7001

# INSTRUCTIONS AND APPLICATIONS

## Tape Recorder Type 7001

The Tape Recorder has been designed as a two-channel precision laboratory recorder with particular emphasis on frequency transformation. It utilizes the frequency modulation (FM) techniques and the frequency response is DC to 20,000 Hz. Four tape speeds are available with frequency transformation ratios of 4, 10 and 40. A direct recording channel is included for tape identification and data reclaim. To allow for sequential analysis of nonstationary signals a variable length loop adaptor is supplied with the instrument. The instrument itself is of a compact solid-state design with plug-in card construction. Both recording and reproduce heads are of the long life ferrite type. The control panel is removable for remote operation.




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# Tape Recorder

## Type 7001

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# Contents

# 1. Introduction

## General Introduction

Magnetic tape recording has proved to be of immense value in modern society. From its early beginning in 1898, when the danish scientist and inventor Valdemar Poulsen demonstrated his first "telegraphone", and up to modern instrumentation tape devices a tremendous amount of scientific effort and ingeniuity has been laid down in modifying and improving the magnetic recording and reproducing technique.

Even though there are many limiting factors in modern tape recording the ability of such systems to store information for later analysis, to expand and compress time scales, and, by multichannel recording technique, to preserve time coincidence between events has made the magnetic tape recorder a key instrument in today's instrumentation systems.

The continuous improvement of magnetic recording technique over the last decades has resulted in the development of various recording principles, such as direct recording, frequency modulation, pulse coding, pulse width modulation, amplitude modulation etc.

All of these types of recording techniques have their advantages and disadvantages, but the most widespread recording principles used for general purposes and analog measurements today seem to be the direct recording (with high frequency bias) and the frequency modulation techniques.

If the recorded (analog) data are to be stored for later ordinary spectrum analysis of single samples the direct recording technique is the simplest and most economical type of data preservation.

On the other hand, if very high amplitude stability is required, or if the stored data are very low frequency vibrations or contain necessary DC (static) information the frequency modulation (FM) technique is far superior to direct recording.

Due to this superiority of FM recording in analog measurement systems the Tape Recorder Type 7001 utilizes the FM technique and great care has been taken in the development of the Recorder to achieve optimum performance and reliability of its various components.

## The Principles of FM Magnetic Tape Recording

In most practical FM*) magnetic tape recording systems the input signal frequency modulates a carrier frequency oscillator of frequency $f_0$ to a

*) For a brief explanation of the concept of frequency modulation the reader is referred to Appendix A.

maximum frequency deviation, $\Delta f$, (frequency "swing") of ± 40 % of the carrier. Furthermore, to obtain a reasonably large dynamic range, even at the highest modulating frequency $f_{max.}$ this is normally chosen to be approximately 1/4 of the *total* frequency deviation (i.e. 20 % of the carrier). All the sidebands necessary for a faithful reproduction of the input signal will then be recorded (see also Appendix A).

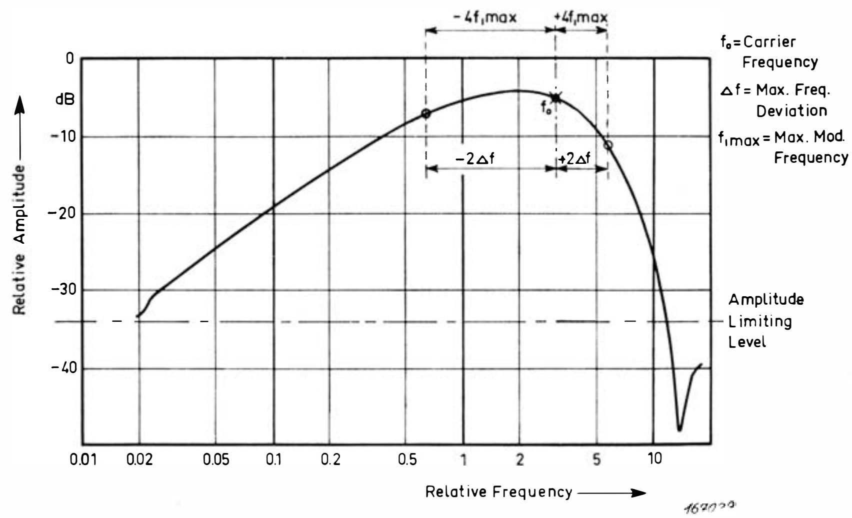


*Fig. 1.1. Typical frequency response characteristic of the reproduce head in a magnetic tape recorder.*
*With constant frequency independent magnetization of the tape and constant tape speed the output voltage from the head will, at low frequencies, increase with frequency because* $e_{out} \sim \frac{d\Phi}{dt}$*. At higher frequencies where the wavelength of the signal present on the tape becomes of the order of magnitude of the head gap width averaging effects take place which cause the output signal* $e_{out}$ *to decrease with increasing frequency. When the signal wavelength equals the effective gab width of the head* $e_{out}$ *should theoretically become zero. At still higher frequencies the averaging effects become predominant and this part of the frequency response curve is not normally used in magnetic tape systems.*

The actual carrier frequency chosen depends basically upon the tape speed and the characteristics of the magnetic head, see Fig. 1.1. In the Tape Recorder Type 7001 the highest carrier frequency used is 108 kHz and consequently the highest input signal frequency component that can be recorded with full dynamic range is approximately 20 kHz.

A maximum tape speed of 1.524 m/sec (60 inches per second) is used.

The choice of carrier frequency, tape speed and input signal frequency range might be regarded as the basic factors in the design of an FM magnetic tape recorder. From these factors, and a careful development of the tape transport mechanism as well as the circuitry used in the record and reproduce electronics, then follows the optimum achieveable dynamic range. The upper limit of this range is set by the so-called deviation ratio*) and the phase non-

*) Deviation Rotation = Maximum Frequency Deviation/Modulating Frequency, see also Appendix A.

linearity in the circuitry while the lower limit is normally determined by the wow and flutter of the tape transport as well as spurious (random) noises inherent in the recorder.

As can be seen from Fig. 1.1 the characteristics of the reproducing process cause the amplitude to vary considerably with frequency. This variation, which in direct recording/reproducing systems is of great importance, is in the case of frequency modulation systems, of practically no importance at all because the amplitude is limited (clipped) anyway before detection of the modulating signal takes place (Fig. 1.1), and the magnetic tape can be magnetically saturated.

Also the amplitude vs. frequency nonlinearity produced by the tape itself due to demagnetizing effects of neighbouring magnetic areas is unimportant in FM systems for the same reason. As stated above, however, phase non-linearities are very important and great care must be taken to minimize and/or compensate for their existence.

The lower limit of the dynamic range is, in single track recording systems. normally determined by wow, flutter and spurious noises.

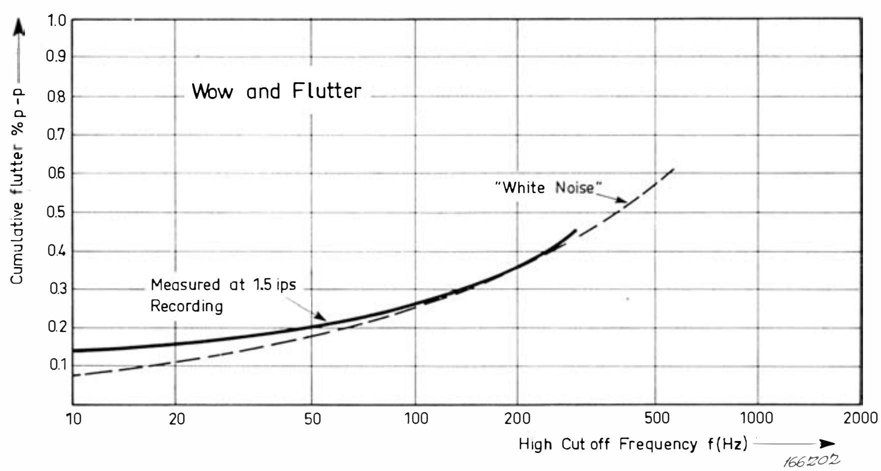


*Fig. 1.2. Typical cumulative noise and flutter characteristic measured at low tape speeds and indicating the dependency of the noise level upon reproduce bandwidth.*

In multi-track recording systems, on the other hand, crosstalk between channels, and a further effect commonly called skew or yaw also enters the picture.

Wow and flutter are affected by many factors: Possible small excentricities in the capstan or pinch rollers, tension variations in the tape, variations in power supply frequency and phase, mechanical vibrations in the recorder, and finally friction effects and tape roughness.

Some of these factors cause periodic flutter components while others are of a more random nature. If the flutter was of a completely random nature and no resonance effects were present in the tape system a more or less white inherent noise would be expected. The output voltage caused by such a noise would increase with the square root of the measurement bandwidth as indicated by the dashed line in Fig. 1.2. In the figure the frequency scale indicates the measurement bandwidth. Actually at low frequencies periodic flutter components and tape system resonances cause the noise voltage, and thus the lower limit of the dynamic range, to vary with measurement bandwidth as the curve drawn in full, indicating that the noise is here not completely "white".

The curve shown has been measured on a prototype Tape Recorder Type 7001 with a tape speed of 3.81 cm/sec (1.5 ips). Similar curves for other tape speeds are given in Fig. 2.4.

Crosstalk between channels is mainly determined by the shielding between the sections of the magnetic heads belonging to different channels and the separation distance. As the crosstalk process is basically different for FM and direct recording systems the two FM channels in the Tape Recorder Type 7001 have been separated on the tape by a direct recording track. (The direct recording channel is, however, only meant as a voice channel for marking and identification of special parts of the tape when desired, and is not intended to be used for measurement purposes.) This together with careful shielding of the heads ensures the crosstalk between the two FM channels to be negligible (below the overall inherent noise level) even when one channel is modulated by a DC producing maximum frequency deviation.

Skew (or yaw) is a measure of the phase (or time) errors between the channels caused by the skewing or yawing of the tape as it passes over the heads. This effect is smallest when the tape is recorded and played back on the same Recorder and can normally be ignored. When different Type 7001 Recorders are used for recording and play back the timing error between the channels due to skew may be roughly estimated to be of the order of one tenth of a step pulse rise time, see also "Specifications".

While wow, flutter and crosstalk cause errors and set the lower limit of the dynamic range for one data channel, skew introduces relative errors between two channels and will thus only be of any importance when the channels are used to determine exact phase relationships between two recorded signals.

# 2. Description

## General

The Tape Recorder Type 7001 is designed basically as a two-channel laboratory recorder for frequency transformation purposes. The recording principles utilized in the two measurement channels is based on frequency modulation (FM) technique while an extra voice channel, which is included for marking and tape identification purposes, employs ordinary direct recording.
A loop adaptor allows detailed analysis of special parts of a recording and four different speeds make it possible either to bring very low frequency signals up into the analysis range of modern analog frequency analyzers,

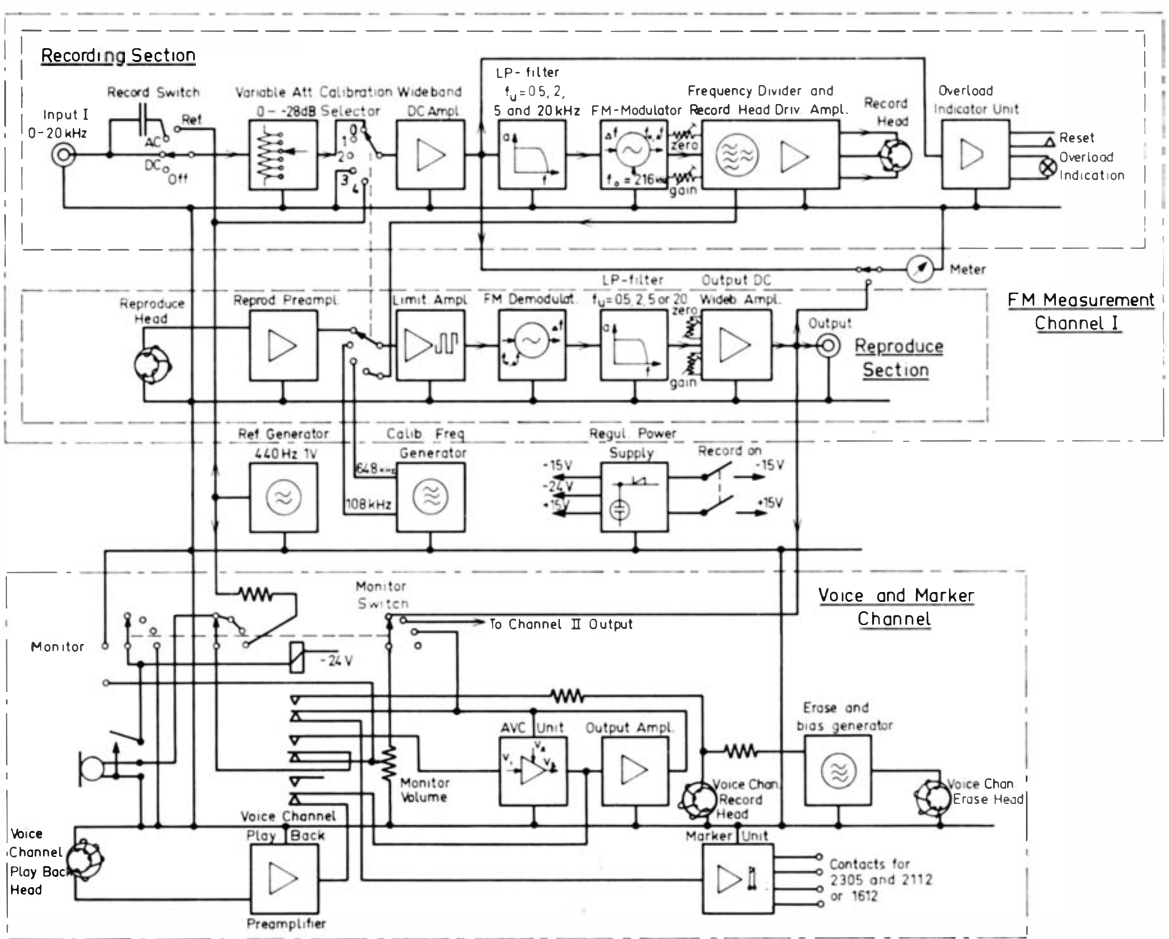


*Fig. 2.1. Block diagram of the signal converter and amplifier sections of the Tape Recorder.*

or to bring more high frequency signals down to the range of direct graphic pen recording. Typical fields of application are shock, vibration and noise measurements as well as room acoustic model experiments. Also the recording, storing and analysis of two time-interdependent phenomena are possible due to the two measurement channels.

To avoid overloading, both measurement channels are equipped with peak responding meters for signal level control, and special overload indicators are triggered if the maximum recording level has been exceeded, see block diagram, Fig. 2.1. In the block diagram only one FM-channel is drawn up together with the voice channel. The second FM-channel, however, is identical to the one shown.

Fig. 2.2 shows the frequency response of a single FM-channel while Fig. 2.3 indicates typical differences in the phase response*) of the two channels contained in one Tape Recorder Type 7001. Finally, Fig. 2.4 shows typical inherent noise and flutter curves measured as a function of the reproduce bandwidth. The wide band dynamic range is of the order of 48 dB. If the recorded signal is to be frequency analysed the dynamic range will, to a certain extent, depend upon the analysis bandwidth. Measurements indicate

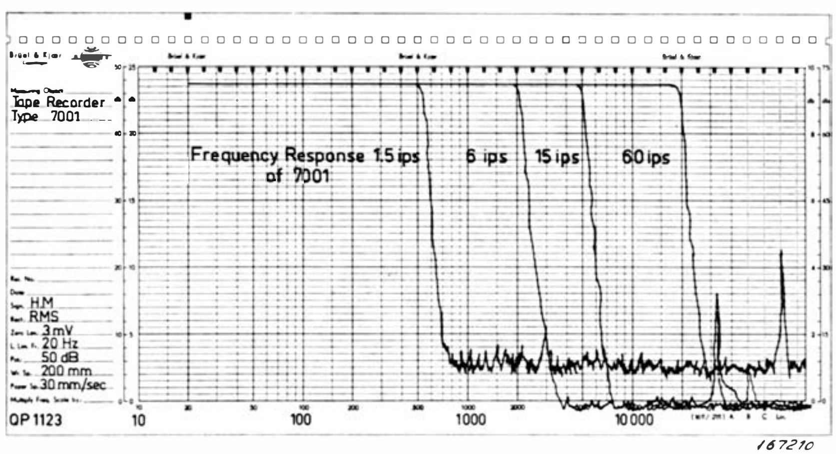


*Fig. 2.2. Typical frequency characteristics of the Tape Recorder Type 7001 valid for various tape speeds.*

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*) The lines shown in Fig. 2.3 represent limit cases for the phase difference to be expected between the two measurement channels. To measure the actual phase difference the inputs to the two channels should be connected in parallel and the frequency of the input signal swept from 0 Hz (DC) to the upper limiting frequency corresponding to the tape speed used. The phase difference between the two outputs should then be measured, for instance by means of a double beam oscilloscope, and stay within the two lines in Fig. 2.3 (0° phase difference at 0 Hz and ± 24° phase difference at the upper limiting frequency. 24° phase "error" corresponds to approximately 1/10 of the pulse rise time). The phase difference due to wow and flutter will be of the order of 10°. By manupulating with the mechanical position of the reproduce head it is possible to reduce the phase "error" to the above mentioned 10° and to ensure that the "error" be symmetrical around zero at the frequency of the signal used for adjustment, see also Appendix B.

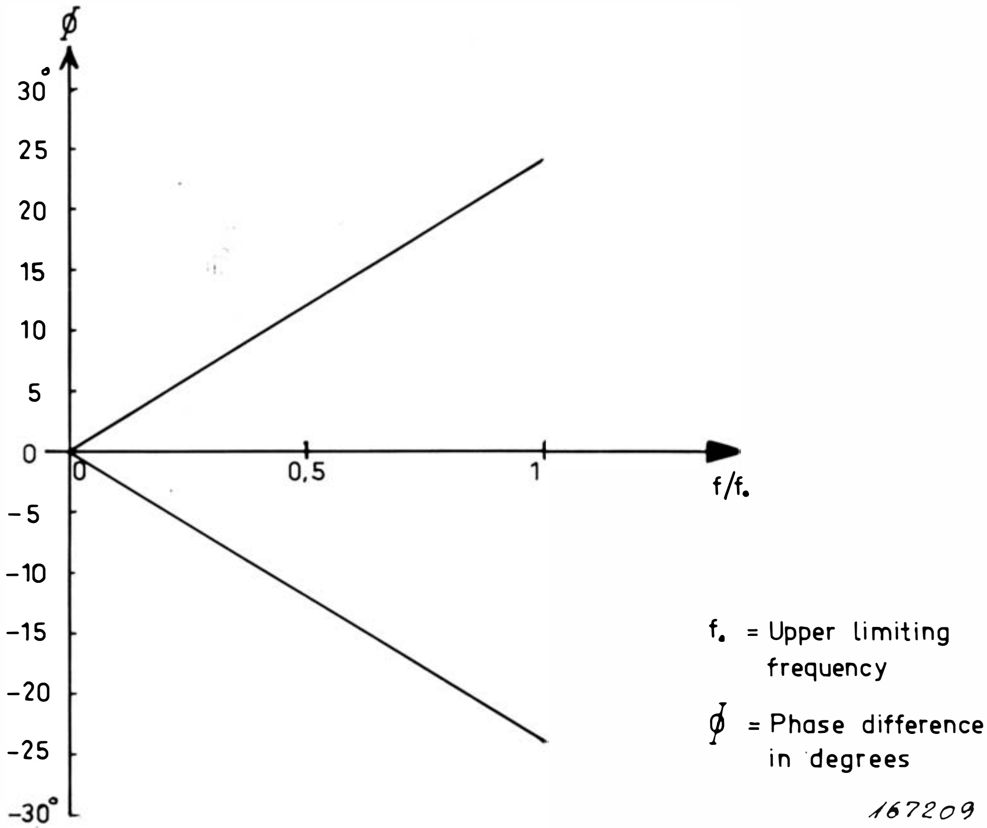


*Fig. 2.3. Limit lines for phase differences between the two measurement channels contained in one Tape Recorder.*

that the dynamic range for one third octave frequency analysis will be as shown in Fig. 2.5a. By still further reducing the analysis bandwidth a dynamic range as given in Fig. 2.5b may be obtained. The analysis was here of the constant bandwidth type, the −3 dB bandwidth used being 8 Hz.

To allow for convenient operation of the tape transport controls, Record-Playback-Stop-Rewind-Fast-Forward and Speed Changes they are all located

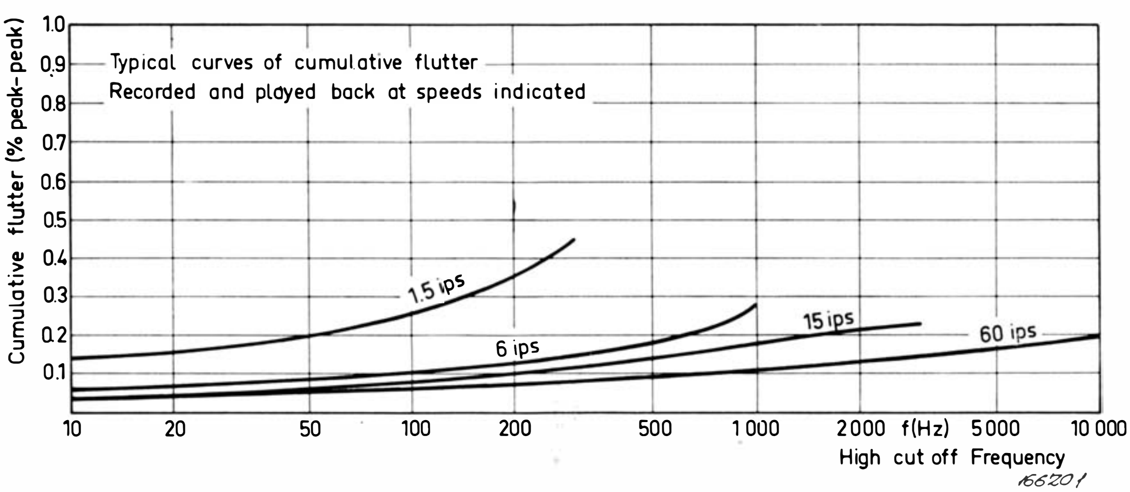


*Fig. 2.4. Typical cumulative noise and flutter curves measured on the Tape Recorder Type 7001 at various tape speeds.*

a.
b.
c.
d.

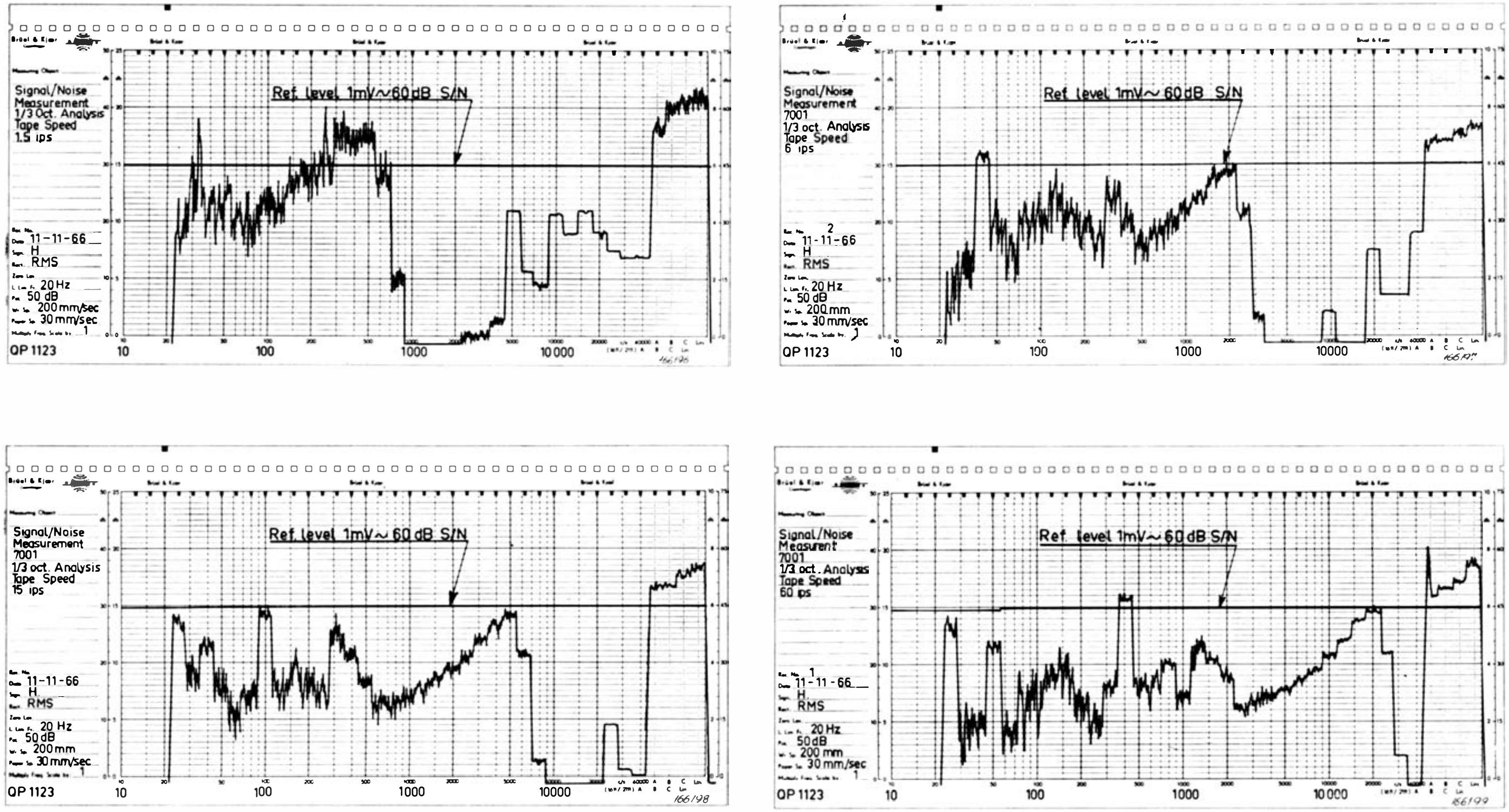


*Fig. 2.5a. Spectrograms showing the results of one third octave frequency analysis of the inherent noise and flutter in the Tape Recorder. The level is here measured in terms of RMS values, re. maximum input signal (1 % distortion level) and level lines of – 60 **dB** are indicated.*

*a) Tape speed 1.5 ips.* *c) Tape speed 15 ips.*
*b) Tape speed 6 ips.* *d) Tape speed 60 ips.*

a. b. c. d.

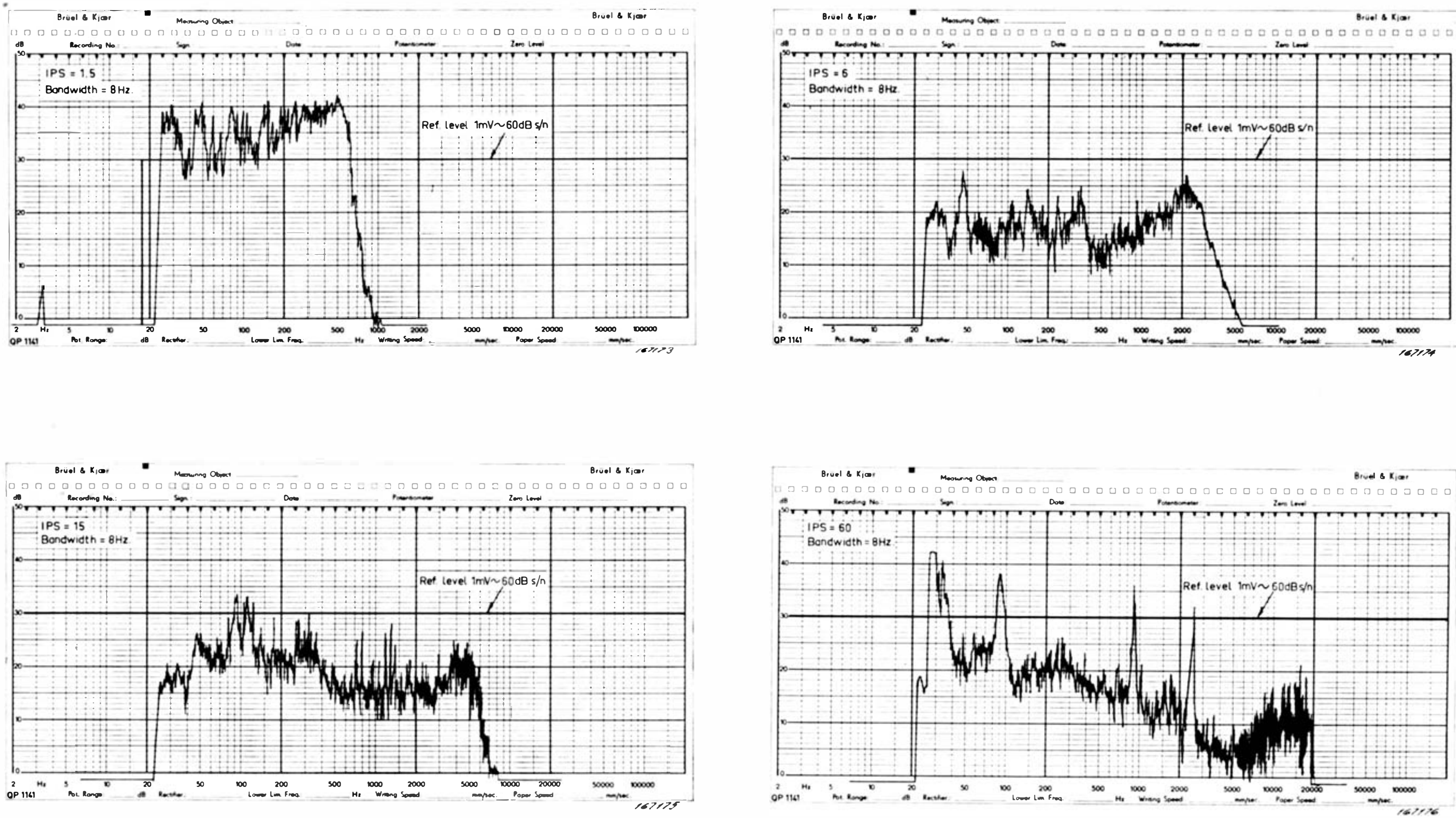


*Fig. 2.5b. Similar to Fig. 2.5a. However the measurement bandwidth was in this case 8 Hz.*

*a) Tape speed 1.5 ips.*
*b) Tape speed 6 ips.*
*c) Tape speed 15 ips.*
*d) Tape speed 60 ips.*

in a small control box which can either be inserted into the front of the instrument, or can be taken out for remote control of the Recorder. The tape reel size to be used is a 26.5 cm (10.5 inches) reel with NARTB hub, or 17.8 cm (7 inches) reel with Cine type hub.
The Tape Recorder is designed to operate in an environmental temperature range of 0 to + 40°C (32 to 105°F).

**Description of the Measurement Channels**
The two measurement channels are identical and utilize the standard FM technique. Each channel consists of a *recording section* and a *reproduce section,* see Fig. 2.1. Separate magnetic heads are used for the recording and reproduction.
The heads are of special construction of glass bonded ferrite material for low wear with gap widths of 3 $\mu m \; {}^{+1}_{-0} \left( 120 \; \mu\text{inches} \; {}^{+40}_{-0} \right)$ for the record head and 1.5 $\mu$m ± 0.3 (60 $\mu$inches ± 12) for the reproduce head.
One should, however, be careful not to damage the polished contact surface of the heads by scratching or by chipping.
In the following a brief description of the various blocks shown in the block diagram, Fig. 2.1 is given, starting with the *recording section:*

From the *INPUT terminal,* which is a standard B & K 14 mm coaxial socket, the input voltage is led to a variable attenuator via a record switch.

The *RECORD switch* should be set to position "Ref.", "AC", "DC" or "Off" depending upon the purpose of the recording, see also "Operation" (or "Control Knobs and Terminals").

The *variable attenuator* is built as a ladder type attenuator and is independent of frequency to within ± 0.1 dB in the frequency range from DC to 20 kHz. Its input impedance is 20 kΩ, which is thus also the recorder input impedance, and a total attenuation range of the input signal of 28 dB is available in the form of fourteen 2 dB steps. The variable attenuator is followed by a *Calibration Selector.*

The *Calibration Selector* has five positions of which two (pos. 1 and 2) serve for the zero and gain adjustment of the reproduce DC amplifier. A further position (3) allows the exact setting of the carrier frequency in the modulator of the recording section while position 4 is used for modulator gain setting.
Finally, position 0 connects the wide band DC amplifier in the recording section to the output of the variable attenuator, i.e. the Recorder is ready for operation when the calibration selector is in position 0.
When the calibration selector is in any position other than 0 the tape transport mechanism is locked.

The *wide-band DC-amplifier* is used for voltage amplification and ensures that a very low output impedance is presented to the succeeding low pass filter and meter circuit. The amplification of the stage is approximately 10 dB and to safeguard the amplifier, input signals higher than 15 volts are automatically clipped. Within the prescribed frequency and dynamic ranges of the Tape Recorder, however, the harmonic distortion in the amplifier is less than 0.1 %. As the amplifier is built as a difference amplifier with a large amount of negative feedback a very high stability (DC drift and temperature dependency less than 0.5 % in 24 hours) has been achieved.

The *low pass filter,* which is connected to the output of the DC wide band amplifier, ensures that only that part of the input signal frequency range which can be correctly recorded on the tape, with the chosen tape speed is passed on to the FM modulator. If a too high modulating frequency was allowed to pass it would result in undesired beat frequencies and would also influence the dynamic range of the recording, see chapter "Introduction" and Appendix A. The low pass filter has been designed as a normal LC-RC filter and the ripple in the pass band is less than 0.2 dB. It is automatically switched to give the correct frequency response by means of the tape transport speed selector. Typical frequency response curves for the low pass filter are shown in Fig. 2.6.

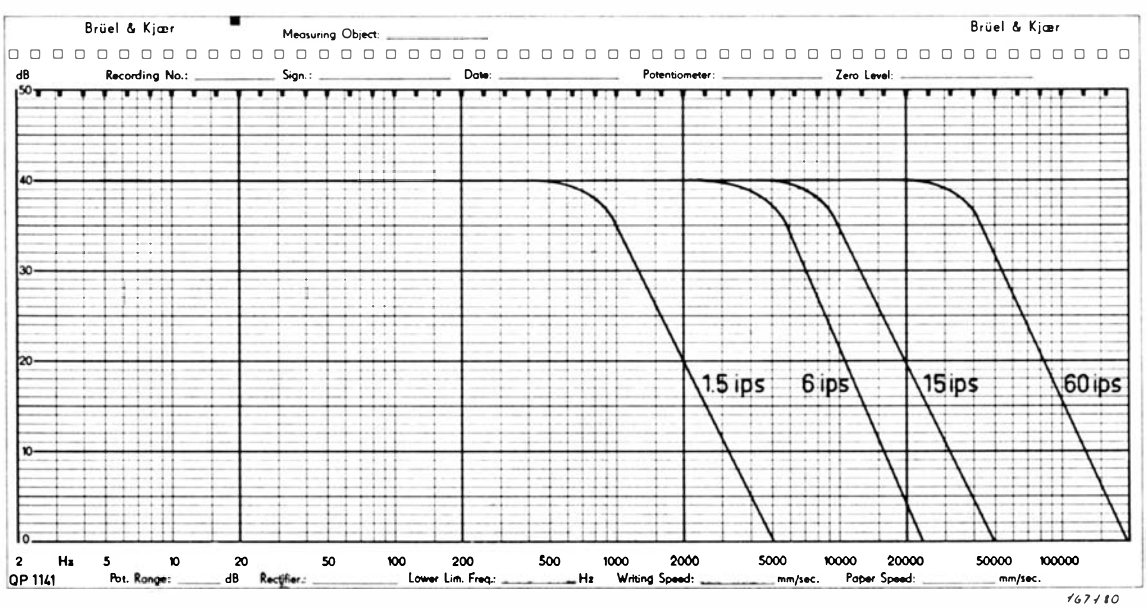


*Fig. 2.6. Typical frequency characteristics for the low pass filters contained in the recording section of the Tape Recorder Type 7001.*

The FM modulator is connected to the low pass filter and consists of an integrating network, a wide band DC amplifier, a signal mixing network, a voltage controlled oscillator, a discriminator drive amplifier and precision limiter, and a frequency discriminator circuit.

In the input to the FM modulator the data signal is mixed with a negative

feedback signal derived from the frequency discriminator output of the wide band DC amplifier. This amplifier, which is of the differential type to ensure low drift characteristics, drives a control current through the cores in a free-running inductive multivibrator. In this way a square wave output signal is produced the frequency of which is proportional to the data signal voltage, i.e. the circuit operates, in essence as a voltage controlled oscillator.
A feedback signal is derived from the output of the voltage controlled oscillator by means of an FM discriminator similar to that used in the FM reproduce unit. This feedback signal is as mentioned above mixed with the data input signal providing an exceptionally stable overall performance and extremely good linearity characteristic for the voltage to frequency convertion.
The center frequency of the FM modulator is 216 kHz and is calibrated against a reference generator as described under "Calibration". Both the carrier frequency and the gain of the FM modulator are adjusted by means of screw-driver operated potentiometers. One of the potentiometers (frequency adjustment) controls the zero-bias current in the magnetic cores of the modulation multivibrator via the bias currents in the DC wide band amplifier stage. The second adjustment potentiometer controls the negative feedback in the amplifier and thereby the gain.
To allow as simple and stable circuitry as possible to be used in the modulator only one carrier frequency (216 kHz) is employed, independent of tape speed. The actual carrier frequency used on the tape is then obtained by frequency division after the modulation process has taken place.

The *frequency divider* used in the Tape Recorder 7001 consists of seven binary frequency dividers dividing the frequency of the "original" FM signal by factors of 2, 8, 20 or 80.
Two of the binary dividers are connected in a special arrangement to achieve a 1 : 2.5 division while the remaining operate as ordinary binary circuits. The last flip-flop also supplies the driving power to the record head. To obtain optimum operating conditions for the tape, the magnetic field produced by the head is adjusted so that it just saturates the tape. If the tape had been "over" saturated it would have affected the crosstalk between the channels, which, in the described arrangement is negligible.
Solid state switches, controlled from the tape speed selector, are used to activate the different flip-flop circuits to ensure correct frequency division.

An *OVERLOAD indicator* has been introduced to avoid overloading of the modulator. It has been adjusted to light up when the input signal peak value exceeds 1.5 Volts. However, as the indicating circuit needs a certain (very small) amount of energy before it will light it will react differently to different kinds of input signals, somewhat dependent upon the signal crest factor*).

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*) Crest factor $= \dfrac{\text{Signal peak value}}{\text{Signal RMS value.}}$

If the input signal consists of rectangular pulses with crest factors lower than 5 the overload indicator will indicate the true peak value of the signal. In the case of wide band (20 – 20,000 Hz) gaussian random noise with a flat power spectrum, on the other hand, the indicator will light up for a voltage around 2.5 $\times$ RMS value of the noise, and this is then *not* the highest value of the input signal.
Should it be desired to record noise signals for later signal analysis where peaks higher than 2.5 $\sigma$ ($\sigma$ = RMS value) are regarded essential for the analysis this should thus be kept in mind.
The overload indicator will when once lit, remain lit until it is released by pressing the reset button (which covers the lamp).
Also the *indicating meter* measures the peak value of the input signal (at the output of the input attenuator) when the *Function Selector* is in position "Record" or "Stop". Again certain limitations are present for the indication due to the (small) power consumption of the meter circuit. For periodic signals the true maximum peak value is measured for signals with crest factors up to 4,5, while in the case of wide band noise the measured value will be of the order of 2 $\sigma$.
If the RECORD switch is in position "Off" and the *Function Selector* in position "Record" the meter circuit is connected directly to the INPUT terminals by-passing the input attenuator. When recording is made on one channel only the meter circuit of the second channel can thereby be used to monitor the signal that has actually been recorded on the tape. To do so it is only necessary to make an external connection between the OUTPUT terminal of channel in use and the INPUT terminal of the channel not in use and to set the RECORD switch of the latter channel in position "Off".
If the *Function Selector* is set to position "Play-back" the indicating meter is automatically switched to monitor the output signal from the reproduce section, see Fig. 2.1.

The *reproduce section* is actually an "inverted" record section. As can be seen from the block diagram, the signal from the tape is picked up by a reproduce head and fed to a preamplifier.
The *reproduce preamplifier* has been designed to give a very high amplification (of the order of 120 dB) and a low noise level. Because the output from the reproduce head varies with frequency and tape speed and is lowest at the lowest center frequency (2.7 kHz) the amplification is greatest at low frequencies and drops off gradually as the frequency increases. Furthermore, to obtain an efficient amplitude limitation with zero phase shift, and thus a stable operation of the amplifier at all frequencies, a diode clipper has been introduced in the negative feedback circuit.

The *limiter amplifier* following the preamplifier actually contains two amplifiers utilizing a diode coupled feedback circuit to accomplish the desired limiting operation. The circuit behaves as a conventional open loop, high gain amplifier until the output voltage exceeds the forward conduction level (knee) of the feedback diodes. Above this level the negative feedback becomes 100 % and thus sharply limits the output amplitude.

The *FM discriminator* (demodulator) contains a monostable multivibrator which is triggered by the pulses developed in the limiter amplifier and differentiating circuit. In this way the frequency of the multivibrator is determined by the frequency of the reproduce input signal. To convert the frequency variations into voltage variation (demodulation of the signal) the output pulses from the multivibrator are shaped to have equal and very sharply defined widths and heights, whereafter they are led to a low pass filter. The number of pulses per second will then determine the magnitude of the output voltage from the low pass filter, or said in other words: the number of equal pulses per second determines the (variable) "DC" output from the filter.

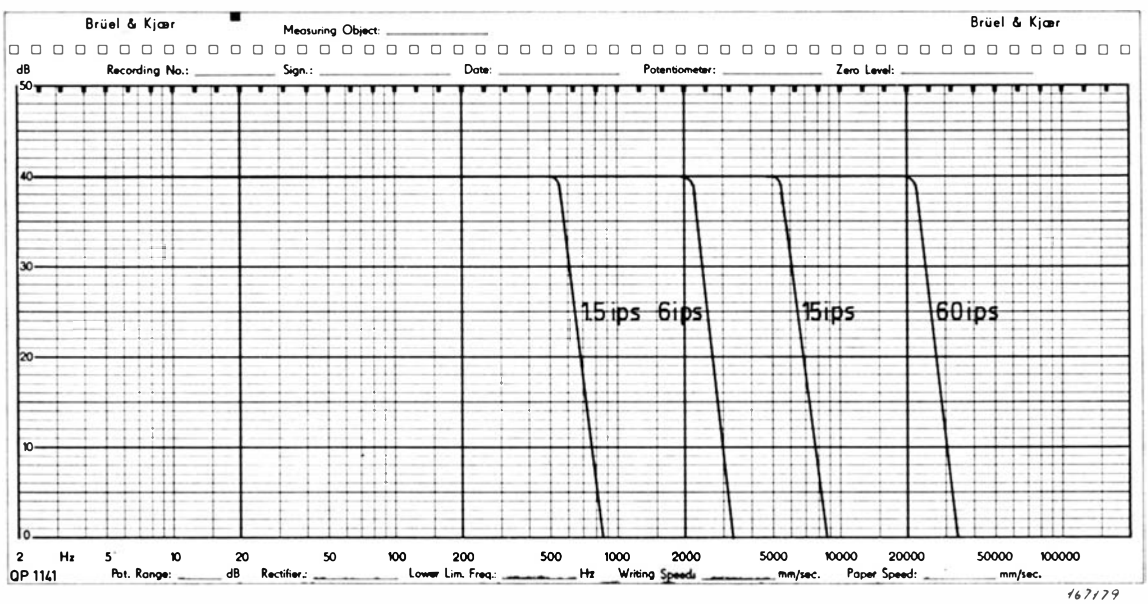


*Fig. 2.7. Typical frequency characteristics for the low pass filters contained in the reproduce section of the Tape Recorder.*

The *low pass filter* is a seven-poled constant-k type filter and the ripple in the passband is less than 0.1 dB. A very high attenuation is obtained outside the passband as can be seen from Fig. 2.7. It should be noted in this connection that the pulses obtained from the multivibrator have a repetition frequency which is twice that of the "instantaneous" carrier frequency. This is due to the fact that one pulse is produced per zero-crossing of the carrier, no matter whether the crossing takes place with a positive or a negative slope. From the low pass filter the demodulated signal is fed to a DC wideband amplifier the output of which is connected to the Tape Recorder output terminal.

The *output DC wideband amplifier* is a differential type amplifier with one input connected to the output of the low pass filter, while the second input is connected to a DC signal with a magnitude corresponding to that obtained from the filter with zero modulation of the carrier. To obtain the desired amount of negative feedback in the amplifier part of the output signal is also fed to this second input. The DC drift is less than 0.5 % per 24 hours, the harmonic distortion is less than 0.1 % and the overall amplification is approximately 10 dB. An output impedance of less than 5 Ω has been achieved and the output may be short circuited without damaging the amplifier. However, even though the output impedance is very low the output should not be loaded with an impedance smaller than 1 kΩ to ensure low distortion (the output amplifier is *no power amplifier*). A maximum output voltage of 1 Volt RMS (sinewave) is the basis for the distortion characteristics given above
The necessary zero and gain adjustments of the amplifier are made by means of screwdriver operated potentiometers. Zero adjustment is carried out by adjusting the base-bias of the input transistor while the gain adjustment takes place in the amplifier negative feedback circuit.

*Calibration* of the FM measurement channels is based on two built-in calibration generators, one of which is used to calibrate the reproduce section (Calibration Frequency Generator) and a second (440 Hz 1 Volt Ref. Generator) which is used for gain adjustment in the FM modulator circuit of the recording section, see also Fig. 2.1.

The *calibration frequency generator* supplies a signal of 108 kHz to the reproduce section when the calibration selector is in position 1. This frefrequency corresponds to the highest unmodulated center frequency (tape speed 60 ips) and is used for zero setting of the recording section. With the *calibration selector* in position 2 a frequency of 64.8 kHz is supplied to the reproduce section which corresponds to a $-40$ % frequency deviation, i.e. the maximum amount of allowable frequency modulation. By adjusting the voltage level at the output terminal, see Fig. 2.1, to 1.4 Volts the nominal gain of the output DC wideband amplifier is then set. The stability of both the calibration frequencies is better than $3 \times 10^{-5}/°C$ in the normal operating temperature range of the recorder (0–40° C).
The stability of the calibration frequency generator allows the reproduce section of the recorder, when properly calibrated, to be used as a frequency meter for adjusting the main center frequency in the FM modulator of the record section (216 kHz). This is carried out by setting the *calibration selector* to position 3, whereby the output from the frequency divider (108 kHz) is connected to the reproduce section, and adjusting the screwdriver operated potentiometer marked "DC Bal.-Record" until the monitoring meter is on zero.
To set the gain control of the FM modulator the adjustment switch is set to position 5 whereby the "440 Hz, 1 Volt Ref. Generator", Fig. 2.1, is connected to the input of the record section.

The *440 Hz, 1 Volt reference generator* is an RC-coupled (double T-circuit) oscillator which is tuned to 440 Hz (musical pitch A). A differential type amplifier is used as amplifying element and a special voltage doubling and limiting circuit ensures constant amplitude of the reference signal as well as a certain desired limitation in the driving power of the oscillator. The output voltage is sinusoidal and has an RMS value of 1 Volt (1.4 Volts peak value). Its amplitude stability, within the operating temperature range of the recorder, is better than 0.02 % per °C, and the frequency drift is less than 0.1 % per °C.

Apart from its use as reference signal in the calibration of the Tape Recorder the generator also supplies the control signal to the marker unit (see next section "Description of the Voice Channel").

**Description of the Voice Channel**

The voice channel has been included in the Tape Recorder to allow for marking and identification of the tape. It utilizes direct recording technique with HF-bias but no special arrangements have been made to obtain high quality recording and reproduction over a wide frequency range. Because the channel is only intended to be used for identification purposes a minimum amount of frequency equalization technique has been utilized and the frequency response is "flat" only from 300 Hz to 3 kHz, the band limits here being the −6 dB points on the frequency characteristic.

A small dynamic type microphone is supplied with the Recorder, which gives an output voltage of approximately 1 mV for an input sound pressure level of around 95 dB (normal close talking level). The normal operating input level of the channel should thus be in the order of 1 mV ± 10 dB. The input impedance is approximately 1 kΩ. An output voltage of around 1 Volt RMS is available on the monitor terminals, and the minimum value of the load impedance should be 2 kΩ.

The voice channel consists of the microphone, an AVC (Automatic Volume Control) unit, an output amplifier for driving of the recording head, a record head, a bias and erase generator, an erase head, a reproduce head and a reproduce preamplifier.

To ensure correct marking of the tape the record and reproduce heads for the voice channel have been built together with the corresponding heads of the measurement channels. The record/reproduce switching of the channel is made by means of relays controlled from a pushbutton mounted on the microphone. If the button is pushed the channel is operated in its recording mode, while, whenever the button is released, it operates in its reproduce mode.

When operated in its voice *recording mode* the signal from the microphone is led via a relay contact to the input of the *AVC unit,* see Fig. 2.1. This unit consists of a set of prebiased diodes followed by a two-stage linear amplifier. The bias on the diodes determines the operating characteristic of the unit.

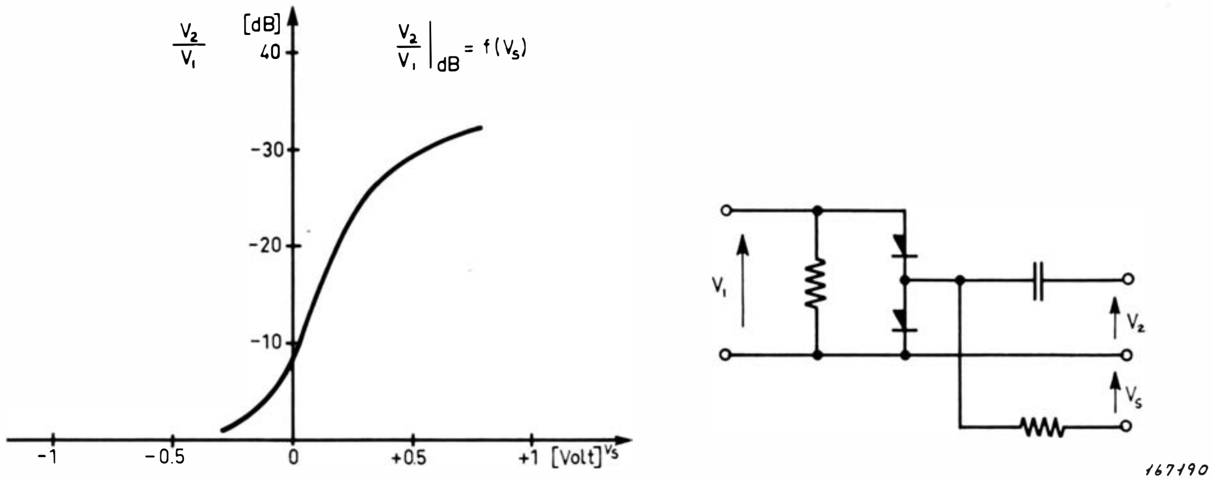


*Fig. 2.8. Principle of operation of the AVC in the voice channel (see also Fig. 2.1).*

see Figs. 2.1 and 2.8. By using the rectified and smoothed output signal from the output amplifier to bias the diodes the desired automatic regulation of the output signal is obtained, whereby an input variation of 20 dB is compressed to an output signal variation of 3 dB. Typical regulation characteristic for the complete recording channel (except for the microphone and the magnetic head) is shown in Fig. 2.9.

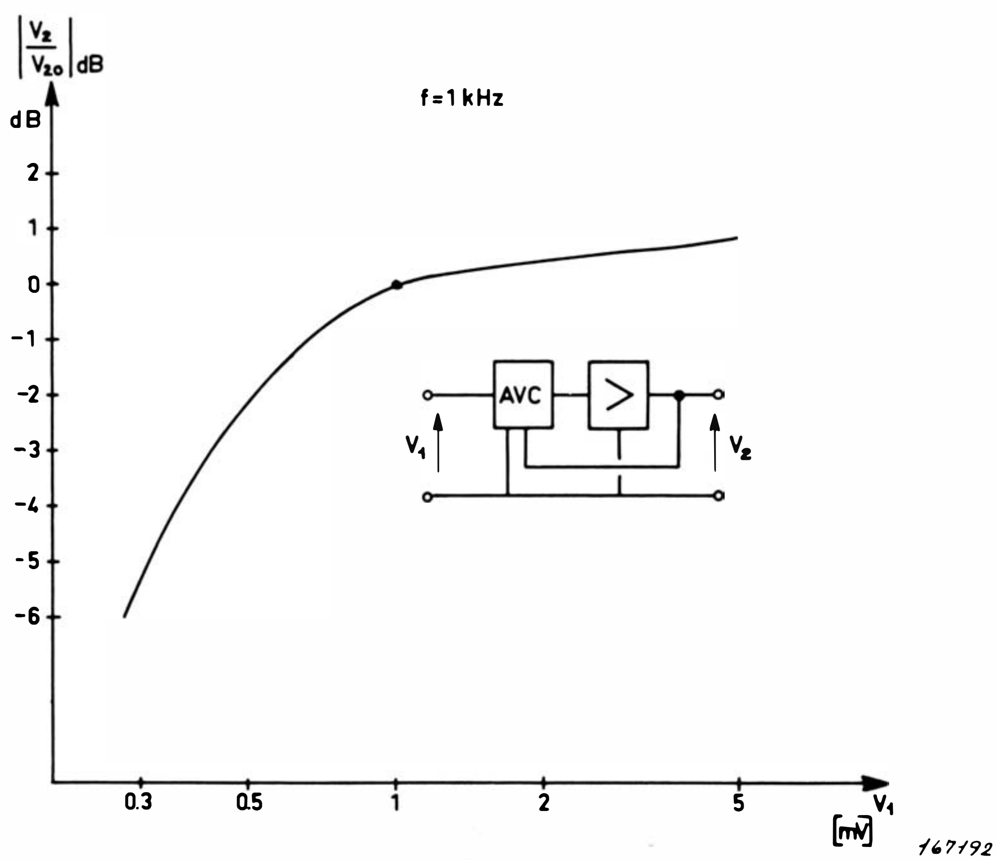


*Fig. 2.9. Typical regulation characteristics for the voice channel when switched for recording.*

The AVC unit is followed by the *output amplifier* which also contains the low and high pass filters necessary to keep the frequency range of the voice channel independent of tape speed.
From the output amplifier the signal is led to the recording head and recorded on the tape together with the HF-bias from the *erase and bias generator,* Fig. 2.1. This generator is built as a push-pull sine wave oscillator to ensure symmetrical bias and erase current. The frequqency of the generator is approximately 100 kHz.
If the pushbutton on the microphone is released the voice channel operates in its *reproduce mode.* All the amplifying stages at the recording section are then also utilized for the reproduction. However, the AVC unit is then switched out of operation and substituted by a *voice channel playback preamplifier.* Apart from adding the necessary amplification to the very low level signal from the reproduce head this amplifier also contains the equalization networks used to compensate for the frequency dependent response of the electromagnetic reproduce process (see Fig. 1.1).
When the voice channel operates in the reproduce mode the microphone acts as "loudspeaker". If desired an extra monitoring device, for instance a set of headphones can be connected to the output marked MONITOR. The impedance of the monitoring device must, however, not be lower than 2 kΩ.

**Description of the Marking Arrangement**

When the *MONITOR* switch is held in the position "Marker" (spring loaded) the signal from the "440 Hz, 1 Volt Ref. Generator" is automatically recorded on the the voice channel. The main purposes of this kind of marking is to use the 440 Hz signal to control the *marker unit* during playback. This unit, which consists of a selective amplifier/rectifier stage and two relays, then controls the switching of the Brüel & Kjær Spectrometer Type 2112 when frequency analyses are made from tape loops and recorded graphically by means of the Level Recorder Type 2305. A diagram showing the operation of the marking unit during playback of a tape loop is shown in Fig. 2.10. To fully understand the operation of the marking system during play-back it may be helpful to split up the explanation of the diagram in two parts.

1. The signal on a tape loop is to be frequency analyzed by means of the B & K Spectrometer Type 2112 and recorded graphically on the Level Recorder Type 2305 the latter being supplied with *uncalibrated recording paper.*

   This is done by marking the loop In one spot and connecting only the plugs marked 7001 and 2112 of the cable AQ 0016, i.e. leaving the plug marked 2305 unconnected. Each time the marked spot of the tape passes the reproduce head of the Tape Recorder the relay marked ① in Fig. 2.10 closes and the filter switch in the Spectrometer steps one filter ahead. In this way a one third octave frequency analysis of the signal is obtained.

If an octave analysis of the data is desired, rather than a one third octave analysis then three spots on the tape loop should be marked, causing the filter switch in the Spectrometer to move three filters ahead per complete cycle of the loop.

2. The signal on a tape loop is to be frequency analyzed by means of the Spectrometer and recorded graphically on the Level Recorder the Level Recorder in this case being supplied with *pre-printed frequency calibrated recording paper.*

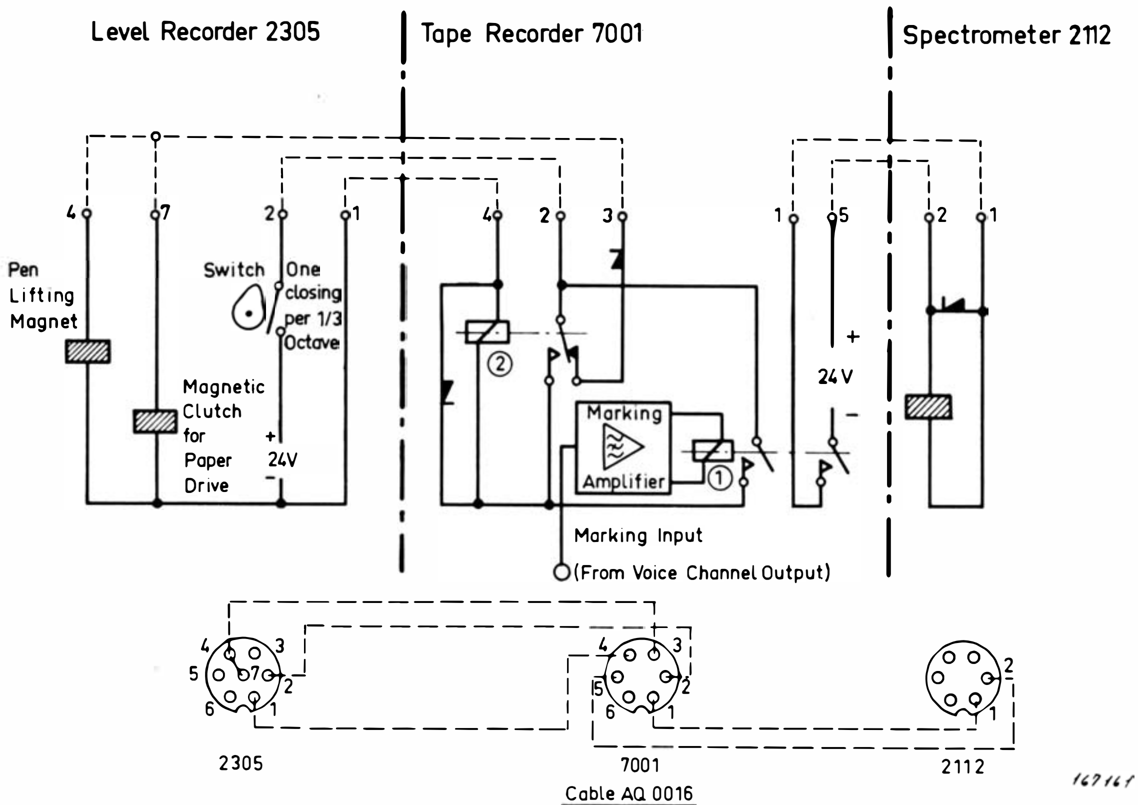


*Fig. 2.10. Block diagram showing the operation of the marking arrangement.*

In this case the plug marked 2305 of AQ 0016 should also be connected. A third octave analysis is then again obtained when only one marking is made on the tape loop. However, to make possible a full synchronization of the tape loop cycle with the frequency calibration on the recording paper a second relay circuit has been incorporated in the marked unit of the Tape Recorder. The operation of the control circuit is then as follows.

When the recording paper has moved a distance corresponding to one third octave a signal from a switch in the Level Recorder activates both the pen lifting magnet and the magnetic clutch for the paper drive via the contact circuit of the relay marked ② in the marker unit, see Fig. 2.10. In this way the writing pen is automatically lifted from the recording paper and the movement of the paper stops.

When the marked spot on the magnetic tape passes the reproduce head the relay marked ① in Fig. 2.10 operates and one of its contact pairs then activates the relay marked ②. This again breaks the control current for the pen lifting magnet and the paper drive clutch whereby the graphic recording continues.

At the same time a second contact pair of relay ① causes the Spectrometer filter switch to step one filter ahead, the net result being that the signal now recorded on the Level Recorder is the output from the next higher third octave filter. The desired synchronism is thus obtained between the movement of the preprinted recording paper and the tape loop cycle. A requirement for such a synchronization is, however, that the tape loop cycle is slightly longer than the required switching intervals of the Spectrometer.

Also in this case an octave analysis is possible, although the marking of the tape is then a little more complicated in that it is necessary to mark the tape according to the Spectrometer switching intervals: The principle of operation is similar to that described under item 1 above, and the detailed marking procedure is outlined under Chapter "Operation".

**Description of the Power Supply**

The power supplies for the various electronic elements in the Tape Recorder are stabilized self-regulating voltage supplies with zero generator impedance. This is necessary because of the many DC amplifiers used in the FM measurement channels. Zener diodes are used as reference elements, and the various voltage supplies are safeguarded against overload currents by means of fuses. The voltages available are + 15 Volts, – 15 Volts and – 24 Volts.

**Description of the Tape Transport System**

The tape transport system consists basically of a *capstan assembly* driven by a *synchronous motor,* a *take-up spool drive motor,* a *rewind motor* and *control and safeguarding circuits* which control the operation of the three motors. To assure low flutter not only the design of the electronic circuits but also the mechanical layout of the tape transport system is of the greatest importance. All the mechanical parts are produced to very close tolerances and to keep the unsupported section of the tape as small as possible a so-called *closed loop drive* has been used, see Fig. 2.11. As can be seen from the figure the tape is here clamped to the capstan by a pinch roller as it enters the loop. It then passes over the recording head, a turn-around idler, past the reproduce head and is finally again clamped to the capstan by a second pinch roller.

Furthermore, outside the closed-loop, the tape tension is controlled by means of a servo-system.

A basic block diagram of the tape transport system is shown in Fig. 2.12, and the only external controls are the ones marked FUNCTION SELECTOR and TAPE SPEED selector. These are housed in a small control box which is mounted beneath the tape deck (Fig. 3.1). If desired, however ,the box can

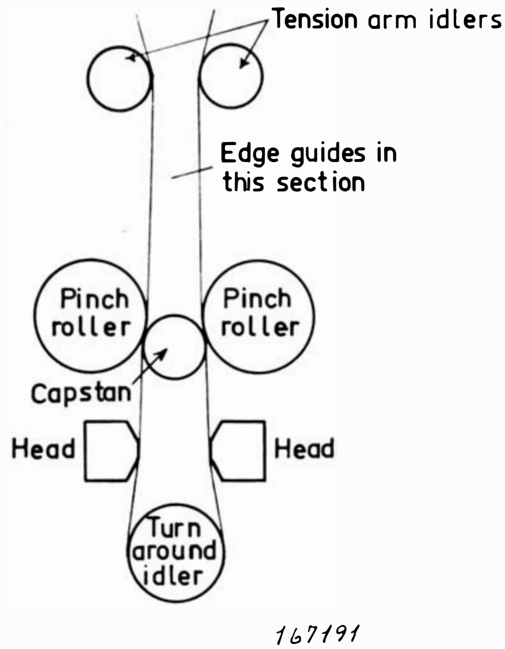


*Fig. 2.11. Basic arrangement for closed loop drive of the magnetic tape.*

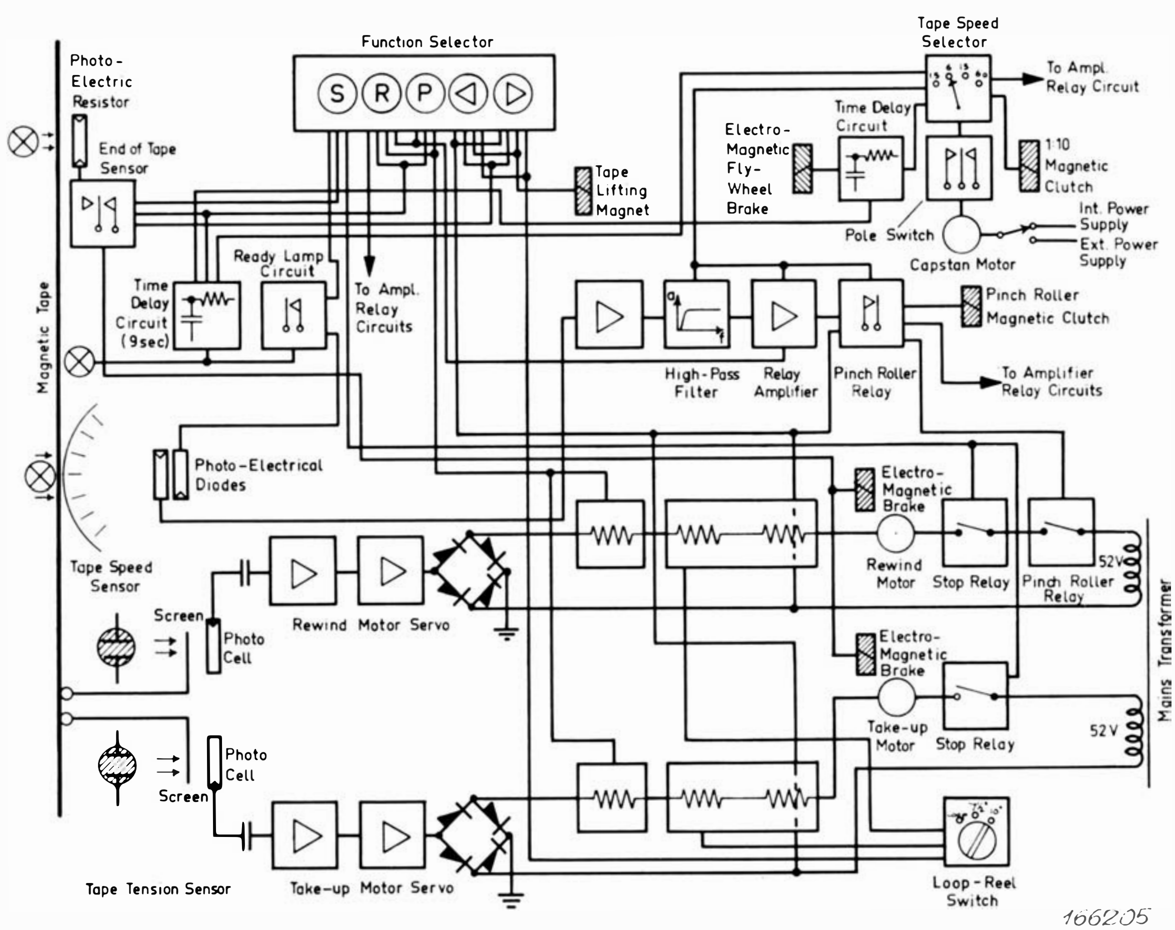


*Fig. 2.12. Block diagram of the tape transport system.*

be removed from the main cabinet and can then be used for remote control. The *Function Selector* controls the five different functions of the tape transport system via relays in the main cabinet:

1. *Record* ("R")
2. *Playback* ("P")
3. *Fast forward* ("►")
4. *Rewind* ("◄")
5. *Stop* ("S")

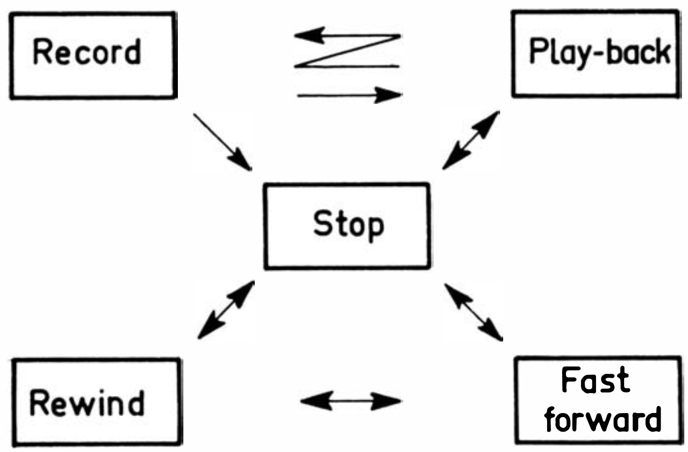


*Fig. 2.13. Principle of operation of the "Function Selector".*

The desired function is chosen by pressing the corresponding back-lit push-button. To avoid damage of the Recorder or undesired erase of already recorded data all the function controls are electrically interlocked, Fig. 2.13, and recording of data can only be made when both the PLAYBACK and the RECORD pushbuttons are pressed simultaneously. A delay circuit, which is operated from the TAPE SPEED selector, ensures that the pinch rollers are not engaged to the capstan until the tape speed is correct. In this way unnecessary and dangerous tape tension- shocks are avoided. A small green lamp on the control box indicates when the Recorder is ready to operate.

The *TAPE SPEED selector* allows the selection of four speeds: 1.5 – 6 – 15 or 60 ips. (inches per second). When the Recorder is switched to a tape speed of 1.5 ips the pinch rollers are, however, engaged to the capstan without delay. If the tape speed chosen is 6 ips. the pinch rollers are engaged after a fixed time delay of 0.5–1 second, which is sufficient for the tape to start moving and thus avoid a too high tape tension during engagement. In the cases of tape speeds of 15 and 60 ips., the tape speed is actually measured by means of a tape speed sensor consisting of a slotted tape drum, a lamp and a photo-diode. The signal from the photo-diode controls a frequency dependent relay circuit which again controls the engagement of the pinch rollers, see Fig. 2.12.

When the tape has reached the correct speed the frequency of the signal from the photo-diode corresponds to that required for activation of the selective relay circuit whereby the pinch rollers automatically engage.

To accomplish the wide range of tape speeds available (1 : 40) it has been necessary to utilize both electrical and mechanical "gearing". The capstan assembly is driven by a dual speed hysteresis synchronous motor. The speed ratio is 1 : 4. In order to cover the speed ratio 1 : 40 a mechanical speed reduction consisting of a pair of idle rollers has been incorporated in the drive assembly. A reduction ratio of 1 : 10 is then accomplished by utilizing the drive clutch and the inside diameter of the flywheel. When the Recorder is switched to one of the two lower speeds a solenoid disengages the drive clutch and at the same time engages the idle rollers.

To bring the speed of the high inertia flywheel down to the lower speed a brake actuated by a solenoid is engaged. The length of time of the braking action is controlled by preadjusted RC discharge circuits.

When the Recorder is delivered from the factory it is connected for 50 or 60 Hz power line frequency according to ordering specification. Should it however, be desirerable to use a Recorder originally ordered for 50 Hz on a 60 Hz power line or vice versa this is possible by simply changing the drive wheels to the capstan. The drive wheels can be obtained in sets from the factory. For 60 Hz this is marked DG 0090 and DG 0091, and the corresponding set for 50 Hz drive is marked DG 0082 and DG 0088.

A *READY lamp* indicates, when the Recorder is ready for recording or playback. When the lamp is out neither the record nor the playback function can be activated. Due to the inertia of the capstan motor a certain time elapses from the moment the Recorder is switched on until the capstan has the required speed of rotation. This time is around 9 seconds. A time delay of this order of magnitude has therefore been introduced in the READY lamp circuit.

Finally, a second photo-diode in the tape speed sensor is also used to control the READY lamp circuit and to ensure that the tape has come to a standstill before the Recorder is switched to another tape transport function. To obtain this effect the signal from the photo-diode is, as soon as the STOP button is pressed, led to a relay control circuit via an AC amplifier. The relay is then activated as long as the slitted drum of the tape speed sensor arrangement rotates, whereby it blocks the FUNCTION SELECTOR. When the tape has come to a stand still the output signal from the AC amplifier disappears and the READY lamp lights up, indicating that the Recorder is now ready to perform the new function.

An *end-of-tape sensor* has been included to stop the tape transport as soon as the end of the tape is reached, or in case of tape breakage. The latter is, however, very unlikely to occur due to the safety measures taken in the layout of the operating control system.

Also in this case a photo-electric sensing device has been used, whereby the end-of-tape sensor unit can be readily utilized also to stop the tape transport automatically at a predetermined "spot" on the tape by inserting a piece of transparent material. The length of the transparent material necessary to ensure a full stop of the tape transport varies from a couple of mm at low tape speeds to some 8–10 mm at a tape speed of 60 ips.
A *tape tension sensor* device ensures constant tension in the tape outside the closed loop drive, independent of the amount of tape present on the tape reels. It consists of a set of rollers supporting the tape just outside the closed-loop, a mechanical-electrical transducing arrangement and two servo amplifiers controlling the speeds of the tape take-up and supply motors, see Fig. 2.12.
The mechanical-electrical transducing arrangement actually contains two transducers one controlling the tape tension as the tape enters the closed-loop, and one controlling the tension of the tape between the closed-loop and the take-up reel. They both utilize photo-electric effects, the amount of light supplied to the silicon photo electric elements being dependent upon the position of the rollers. As the light sources are ordinary neon lamps fed from the mains the servo amplifiers are of the AC type. A further advantage of the circuitry used is that the output transistor in the amplifier receives the control AC signal in synchronism with the rectified, unsmoothed collector-to-emitter voltage of the output transistor. In this way the amplifiers operate as variable resistors in the motor supply circuit, see Fig. 2.14, which allows for a very efficient torque regulation.

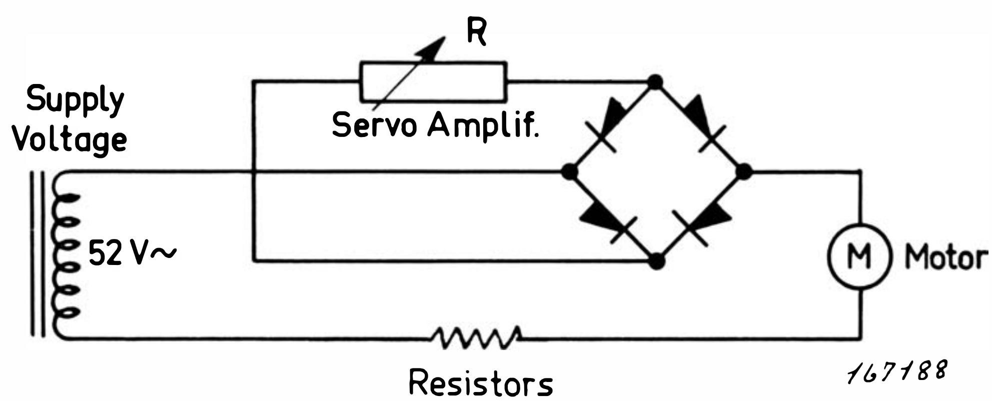


*Fig. 2.14. Principle of operation of the servo-circuits for the tape supply and tape take-up motors.*

It should be noted, however, that small, rapid tape tension variations are taken up directly by the springs loading the rollers, while the slower tension variations due to changes in the amount of tape on the reels are controlled by the servo system. To obtain the necessary damping and time delay in the servo the mechanical arrangements controlling the light to the photo-electric elements have been supplied with considerable amounts of viscous damping. The force acting on the tape is of the order of 100 grammes (0.22 lbs.). Both the *take-up motor* and the *tape supply motor* are supplied from the mains via a number of series resistors, contact mechanisms and the above described servo mechanisms. The total resistance actually in series with the motors depends upon the particular function chosen by the Recorder FUNCTION SELECTOR.

During normal record or reproduce functioning of the Recorder the maximum voltage (52 Volts RMS) is supplied to the take-up motor until the correct tape speed is reached. In the same period of time the voltage to the tape supply motor is disconnected whereby maximum acceleration of the tape is achieved. As soon as correct tape speed is obtained, however, the servo systems are connected and both motors will then be supplied with servo controlled voltages. The actual voltage on the motors will then also depend upon whether the Recorder is used with 10.5" or 7" reels, or with the tape loop arrangement, see Fig. 2.12. With the FUNCTION SELECTOR set for "Fast forward" the take-up motor is again connected directly to the maximum voltage (52 Volts) while the voltage on the tape supply motor is reduced. By switching to the "Rewind" function the situation is exactly reversed.

When the FUNCTION SELECTOR is set to either "Fast Forward" or to "Rewind" a set of rollers automatically lifts the tape away from the magnetic heads, thus minimizing the mechanical wear of the heads.

Because the Tape Recorder Type 7001 has been designed to accomodate two different reel sizes as well as a tape loop arrangement, and because all these arrangements require different operating voltages on the take-up and supply motors a "coin-operated" switch marked "Loop-7"–10.5" Reel", has been incorporated.

The LOAD COMPENSATION SWITCH performs the following functions: When switched to position "Loop" two "extra" series resistors are connected both in the take-up and in the supply motor circuits. This is the maximum series resistance used during normal operation of the Recorder. In position "7" Reel" only one extra resistsor is in circuit. When in position "Loop" the switch also disconnects the *"Rewind"* and *"Fast forward"* controls.

*Tape Recorder Power Supply.* The Tape Recorder is normally supplied from the mains at voltages of 100 – 115 – 127 – 150 – 220 or 240 Volts AC, and mains frequencies of 50 or 60 Hz.

The power consumption is 100–180 W. However, if the mains is very unstable or contains a lot of surges, produced for instance by electric welding machinery, it is adviceable to drive the Capstan motor from a separate, frequency stabilized power supply. This is possible by connecting the special power supply to the socket marked PRECISION FREQUENCY GENERATOR at the rear of the instrument and switch the toggle switch located just above this socket to position "Precision Frequency Driven Capstan", see Fig. 2.15. The voltage and power requirements to the external generator are: 115 Volts, 60 VA.

In cases where it is more convenient to drive the Recorder from batteries (field use) this can be done by inserting a precision DC – to – AC converter between the batteries and the Recorder. A suitable converter of this type is the *KL Inverter SF-1* *) which is driven from 24 Volts DC (nominal). The inverter SF-1 can supply up to 200 VA of power at a frequency of 50 Hz and a voltage of 220 V. It is safe-guarded against overloads and operates according to specifications over an input voltage range of 21 to 30 V DC.
The efficiency is 72 % at 24 V DC-200 W.

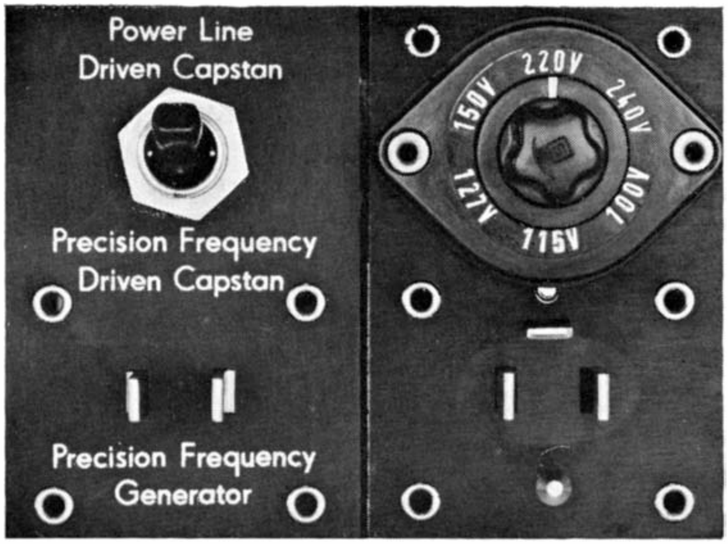


*Fig. 2.15. Power supply input terminals.*

*) Obtainable from: Knud Lindberg A/S, 200 Islevdalvej, Roedovre, Copenhagen, Denmark.

# 3. Control Knobs, Terminals etc.

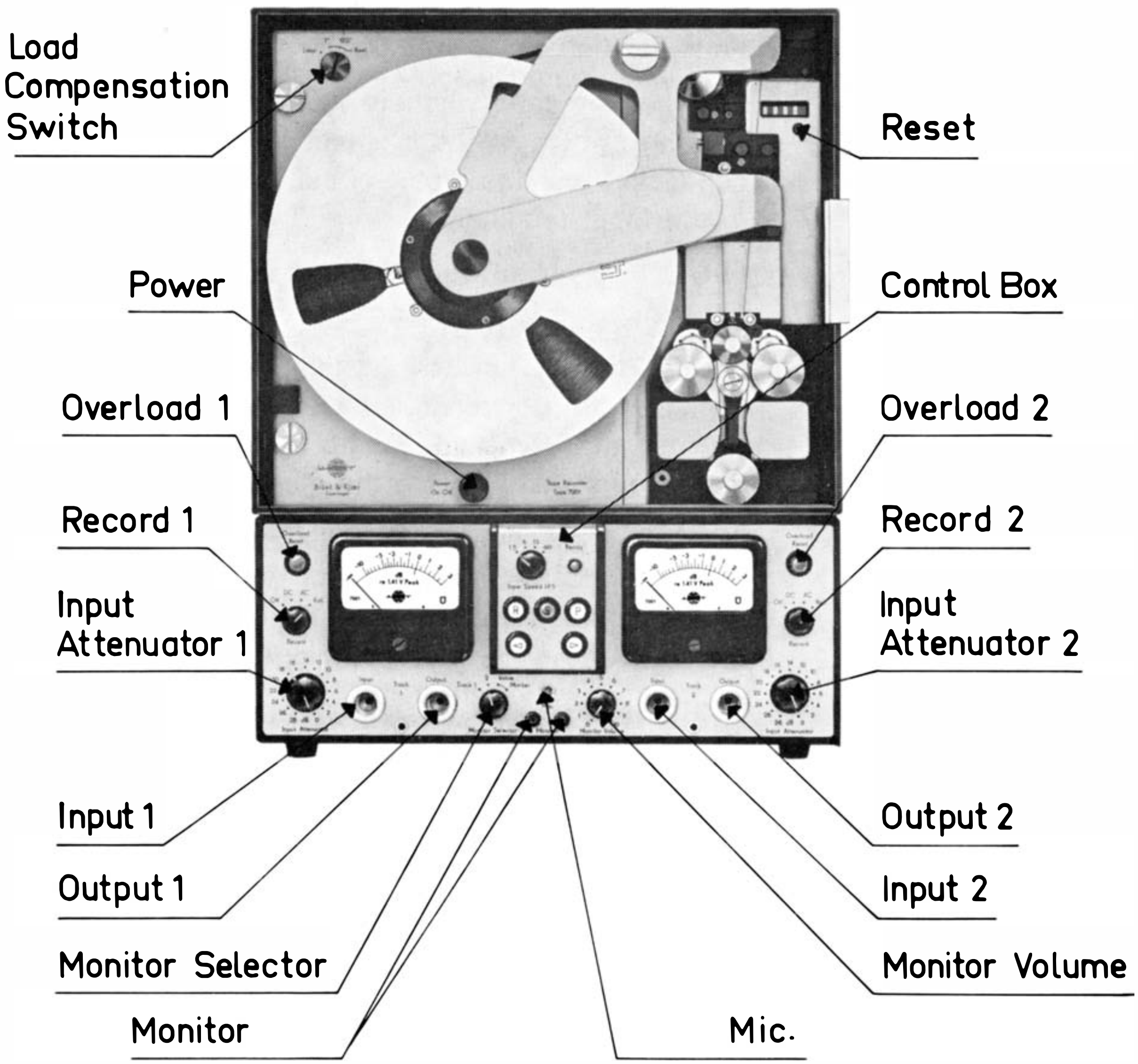


*Fig. 3.1. Front view of the Tape Recorder.*

**Front (Re. Fig. 3.1):**

LOAD COMPENSATION SWITCH: Three position, coin operated switch.

*"Loop"*, to be used when the Recorder is fitted with the loop adaptor.

*"7" Reel"*, to be used when the Recorder is fitted with 7" tape reels.

*"10.5" Reel"*, to be used when the Recorder is fitted with 10.5" tape reels.

POWER: Mains power switch. Push-button operated.

OVERLOAD: Overload indicator. Lights up when the signal has overloaded the modulator (p. 14). Resetting of the indicator is made by a light push.

RECORD: Four position input switch.

*"Off":* When the switch is in this position the recording system of the channel in quqestion is disconnected and the meter circuit connected directly to the input terminal.

*"DC":* To be used when DC and very low frequency information is being recorded.

*"AC":* With the switch in this position only AC-signals with frequencies higher than some 4 Hz (– 3 dB) are recorded. To be used when very low frequency signals disturb the measurements.

*"Ref".* This position of the switch serves to connect the built-in reference generator (440 Hz, 1 V RMS) to the input of the variable INPUT ATTENUATOR thereby allowing a reference signal of suitable level to be recorded on the tape.

INPUT ATTENUATOR: Allows attenuation of the input signal of up to 28 dB in the form of fifteen 2 dB steps.

INPUT: Input terminal for connection of the signal to be recorded. Input impedance 20 kΩ parallel to 100 pF.

OUTPUT: Output terminal. Min. load impedance 200 Ω.

MONITOR SELECTOR: Four position switch for monitoring and tape identification purposes. The fourth position is spring loaded.

*"Track 1":* With the switch in this position the monitoring outputs are connected to measurement channel 1 (left).

*"Track 2":* The monitoring outputs are connected to measurement channel 2 (right).

*"Voice":* The monitoring output (and input) are connected to the voice channel.

*"Marker":* This position of the switch is spring loaded and intended for marking of the tape. The built-in reference signal (440 Hz) is applied to the voice channel as long as the switch is held in the "Marker" position.

MIC: Terminal for connection of the small dynamic microphone supplied with the Recorder.

MONITOR: Monitor output. Min. load impedance 2 kΩ.

MONITOR VOLUME: For continuous regulation of the monitoring volume.

Control Box

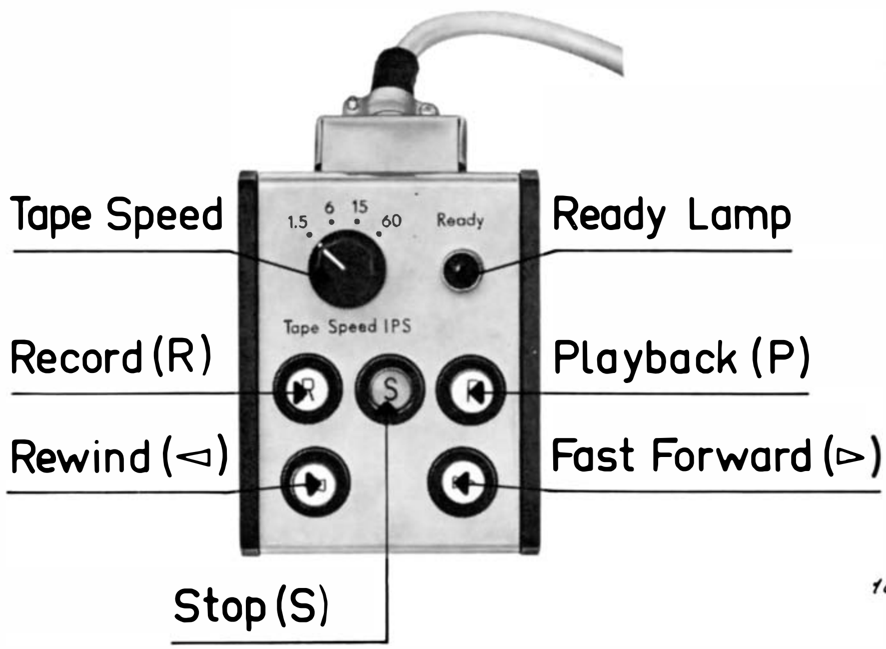


*Fig. 3.2. The Control Box.*

**TAPE SPEED AND FUNCTION SELECTOR UNIT (Control Box):**

*"Tape Speed":* Selectable tape speed: 1.5 – 6 – 15 – 60 inches per second.

*"Record" (R):* To avoid accidental data erasure both the Record and the Play-back button must be depressed to initiate the recording.

*"Rewind"* (◀): For rewinding the tape.

*"Stop" (S):* When the STOP button is depressed all relays are reset. This means that if mains is switched off or

fails the voltage to the relays fails and they are reset, in fact the same as if the STOP button was activated.

*"Ready":* The READY LIGHT indicates when the capstan has reached the correct speed after switching the TAPE SPEED selector, approximately 9 sec. Depressing the pushbutton RECORD and PLAYBACK during this time interval will not activate the corresponding relays.

*"Playback" (P):* The PLAYBACK button can be operated when the recorder is stopped or if it operates on "Record".

*"Fast Forward" (▶):* Fast forward can be activated after resetting Record or Playback by depressing the STOP button. During FAST FORWARD or REWIND the tape is lifted from the Magnetic Heads to prevent unnecessary wear of the heads. In position "Loop" of the "Loop – 7" – 10.5" Reel" switch both FAST FORWARD and REWIND are out of operation.

*"Footage Counter":* Mechanical counter indicating tape lengths in feet. Can be reset to 0 by pressing the pushbutton marked "Reset" in Fig. 3.1.

**REAR (Re. Fig. 3.3):**

CAPSTAN DRIVE SWITCH: Toggle switch which allows the Capstan motor to be driven either internally from the mains, or from an external precision frequency generator.

PRECISION FREQUENCY GENERATOR: Terminal for the connection of an external precision frequency generator. Power requirements: 60 V A (115 V).

FUSE AND MAINS VOLTAGE SELECTOR: Fuse in circuit with primary of mains transformer Voltage selector, for setting the Recorder to various mains voltages (100 – 115 – 127 – 150 – 220 – 240).

MARKER OUTPUT: For control of external synchronization, with tape loop operation, see also p. 20 and Fig. 3.3.

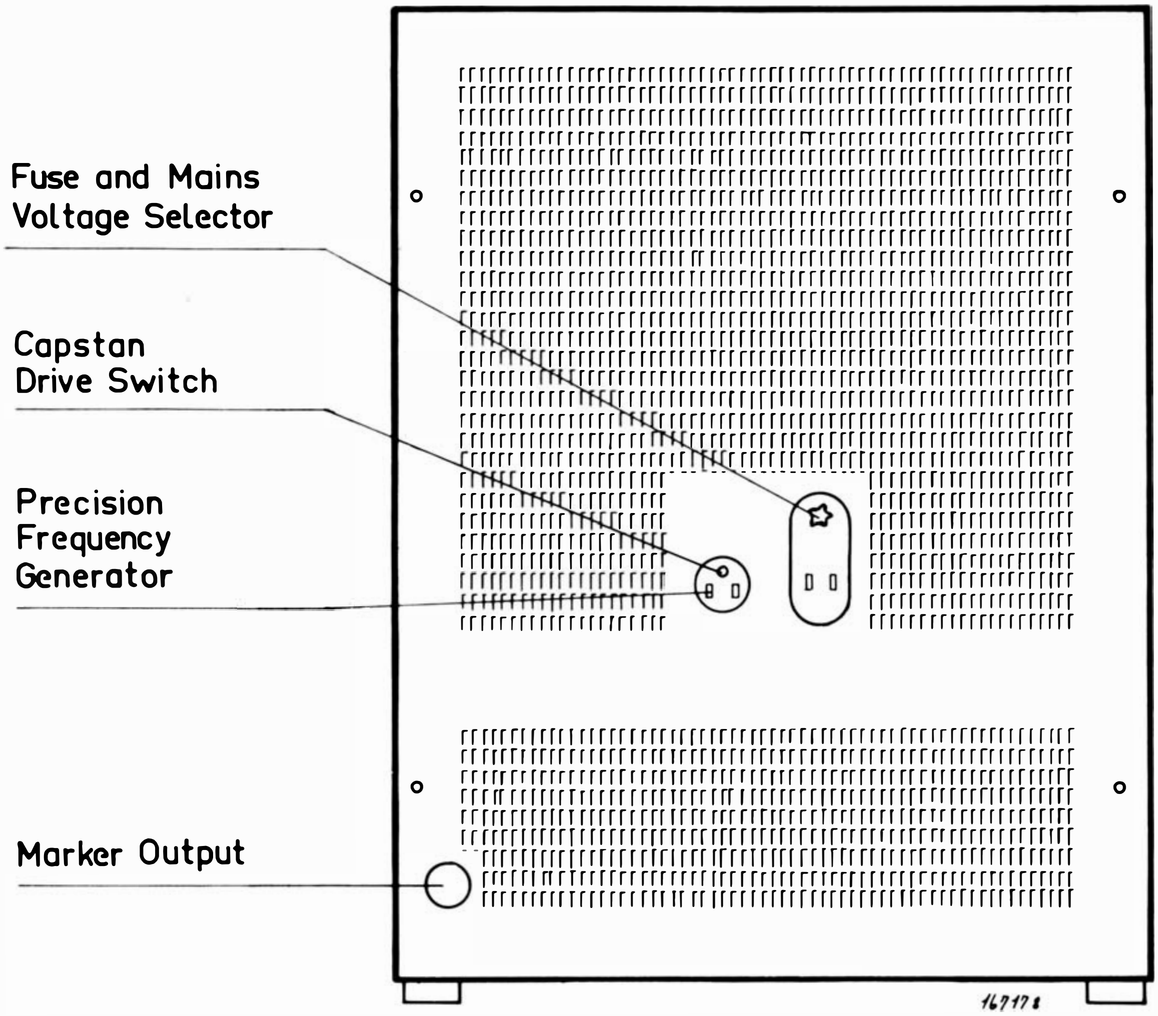


*Fig. 3.3. Rear view of the Tape Recorder.*

# 4. Tape Loading

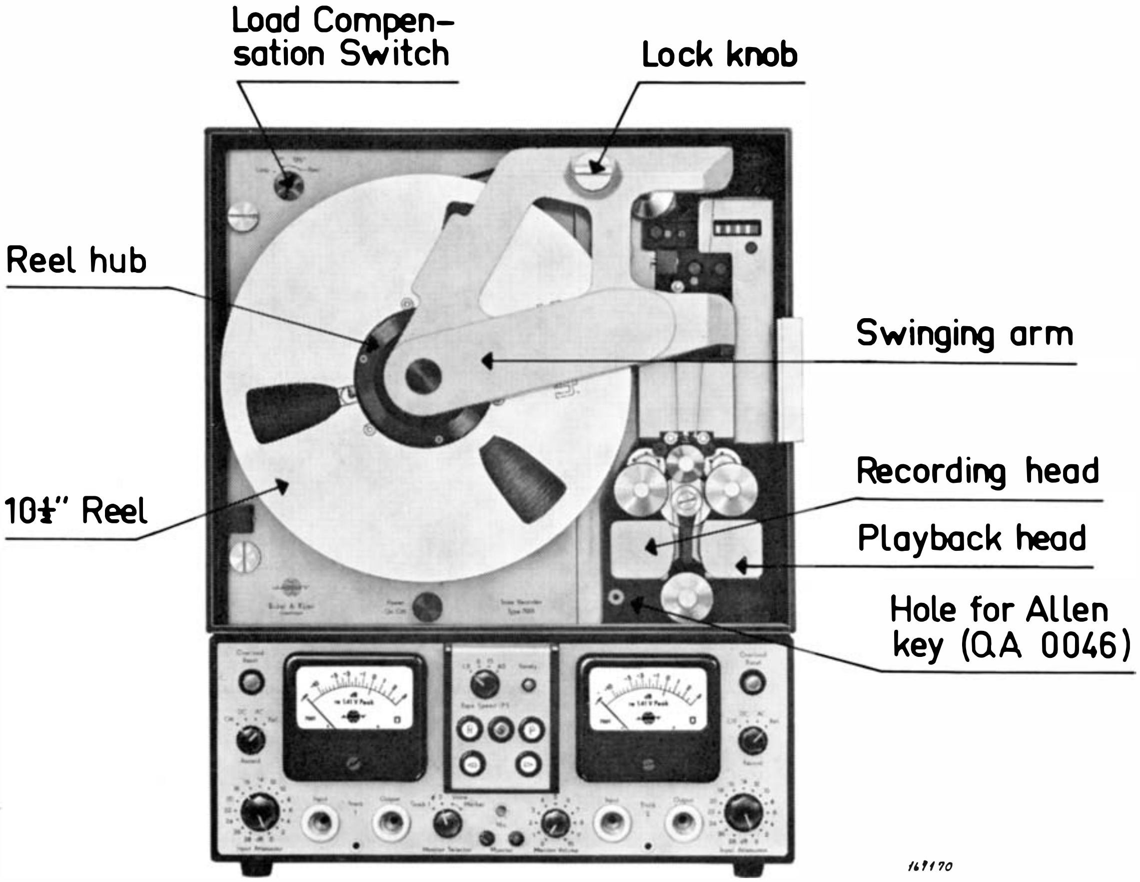


*Fig. 4.1. The Tape Recorder Type 7001 fitted with 10,5" reels.*

**Reel Mounting**

1. Turn lock knob (see Fig. 4.1) 90° anticlockwise to release the swinging arm and turn it out as shown in Fig. 4.4.
   The supply reel is mounted on the main base and the take-up reel is mounted to the swinging arm as follows:

   *10.5" Reels*

2. For mounting the 10.5" reels the large diameter hubs UD 0008 (see Fig. 4.3) are required.
   Fig. 4.2 shows the reel spindle on the swinging arm. (Both spindles are identical). The reel lock (2) is released by loosening the Allen screw (3) with the Allen key QA 0046, located beneath the record head (see Fig. 4.1).
3. Place the hubs onto the spindles (Fig. 4.3) and lock them into position by tightening the Allen screws (3).

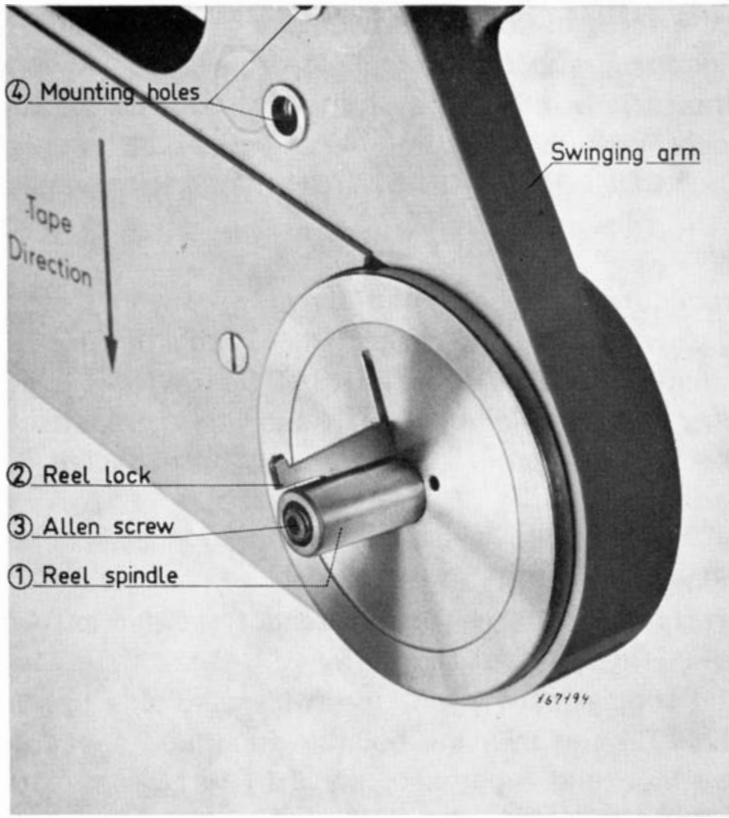


*Fig. 4.2.*
*Reel spindle.*

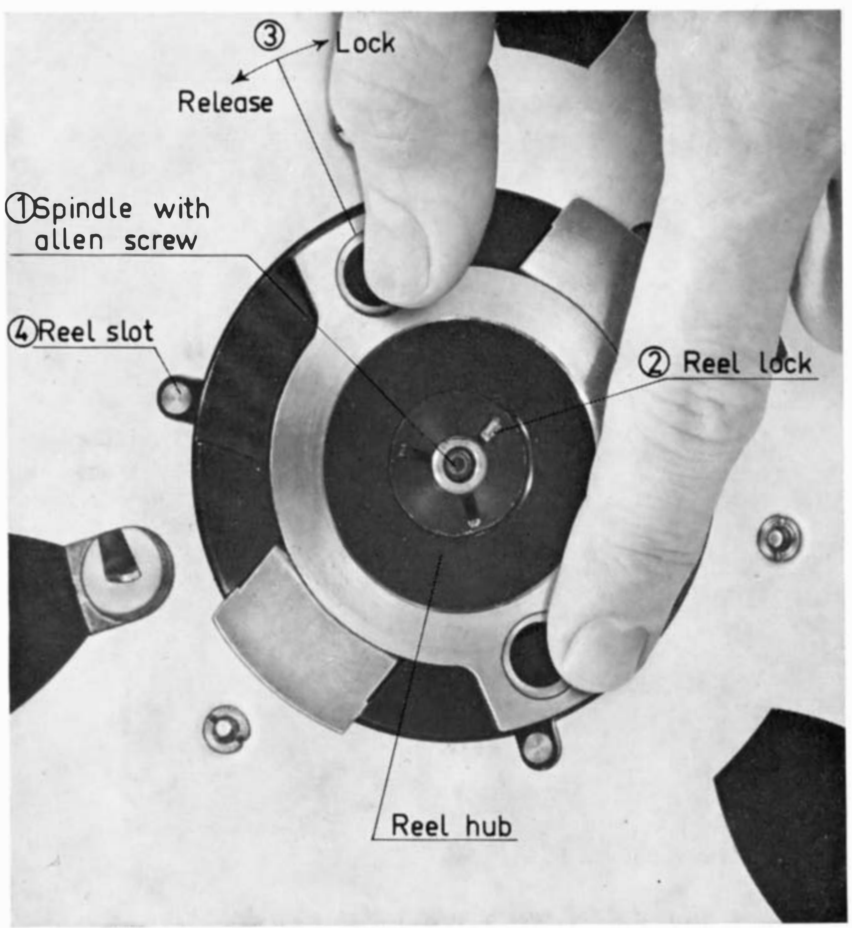


*Fig. 4.3. The large diameter hub (UD 0008) for mounting the 10,5" reels.*

4. Place the reels onto the hubs ensuring that the three slots around the inside circumference of the reels locate with the studs on the hubs.
5. Lock the reels in position by turning the center piece of the hubs clockwise (see Fig. 4.3).
6. Set LOAD COMPENSATION SWITCH (Fig. 4.1) to position "10.5"".

*7" Reels*

The procedure is as described above, except that the hubs are not used (item 3 above is not carried out). The 7" reels fit directly onto the spindles. Under item 6 the LOAD COMPENSATION SWITCH is set to position "7"".

NOTE: Quality and precision of 7" reels can vary a great deal and the specifications for the Tape Recorder cannot always be expected to be fulfilled when using this size reels.

**Tape Threading**

When the reels are attached to the Tape Recorder as described above the tape threading is carried out as follows (see Fig. 4.4):

1. From the supply reel (1) the tape (with base side up) is taken around the tape guide (2) and over the counter drum/tape speed sensor (3).
2. The free tape end (approximately 5 ft) is now passed across the voice track erase head (4) to the right side of the left arm of the tape tension

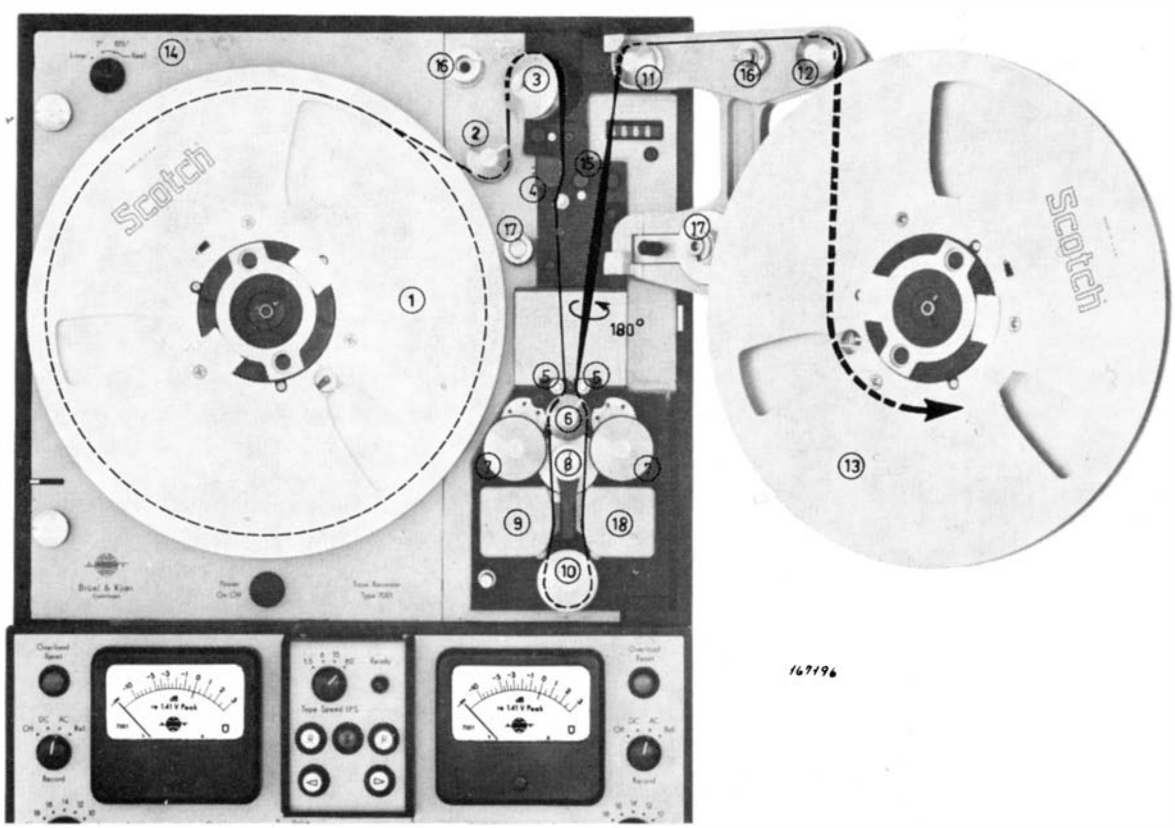


*Fig. 4.4. Tape loading diagram (reels).*

sensor (5), to the left of the tape guide (6), between the left pinch roller (7) and the capstan (8) across the record head (9), around the turn-around idler (10) across the reproduce head (18) and between the capstan (8) and the right pinch roller (7) and the tape guide (6) to the left side of the right tape tension sensor arm (5).

3. Twist the tape 180° anticlockwise (same direction as when opening the swinging arm).
4. With the coated side upwards the tape is taken around the tape guides (11) and (12) and finally fixed to the take-up reel in the direction shown on the swinging arm.
5. Close and lock the swinging arm by turning the Lock Knob (Fig. 4.1) 90° clockwise.
6. Check that the tape is not twisted, especially between the tape tension sensor (5) and the tape guide (11), and that it passes between the lamp housing and the photocell housing of the tape sensor (15).
7. Check that the LOAD COMPENSATION SWITCH is in the correct position.

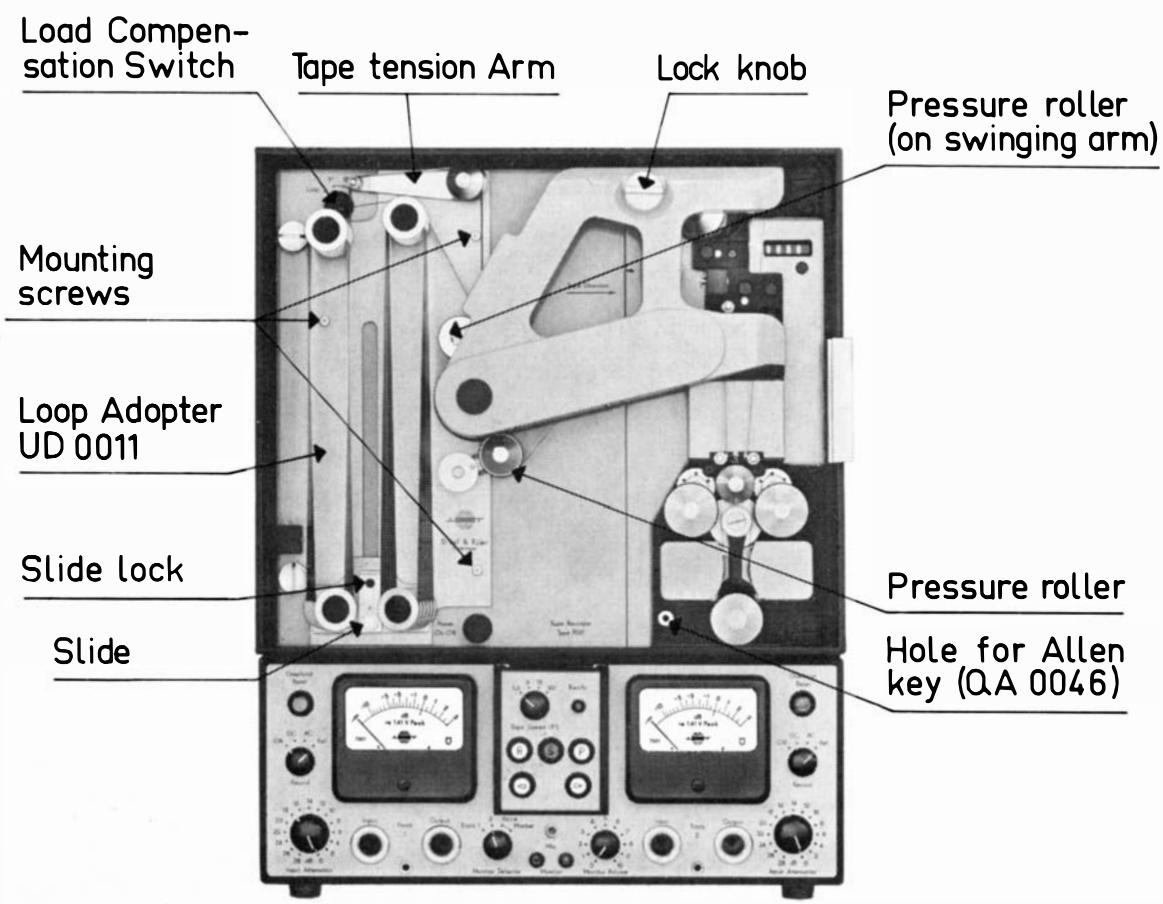


*Fig. 4.5. The Tape Recorder Type 7001 fitted with Loop Adaptor UD 0011.*

**Mounting of the Loop Adapter UD 0011**

The Tape Recorder Type 7001 is also designed to accept closed tape loops with a tape length from 8 ft – 25 ft (2.4 m – 7.5 m).

For this purpose the Loop Adaptor type UD 0011 must be attached to the Tape Recorder following the procedure described below.

1. Set LOAD COMPENSATION SWITCH to "Loop".
2. Turn the lock knob (see Fig. 4.5) 90° anti-clockwise and open the swinging arm.
3. Release the reel lock by loosening the Allen screw (Fig. 4.2). Allen key QA 0046 (Fig. 4.1). If the hubs are mounted they must be removed.
4. Attach the cores (DP 0013) to the spindles.
5. Lock the cores by tightening the Allen screws.
6. Mount a pinch roller (UA 0174) on to the swinging arm (see (17) Fig. 4.6). The mounting holes for the two Allen screws are situated just above the spindle (see (4) Fig. 4.2).
7. Attach the Loop Adaptor deck by means of the three mounting screws (Fig. 4.5).
8. The springloaded pinch rollers on the swinging arm and on the Loop Adaptor deck are fitted with a locking device which is activated by lifting the roller away from the core and depressing the pin. The pinch rollers should be locked in their open position before the tape loading procedure is commenced.

**Tape Threading of the Loop Adaptor**

The following procedure assumes that the Loop Adaptor UD 0011 is mounted as described above.

1. Prepare a tape loop of the desired length (8 ft – 25 ft).
   The counter indicates the tape length in feet. Mark the playback direction on the tape in case this is of importance.
2. Place the tape with base side (glossy) uppermost around the core (1) on the supply spindle and anticlockwise around the pinch roller (2) (see Fig. 4.6).
3. Release the locking device on the pinch roller (2) by lifting it away from the core (1). This will hold the tape in position.
4. The part of the loop coming from the roller (2) is taken around the tape guide (3) over the counter drum/tape speed sensor (4) down to and across the voice channel erase head (5) between the left tape sensor arm (6) and the tape guide (7) between the capstan (8) and the left pinch roller (9) across the record head (11) around the turn around idler (10) across the reproduce head (12) and between the capstan (8) and the right pinch roller (9) between the tape guide (7) and the right arm of the tape tension sensor (6).

5. Twist the tape 180° anticlockwise (same direction as when opening the swinging arm) and take it over the tape guides (14) and (15) with the coated side up.
6. Following the tape direction indicated on the swinging arm take the tape around the core (16) on the take-up spindle and clockwise around the pinch roller (17).
7. Release the pinch roller (17) to keep the tape in position.
8. Close and lock the swinging arm by turning the lock knob 90° clockwise.
9. The tape end coming from the pinch roller (17) is taken over the tape guide (18) and the tape tension arm (19) to hang down between the two pairs of loop rollers (20) and (21).
10. The tape end coming from the pulley (1) is taken over the track, closest to the tape deck, of the upper right loop roller (21) and down between the loop roller sets (20) and (21).
11. The rest of the tape loop should be distributed equally over the two sets of rollers (20) and (21) beginning with tracks close to the tape deck.

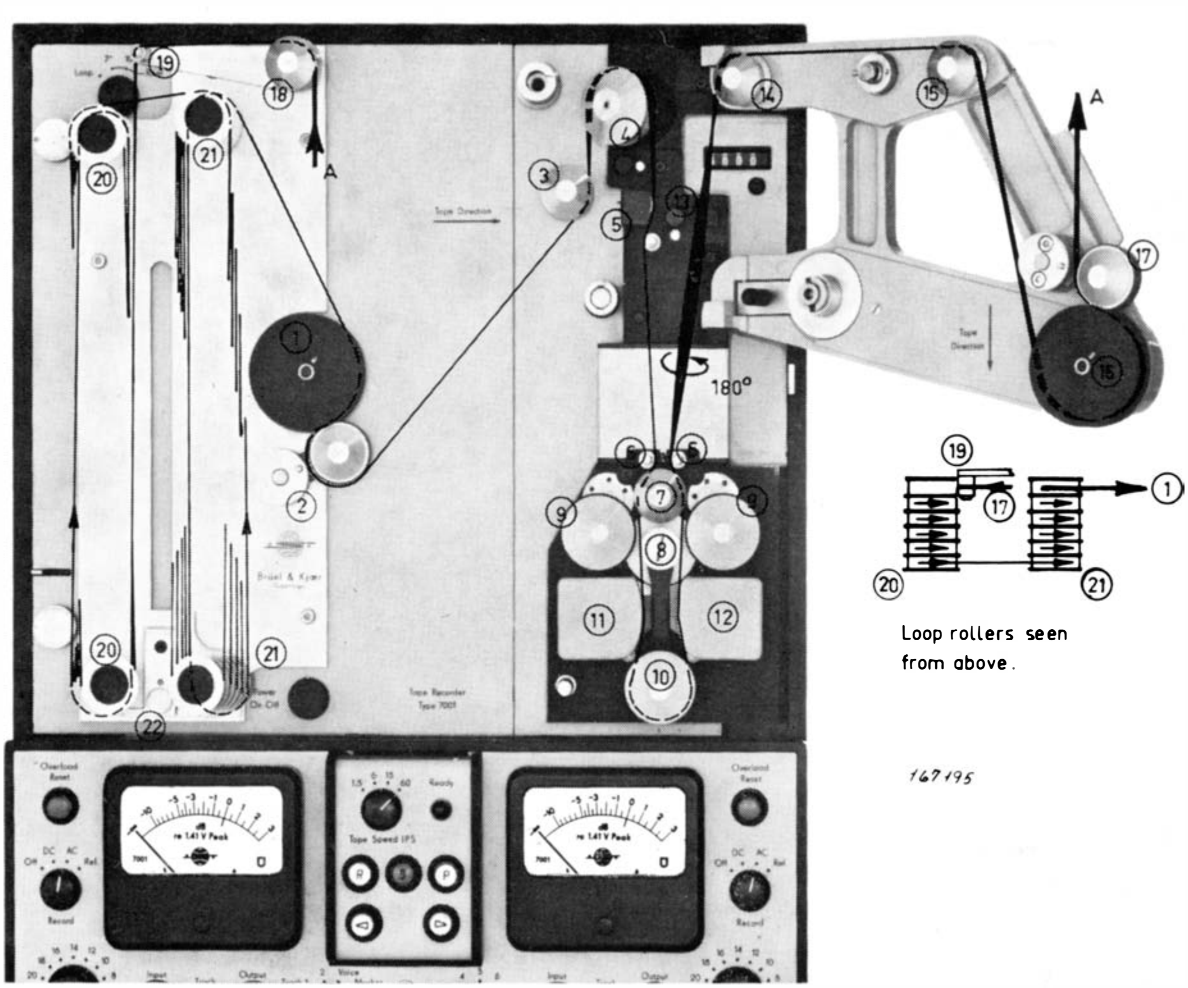


*Fig. 4.6. Tape Loading diagram (loop adaptor).*

12. Adjust the slide (22) so that the loop ends over the top set of rollers. (The slide is released by pressing the springloaded arm).
13. Fine adjustment of slide (22) is made so that the tape tension arm (19) is pulled half way down.
14. Check that the tape is not twisted and that is passes between the lamp and the photocell housing of tape sensor (13).

# 5. Operation

**Calibration**

A CALIBRATION SELECTOR is located behind the control box between the two indicating meters, Fig. 5.1. The switch has five positions:

Pos. 0: "Calibration off": This is the operational position of the switch. In all other positions the inputs are disconnected from the amplifiers and the tape transport mechanism is blocked.

Pos. 1: In this position the DC balance of the playback amplifiers of the two channels Track 1 and Track 2 respectively, can be adjusted by means of two multiturn potentiometers situated on the white line corresponding

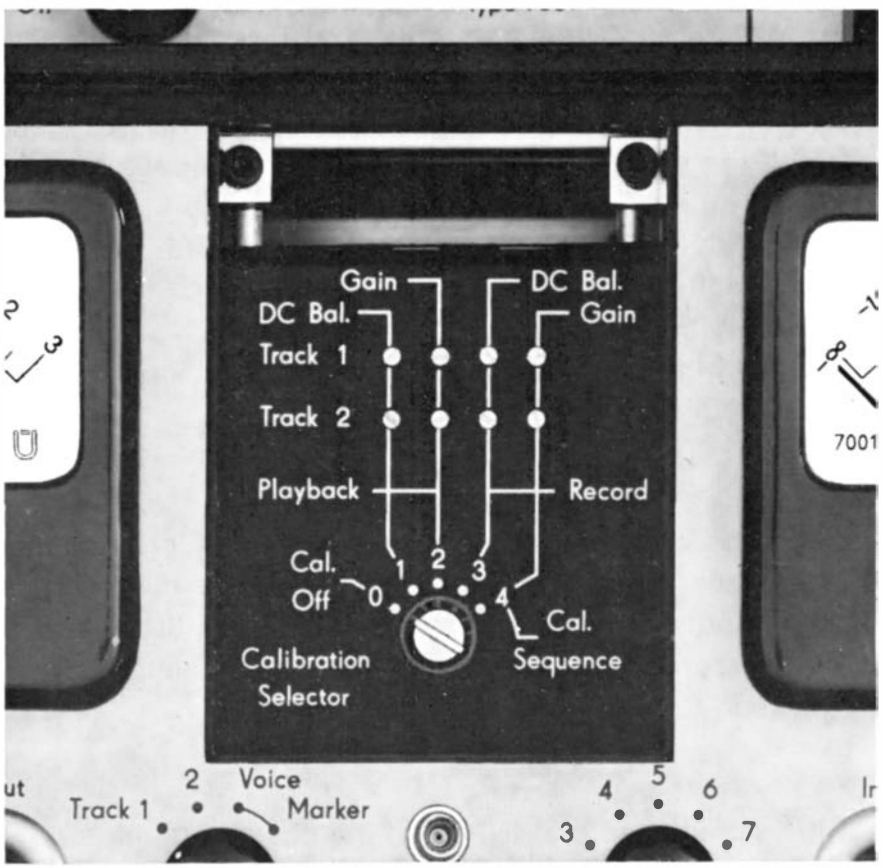


*Fig. 5.1. Calibration Selector.*

to the position of the switch.

Pos. 2: Serves to calibrate the gain of the playback amplifiers.

Pos. 3: Serves to set the DC balance of the record amplifiers by adjusting the carrier frequency of the modulator.

Pos. 4: Gain adjustment of record amplifiers by adjusting modulator gain.

**Procedure**

1. Allow a fifteen minutes warm-up time.
2. Set INPUT ATTENUATOR to "0 dB".
3. Pull out the Control Box between the two indicating instruments.
4. Set CALIBRATION SELECTOR to position "1" and adjust to "Zero-deflection" ($-\infty$) on the respective meters.
   NOTE: Normally the DC balance obtained by using the built-in meters is quite sufficient, but if necessary a more accurate "zero-setting" can be obtained by connecting an "AVO meter" across the output of the Tape Recorder.
5. With CALIBRATION SELECTOR in position "2" adjust meter pointer deflections to the red marks on the scales ("0" dB).
6. Set CALIBRATION SELECTOR to position "3" and adjust to "zero-deflection" on instruments. See also item 4 above.
7. Set CALIBRATION SELECTOR to position "4" and adjust meter pointer deflections to red mark on scale.
8. Repeat items 4 to 7 until meter readings are correct in all four positions of the CALIBRATION SELECTOR. This is necessary because the different calibration procedures have a certain influence on each other. The multiturn potentiometers for DC and gain calibrations are intended for fine adjustment. If the variation range is not sufficient a coarse adjustment can be carried out as described in Appendix C).
9. Set CALIBRATION SELECTOR to position "0" and RECORD switch to "Ref." and check that the reference voltage is correct. (Meter pointer should deflect to the red mark on the scale).*)
10. Set RECORD switch to the desired position and the Tape Recorder is ready for operation.

**Operation**

During operation the dust cover should be closed to protect the tape and heads and to prevent "drop outs" on the tape due to dust particles. Before recording it is furthermore recommended to bulk erase the tape reel.
When the Tape Recorder is loaded with tape and calibrated as described earlier the operation procedure is as follows.

*Record*

1. Connect the signal source to INPUT of the channel required (1, 2 or both).
2. Set RECORD switch to the desired position for each channel.
   "Off": *When recording on one channel only this position must be used on the other channel if information previously recorded on this channel must be preserved.*

---

*) The reference voltage (1.41 V Peak) is adjusted at the factory and further adjustment should not be necessary. If for one reason or an other an adjustment is necessary the procedure is described in Appendix C, items 1 to 7.

Also, with the switch in this position the meter circuit of the channel not in use can be employed to monitor the output from the channel in use by making an external connection between the INPUT of the channel not used to the OUTPUT of the channel used, see page 15.

"DC": This position is used if the input signal contains a DC component or frequencies below some 10 Hz.

"AC": In this position the lower limiting frequency of the Tape Recorder is 4 Hz (−3 dB).

3. To obtain the best possible signal to noise ratio the input level should be as high as possible without overloading the input (< 1.4 V, peak amplitude).
4. If the OVERLOAD indicator lights up the input amplifier is overloaded and the input signal level must be reduced or attenuated by means of INPUT ATTENUATOR. Reset OVERLOAD indicator by depressing the back-lit button.
5. Note INPUT ATTENUATOR setting.
6. Note tape counter reading or reset to "Zero" by depressing the button just beneath the counter if it is important to know the position and length of the recording.
7. Set TAPE SPEED to the desired position considering frequency range and possibilities of frequency transformation.
8. When the green "Ready" lamp lights. Depress the two buttons on the Control box (see Fig. 5.2) marked "P" and "R" simultaneously and release again. (Note: "P" should be released before "R").
   The lamp behind button "R" will light and recording will commence.
   The recorded signal can be monitored during recording via the MONITOR outputs or directly from the OUTPUT sockets.
9. Stop recording when required by depressing the red button marked "S" on the control box.

*Playback*

1. Connect OUTPUT to whichever instrument is to be used for analysis of the recorded signal.

2a. Calibrate these instruments in accordance to the respective instruction books. When the Tape Recorder is calibrated as described under section "Calibration" it will reproduce the recorded signal with unchanged level.*)

2b. Set RECORD switch to "Ref" and INPUT ATTENUATOR to the setting used during recording. The output level obtained then corresponds to 1.41 V peak amplitude and it can be used as a reference to determine the signal level.

---

*) If the INPUT ATTENUATOR switch has been set to any other position than "0" during recording the recorded signal is *not* the same as the input signal.

3. Set TAPE SPEED to the desired tape speed.
4. Depress playback button (P) on the control box. The function will be blocked until the green "Ready" lamp lights up.
5. To stop playback the button marked "S" is depressed.

*Fast Tape Transport*

On the control box (Fig. 3.2) are found two buttons each marked with an arrow. The one to the right is for "Fast Forward" and the one to the left for "Rewind". To protect the magnetic heads and tape during fast winding a pair of rollers are situated just beneath the heads. During fast winding they will automatically lift the tape away from the heads.

NOTE: When the LOAD COMPENSATION switch is in position "Loop" the fast tape transport is blocked.

*Fast Forward* (▶)

Before this button will operate the tape transport must be stopped. Then depress the pushbutton (▶) (to the right) on the control box. To stop the tape transport depress the pushbutton (S).

*Rewind*

Stop the tape transport and depress (◀).

It is possible to change directly from one fast winding direction to the other by depressing the pushbutton for the opposite winding direction (without using the (S) button).

For a standard tape of 2400 feet the full winding times in both directions are less than 95 sec.

*Automatic Stop*

The photo-electric end-of-tape sensor can be used to purposely stop the tape transport by introducing a piece of transparent tape wherever desired (for instance before the tape leaves the reels during a fast winding process). The length of transparent tape necessary to stop the tape transport does, however, depend upon the tape speed, see table below:

| Tape Speed (ips) | 1.5 | 6 | 15 | 60 | Fast winding |
|---|---|---|---|---|---|
| Min Length of Transparent Tape mm<br>Inch | 2<br>3/32 | 2<br>3/32 | 2<br>3/32 | 8<br>5/16 | 60<br>2½ |

After the end-of-tape sensor has been activated it takes approximately 3 seconds before the tape transport stops. In the case of fast winding it is therefore recommended to keep some 50 feet (15 m) of tape on the reels after the piece of transparent tape which activates the end-of-tape sensor.

**Monitoring**

The MONITOR SELECTOR switch selects one of the measuring channels or the voice track for the following outputs:

*"Mic"* A monitor microphone is connected to the coaxial socket marked "Mic". This microphone is a small dynamic type which acts as a miniature "Loudspeaker", (playback) when the pushbutton on top of it is *not* activated and as microphone (record) when activated (see section "Description of the Voice Channel" page 18).

*Monitor* The MONITOR output should not be loaded by less than 2 kΩ for low distortion.

The output level on both outputs is adjustable by the MONITOR VOLUME control.

**Voice Track**

The Tape Recorder Type 7001 is supplied with a third track situated between the two measuring channels. It serves two purposes:

A. To carry information pertaining to measuring data recorded on measuring channels.

B. Recording of marker pulses.

*Recording on Voice Track*

This can be done in two different ways referring to the two purposes mentioned above.

NOTE: Recording can take place on the voice track when the Tape Recorder is operated in the recording mode as well as in the playback mode under the following conditions:

*A. Recording via Monitor Microphone*

1. Plug the monitor microphone into the coaxial socket marked "MIC" just beneath the control box.
2. Depress the pushbutton situated on the microphone itself and give the desired information to the microphone.

*B. Recording via MONITOR SELECTOR, – "Marker"*

1. Set MONITOR SELECTOR to position "Voice".
2. Turning the MONITOR SELECTOR further clockwise to the spring loaded position "Marker" produces a 440 Hz marker tone which will be recorded on the voice track for as long as the MONITOR SELECTOR is activated. As described under section "Remote Control" these marker tones can be used for instance for syncronising the Level Recorder Type 2305 and switching the filters in the Spectrometer Type 2112.

*Erasing Voice Track*

The voice track can only be erased separately by depressing the pushbutton on the monitor microphone and preventing any signal from reaching the microphone.

**Remote Control**

Situated at the rear of the Tape Recorder is a 6-pinned socket marked MARKER OUTPUT. Via this socket it is possible, by means of marker pulses on the voice track, to establish synchronism between the recordings on the Tape Recorder, the Spectrometer Type 2112 and the Level Recorder Type 2305. A special remote control cable, AQ 0016, is delivered with the Tape Recorder for this purpose.

**Frequency Analysis on Uncalibrated Paper**

1. Connect the instrument as shown in Fig. 5.3, except for the remote control, AQ 0016.
2. Set the TAPE SPEED to the desired position.
3. Set the FUNCTION SELECTOR (2112) to "Lin."
4. Set the signal level (see the instruction books for the Level Recorder Type 2305 and the Spectrometer Type 2112).
5. Set the FUNCTION SELECTOR to desired position.
6. Prepare a tape loop containing the signal which is going to be analyzed.

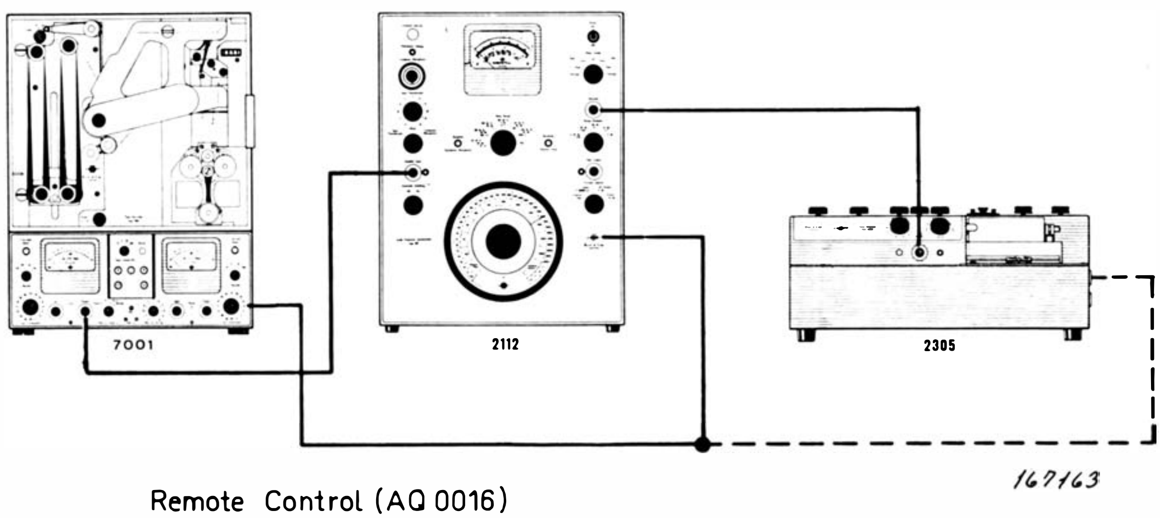


*Fig. 5.3. Set-up for automatic frequency analysis.*

7. Record marker pulses on the voice track, as described in section: "Voice Track". The pulses should not be longer than 0.5 second approximately and must be recorded at the actual tape speed.

Note: If third octave analysis is desired one pulse per loop length will ensure that the loop cycle will be within each third octave filter. If octave analysis is desired three pulses must be recorded to obtain the same effect. The distances between these pulses are not critical.

8. Connect the remote control cable AQ 0016 to the Tape Recorder and the Spectrometer. (The plugs are marked with type numbers). Leave the Level Recorder plug unconnected.
9. Start playback by depressing the pushbutton (P) on the Control Box.

**Frequency Analysis on Precalibrated Paper**

1. Connect the instruments as shown in Fig. 5.3, except for the remote control cable AQ 0016.
2. Set the TAPE SPEED to the desired position.
3. Set the FUNCTION SELECTOR (2112) to "Lin."
4. Set the signal level (see the instruction books for the Level Recorder Type 2305 and the Spectrometer Type 2112).
5. Set the FUNCTION SELECTOR to the desired filter position.
   When the time for one loop cycle at the actual tape speed is greater than the time used to move the paper one third octave at the actual paper speed*) the following procedure can be followed.
6. Prepare a tape loop with the signal which is going to be analyzed.
7. Record one marker pulse on the voice track if the same part of the loop cycle should be repeated within each third octave filter. The pulse should not be longer than 0.5 second and must be recorded at the actual tape speed.

Note: If octave analysis is carried out it is necessary to let the loop complete three cycles within each octave filter.

8. Connect the remote control cable AQ 0016 to the respective instruments (type numbers are written on the plugs).
9. Draw out the GEAR LEVER on the right side of the Level Recorder.
10. Turn the nicked mark on the SWITCH RELEASE screw (S) (Fig. 2.3 in the instruction book for the Level Recorder Type 2305) to the upper position.
11. Set the PAPER DRIVE to "Start" and "Forward".
12. Lock the SINGLE CHART – CONTINUOUS RECORDING button in position: "Cont. Record".
13. The PAPER SPEED switch on the Level Recorder must be set so that the time it takes the paper to move one third octave (the time between two pulses from the Level Recorder) is shorter than the time for one loop cycle.
14. Synchronise the precalibrated paper on the Level Recorder with the Spectrometer as described in the instruction book for the Spectrometer Type 2112.
15. Start playback by depressing the pushbutton (P) on the Control Box.

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*) Note: If the loop length is so short and the desired paper speed so slow that this relation cannot be fulfilled the filter switch on the Spectrometer can be controlled separately from the Level Recorder by connecting these two instruments with remote control cable AQ 0002 (see the instruction book for the Level Recorder Type 2305 or the Spectrometer Type 2112).
In this case the best analysis is obtained when several loop cycles are completed within each filter.

**Record and Playback Times**

*Reels*

A Standard tape (3600 ft.) will give the following maximum recording time at the different tape speeds:

| Recording Speed | Recording Time |
|---|---|
| 60 IPS | 12 min. |
| 15 IPS | 48 min. |
| 6 IPS | 2 hr. |
| 1.5 IPS | 8 hr. |

*Tape Loops*

As mentioned before it is possible to run tape loops with a tape length between 8 ft. – 25 ft. This will give the following limits of recording time.

| Tape Loop Length | 8 ft. (2.4 m) | 25 ft. (7.5 m) |
|---|---|---|
| 60 IPS | 1.6 sec | 5 sec |
| 15 IPS | 6.4 sec | 20 sec |
| 6 IPS | 16 sec | 50 sec |
| 1.5 IPS | 64 sec | 200 sec |

# 6. Combined Units

**Combined Units.**

The Tape Recorder Type 7001 can be delivered in combination units together with the Level Recorder Type 2305 and other B & K instruments. These combinations offer a wide variety of measurement possibilities and have been designed to meet a requirement for a more permanent set-up where rack systems are not required and where space is at a premium.

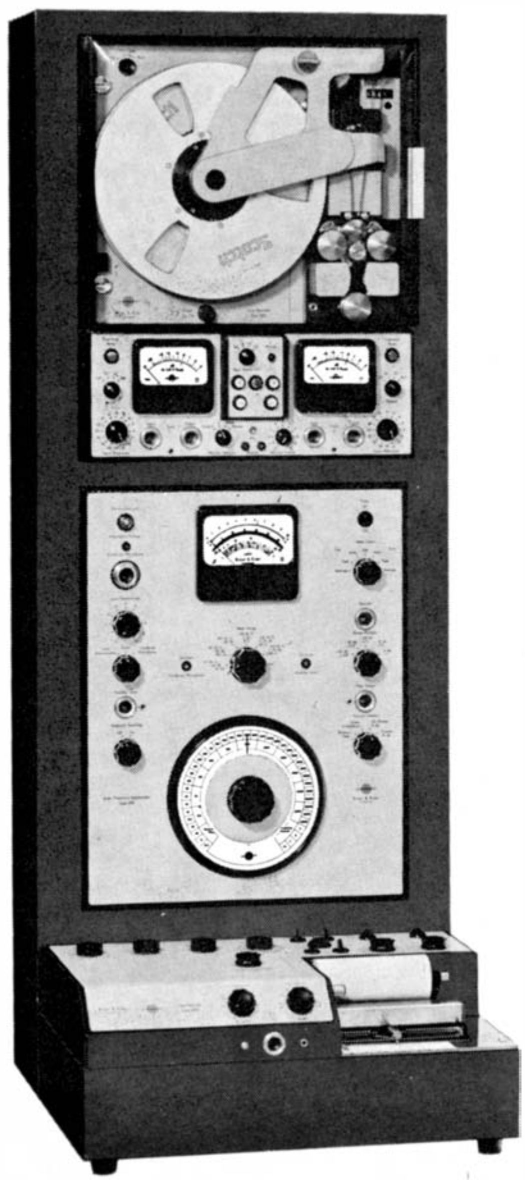

*Fig. 6.1. The Low Frequency Spectrum Recorder Type 3339.*

**Tape- and Graphic Recorder Combination Type 3336.**

This unit contains the Tape Recorder Type 7001 and the Level Recorder Type 2305. Considering the function of frequency transformation by means of the Tape Recorder it is possible to make recordings of variations in signal levels with a frequency from DC to approximately 800 Hz as well as response curves in the frequency range from DC to 20 kHz.

**Tape- and Graphic Recorder Combination Type 3337.**

Consists of the Tape Recorder Type 7001, the Level Recorder Type 2305 and the Microphone Amplifier Type 2603, which can be used as a preamplifier and power supply for the microphone (including cathode follower) and for the accelerometer (including preamplifier).

**Low Frequency Spectrum Recorder Type 3338.**

This unit consists of the Tape Recorder Type 7001, the Level Recorder Type 2305 and the Frequency Analyzer Type 2107. This combination provides narrow band spectrum analysis in the frequency range of 0.5 Hz to 20,000 Hz.

**Low Frequency Spectrum Recorder Type 3339.**

Consists of the Tape Recorder Type 7001, the Level Recorder Type 2305 and the Audio Frequency Spectrometer Type 2112, which makes it possible to make third octave and octave frequency analysis in the frequency range from 0.6 Hz to 20,000 Hz.

# 7. Applications

**Measurement and Analysis of Acoustic Noise.**

In many cases of noise measurement it is convenient and some times necessary to be able to record and store the original noise signal for later reproduction and analysis in the laboratory. Typical examples are the measurement and evaluation of impulsive noise like sonic bangs, transient or intermittent noise, and various kinds of semi-stationary noise. The output signal from the measur-

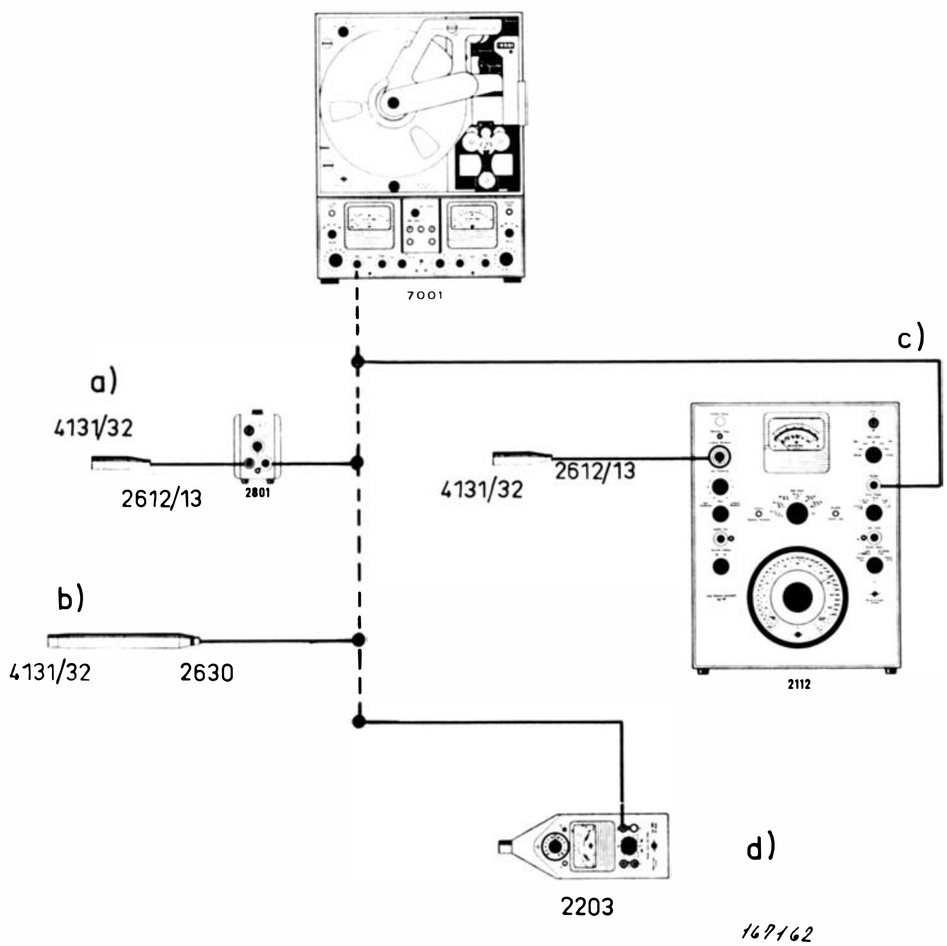


*Fig. 7.1. Typical measurement arrangements used to record acoustic noise on the Tape Recorder 7001.*

*a) Use of a B & K Condenser Microphone with associated Cathode Follower and Microphone Power Supply Type 2801 (or 2803).*

*b) Use of a B & K Condenser Microphone with Cathode Follower Type 2630 including battery power supply.*

*c) Use of a B & K Condenser Microphone and Cathode Follower and the Spectrometer Type 2112.*

*d) Use of the B & K Precision Sound Level Meter Type 2203.*

ing microphone is then fed to the Tape Recorder, either directly or via some amplifying device, see Fig. 7.1.

During recording care should be taken not to overdrive the recorder amplifiers. For this purpose the Tape Recorder has been supplied with overload indicators which warn the operator when spurious overloadings occur. In cases where impulse noise is recorded it is advisable to set the recorder gain control 10 to 28 dB lower than normal due to the very high crestfactors involved.

A problem which might also cause confusion on some occasions is the calibration of the tape, i.e. a determination of the absolute sound pressure level of the recorded noise. Here the use of the PISTONPHONE Type 4220 is extremely helpful, in that it makes possible the recording of a reference signal with a very accurately known sound pressure level. Care need only be taken either not to touch the gain controls of the instrumentation after the reference signal has been recorded or to give exact information on changes in adjustment directly onto the tape (voice channel).

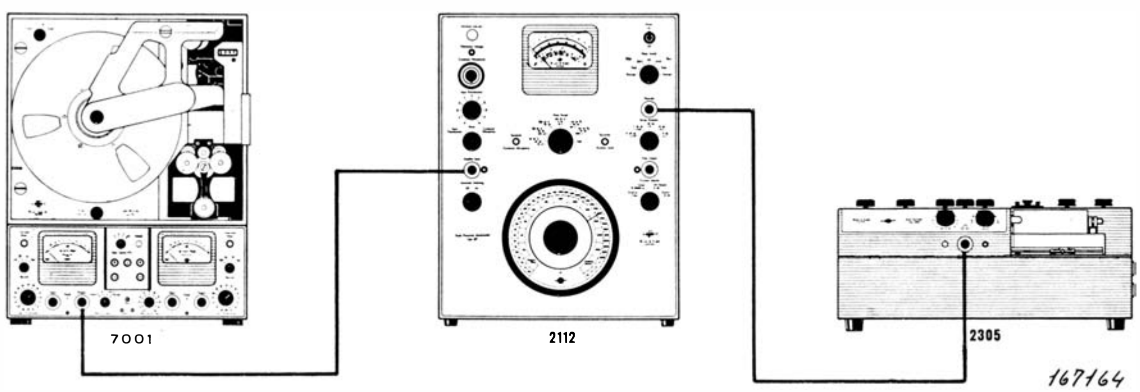


*Fig. 7.2. Arrangement used for laboratory analysis of magnetically taped data.*

The actual ultimate analysis of the recorded noise may take many forms and serve many purposes. It might, for instance, consist in the use of the signal for psycho-acoustical experiments and subjective comparison tests. In this connection multi-track recording and reproduction utilizing stereophonic principles are some times employed. Or it may consist in a frequency or time transformation of the originally recorded signal by playing the tape back at a speed different from the one used during recording Fig. 7.2.

This might be desirable to either bring a very low frequency signal up into the frequency range of commonly available frequency analyzers, or to bring a recorded "high" frequency signal down into the operating range of graphic pen recorders. An example of the first is the frequency analysis of a sonic boom and of the latter the transformation of a short impulse, say that produced by an explosion, down in frequency (lower tape speed) so that the exact shape of the impulse may be recorded graphically.

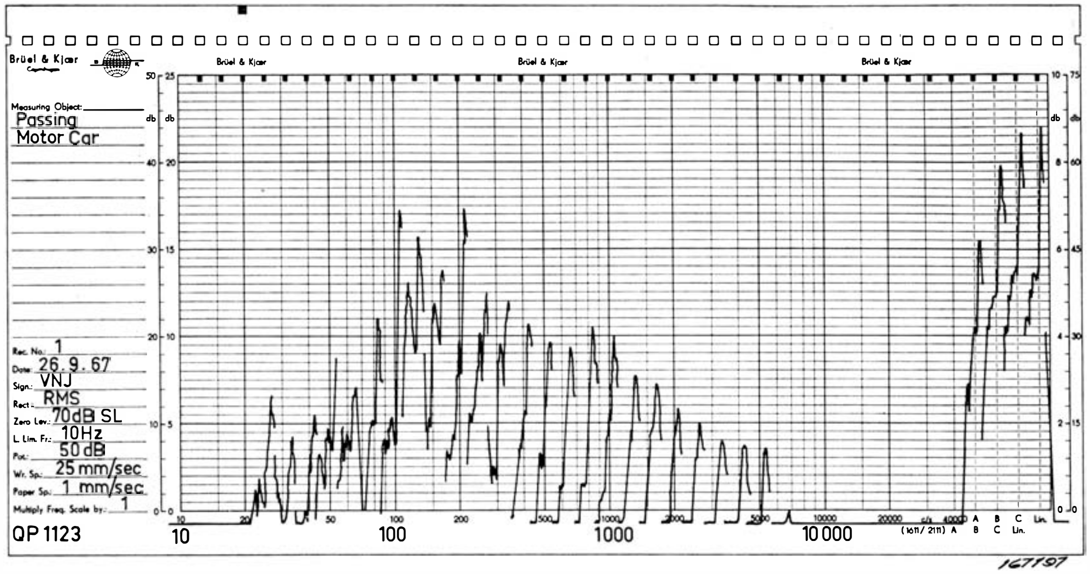


*Fig. 7.3. Frequency analysis of the noise from a passing motor car.*

Finally, certain representative samples of the noise may be selected from the tape and formed into endless tape loops allowing very careful frequency analyses to be made (Fig. 7.3). It is then also possible to obtain a three-dimensional picture of for instance transient noise, see Fig. 7.4.

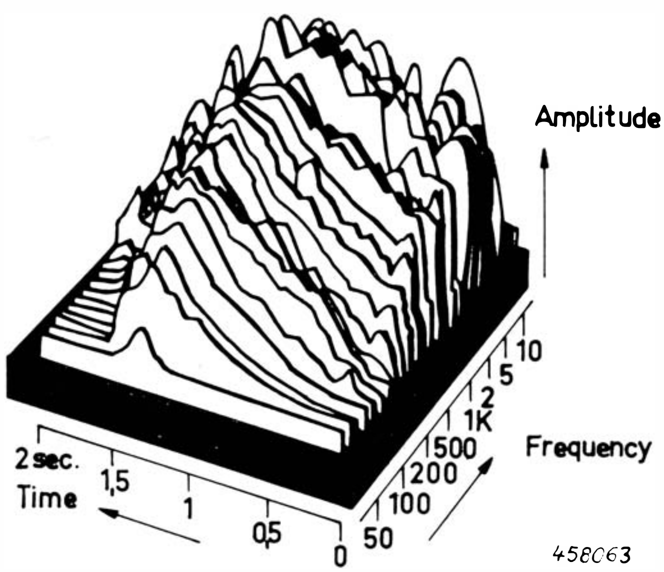


*Fig. 7.4. Three-dimensional analysis of transient acoustic noise from a passing motor cycle suddenly halting.*

**Analysis of Low Frequency Vibrations.**

Mechanical vibrations encountered in practice often contain components of very low frequencies. Several methods may be used to analyze such vibrations, one of the most elegant ones, however, being a frequency transformation by means of tape recording. The mechanical vibrations are then transformed into electrical signals by means of suitable mechanical electrical transducers, and

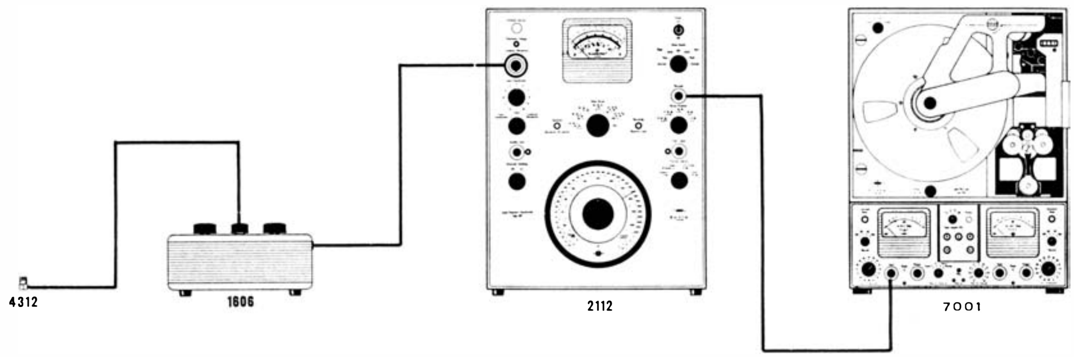


*Fig. 7.5. Measuring arrangement used to record low frequency vibrations onto magnetic tape.*

the electrical signals are recorded on magnetic tape. Depending upon whether it is desired to study the vibration waveform or the vibration frequency spectrum, the magnetic tape can, during play-back, either be slowed down or speeded up. As the vibration frequency spectrum constitutes a powerful tool in estimating vibration transmission properties it may, in the majority of cases, be the speeding-up procedure that is used. Low frequency vibrations can then be brought up into the frequency range of conventional frequency analyzers, and analysis time is automatically also reduced for the same degree of spectrum resolution. An example of such a frequency transformation is the measurement of background vibrations in buildings where, for instance, very vibration sensitive experiments are to be conducted. If the lowest vibration frequency of interest is some 2 Hz a typical measurement arrangement which may be used to record the vibrations is shown in Fig. 7.5. It consists of an Accelerometer Type 4332, a Vibration Pick-up Preamplifier Type 1606, an Audio Frequency Spectrometer Type 2112 (switched to its "Linear 2–45000 Hz" range) and the Tape Recorder Type 7001.*)

When the vibrations have been recorded on the tape this can be played back at a higher speed and analyzed by means of the arrangement shown in Fig. 7.2. Using pre-printed, frequency calibrated paper on the Level Recorder Type 2305 shown in Fig. 7.2 a spectrogram as given in Fig. 7.6 is obtained. Here one third octave analysis of the vibrations were made which gave an adequate resolution of the spectrum in this case.**)

*Note:* The frequency scale on the paper corresponds to the actual vibration frequencies (i.e. before frequency transformation was made).

---

*) If the low frequency vibrations are very strong and only little amplification is required of the output signal from the Accelerometer, Type 2112 may be substituted by the Power Supply Type 2801 (or 2803). In this way it is also possible to record vibrations with frequencies lower than 2 Hz.

**) Due to the very low level vibrations ($3 \times 10^{-5}$ m/sec.) a special accelerometer had to be used, see also B & K Technical Review No. 1-1967.

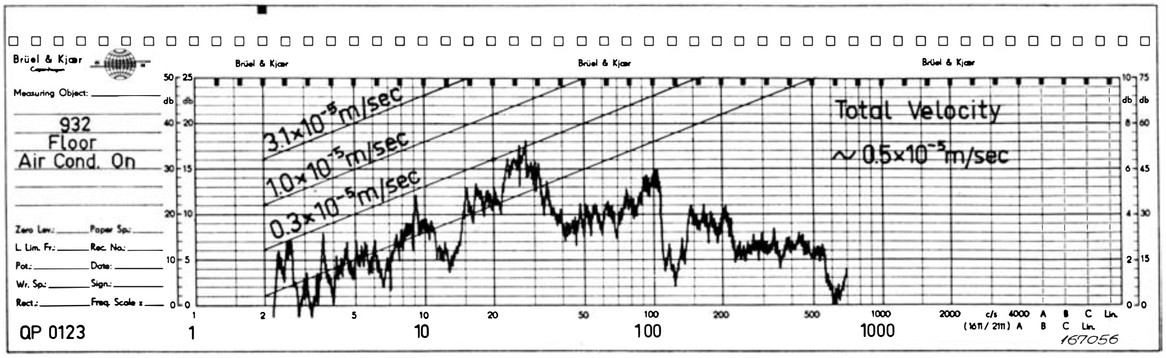


*Fig. 7.8. Spectrogram of the background vibrations in a modern building.*

**Frequency Analysis of Dynamic Strain.**

An excellent method for frequency analyzing low frequency dynamic strain is to use the Tape Recorder as a speed up device. If only relative measurements are desired, i.e. in cases where it is not strictly necessary to calibrate the recording in terms of $\mu$Strain, a simple and straight-forward recording arrangement can be used as shown in Fig. 7.7. Should it be desired to make "absolute" measurements a suitable calibration of the tape can be made dynamically by

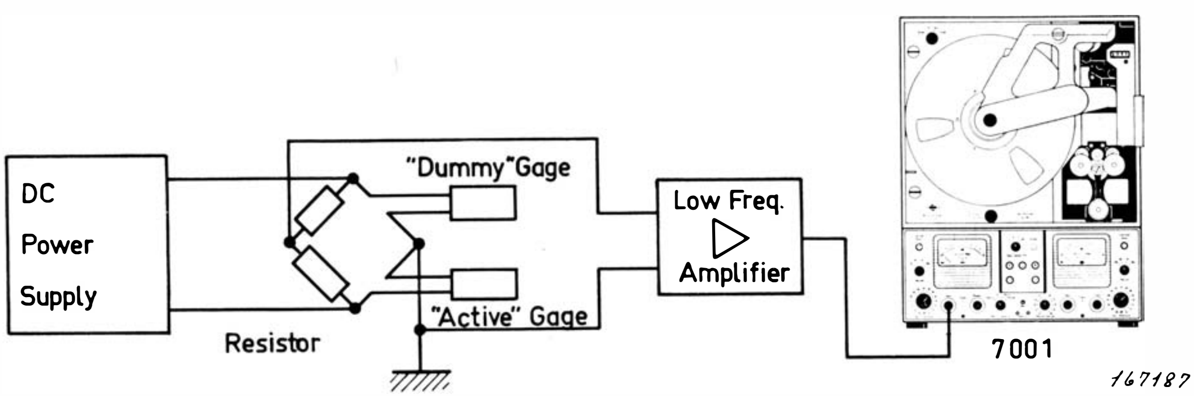


*Fig. 7.7. Measuring arrangement used to record uncalibrated strain gage data onto magnetic tape.*

means of the Strain Gage DC Bridge Supply Unit Type 1535 Fig. 7.8. As shown in the figure, however, it is in this case necessary to use an external signal generator which can supply a voltage of 3 Volts (RMS) into a load of 100 Ω. The frequency of the signal generator should, of course, be inside the frequency range of the Tape Recorder at the tape speed chosen for recording. The Balancing Unit Type 1530 is during calibration used to balance the internal resistance bridge in Type 1535 when this is switched to "Ref. Adjustment".

By switching the DC Bridge Supply Unit to "Ref. 1000 $\mu$Strain", one of the resistors in the bridge is shunted by 50 kΩ, see Fig. 7.9 whereby the desired calibration signal of 1000 $\mu$Strain is produced on the tape.

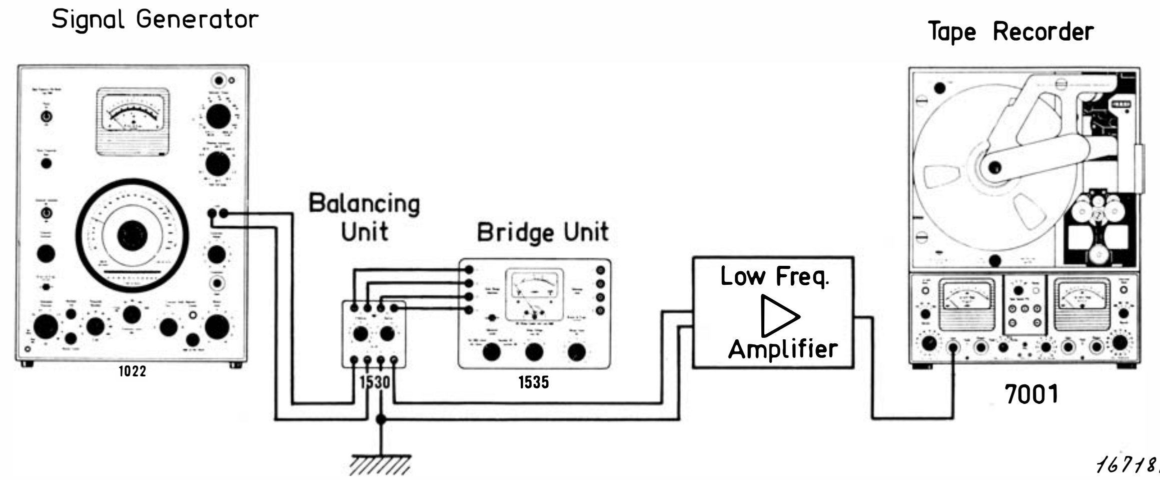


*Fig. 7.8. Arrangement used to calibrate the tape recording in terms of μStrain.*

During recording of the actual signal from the strain gage installation being investigated, Type 1535 should be used to supply the necessary voltage to the installation, see Fig. 7.10. The BRIDGE VOLTAGE switch on Type 1535 must then be in position "3" and the ADJUSTMENT SWITCH in position "Operation DC". When the lowest frequency of interest in the investigation is greater than 2 Hz, the unit marked "Low Frequency Amplifier" in Figs. 7.8 and 7.10 could be any of the Brüel & Kjær measurement amplifiers. If analysis of signals containing frequencies lower than 2 Hz is required, a special low frequqency amplifier (or DC-amplifier) must be used.

When the signal has been recorded the tape can be made into a loop and frequency analyzed at a higher tape speed as discussed under "Analysis of Low Frequency Vibrations", Fig. 7.5.

An example of such an analysis is shown in Fig. 7.11. Here a two degrees-of-freedom mechanical system was vibrated on an electrodynamic vibration machine fed from a wide-band random noise source and the strain, caused

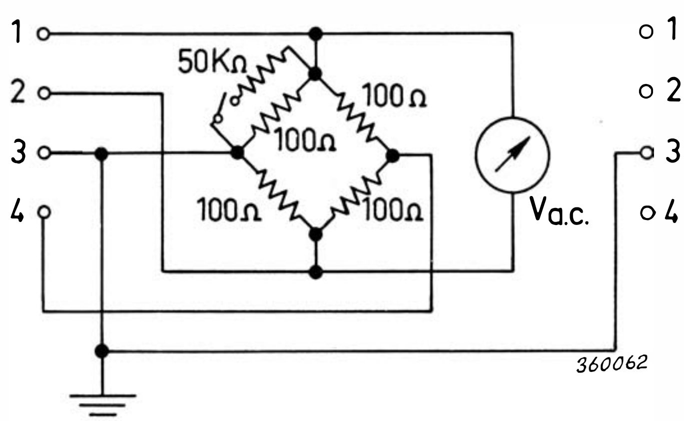


*Fig. 7.9. Circuit diagram of the calibrated resistance bridge built into the Strain gage DC Bridge Supply Unit Type 1535.*

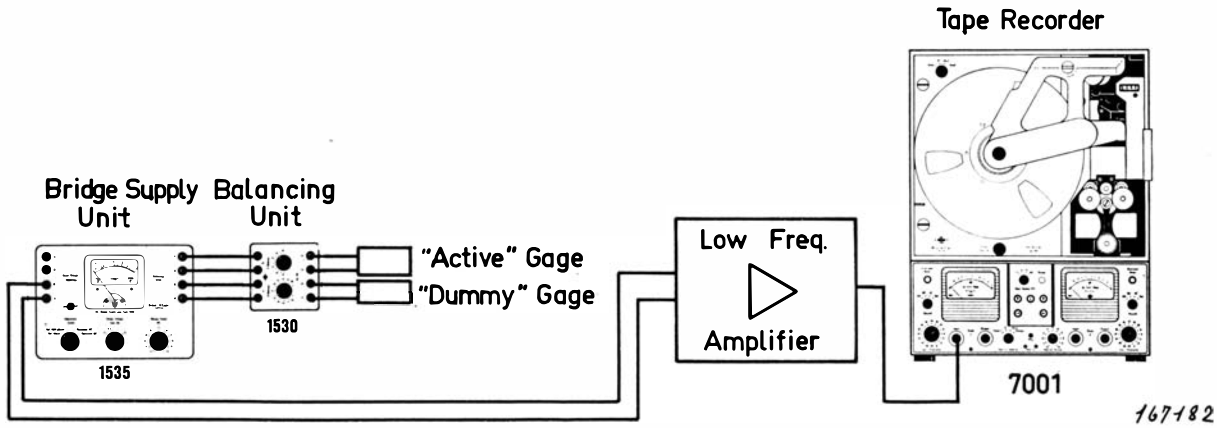


*Fig. 7.10. Arrangement used to record calibrated strain data onto magnetic tape.*

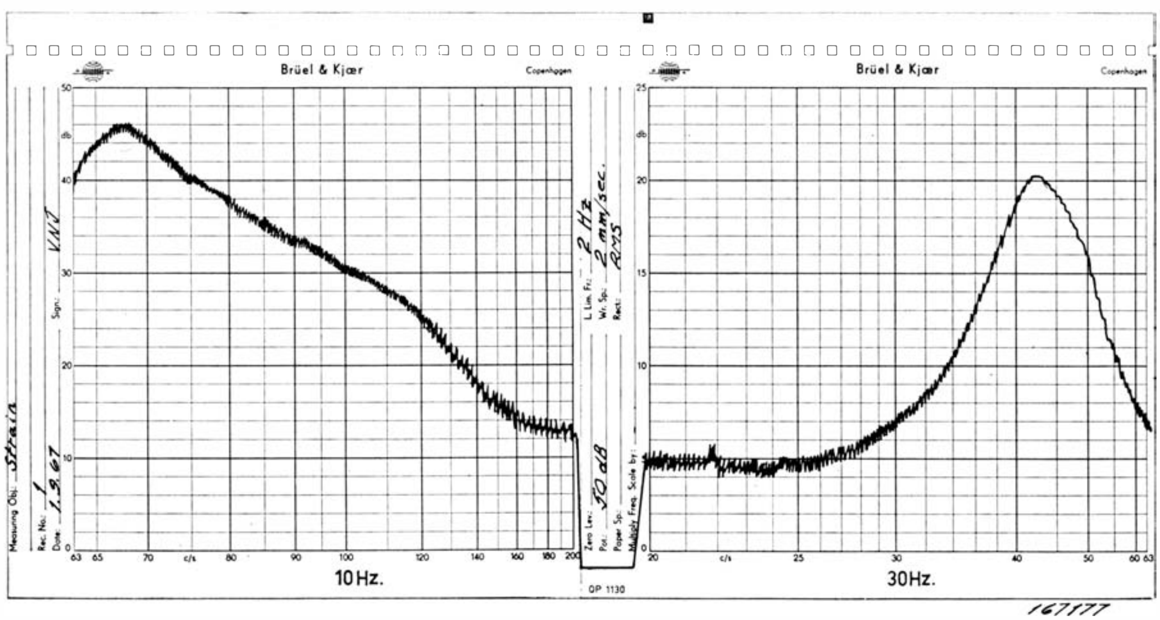


*Fig. 7.11. Example of the frequency analysis of strain measurements. The Analyzer used in this case was the B & K Frequency Analyzer Type 2107 which has a considerably higher frequency resolution than the Spectrometer (Type 2112).*

by bending stresses, measured. A frequency transformation ratio of one to ten was used and the frequency analysis was made by means of a Frequency Analyzer Type 2107. The 0 dB reference corresponded to 40 $\mu$Strain.

**Graphic Recording of the Vibration Waveform.**

When it is desired to graphically record the vibration waveform the Tape Recorder can be used to bring "high" frequency vibrations down into the frequency range of ordinary graphic pen recorders. Fig. 7.12 shows an example of such a transformation in that the strain which was frequency analyzed by means of a speed-up procedure in Fig. 7.11 has here been recorded on the Level Recorder Type 2305 after a one to forty step-down transformation.

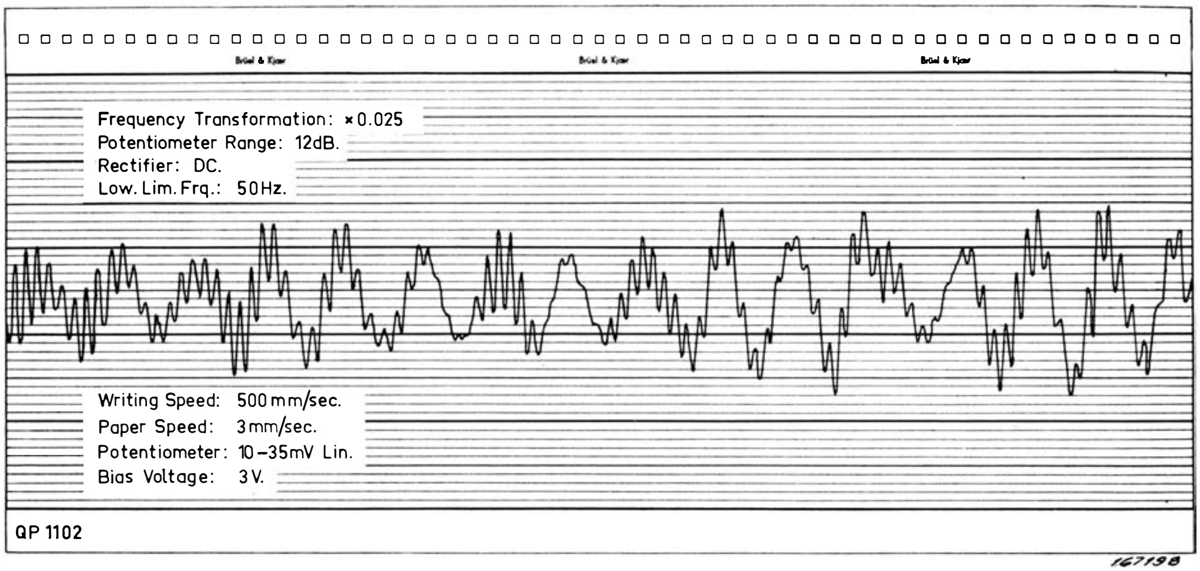


*Fig. 7.12. Graphic recording of the vibration waveform corresponding to the frequency spectrum shown in Fig. 6.11.*

**Room Acoustic Measurements.**

In all room acoustic work the Tape Recorder can be used simultaneously as a signal source and for recording the measurement data. For instance, one of the channels of the Recorder can be used to pre-record the desired excitation signal wide band noise, narrow band random noise, pure tones, music etc. etc. While this channel is being used to excite the room, the second channel of

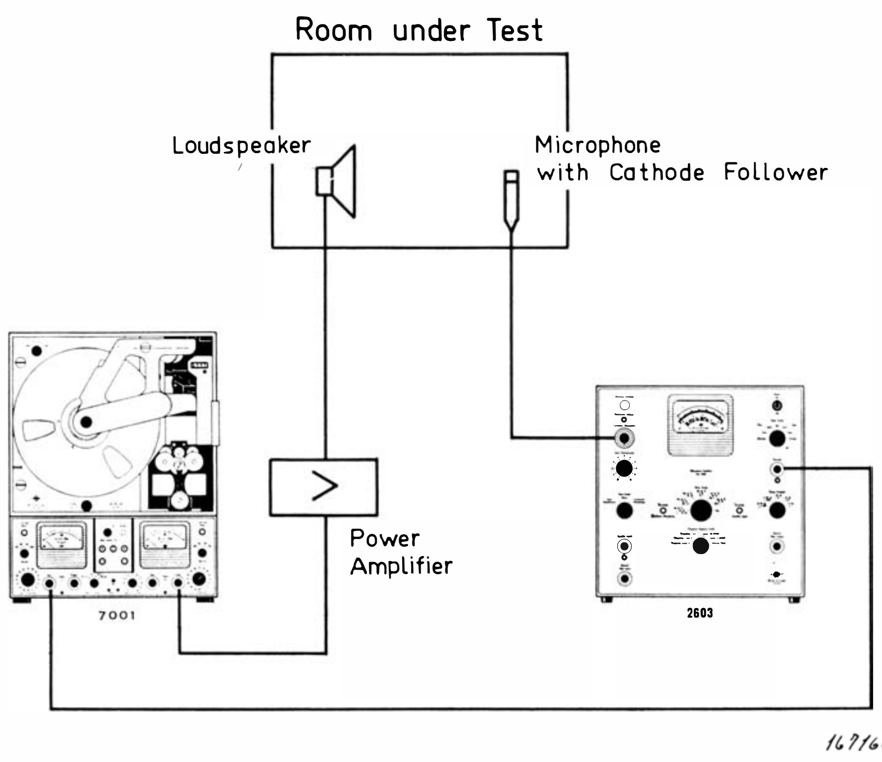


*Fig. 7.13. Example of the use of the Tape Recorder for room acoustic measurements.*

the Recorder can be used to record the measurement data which can then be processed back in the laboratory under more convenient conditions and as often as is desired. Special applications of the Tape Recorder in room acoustics include the measurement of reverberation time and the comparison of the intelligibility of rooms.

**Sound Insulation Measurements.**

When a great number of sound insulation measurements have to be made in the same building it will be of an advantage to use a short duration signal such as a gun shot, and to record the sound level on the two channels simultaneously. The necessary investigations can be made back in the laboratory where the reverberation times of the rooms can also be found.

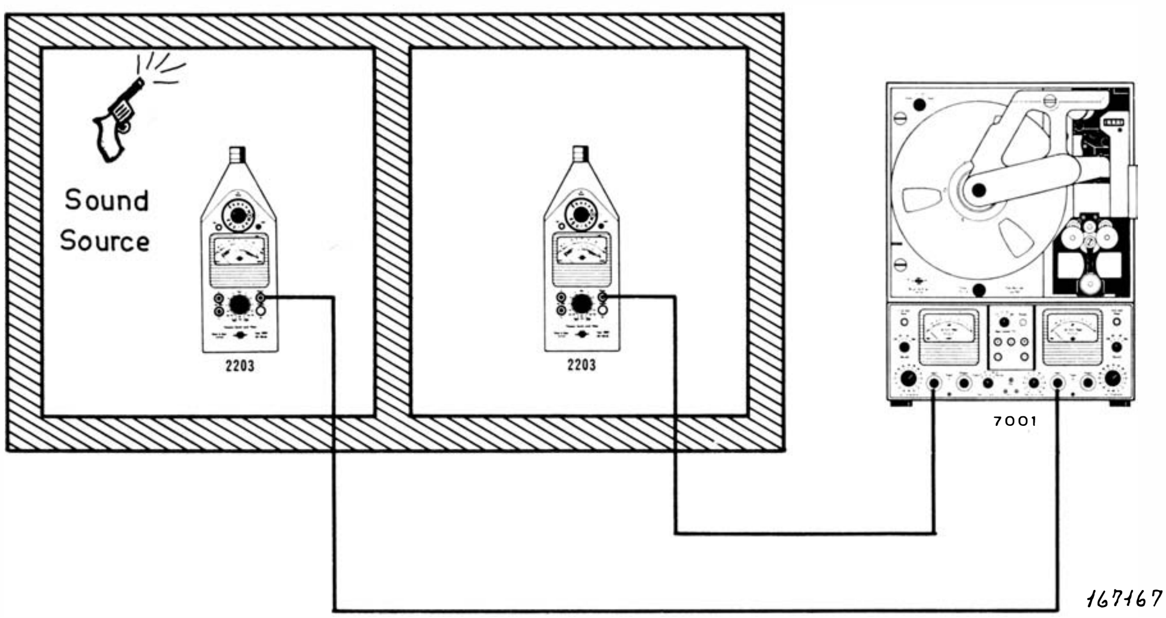


*Fig. 7.14. Sound insulation measurements by means of the Tape Recorder.*

# 8. Appendices

**Appendix A.**

*Frequency Modulation.*

There are many excellent and thorough textbooks describing the principles of frequency modulation in great details*). On the following few pages only a brief recapitulation of the most basic facts pertinent to the use of FM technique in magnetic tape recording is thus made.

Almost any practical AC signal can be interpreted as a sum of simple sinusoidal and cosinusoidal "waves". For a basic understanding of for instance a modulation process it is thus often sufficient to just consider one cosinusoidal signal

$$a = A_o \cos \varphi \qquad (1)$$

where $A_o$ is the maximum amplitude of the signal and $\varphi$ is a continuously varying, generalized angle. For a constant frequency signal of frequency f, $\varphi$ can be written

$$\varphi = \int 2\pi f\,dt = 2\pi f t + \Phi = \omega t + \Phi$$

where $\omega = 2\pi f$ = angular frequency.

If the signal frequency is *not* constant it is useful to define an *instantaneous angular frequency*

$$\frac{d\varphi}{dt} = 2\pi f = \omega \qquad (2)$$

In frequency modulated systems the amplitude factor $A_o$ in equation (1) is kept constant while the instantaneous frequency is varied according to some function determined by the modulating signal.

Using a simple cosine representation of the *modulating* signal the instantaneous frequency is given by

$$f = f_o + \Delta f \cos(\omega_1 t) \qquad (3)$$

Here $f_o$ is the carrier frequency around which the modulating signal varies with a frequency $f_1 = \frac{\omega_1}{2\pi}$ and a maximum *frequency deviation* of $\Delta f$.

Multiplying equation (3) by $2\pi$ and utilizing equation (2) the angle $\varphi$ in equation (1) can be determined:

$$\varphi = \int [2\pi f_o + 2\pi \Delta f \cos(\omega_1 t)]\,dt =$$

$$= \omega_o t + \frac{\omega \nabla}{\omega_1} \sin(\omega_1 t) + \Phi_o \qquad (4)$$

where $\Phi_o$ is a constant, time independent angle (phase angle).

*) See for instance A. Hund: "Frequency Modulation". McGraw-Hill Book Company, Inc. New York 1942.

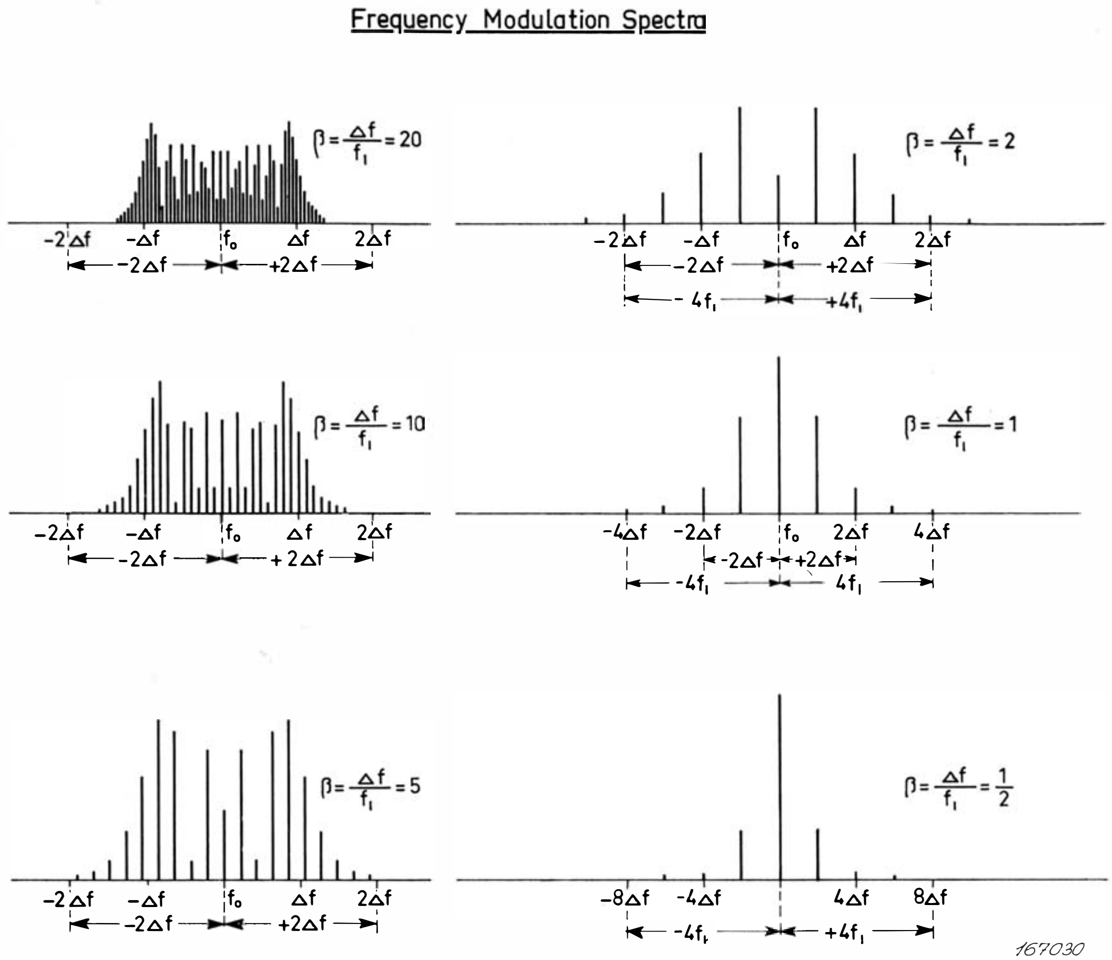


*Fig. A.1. Frequency modulation spectra.*

An expression for the complete frequency modulated signal is thus:

$$a = A_o \times \cos\left(\omega_o t + \frac{\Delta f}{f_1} \sin(\omega_1 t) + \Phi_o\right) \qquad (5)$$

It can be shown that if $\Phi_o$ is assumed to be 0 the expression given by equation (5) can be mathematically transformed into the following formula:

$$\begin{aligned} a = A_o [&J_o(\beta)\cos(\omega_o t) + \\ &+ J_1(\beta)\cos(\omega_o + \omega_1)t - J_1(\beta)\cos(\omega_o - \omega_1)t + \\ &+ J_2(\beta)\cos(\omega_o + 2\omega_1)t + J_2(\beta)\cos(\omega_o - 2\omega_1)t + \\ &+ J_3(\beta)\cos(\omega_o + 3\omega_1)t - J_3(\beta)\cos(\omega_o - 3\omega_1)t + \\ &+ ---------] \end{aligned} \qquad (6)$$

where $J_n(\beta)$ is the Bessel function of the first kind with argument $\beta$ and order n, n being and integer. $\beta = \frac{\Delta f}{f_1}$ is a kind of modulation "index" and depends, as can be seen, not only upon the maximum frequency deviation frequency "swing"), $\Delta$f, but also upon the frequency of the modulating signal itself, $f_1$. This is due to the dependency of the actual modulating "phase" angle upon the *instantaneous* frequency see equation (2).

The ratio $\Delta f/f_1$ max. is commonly called *deviation ratio* and is in wide-band FM magnetic recording in the order of 1 to 2 or greater.
Equation (6) describes the frequency modulated signal in terms of *sidebands* with frequencies $\omega_o \pm \omega_2$; $\omega_o \pm 2\ \omega_1$; $\omega_o \pm 3\ \omega_1$ etc. Now, how many sidebands must be correctly handled by the measurement system to be able to reproduce the original modulating signal with negligibly small errors?
To be able to answer this question it is necessary to consider Fig. A.1. Here modulation spectra of a frequency modulated signal of the kind discussed above are shown for various values of the modulation "index". It is seen that as long as $\Delta f/f_1$ is great then a great number of sidebands are necessary for a complete description. However, most of the important sidebands are found within the limits $\pm 2\Delta f$ the spacing between the sidebands being $f_1$.
On the other hand if $\Delta f/f_1$ is small only one (or two) sidebands are present and a general bandwidth requirement for FM-systems would thus be $4\Delta f$ or $8 f_1$ which ever is the greater, a requirement which is practically always fulfilled in FM magnetic tape recording.

**Appendix B.**

*Maintenance.*

In order to maintain the Recorder operating at top efficiency the tape transport must be kept strictly clean. It is of outmost importance that the entire tape path be kept free from dust particles and tape residues. Special attention should be made to the two Ferrite Heads. The covers over the heads together with the shield between them can be removed. The surface of the heads should be cleaned with a soft lint-free cloth damped with alcohol. As all rotating parts utilize oilless bearings or precision ball bearings there is under normal circumstances no need for lubrication.
The tension of the belt from the synchronous motor should be checked at about 6 months intervals. A force of approximately 300 grams (10.5 ounce) applied to the belt midway between the drive wheels should displace the belt 6 mm (0,240 inch). The belt drive inside the reel take-up arm should also be inspected. The position of the tension roller is critical for the correct performance of this belt and should not be disturbed.
The braking arrangement at the clutch near the hinge of the reel arm should be inspected for sufficient clearance when the reel arm is closed. The clearance should be at least 0.5 mm (0,020 inch).
By opening the hinged tape transport base the reel motors can be inspected. When opening the transport base a full 90° the stop lever at the top hinge must be lifted and the support leg located along the left side of the transport should be released and allowed to drop. In order for the solenoid operated brakes of the reel motors to function correctly, a minimum clearance of 1 mm (0.4 inch) should be kept between the fork at the end of the brake lever and the hexagon nut of the solenoid plunger. By loosening the two screws holding the brake lever, the lever can be repositioned in order to obtain this clearnace.

*Track Location.*
Fig. B.1 shows how the tape is located on the heads. As the forth channel on the head is not used the tape is taken symmetrical across the three upper channels. This is done to avoid edge effect on the tape.

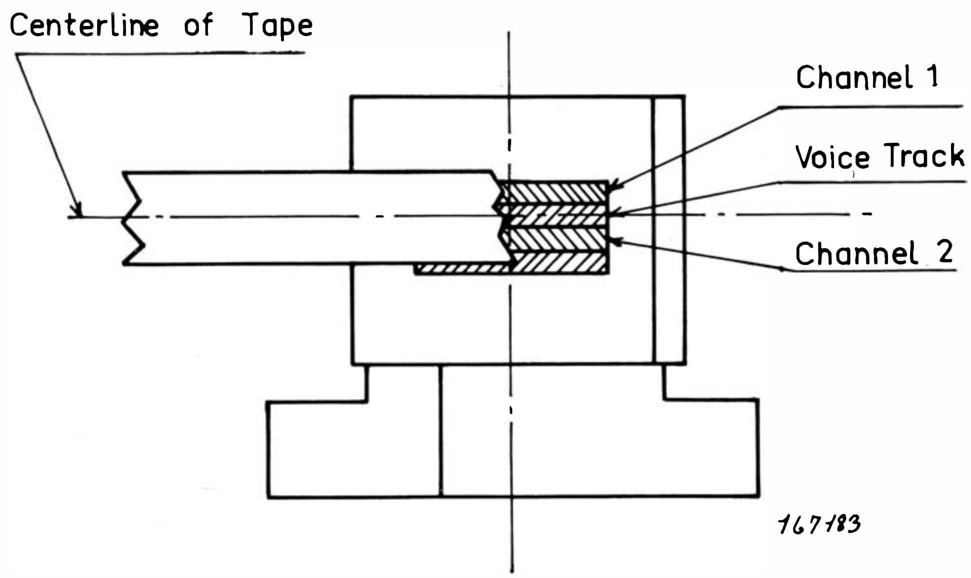


*Fig. B.1. Tape location on heads.*

*Adjustment to the Reproduce Head.*
The heads are adjusted from the factory but if desired it is possible to tilt the reproduce head to adjust the phase shift between the two channels. By recording the same input signal on both channels the phase shift between the output signals can be directly checked on a double beam oscilloscope connected to the two outputs. Then, by pulling the cover away from the reproduce head, the adjustment can be made simply by loosening one and tigthening the other of the slotted screws shown in Fig. B.2. When the two beams on the scope coincide with each other the two channels are in phase.

*Note:* As this adjustment is *very* critical it should not be touched unless it is *strictly* necessary.

*Replacement of Lamps.*
The lamps behind the pushbuttons can be replaced in the following way:

1. Push the button slightly and turn it anticlockwise.
2. Pull out the button.
3. With the lamp removing tool QA 0034, delivered with the Tape Recorder remove the old lamp and insert the new one.
4. Remount the pushbutton by pressing and turning it clockwise.
   The "Ready" lamp on the Control box is changed by pulling out the green glass and using the same tool (AQ 0034).

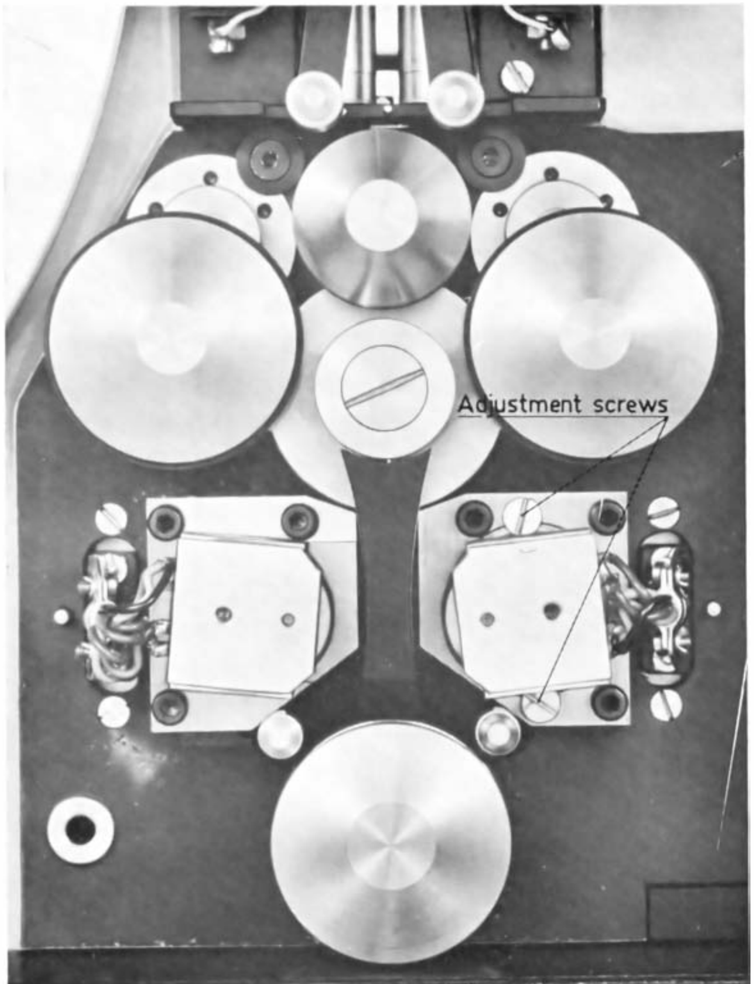


*Fig. B.2. The reproduce head.*

**Appendix C.**

*DC Balance.*

Under normal circumstances the DC balance potentiometers situated behind the Control Box should have sufficient adjustment range to calibrate the amplifiers and the calibration is carried out as described under section "Operation". If it should happen that one or both of the amplifiers cannot be balanced the trouble may be caused either by a change in the DC balance, in one of the carrier frequencies or in the reference voltage. The following procedure should then be carried out.

1. Remove the rear cover.
2. Loosen the four screws holding the aluminium bar marked with the different circuit card number (X C).
3. Lift this bar and draw out the print card marked XC 0100.
4. Plug in the extension card (XC 0387).
5. Plug the circuit card XC 0100 into the extension card.
6. With an electronic counter measure the frequency of the reference voltage across terminals 16 and 6 (6 is grounded). It should be 440 Hz ± 2 Hz. If

not adjust the potentiometer shown in Fig. C.1 for 440 Hz frequency adjustment.

7. Across the same terminals 1 Volt RMS should be measured with an electronic voltmeter. If not, adjust the potentiometer shown in Fig. C.1 for 440 Hz voltage adjustment.
8. Set CALIBRATION SELECTOR to position "1" and connect an electronic counter across terminals 1 and 6 (6 is grounded). The frequency should be 108 kHz ± 50 Hz. If not adjust the trimmer (see Fig. C.1) for 108 kHz.

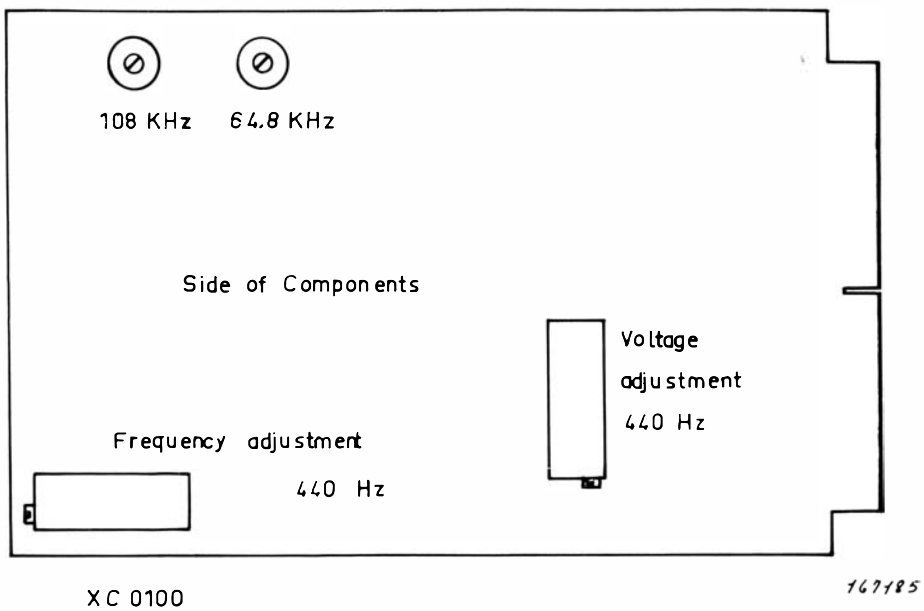


*Fig. C.1. Circuit card XC 0100.*

9. Set CALIBRATION SELECTOR to position "2". The frequency measured across the same terminals should now be 64.8 kHz ± 30 Hz. If not adjust trimmer marked "64.8 kHz" (Fig. C.1).
   If at this point the amplifiers still cannot be balanced from the front potentiometers then continue the procedure as follows: The two circuit cards marked XC 0099, one for each channel, Fig. C.2 contain the potentiometers for coarse balance of the DC-amplifiers as shown.
10. Disconnect the control box and loosen the two Allen screws located behind it (Fig. 5.1). Pull out the complete electronic section.
11. Remove the two screws located at the left hand side of and immediately behind the meter panel and swing the meter panel away from the electronic section. The following procedure is first carried out for one channel and then for the other.
12. Take out circuit card XC 0099 and insert extension card XC 0387. The XC 0099 is plugged into XC 0387.
13. Set CALIBRATION SELECTOR to position "1". The corresponding DC-balance on the front should be left in the middle position.

14. Connect an AVO-meter across OUTPUT and adjust potentiometer III, (Fig. C.2) to zero deflection on the meter.
15. The built-in meter on the Tape Recorder should now indicate: $-\infty$. Otherwise adjust the potentiometer located close to the relays mounted on the print card just above the built-in meters (see Fig. C.3).
16. Set CALIBRATION SELECTOR to position "2", INPUT ATTENUATOR to "0" dB and short circuit the input.
17. Connect an AVO-meter across the terminals 6 and 13 on the circuit card XC 0099.
18. Set RECORD switch to pos. "DC" and adjust potentiometer I (Fig. C.2) for zero Volts on the AVO-meter.

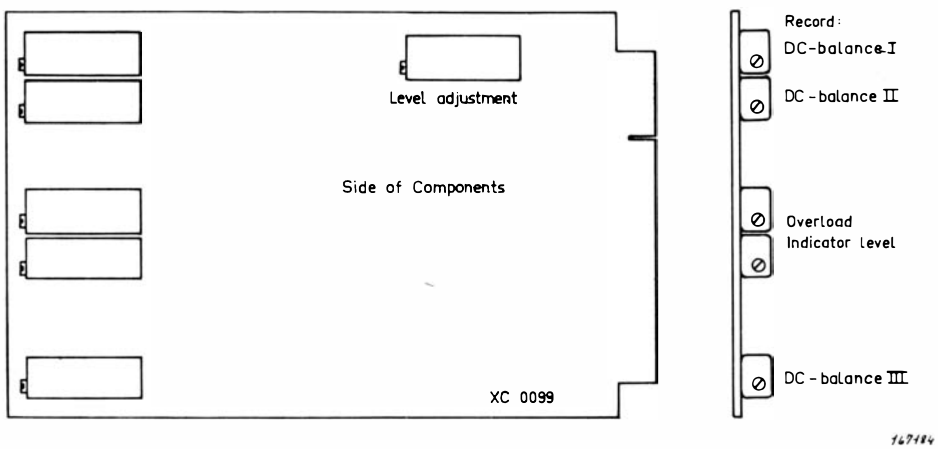


*Fig. C.2. Circuit card XC 0099.*

19. Set RECORD switch to position "AC". Adjust potentiometer II for zero Volt.
20. Repeat items 18 and 19 as the two adjustments have a certain influence on each other.
21. Set RECORD switch to "AC", ATTENUATOR to "0" dB and CALIBRATION SELECTOR to position "0". A 1000 Hz, 1 Volt RMS sinusoidal voltage connected to the input should now produce a deflection on the built-in meter of "0" dB.
    If not adjust the potentiometer marked "Gain" (see Fig. C.3).
22. Connect the AVO-meter across the OUTPUT.
23. Set CALIBRATION SELECTOR to position "2" and adjust the potentiometer located on the top of circuit card XC 0099 close to the card connections until the AVO-meter shows $-1.4$ Volt DC.
24. With CALIBRATION SELECTOR in position "3" adjust to 0 Volt on the OUTPUT using the potentiometer above the CALIBRATION SELECTOR.
25. Set CALIBRATION SELECTOR to position "4" and adjust the gain until the built-in meter indicates "0" dB (red mark).

26. Check that the calibration is correct and if necessary recalibrate as described under section "Operation". This means using the potentiometers located behind the control box only.

*Note.* During items 24 tnd 25 it might be necessary to reassemble the electronic section to avoid parasittic oscillations.

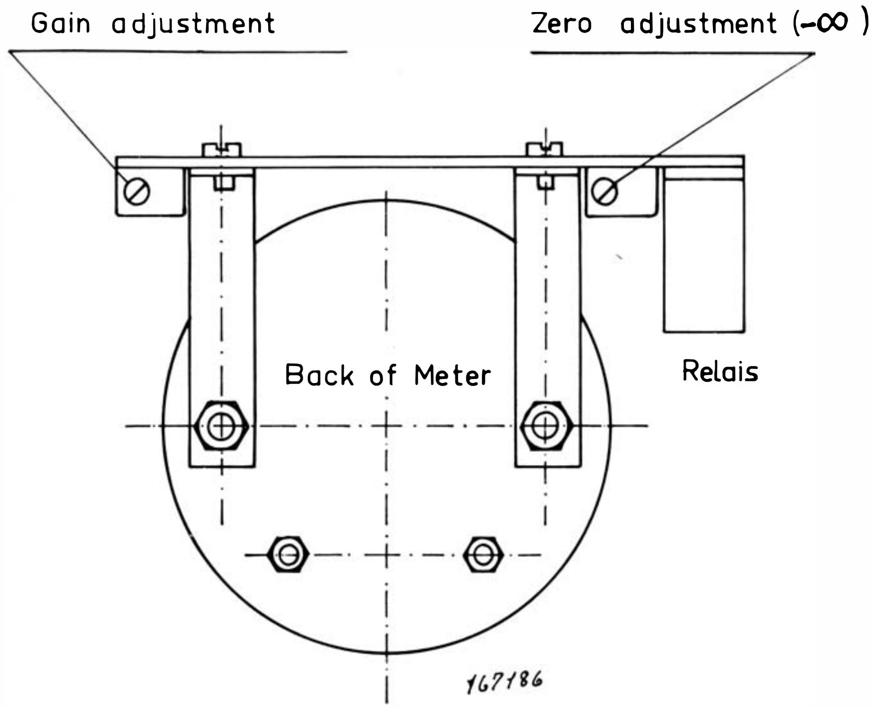


*Fig. C.3. Rear view of indicating meter.*

# 9. Specifications

(Obtained using 3M Scotch 991 tape on 10.5″ precision reels)

**ELECTRICAL**

**FM Channels:**

| | | | | | |
|---|---|---|---|---|---|
| Tape Speeds | 38.1<br>1.5 | 152.4<br>6 | 381<br>15 | 1524<br>60 | mm/sec<br>ips. |
| Frequency Ranges<br>(± 0.5 dB) | 0–0.5 | 0–2 | 0–5 | 0–20 | kHz |
| S/N Ratio | > 44 | > 48 | > 48 | > 48 | dB |
| Carrier Frequency | 2.7 | 10.8 | 27 | 108 | kHz |
| Rise Times | < 1200 | < 300 | < 120 | < 30 | $\mu$sec |

**Linearity:** Better than 1 % of full scale deviation from best straight line through zero center.

**Input Level:** ± 1.4 Volts peak with attenuator in most sensitive position.

**Record Switch:** Allows choice of AC or DC input. The Lower Limiting frequency of the AC input is 4 Hz (– 3 dB).

**Input Attenuator:** 0–28 dB in 2 dB steps.

**Input Impedance:** 20 kΩ parallel to 100 pF.

**Output Level:** ± 1.4 Volts peak with no load. Harmonic distortion < 1 %). Max. output 10 V.

**Output Impedance:** Less than 150 Ω.

**Load Impedance:** Min. 200 Ω.

**Distortion:** Less than 1.5 % with 1 Volt RMS output.

**Cross Talk:** 50 dB.

**Polarity of FM Recording:** A positive input signal produces increasing frequency.

**Built-in Ref. Generator:** 1 Volt ± 1 %, 440 Hz ± 1 % sinewave. (Harmonic distortion < 1 %).

| | |
|---|---|
| **Meters:** | Both data channels are equipped with peak reading, illuminated meters. |
| **Heads:** | Special long life ferrite heads. (Guaranteed life-time > 10,000 hours). Track width: 0.5 mm. Track spacing: 1.524 mm. Maximum Gap scatter: 0.001 mm. Gap. azimuth: ± 1 minute of arc. Recording gap width: 0.003 mm. Reproduce gap width: 0.0015 mm. |
| **Equivalent Wave Lengths:** | Carrier Frequency 14 $\mu$m–0.56 mils<br>Rise Time 50 $\mu$m–2.0 mils<br>Upper frequency limit 75 $\mu$m–3.0 mils |
| **Voice Channel:** | For marking and identification of the tape. The frequency response is flat to within ± 3 dB from 300 Hz to 3 kHz, and the channel is equipped with AVC (Automatic Volume Control). Connection for special dynamic type microphone, and built-in marking arrangement. |

**MECHANICAL**

| | |
|---|---|
| **Tape width:** | 6.35 mm (0.25 inch). |
| **Reel Size:** | 267 mm (10.5 inches) with large diameter hub (or 178 mm (7 inches) with Cine type hub). |
| **Closed Loop:** | Provisions for changing reels with closed loop arrangement with loop lengths from 2.4 to 7.5 meter (8 to 25 feet). |
| **Tape Speed Accuracy:** | ± 0.25 % ± accuracy of power line frequency. |
| **Wow and flutter:** | See curves Figs 2.4 and 2.5. |
| **Start Time:** | Less than 3 seconds. |
| **Stop Time:** | Less than 1 second. |
| **Time Required for Speed Change:** | 9 seconds. Drive controls blocked during speed changing. |
| **Rewind Time (and "Fast Forward" spooling):** | Approximately 95 seconds for 730 m (2400 feet) tape. |
| **Braking:** | Dynamically during motion. Mechanically during stopping and when stopped. |
| **Automatic Stop:** | Actuated by photoelectric sensor which ensures stop of the tape transport at the end of the tape or in cases of tape breakage. |
| **Tape Tension:** | 100 ± 10 gram (0.22 ± 0.02 lbs) force during record and playback. Automatically controlled from servo amplifiers. |
| **Tape Counter:** | 4 digit reset counter counts length in feet. Accuracy better than 0.1 %. |

| | |
|---|---|
| **Tape Transport:** | Back-lit pushbuttons for: Record, Stop, Playback, Fast Forward and Rewind. Rotary switch for tape speed selection. Pushbuttons electrically interlocked for safe operation. Activation of capstan pinch rollers delayed during start until tape has correct speed. |
| **Remote Control:** | Control box removeable. Extra lengths of cable can be inserted. |
| **Capstan Motor:** | Two speed synchronous hysteresis motor. |
| **Reel Motors:** | AC torque motors. |
| **Dimensions:** | 480 × 380 × 270 mm.<br>19 × 15 × 11 inches. |
| **Weight:** | 39 kg (85 lbs) approx. |
| **Power Supply:** | 100 – 115 – 127 – 150 – 220 or 240 Volts AC. 100–180 W. Frequency 50 or 60 Hz should be specified. Built in switch allows the Capstan motor to be driven from an external precision generator. The requirements of the external generator will be: 115 Volts 60 VA, 50 or 60 Hz. |
| **Battery Operation:** | The Tape Recorder 7001 may be driven from batteries (accumulators) when a suitable DC to AC converter is used. Such a converter would be for instance the *KL Inverter SF-1* which is driven from 24 Volts, DC.*) |
| **Cabinet:** | Steel cabinet Type 7001A.<br>Mahogany cabinet with handles: Type 7001B.<br>Steel cabinet for mounting in 19" rack: Type 7001C. |

*) Obtainable from: Knud Lindberg A/S, 200 Islevdalvej, Roedovre, Copenhagen, Denmark.