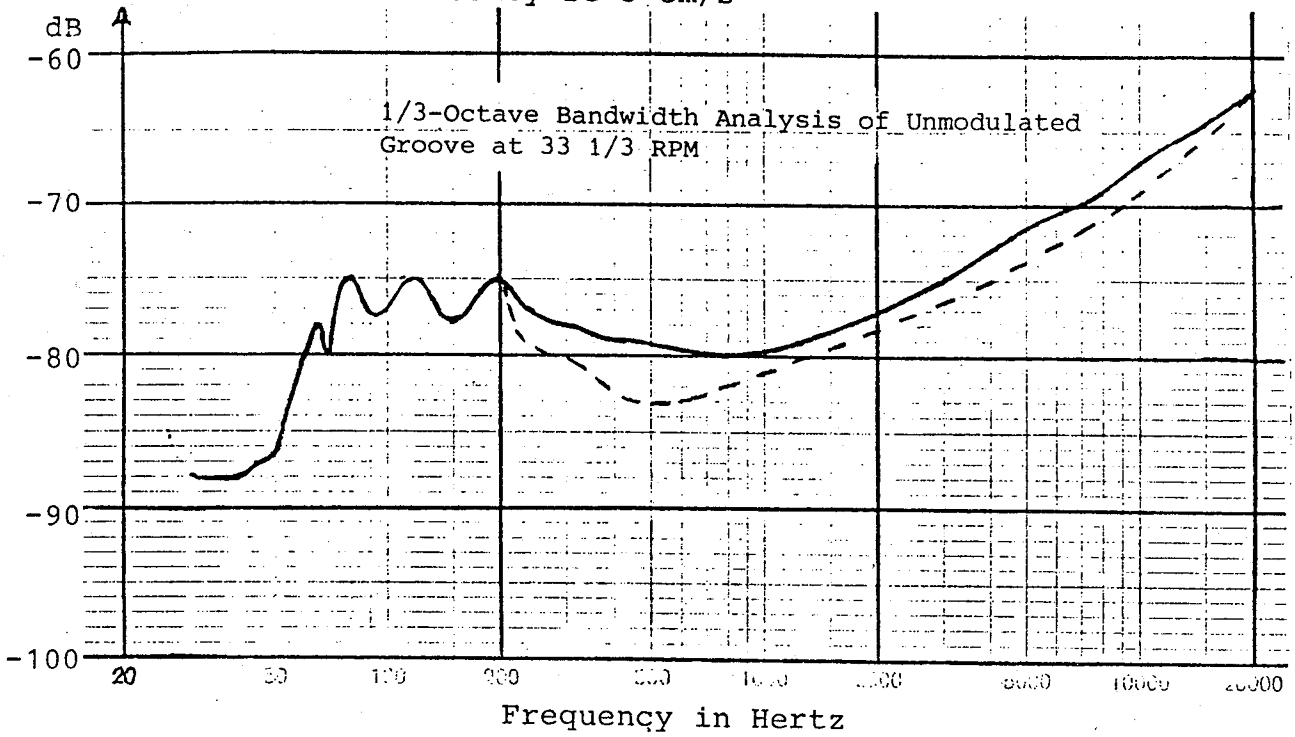


Figure 8.5 - Pressed Vinyl Disc Noise
RMS Lateral Noise Velocity re 5 cm/s



——— 10½" diameter; ------- 6" diameter

figures 8.3 and 8.4. The figures also show that it is primarily high frequency noise which is reduced by the use of a heated cutting stylus. The curves shown refer to the lacquer original. However, during the production of matrices and the pressing of records, the dynamic range is further deteriorated because of impurities in the record material and the impact of electrolytic baths in connection with the production of matrices. Figure 8.5 shows a corresponding noise analysis of the finished product. The main part of the increased noise seems to derive from the production of the master original (plate), see chapter 3.

The measurements of the random noise on records refer to a steady rate of modulation corresponding to 3.54 cm/sec. rms for each channel. During the recording of the records, however, the high frequencies are preemphasised as shown in figure 3.4, and corresponding equalisation is therefore provided for in the play-back amplifier (see table 8.2).

If, therefore, the measurements in figure 8.5 are corrected accordingly, an A-weighted noise level which is more than 63 dB below a reference level of 50 mm/s per channel at 1 kHz can be found. (On average, the reference level corresponds to the long-term means level of the recorded signal). Thus, the dynamic range of gramophone records is up to the dynamic range of tape recorders for normal non-professional use. But it must be remembered that the conditions mentioned here refer to gramophone records which have been treated with care at all stages of the production process.

TABLE 8.2

Recording and reproducing characteristics

Recording - Relative level (dB)		Frequency (Hz)	Reproducing - Relative level (dB)	
Coarse groove	Fine groove		Coarse groove	Fine groove
—	—	2	− 3.2	− 0.2
—	—	2.5	− 1.3	+ 1.8
—	—	3.15	+ 0.7	+ 3.7
—	—	4	+ 2.7	+ 5.7
—	—	5	+ 4.5	+ 7.6
—	—	6.3	+ 6.4	+ 9.4
—	—	8	+ 8.2	+ 11.2
—	—	10	+ 9.7	+ 12.8
—	—	12.5	+ 11.1	+ 14.1
—	—	16	+ 12.4	+ 15.4
− 16.3	− 19.3	20	+ 13.3	+ 16.3
− 16.0	− 19.0	25	+ 13.8	+ 16.8
− 15.5	− 18.5	31.5	+ 14.0	+ 17.0
− 14.8	− 17.8	40	+ 13.8	+ 16.8
− 14.0	− 16.9	50	+ 13.3	+ 16.3
− 12.9	− 15.9	63	+ 12.5	+ 15.4
− 11.6	− 14.5	80	+ 11.3	+ 14.2
− 10.2	− 13.1	100	+ 10.1	+ 12.9
− 8.8	− 11.6	125	+ 8.7	+ 11.5
− 7.2	− 9.8	160	+ 7.1	+ 9.7
− 5.8	− 8.2	200	+ 5.7	+ 8.2
− 4.5	− 6.7	250	+ 4.5	+ 6.7
− 3.3	− 5.2	315	+ 3.3	+ 5.2
− 2.3	− 3.8	400	+ 2.3	+ 3.8
− 1.5	− 2.7	500	+ 1.5	+ 2.6
− 0.9	− 1.6	630	+ 0.9	+ 1.6
− 0.4	− 0.8	800	+ 0.4	+ 0.8
0	0	1000	0	0
+ 0.4	+ 0.7	1250	− 0.4	− 0.8
+ 0.9	+ 1.6	1600	− 0.9	− 1.6
+ 1.4	+ 2.6	2000	− 1.4	− 2.6
+ 2.1	+ 3.7	2500	− 2.1	− 3.7
+ 3.0	+ 5.0	3150	− 3.0	− 5.0
+ 4.2	+ 6.6	4000	− 4.2	− 6.6
+ 5.5	+ 8.2	5000	− 5.5	− 8.2
+ 7.0	+ 10.0	6300	− 7.0	− 10.0
+ 8.7	+ 11.9	8000	− 8.7	− 11.9
+ 10.5	+ 13.7	10000	− 10.5	− 13.7
+ 12.2	+ 15.6	12500	− 12.2	− 15.6
+ 14.3	+ 17.7	16000	− 14.3	− 17.7
+ 16.2	+ 19.6	20000	− 16.2	− 19.6

8.3 Cutting Characteristics and Signal Corrections

In chapter 3 it was mentioned that, to take the playing time of the records sides and the signal/noise ratio into account, the signal is preemphasised during cutting, and the signals are then correspondingly de-emphasised during the play-back. The recording characteristic is an international standard and is shown in figure 3.4 and in table 8.2. The recording characteristic, i.e. the relation between the modulation velocity of the recorded signal in proportion to the amplitude of the signal to be recorded, is determined by

$$N = \left\{ (1 + w\tau_1)^2 \frac{1 + (w\tau_3)^{-2}}{1 + (w\tau_2)^{-2}} \right\}^{\frac{1}{2}}$$

or

$$N(dB) = 10 \log(1 + (w\tau_1)^2) - 10 \log(1 + (w\tau_2)^{-2}) + 10 \log(1 + (w\tau_3)^{-2})$$

where $w = 2\pi f$ and τ = time constant

where the three time constants for 45 and 33 1/3 rpm recordings are determined by

τ_1 = 75 µS ; τ_2 = 318 µS ; = 3180 µS

corresponding to the cutoff frequencies

f_1 = 2120 Hz f_2 = 500 Hz f_3 = 50 Hz

For 78 rpm recordings the time constants are

τ_1 = 50 µS ; τ_2 = 450 µS ; τ_3 = 3180 µS

respectively.

In table 8.2 the IEC (International Electrotechnical Commission) recording and play-back characteristics are shown, which depart from each other in that the play-back only is specified below 20 Hz, thus adding a fourth time constant of 7950 µS.

With respect to the recording characteristic, no final decision is available in the case of quadraphonic recordings. The level of the pilot tone and the side bands must be substantially reduced because of the preemphasis, and there is therefore a possibility of standardising at a lower value of τ_1. In recent years the surface noise has been substantially reduced as a consequence of improved technology applied at the cutting, matrix production and pressing stages, and modern music also contains stronger high-frequency signals. This all speaks for a reduction of τ_1 and a change of the value of τ_1 to 50 µS must be considered for future normal 33 1/3 rpm records. Moreover, such a change will provide for better tracking of the pick-up stylus, less geometrical distortion etc.

In addition to this recording characteristic other corrections are made in the signal to compensate for the well-known tracking errors at the play-back. The tracking errors depend on the modulation amplitude and the curvature radius of the stylus.

Therefore, exact compensation (equalisation) of the signal is only possible if the curvature radius of the pick-up stylus is known. The tracking errors partly consist of a linear distortion of the signal amplitude, partly of non-linear distortion (harmonic distortion and intermodulation). The linear distortion causes the high frequencies to fall at small groove radius values. Generally, the compensation is made by giving the recording characteristic an extra rise at small groove radius values independently of the modulation velocity. The rise is approx. 2 - 4 dB at 10 kHz. The non-linear distortion can be diminished by means of the previously mentioned simulators, where the distortion products are sent in phase opposition to the main signal.

In addition to the above signal corrections, which have the purpose of diminishing the resultant distortions in the system, other corrections and steering of the cutterhead are made in order to obtain the longest possible playing time for each record. The records are therefore cut with a variable - signal controlled - groove pitch and depth. If the groove pitch is kept constant, it must be determined by maximum amplitudes, and the playing time of a 30 cm record (33 1/3 rpm) would then be approx. 12 minutes. Therefore, the pitch is controlled in step with the modulation, in that, by means of an extra tape head on the tape recorder which plays back the master tape in advance (preview), the sum signal is played back one revolution before the signal is cut. The sophisticated versions of this system will also have a memory, storing information of the signal which was recorded one revolution earlier. These changes of the groove pitch correspond to the effect of a signal being superimposed at some low-frequency amplitudes around 0.5 - 1 Hz, which cannot be reproduced by a play-back system anyway. In this way the playing time can be increased from approx. 12 minutes to approx. 25 - 30 minutes.

Similarly, a simultaneous change of the cutting depth is made. To ensure that the pick-up stylus is in contact with both groove walls at any time, IEC Publication 98 (1964) prescribes that the groove width must be larger than 25 µm. A vertical modulation of a 50 µm peak corresponds to a maximum groove width of 225 µm and a stationary width of 125 µm. As the vertical modulation corresponds to the difference signal, and this seldom comprises any strong low-frequency signals, it is not necessary constantly to cut deeply into the lacquer original. It is desirable that the cutting depth is not larger than necessary, not least out of regard to the durability of the cutting stylus. It is therefore a normal procedure to vary the cutting depth in step with the modulation of the difference signal according to the principle mentioned above for the sum signal. Several firms go a step further, as they consider a strong low-frequency signal undesirable. Therefore, before the recording is made, the low frequencies of the difference signal are reduced (below approx. 200 Hz) with a correspondingly minor stereo effect in the frequency range as the consequence. A few firms automatically compress the low frequencies, and some use a level-dependent hi-pass filtering, which could possibly be compensated for in the play-back amplifiers.

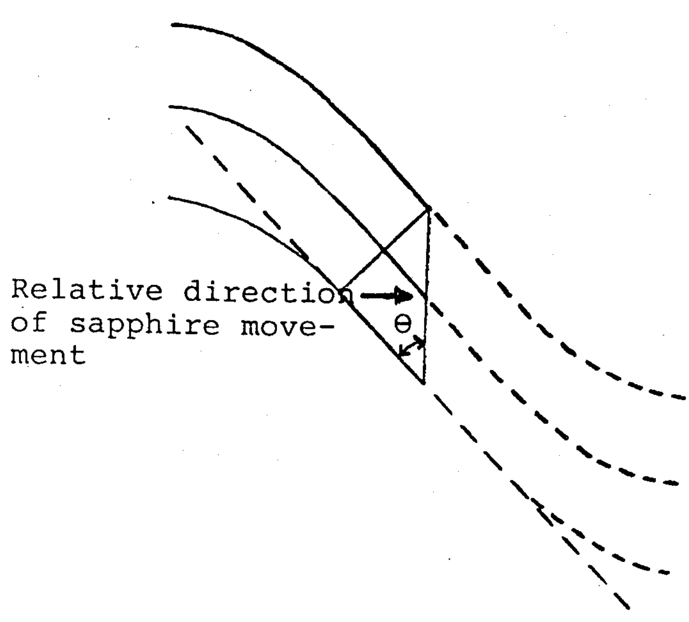
It is important that the pitch is not too narrow, either, because it may create preecho. This phenomenon is probably owing to the elasticity of the lacquer material and the following deformations from the cutting, cf. section 8.1. However, most preecho faults occur at the pressing stage.

8.4 Maximum Levels of Ortofon Cutterheads

For low frequencies the level is determined by the mechanical stop of the cutterhead, which allows for a movement of 150 µm peak-to-peak. At 1 kHz an amplitude of 50 µm will give a signal which is 16 dB above 5 cm/s at the same frequency.

In the mid-range, the level is limited by the geometry of the cutting sapphire relative to the velocity of the record material. The limitation, which is illustrated in figure 8.6, appears when the movement of the sapphire is so fast in relation to the record material that the sapphire cuts with the back edge.

Figure 8.6
Limitation in Cutting Velocity Because of Back Edge



The combination of level and frequency at which this will happen depends on the radius of the record, because the velocity of the material also depends on that. If the angle between the back and cutting edges is 45°, the maximum velocity in the inner and outer groove of an LP (33 1/3 rpm) will be 70.7 cm/s and 170 cm/s (peak) respectively.

The last limitation is the acceleration which can be added to the cutterhead. The continuous load is 1,500 g and the transient acceleration is approx. 10,000 g. All these limitations are combined in figure 8.7.

Figure 8.8 shows what can be reproduced by an elliptical pick-up from the outer and inner grooves and a spherical pick-up from the inner groove, respectively.

Figure 8.9 finally shows the power load which is required to cut 30 cm/s at different frequencies.

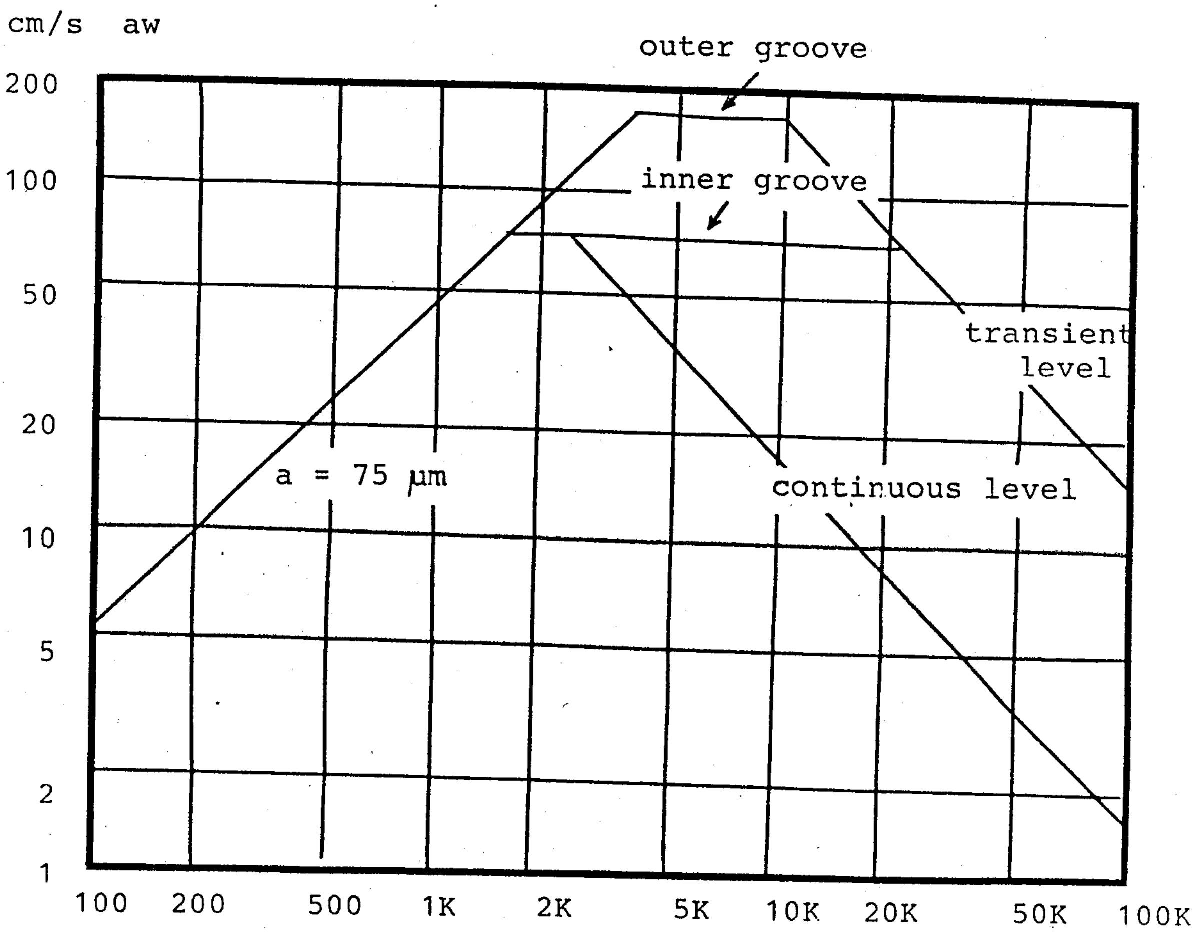
If the outer limits are compared with the IEC-curve, the high end of the frequency spectrum appears to be the most critical one because of the rise of the signal in this frequency range. To avoid the cutting of signals which cannot be reproduced, and to protect the cutterhead, one or other form of limiter is normally used.

Neumann use an accelerator limiter, and Ortofon use a dynamic LP-filter.

Figures 8.7 to 8.9 are repeated with IEC-corrections in figures 8.10 to 8.12 in that the cutting velocity is converted to a line signal.

Figure 8.7

Peak Values for Maximum Cutting Levels
Lateral



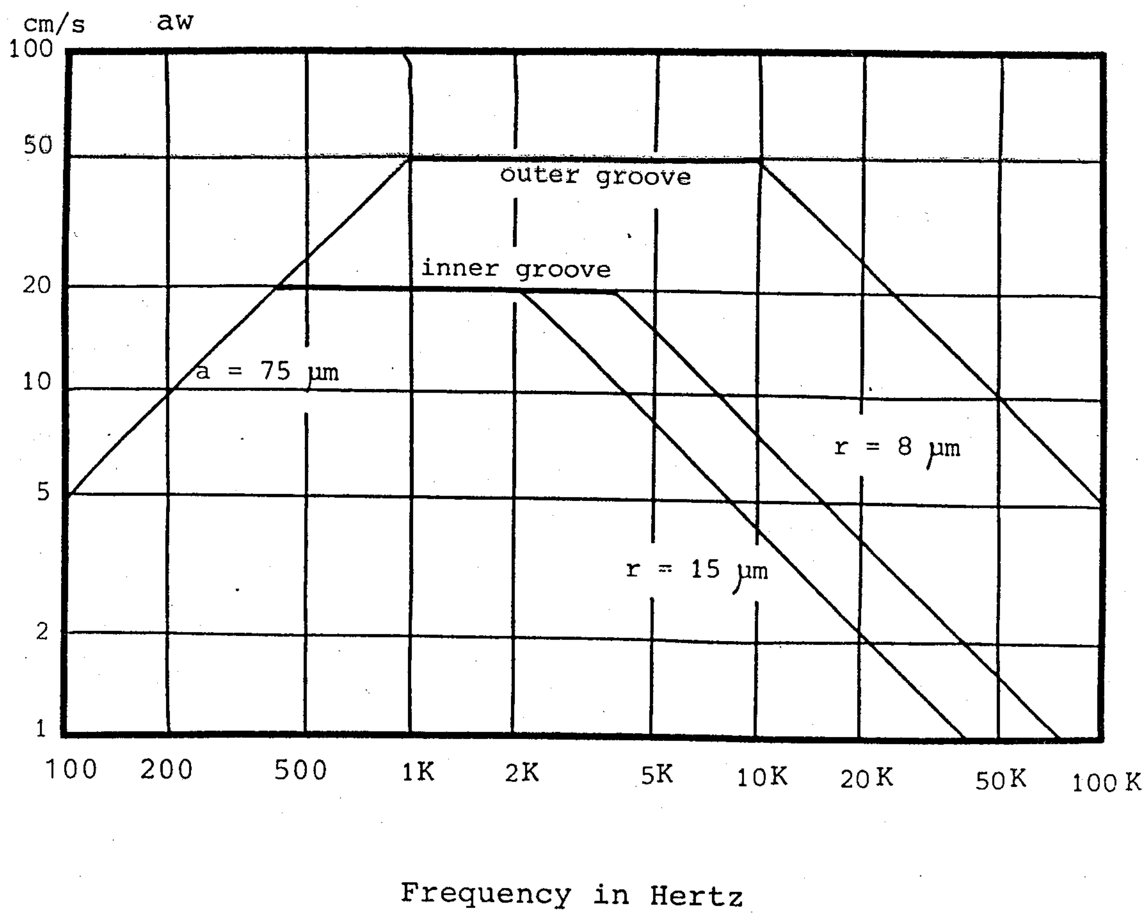
Frequency in Hertz

a : Excursion

w : Angle frequency (2πf)

Figure 8.8

Peak Values of Tracking Ability of Pick-up Cartridge



a : Excursion

w : Angle frequency (2π f)

r : Play-back stylus tip radius

Figure 8.9

Power Requirements for v_{peak} = 30 cm/s (Ortofon Cutterhead)

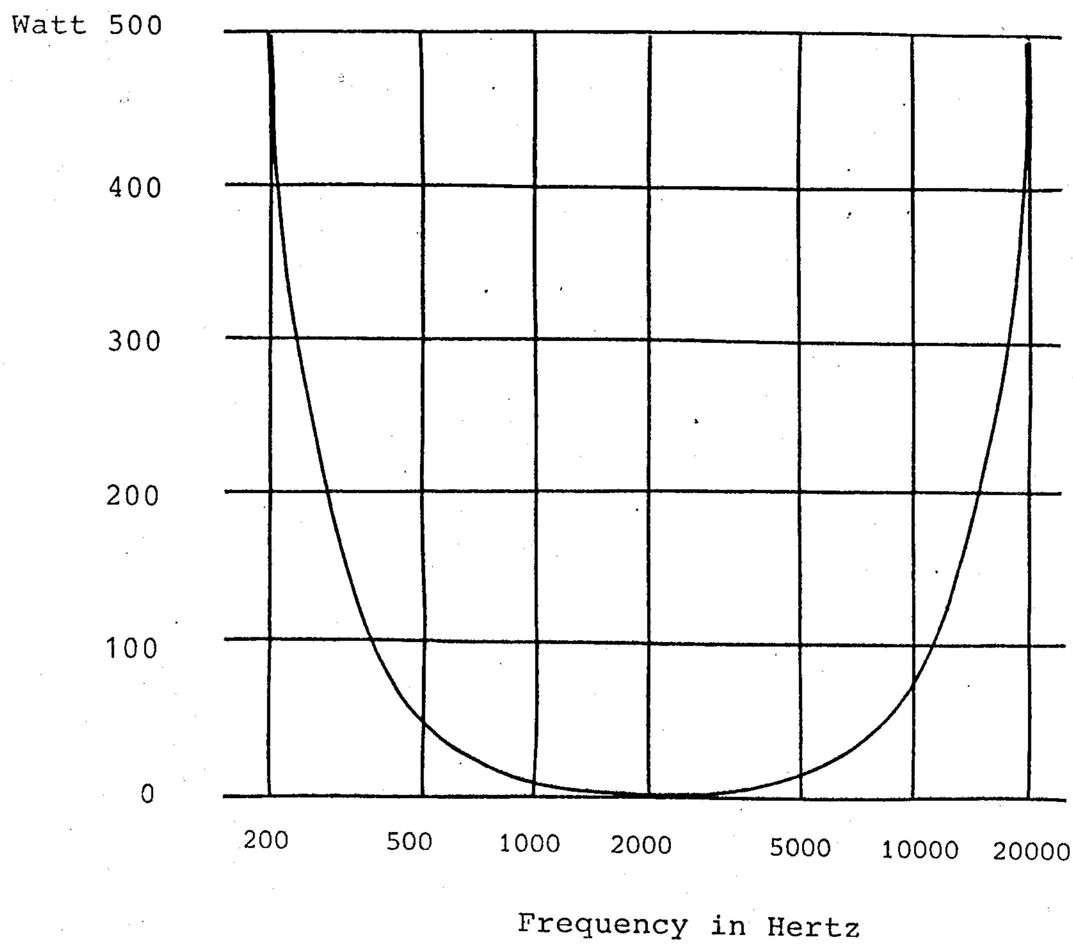
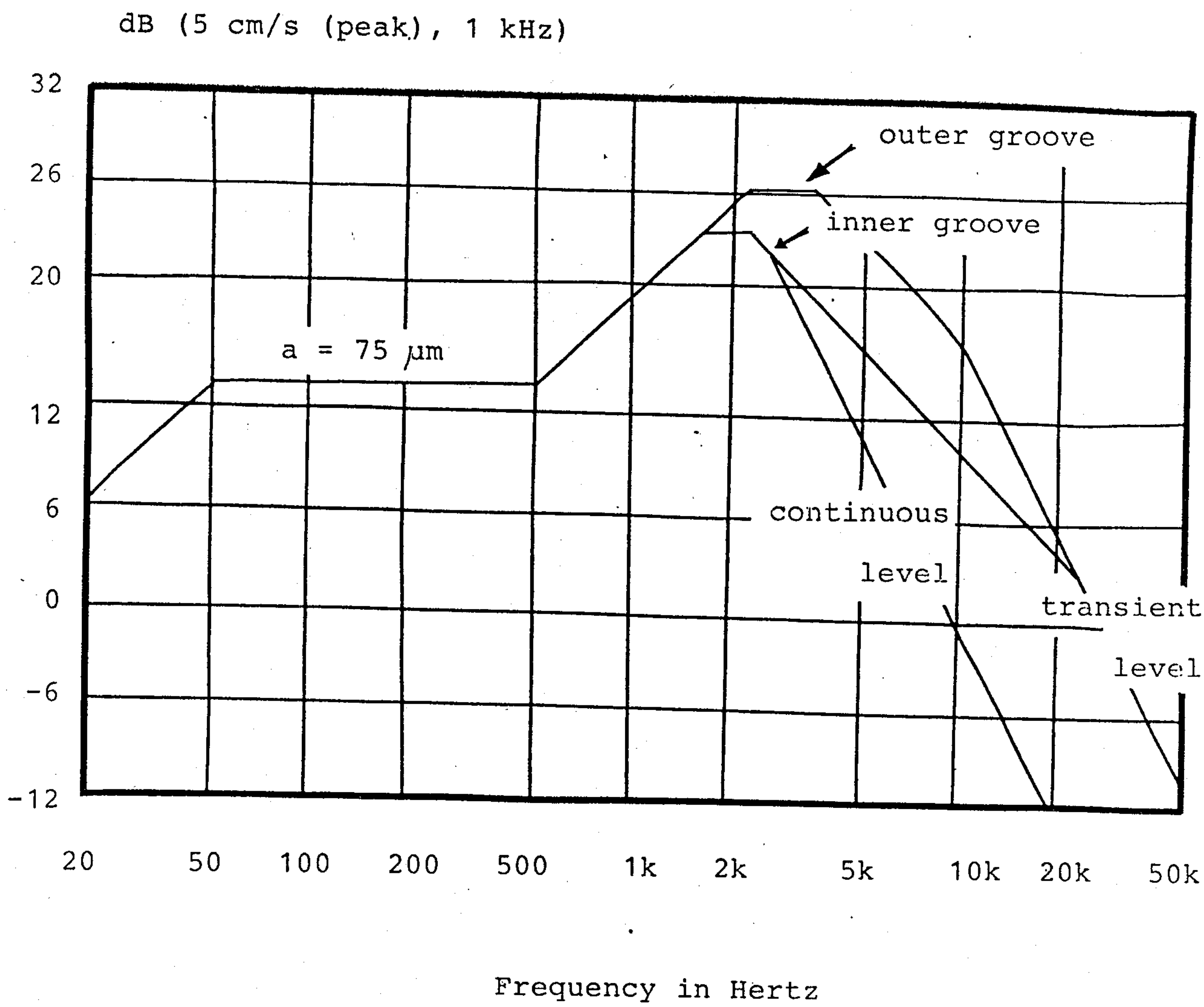


Figure 8.10

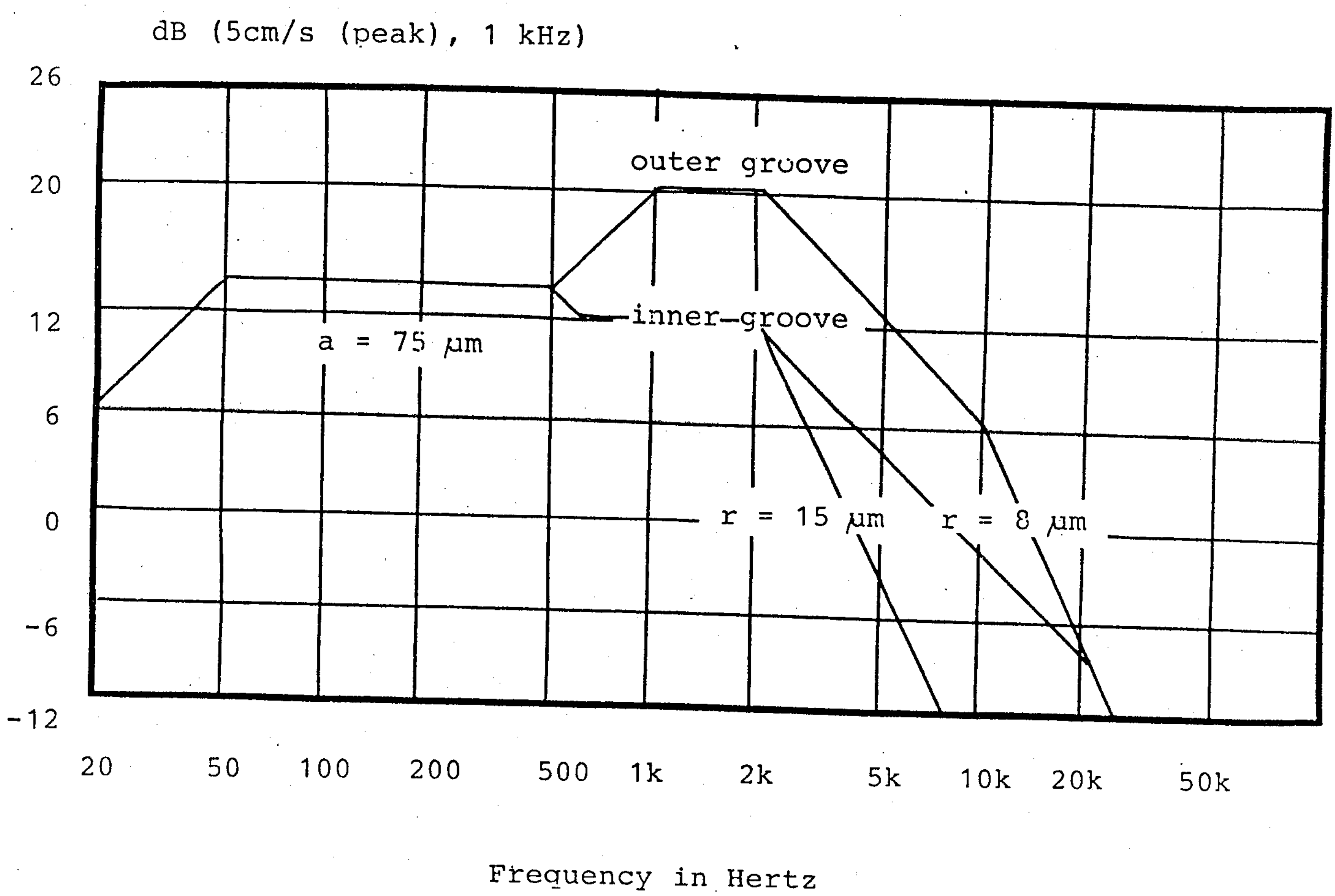
Peak levels for max. cutting velocity lateral (from figure 8.7) converted from velocity to line level by means of IEC Recording characteristic and 1 kHz 5cm/s as reference (0dB).



a : Excursion

Figure 8.11

Peak levels for maximum tracking ability of pick-ups (from figure 8.8) converted from velocity to line level by means of IEC Reproducing characteristic and 1 kHz 5 cm/s as reference (0dB).



a : Excursion

r : Play-back stylus tip radius

Figure 8.12 a

Power requirements necessary to cut a constant line signal (Ortofon cutterhead), which is corresponding to 3.14 cm/s (peak) at 1 kHz. This is 30 cm/s at 20 kHz after IEC pre-emphasis.

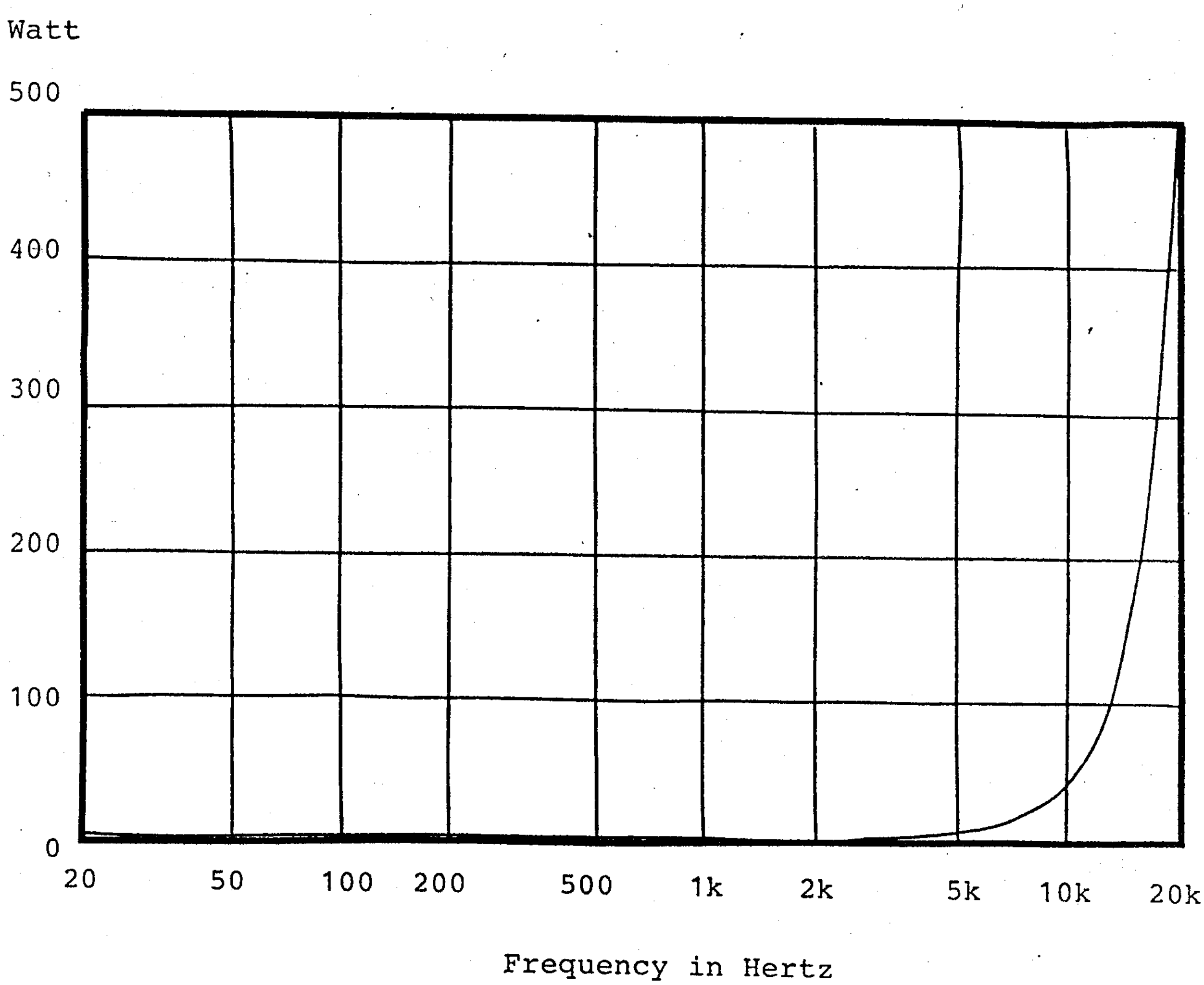
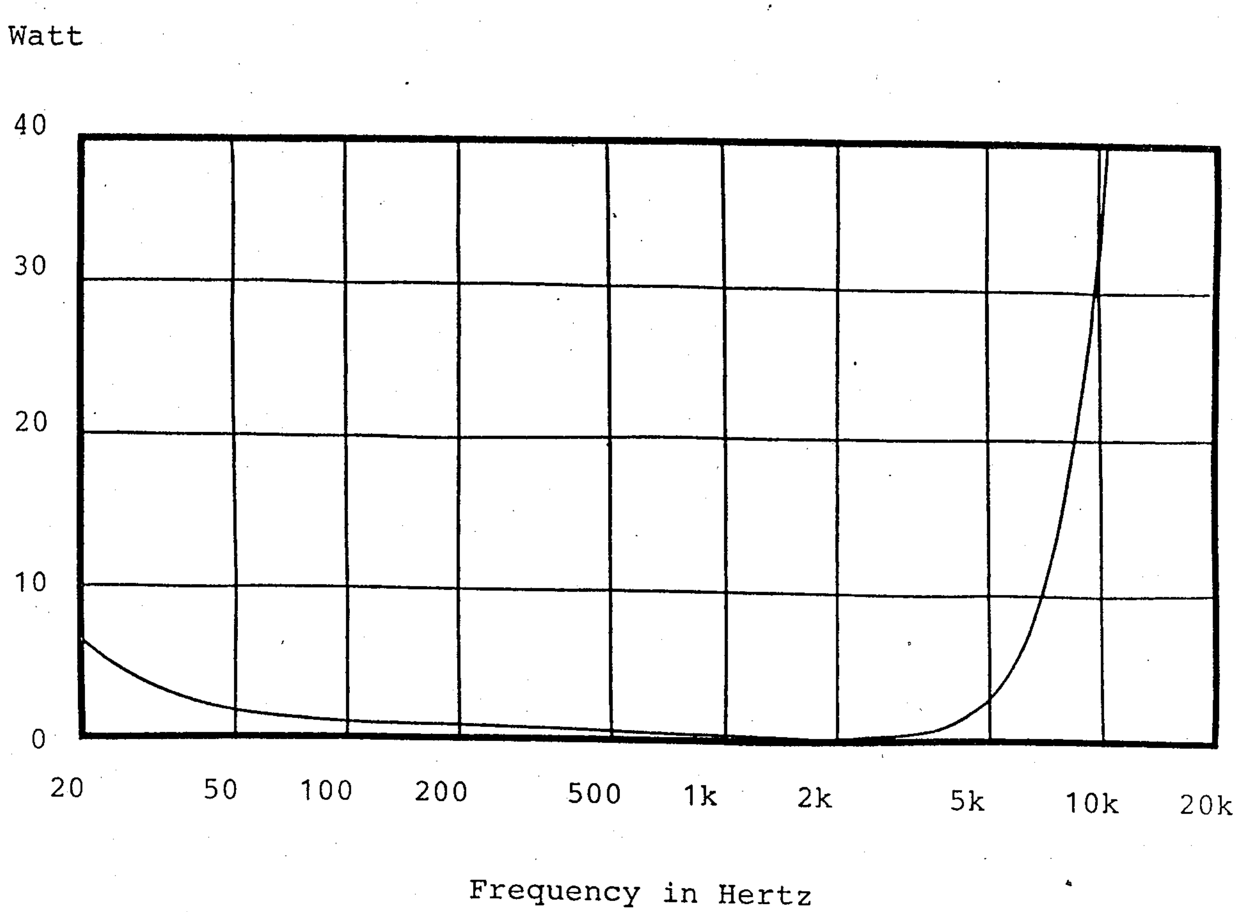


Figure 8.12 b
Expanded scale of figure 8.12 a)

Power requirements necessary to cut a constant line signal (Ortofon cutterhead), which is corresponding to 3.14 cm/s (peak) at 1 kHz. This is 30 cm/s at 20 kHz after IEC pre-emphasis.



CHAPTER 9

How a Cutting Studio is Combined

This chapter discusses the process, by which the signals are transferred from a master tape to a lacquer record. The discussion is based on a standard studio, to which can be added quite a number of sophisticated units. The standard studio described only has the function of transferring sound information from one medium to another without changing it. This means that the possibilities of including the special effects which are used in some studios will not be examined.

Figure 9.1

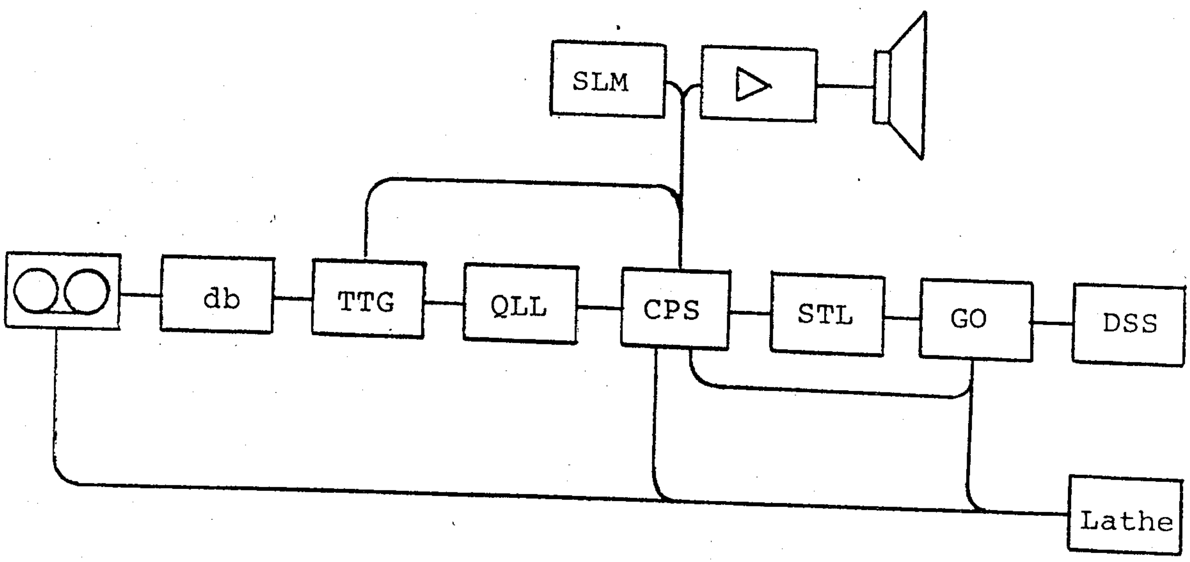
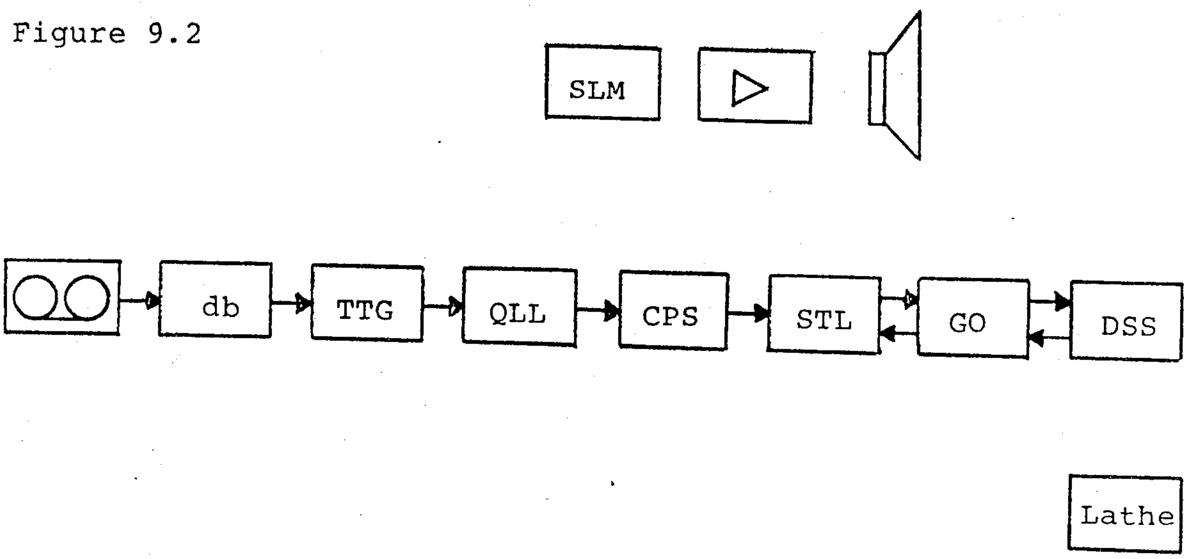


Figure 9.1 shows the units used in our fictitious studio, which has been built up with Ortofon units. Therefore, Ortofon's own names are used for the units. The figure does not show every possible connection between the units, but only those which are connected with each other. The various connections from figure 9.1, repeated in figure 9.6 which combines all the connections, are examined in the following section.

9.1 The Signal Path

The signal path from tape to record is examined, and the various units it passes on its way are described. The signal path is shown in figure 9.2.

Figure 9.2



The source of the signal is the tape, from which the record is copied. It is reproduced by the tape recorder, and the signal is transmitted to the noise-reducing dolby system. If the tape is preemphasized by means of dolby, this unit should be used. Otherwise, it should be switched to by-pass.

The unit used may comprise a Dolby 360, which is a single-channel A-type noise-reducing unit. Unlike a B-type, the frequency range of this unit is divided into 4 bands which are processed individually. On each band the amplification is regulated according to the level. During the recording the amplification is increased, when the level gets below the corresponding flux density of 185 nWb/m (NAB) on the tape. In this way, a larger distance to the random noise of the tape is obtained without changing the maximum output level. During the reproduction the amplification is changed correspondingly, so that the low passages and the noise are reduced. This means that the dynamic range of the music has been reestablished and that the random noise from the tape has been reduced in the low passages. In this way the dolby unit increases the s/n ratio.

The next unit (the TTG) is also a by-pass one. This is a tone generator which is used to line up the system, for which reason the signal is transmitted directly to the QLL limiter amplifier. This automatically regulates the amplification, so that the level does not rise too much above the zero level. The regulation of the release and attack times can be varied individually, i.e. about 1 second for the attack time and 10 seconds for the release time. The release time must be that long so that the amplification is not affected, if a short silent passage occurs. These times ensure that the change of amplification is not audible.

The CPS, a correcting amplifier, provides various test and switching facilities. It is possible to cut off one channel, so that they can be examined individually. It is also possible to invert a channel, so that a tape with 180^{o} phase error can be corrected. Both the level, the stereo balance and the width of stereo information can be varied. Each channel has bass, treble and presence control and various filters. These are low-pass filters in the range of 8 - 15 kHz, a rumble filter and finally a filter (compatible), which reduces the low-frequency stereo information, because large vertical amplitudes make cutting difficult. Finally, it is possible to cut off the output by means of a relay, which ensures that no signals will pass through. This function is used for instance when fast winding the tape.

The next unit, the STL, is a dynamic low-pass filter, whose upper cut-off frequency is changed dynamically during the cutting. The unit is used to limit the level of the high frequencies. This means that it works as an acceleration limiter or de-esser. As there is a limit as to how high an acceleration a pick-up can track, the STL ensures that the record can be played back. The limitation of the acceleration also protects the cutterhead against thermal overloading, because the acceleration is created by the currents in the drive coils of the cutterhead.

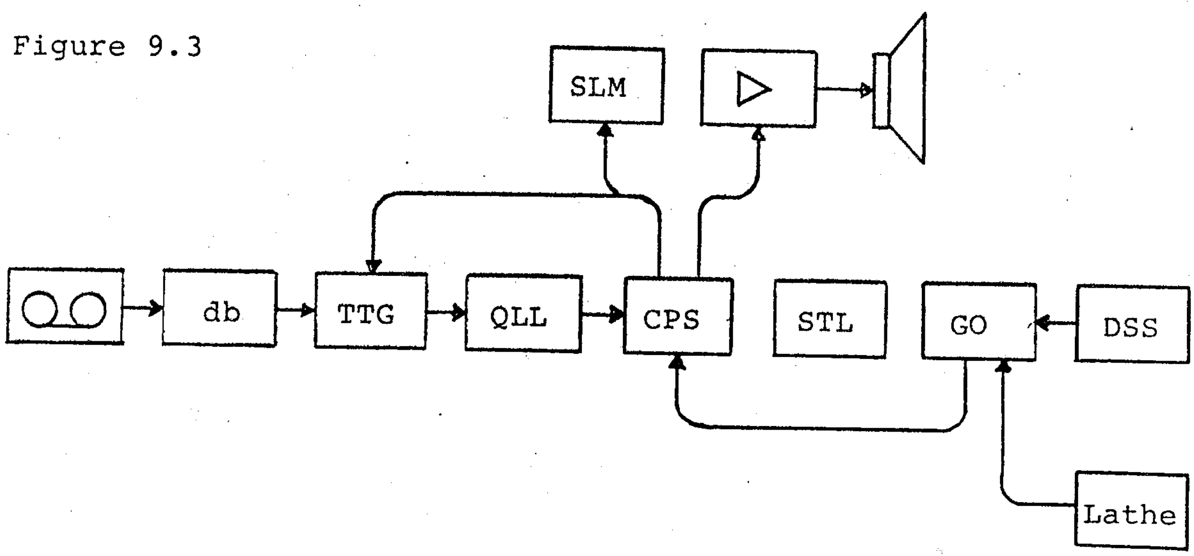
The signal being cut is corrected for RIAA, and the signal used to regulate the STL unit therefore also has to be RIAA-corrected. The regulation signal is obtained from the cutting amplifier (GO), in which a voltage proportional to the cutting current, which is again proportional to the acceleration is generated. The sensitivity of the regulation can be adjusted, as well as the attack and release times.

After this unit the signal is amplified in the cutting amplifier GO, which has the RIAA-correction filters. The cutting amplifier is matched to the cutterhead DSS, and they are coordinated in a closed loop. The loop partly consists of the signal path through the cutting amplifier to the drive coil of the cutterhead, and partly of a signal from the feedback coils of the cutterhead, to the cutting amplifier. The feedback signal registers the actual movement, which, in the amplifier, is compared with the signal fed to the drive coil. The feedback signal is therefore normal negative feedback, as used in a conventional amplifier design. In this way the distortion is kept to a minimum.

9.2 Indication and Monitoring

In order to check the signal which is being cut it is possible to listen to the signal and measure the level both before, during and after the cutting.

Figure 9.3



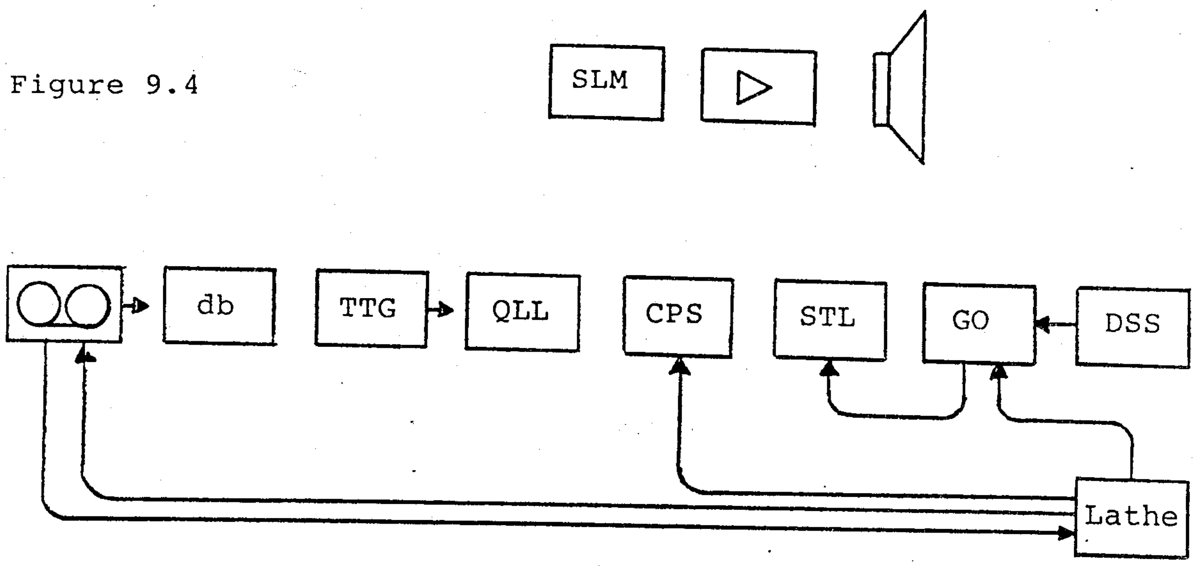
Here, the central unit is the CPS. This unit incorporates switch facilities for listening and metering before, during or after the cutting. If you choose to listen before the cutting, the signal from the CPS output is transmitted partly to the level meters (SLM) and partly to a potentiometer, which regulates the level transmitted to the monitor amplifiers (▷). The monitor amplifiers are linear power amplifiers feeding the loudspeakers which are used to monitor.

If you want to listen to the signal during or after the cutting, the CPS is switched so as to reproduce the monitor signal which comes from the cutting amplifiers. The cutting amplifiers have the option of listening to the signal already cut or to the signal being cut. The signal which is being cut comes from the feedback signal from the cutterhead. (Before it can be used for monitoring, it must pass through an anti-RIAA networks, because the signal cut is preemphasized). If you choose to listen to the signal after the cutting, the signal must come from the pick-up input of the cutting amplifier. However, this signal must also pass through an anti-RIAA networks before it can be used. The two networks are different, because the recording and play-back characteristics are slightly different.

The signal for the pick-up input is transferred from the pick-up which is mounted on the lathe. In this way it is possible to play back the signal cut a groove or so after the cutting.

The signal paths mentioned in the above are shown in figure 9.3.

Figure 9.4



9.4 Test Signals

The test signals are partly the ones used for the calibration of the equipment, and partly those which are transmitted to the units for regulation purposes. Of the latter it has already been mentioned that the STL receives a regulation signal from the GO, so that the filter is adjusted according to the cutting current which is sent to the cutterhead. It has also been mentioned that the feedback signal from the DSS is used to regulate the signal from the GO to the DSS, so that the signal cut becomes as correct as possible. Finally, it has been mentioned that it is possible to play a record on the lathe by means of a pick-up. This method is employed when adjusting the cutting level. The pick-up can be used to compare a reference record with the signal which is being cut, so that a certain signal level gives the required cutting velocity in the groove. The adjustment procedure itself is described in chapter 11.

For the adjustment of the feedback level at the GO a tone generator is used as the signal source. The signal is supplied from the TTG, which is inserted instead of the tape recorder. The procedure is described in chapter 11.

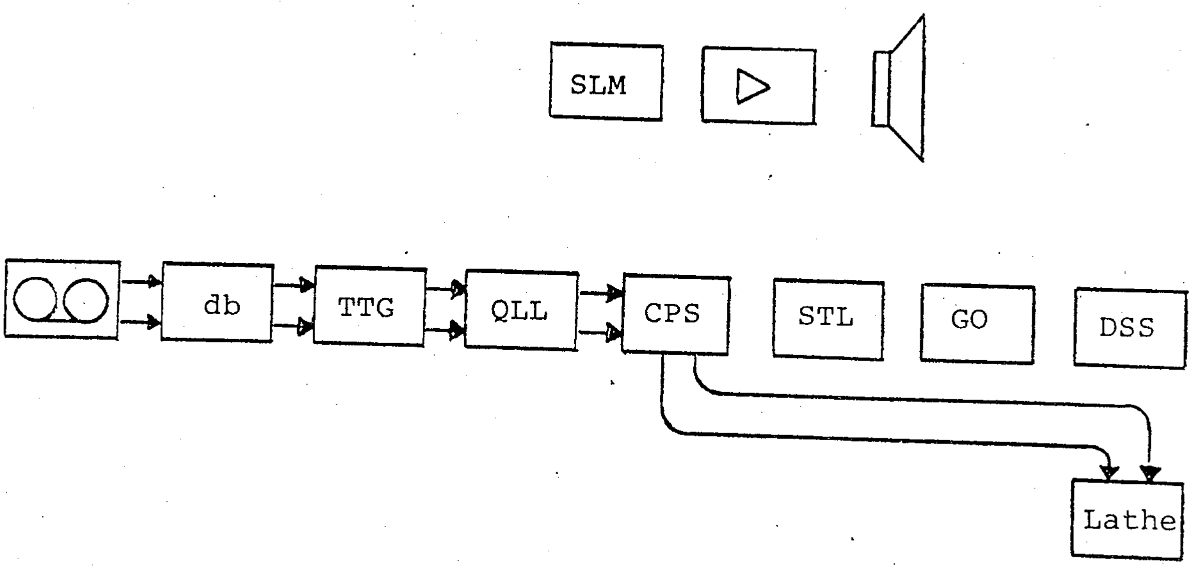
If setting of the other equipment is required, this can be done either by the TTG, or by means of a test tape on the tape recorder, which will allow of testing the equipment at various frequencies and levels.

When the cutting starts, a signal from the cutting lathe will start the play-back of the tape. Shortly afterwards, a signal to the CPS causes its output to open. As undesired signals may appear when starting the tape, the cutting is protected in that the output is disconnected during the start of the tape.

When spacing must be made between two pieces of music during the cutting, a signal from the tape recorder to the lathe starts the spacing, which lasts for a certain pre-set time. When the cutting is ended, there will be a signal from the tape recorder to the lathe, which automatically finishes the cutting.

All the connections mentioned are drawn in figure 9.4.

Figure 9.5



9.5 Preview Signal

In order to save as much space on the record as possible, the pitch and the depth of the cutterhead is adjusted according to the signal levels. A change in the pitch has the effect that an additional signal will be cut which will be played back similarly to the audio signal, for which reason changes have to be made very slowly. This causes a low-frequency signal with a small amplitude, which will not disturb the audio signal, if the frequency is sufficiently low.

Such a change requires some information a reasonable time in advance. This information can be obtained by using an extra play-back head on the tape recorder, and this is placed in an advanced position relative to the normal play-back head. The signal from the head serves as a preview of what will be cut; the size of the land necessary between the pitches can be calculated in order to avoid overcut.

Because the change of width of the groove due to change of depth is twice as great as the change of depth, the cutting depth also influences how much land can be saved. One therefore tries to cut as shallow a groove as possible. However, there are certain minimum dimensions which must be adhered to under all circumstances.

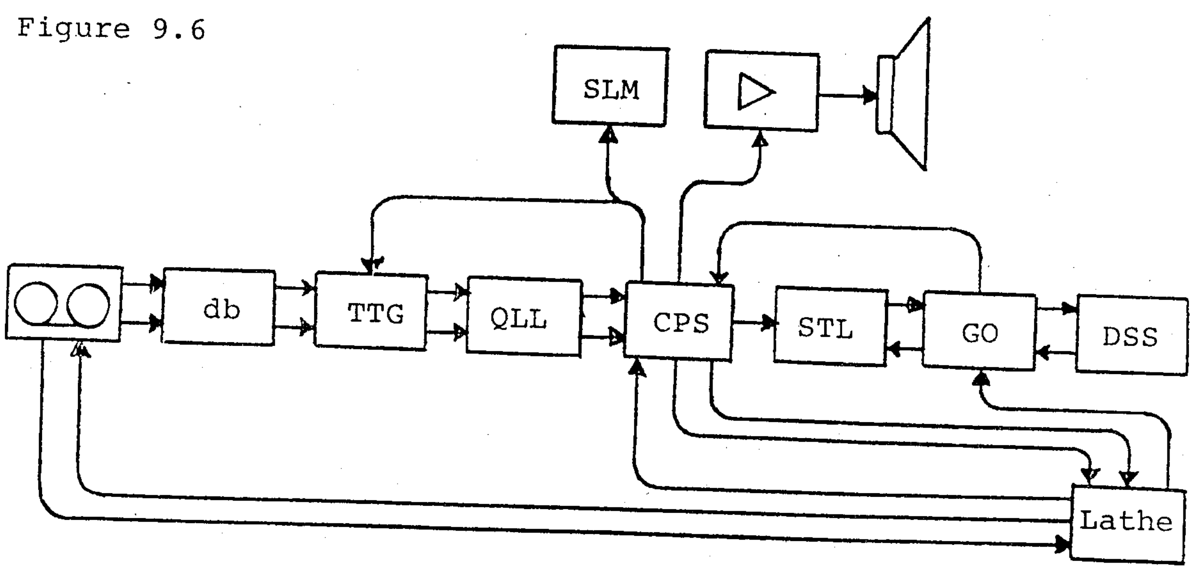
As the stereo information is cut in a vertical direction, the cutting depth is modulated by this signal. The minimum value of the cutting depth must therefore be so sufficient that the minimum dimensions of the groove are kept at the modulated signal, but as small as possible in order to save space. It is therefore necessary to vary the mean value of the cutting depth during the cutting. Here, as for the lateral case, the variation must take place so slowly that no audible signals are cut. This can be achieved, if the preview signal is also used for the regulation of the depth.

This means that the preview signal is used both to regulate the cutting depth and the pitch.

To obtain a correct regulation the level of the preview signal and of the audio signal must be identical for all frequencies. If the audio signal is changed, the preview signal must consequently be changed too, if the automatic controls of the cutting depth and pitch are applied.

Therefore, up to and including the CPS the preview signal proceeds parallel to the programme signal. After the CPS it is transmitted to the lathe, where it is used for the regulation. Similarly, the audio signal used for the regulation is also derived from the CPS. These signal paths are outlined in figure 9.5.

Figure 9.6



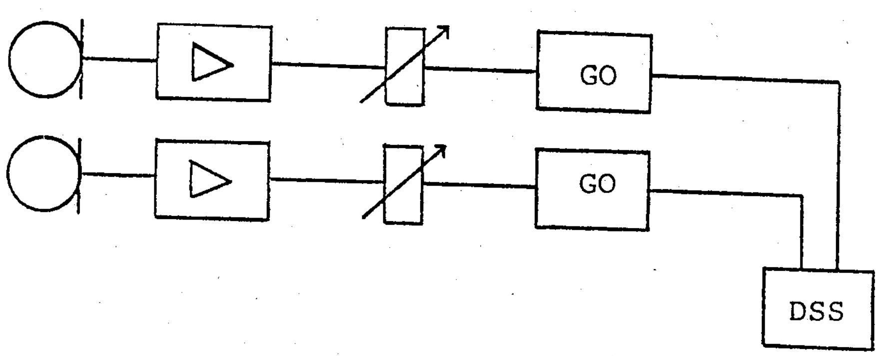
9.6 Summary

The signal paths which exist in our fictitious cutting studio have been discussed in the previous sections. In figure 9.6 these signal paths are coordinated.

Direct-Cut Records

The reason for direct-cut records (i.e., master lacquers) is to get better eventual pressings in respect of the s/n ratio and the frequency range. The idea is to leave out as many links as possible to improve fidelity. As nowadays a tape recorder is one of the weakest links of the system, quite a lot is gained by avoiding using it. The dynamic range is typically 70 dB for the tapes which are marketed today. During the editing of the master tape the noise increases, for which reason the data are typically worse than the 70 dB s/n ratio. Much will also be gained if all the limiters and filters are left out, because they all deteriorate and distort the s/n ratio and the frequency range. This also has the advantage that the phase relationship is fully under control, enabling the use of time delay stereophonics if required. If only 2 microphones are needed, the combination will be as shown in figure 10.1, where the signal from the microphones is led to a microphone amplifier and from there directly to the cutting amplifiers. If several microphones are used a simple mixer console is inserted between the microphone outputs and the cutting amplifiers.

Figure 10.1



No QLL, CPS or STL units are used, and the level must therefore be more cautiously checked under a direct cutting session, as you otherwise run the risk of cutting such high levels that the records cannot be played back with ordinary pick-ups.

As it is not possible to use a preview signal for direct cutting, the automatic control of the cutting lathe cannot be used. This means that the cutting must be made either with a fixed cutting depth and pitch, or they must be regulated manually during cutting.

At a fixed cutting depth and pitch, a playing time of about 12 minutes per LP side is obtained; whereas a manual regulation gives about 17 minutes per LP side.

With the use of Ortofon's cutting equipment, a frequency range from 10 to 26K Hz within ± 0.5 dB can be obtained. If the processing is made very cautiously, i.e. without polishing and few copies, a s/n ratio of about 90 dB is obtainable. Normally, about 100,000 records can be made from a father matrix, whereas, with direct cutting, about 20,000 records is the normal limit to maintain high quality.

It is important to use a high-quality pressing material to ensure that the quality of the lacquer is maintained in the final record. It has been found that some of the record materials developed for CD-4 records are highly suitable, because the demands on the material for CD-4 and direct cuttings are almost identical, i.e. great frequency range and high s/n ratio.

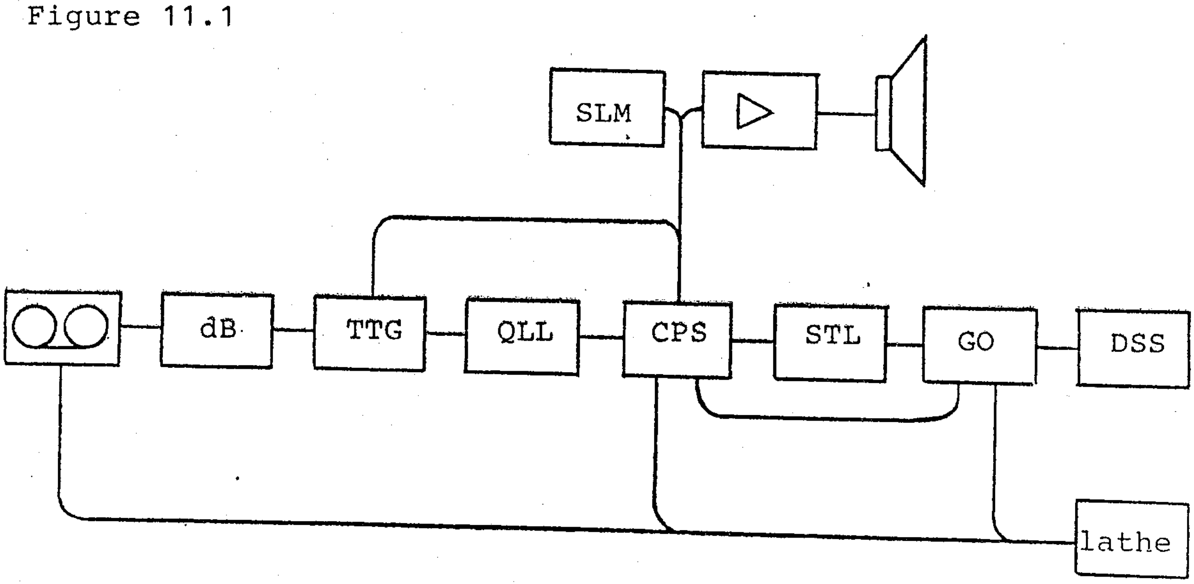
If one is careful, it is therefore possible, by direct cutting, to achieve an improved record quality at the expense of the number of copies.

CHAPTER 11

Adjustment of the Equipment

Before a transfer of the signal from tape to record can begin, the equipment must be properly adjusted. In this chapter we shall discuss the adjustments which must be made at regular intervals, whereas the adjustments which are made at the installation of the equipment will only be mentioned. The examination follows the signal path, and figure 9.1 is therefore repeated in figure 11.1.

Figure 11.1



In order to obtain the full frequency range at the play-back of the tape, it is important that the angle of the play-back head is the same as the angle of the recording head. This angle, the azimuth angle, is therefore adjusted before the play-back begins. This is done in practice by adjusting the inclination of the head by means of a screw. For the adjustment a 10 kHz pilot tone is used which has been recorded beforehand on the tape for this purpose. When the adjustment is correct, the signal level must be at a maximum, and the phase relationship between channels A and B must be correct. - The phase level is used for precise adjustment. Provided that a mono signal has been recorded, the adjustment will be correct when the two signals are in phase.

If the tape has been recorded with the use of dolby, the dolby level must then be adjusted. For this purpose two tones will have been recorded on the tape, namely 1 kHz and 10 kHz respectively. When the dolby level is the same at the play-back as at the recording, the level of the two tones will be identical.

On the limiter both the level which is wanted for line level and the release and attack times found suitable are preset.

On the STL, the threshold level, being the level where regulation starts, and the attack and release times, are similarly preset.

11.1 Adjustment of the Feedback Level

The lining-up of the cutterhead is made by regulating the feedback level, until the frequency range is as required. As reference tone 5 kHz is used. This frequency was chosen because the reference frequency must be so far from the main resonance, which is about 2 kHz, that the level is not influenced by the resonance Q. Furthermore, it must preferably be placed in the mass controlled range, being the range above resonance. Finally, it must not be placed too high, as the feedback is changing its sign at about 18 kHz, where there is a small rise if correctly lined up. The reference frequency must therefore be reasonably low compared with 20 kHz. 5 kHz is a reasonable compromise between these two limits.

When the cutterhead is correctly regulated, there is a rise of 1 dB at 20 kHz. This rise ensures that the frequency range of a cut lacquer is correct up to 20 kHz, as the RIAA curve prescribes that the amplification must go up by 20 dB/decade above 2 kHz. In practice it is not possible to increase the amplification indefinitely, for which reason a frequency must be chosen where the gain stops rising. As to Ortofon's equipment, a frequency of about 45 kHz has been selected. This has the effect that at 20 kHz there will be a deviation of 1 dB from the RIAA curve, resulting in a corresponding rise in the level here. The adjustment of the feedback level is therefore made by raising the feedback until the level at 20 kHz is 1 dB above the level at 5 kHz.

11.2 Adjustment of the Cutting Lathe

A chosen relation between the line level and the cutting velocity is used as a reference. For lining-up a reference record with a known level and frequency is used. This record is played back with a pick-up, and the level at the GO 741 pick-up amplifier is adjusted to an easily readable value on the level meter. Then, the same frequency is cut with an adjusted cutterhead using the line level which corresponds to the velocity of the reference record.

The cut signal is played back with the pick-up, and the cutting level at the input of the GO 741 is adjusted to obtain the same level as from the reference record. Then, the cutting level is adjusted. In order to get a monitored feedback signal, change from the pick-up to the feedback of the GO 741. After this, the monitor level is adjusted at the same level as the line level, which corresponds to the signal being cut. Finally, change back to the pick-up, and the level from the pick-up is adjusted to the same level as the play-back of the reference level.

An exact relationship between a line signal and the cutting velocity, and between the cutting velocity and the monitor level obtained both from the pick-up and the feedback, has now been established.

11.3 Adjustment of the Cutting Lathe

There are many mechanical adjustments to be made. However, most adjustments only have to be made at installation, and they are therefore not included in this section. Reference is made to the manual which covers the appropriate cutting lathe, and only the points which need special attention will be mentioned here.

The vertical axis of the cutterhead must be perpendicular to the lacquer and exclude any risk of rotation. Further, the cutting angle must be adjusted so as to obtain a correct play-back angle. The height is adjusted to obtain a suitable depth and to ensure that it is in accord with the indicator. The lift-and-drop system is adjusted to make it operate reasonably fast, but it is yet sufficiently damped so that it does not swing up and down during the cutting. Finally, the speed of the turntable must be correct.

11.4 Length of Sapphire

As shown in chapter 6 it is important that the sapphire length is correct. If not, cross-talk is introduced. As appears from formula 6.2, the tolerances acceptable for variations in the sapphire length are very samll. For Ortofon's system a tolerance of ± 0.1 mm, corresponding to a channel separation of 38 dB, is normally accepted. A microscope is used to achieve an accurate mounting.

This paper was made in order to collect, at one place, as many pages as possible on the problems attached to the cutting of records.

The writer has tried to keep the paper in an easily understandable English without the use of mathematical subtleties. The terminology as used in the cutting trade has been employed as far as possible in order to prevent any misunderstanding between readers and people from the trade. The contents cover as many areas as possible in relation to the technical problems which may be relevant in your discussions with cutting engineers.

A more profound exposition of subjects which require a special background has been deliberately left out; the mathematical calculation of tracing distortion can be mentioned as a case in point.

Everybody who wants to increase his knowledge of what happens in a cutting studio and of the natural limits existing during the cutting process should therefore have a chance of using the text. It is also possible for people in the cutting business to benefit from the paper, because it may clarify conditions which may not have been thought of before.

The text is based on educational material from Danmarks Tekniske Højskole, which has been worked out by Knud Rasmussen, Laboratory of Acoustics. The translation into English was made by Kirsten Hauberg with Tony Batchelor (owner of TAM Studio, London) as the consultant. I want to express my thanks for their great effort.

Frits Nygaard