

Technical Manual

On the Development and Design of Direct Drive Turntable



Technics
by Panasonic

Direct Drive Turntables— A Revolution in Rotational Motion

Introduction

In a relatively short period, the direct drive turntable has become firmly established as the top performing turntable in today's audio world. Noise (particularly motor rumble) and speed fluctuations (wow and flutter) have been almost forced out of existence, due to the incredible degree of precision in motor design, and the elimination of

speed transmission devices such as belts and idlers prone to introduce unwanted speed deviations. The direct drive concept is remarkably very simple. The motor joined directly to the turntable platter via a central spindle shaft, rotates at the very low speeds of 33-1/3 and 45 rpm, thereby driving the turntable platter at the required phonograph record speeds. No speed reduction system, belts, idlers, or any other intervening speed transmission devices are employed whatsoever.

In practice, however, the development and manufacture of direct drive turntables has proved to be far from easy. High precision system designs and speed control mechanisms have had to be developed in order to maintain constant rotational speeds under varying conditions, such as load (i.e. when different size phonograph records are placed on the turntable platter), temperature, and humidity, etc.

Technics, a leading manufacturer of high grade audio equipment, and widely known for its originality and high standard of performance in audio systems, first hit upon the idea of driving the turntable platter "directly" in 1967. With a vast wealth of technological and electronic expertise and experience to call upon (Technics being a division of the Matsushita Electric Industrial Co., Ltd.), Technics engineers and designers overcame all developmental problems, and by 1970, the first direct drive turntable—the Technics SP-10—made its stunning debut. At that time, rumble (S/N ratio) of 60 dB (70 dB DIN 45539B) and wow & flutter of 0.03% WRMS represented new frontiers in turntable performance and served as the standards for all other manufacturers to aim at.

Almost without exception, all prominent turntable manufacturers throughout the world produce direct drive turntables, there being over 100 different models available at present. The main differences lie in the variety of speed control employed, but all are derived from the same basic design of the original SP-10.

During the intervening years, Technics has maintained its leadership, employing more and more advanced system designs and electronic circuit components, developing, for example, a unique quartz synthesizer pitch control. These continued efforts have culminated in the creation of one of the most highly sophisticated series of high grade direct drive turntables ever manufactured, the Technics SL-1300MK2, SL-1400MK2, and SL-1500MK2.

Major advantages and features of direct drive turntables in general, and of the SL-1300MK2 in particular, are taken up in greater detail in the following pages.



Contents

Introduction	3
The Original Direct Drive Turntable—The Technics SP-10: Basic Role of a Turntable	4
Birth of the Direct Drive Turntable	5
Proliferation of Direct Drive Motors: Basic Direct Drive Motor Construction	6
AC Motor or DC Motor	6
Speed Control Systems	7
Quartz Locked Phase Control Systems	8
Speed Change Detection Methods	8
Seven Essential Features for High Grade Direct Drive Turntables	9
Major Drive and Control Features of the Technics SL-1300MK2: Quartz Synthesizer Pitch Control with Digital Display	12
Quartz Phase Control Servo System	13
Hetero-Polar Motor and Full-Wave Bi-Directional Drive Circuit	14
Turntable Structure and Integrated FG Servo Mechanism	15
Auto-Return Mechanism and Logic Circuit	15
Suppression of Acoustic Feedback in the SL-1300MK2	16
High Performance, Sophisticated Tonearm	17
Straight Arm Versus S-Shaped Arm	20

1 The Original Direct Drive Turntable—The Technics SP-10

Basic Role of a Turntable

In order to “extract” the audio signals from a phonograph record, all the turntable has to do is rotate the record at constant designated speeds (33-1/3 and 45 rpm) without introducing any extraneous unwanted signals. Any signals not originating from the record grooves, such as those caused by motor vibrations, are referred to as rumble or noise, while any periodic deviations from the fixed rotational speeds are referred to as wow and flutter.

In idler and belt drive turntables (where the motor rotates at relatively high speeds, and is thereby apt to cause a greater amount of vibration), it was practically impossible to remove the effects of rumble and wow & flutter on the quality of sound in high fidelity turntables. Even where the most advanced turntable technology was employed, the best belts and idlers available were still prone to slippage, and subject to changes due to temperature and humidity variations.

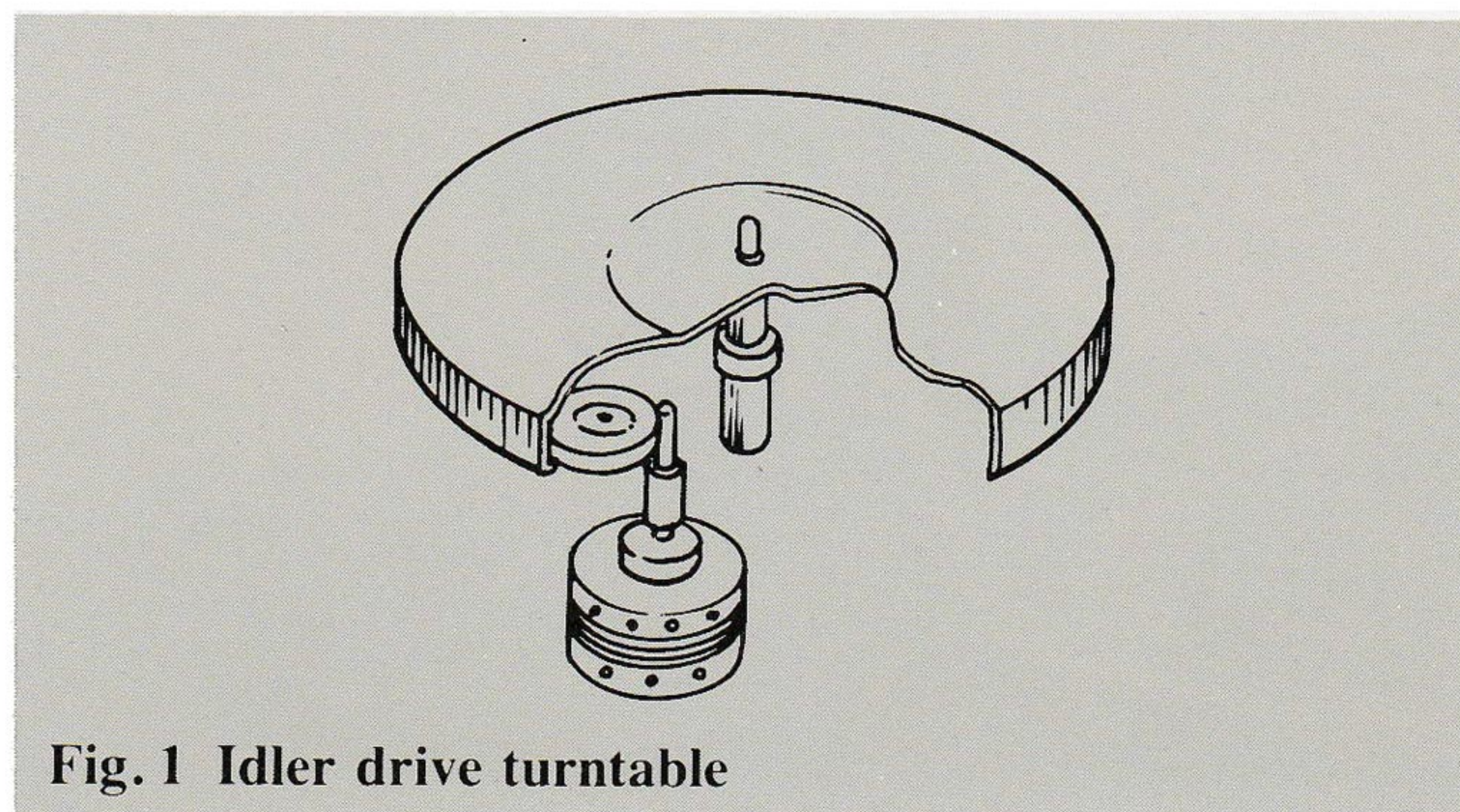


Fig. 1 Idler drive turntable

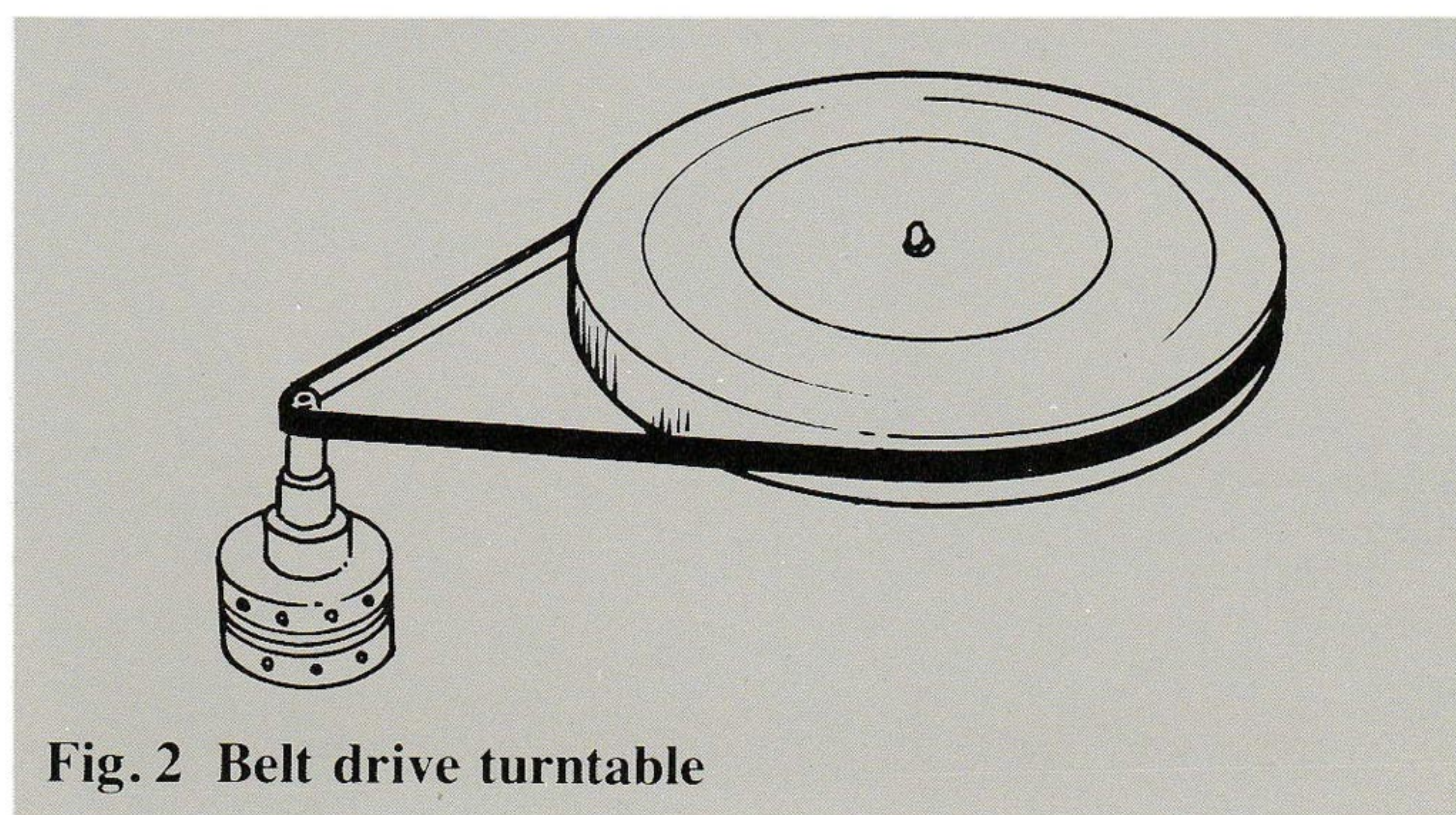
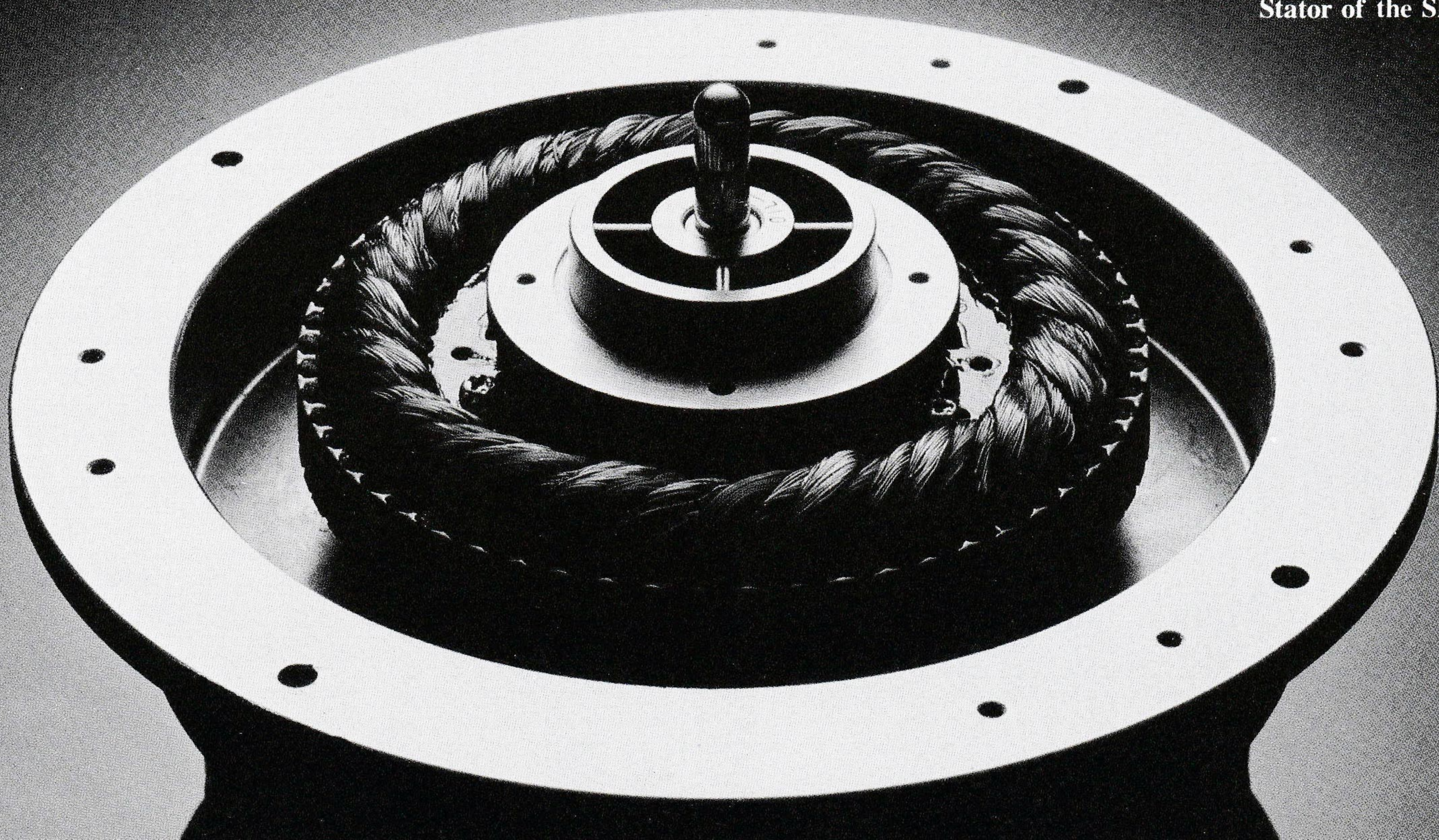


Fig. 2 Belt drive turntable

Stator of the SP-10



Birth of the Direct Drive Turntable

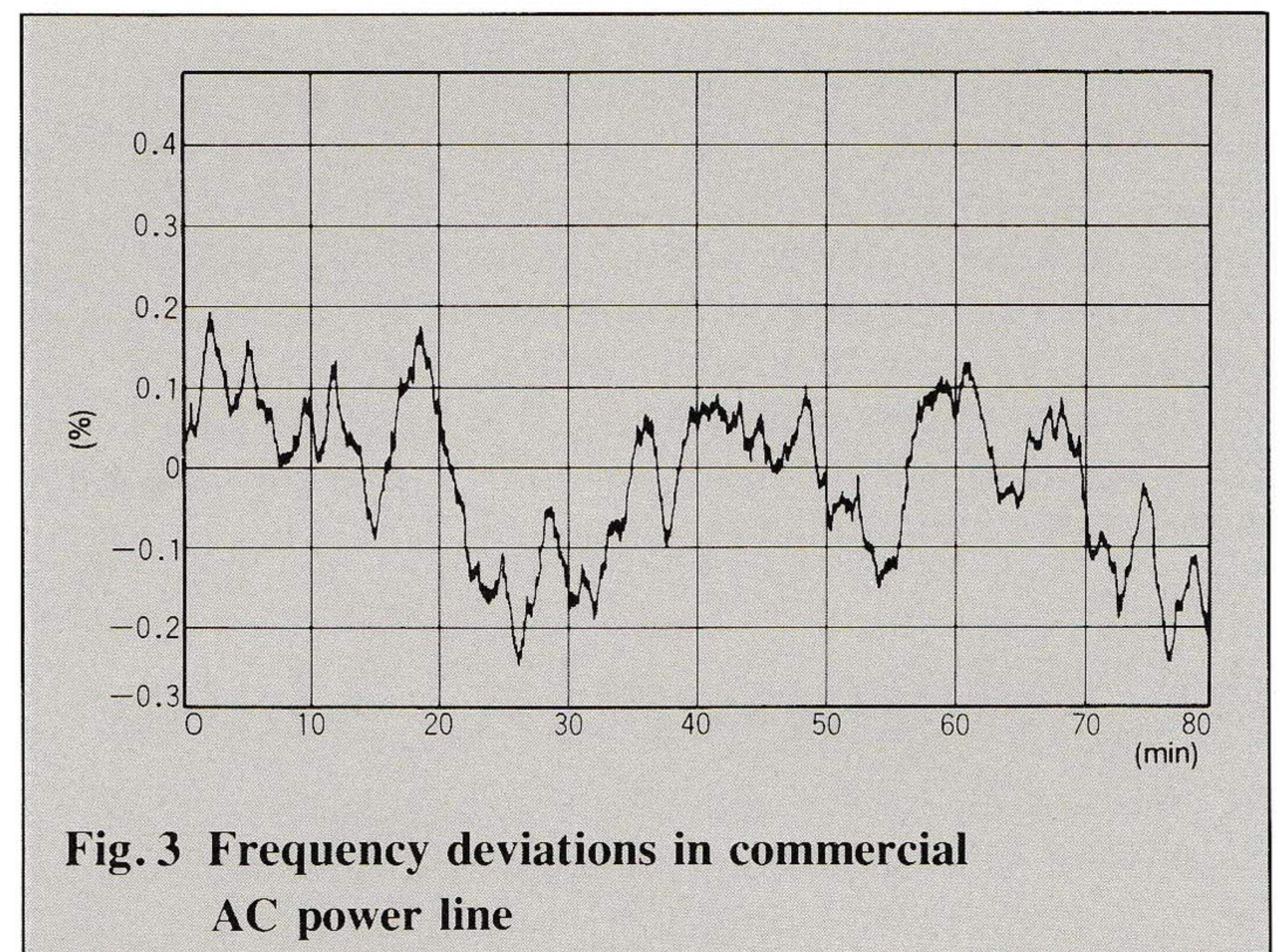
In 1967, Technics, realizing the inherent deficiencies of the idler and belt drive turntables, turned its attention to the possibility of eliminating these speed transmission devices altogether, that is, the development of a highly accurate slow speed motor coupled directly to the turntable platter. This would have to be an entirely new kind of motor, both in design and performance. And it would require a very strict speed control system. But by 1970, Technics engineers had solved all the major problems, and announced the successful development of the first-ever direct drive turntable, the SP-10.

New Standards of Performance

The SP-10 was indeed a success, marking an important turning point in the history of hi-fi turntables. Rumble and wow & flutter were reduced to unprecedented, almost imperceptible levels. In fact, the S/N ratio of 60 dB (or 70 dB DIN 45539B) achieved in the SP-10 even exceeded the S/N ratio of the best existing test records employed at that time. Technics was thus compelled to manufacture special lacquer test records for specific use in the measurement of the SP-10's S/N ratio. The wow & flutter rating of 0.03% WRMS was also unheard of in turntable performance at that time.

But these were not the only advantages gained by the SP-10 direct drive turntable. It also became possible to apply much greater starting torque, thereby attaining rated speed (e.g. 33-1/3 rpm) within the first 1/2 revolution (or within the first second). The DC brushless motor employed was completely free of the effects of power supply frequency drift, and also generated very little heat. Nor was it necessary to include 50/60 Hz switching facilities.

It is of added significance that Technics always measures S/N ratios under normal operating conditions. The ratings are therefore composite values, and not those gained by measuring under unreal conditions, employing a glass plate etc. (as quoted by some manufacturers).



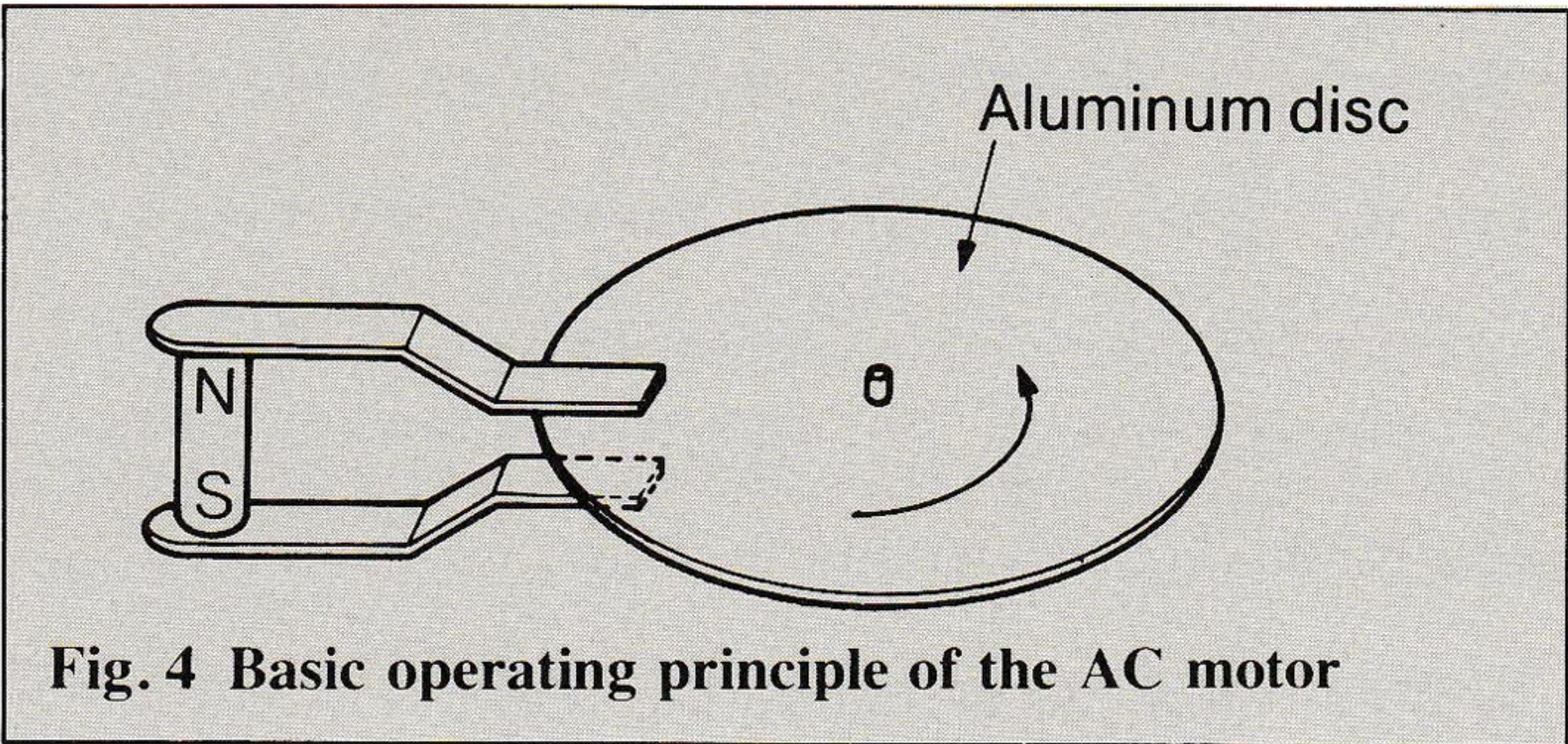
2 Proliferation of Direct Drive Motors

Basic Direct Drive Motor Construction

The motor construction of all direct drive motors consists basically of the actual motor which generates the rotational motive force, and a speed control mechanism which maintains constant rotational speed. The two major types of motors employed are the AC motor and the DC motor, these being further classified according the method of generating the magnetic field, and the shapes of the rotors and stators. In addition to a speed control system, some direct drive motors also feature a phase control system for even greater precision in speed control. But the major variation between different control systems lies in the way changes in rotational speed are detected (see the following chart).

AC Motor or DC Motor

AC motors employ a metallic rotor (copper cup or aluminum disc) placed within a rotating magnetic field, thereby generating the motive power by induction.



Although AC motors are relatively simple in principle and structure, they are not particularly stable when operating with light loads (due to the lack of any electro-magnetic control between rotors and stators). Hence, AC motors must be equipped with a braking device. Overcurrents also have a detrimental effect on operating efficiency, making it rather difficult to design high torque motors.

On the other hand, the disadvantages in DC motors are relatively few, and even these have been minimized in Technics direct drive turntables. The efficiency of DC motors is very high, power consumption is small, minimal heat is generated, and very high torques can be obtained. Speed and

Drive Systems	Type of Motor	Method of Generating Magnetic Field		Rotor Shape	Stator Shape
	AC motor — Induction type DC motor	Phase advance capacitor	Brush	Copper cup Aluminum disc	Multi-polar core
		Electronic commutator	Electronic commutator	Multi-polar core	Ring magnet
		(AC coupling Hall elements Magnetic saturation)		Ring magnet	Skew alignment
					Hetero-polar
					Coreless
					Slotless
					Uni-torque

Control Systems	Control Feature	Rotational Speed Detection System	Detection Mechanism
	Speed control Phase control	Back electromotive force FG	Generator coil Slits Push-pull gear BFG Magnetic pulses Printed coil Comb-shaped yoke

The Various Types of Direct Drive Motors Available in Direct Drive Turntables Presently on the Market.

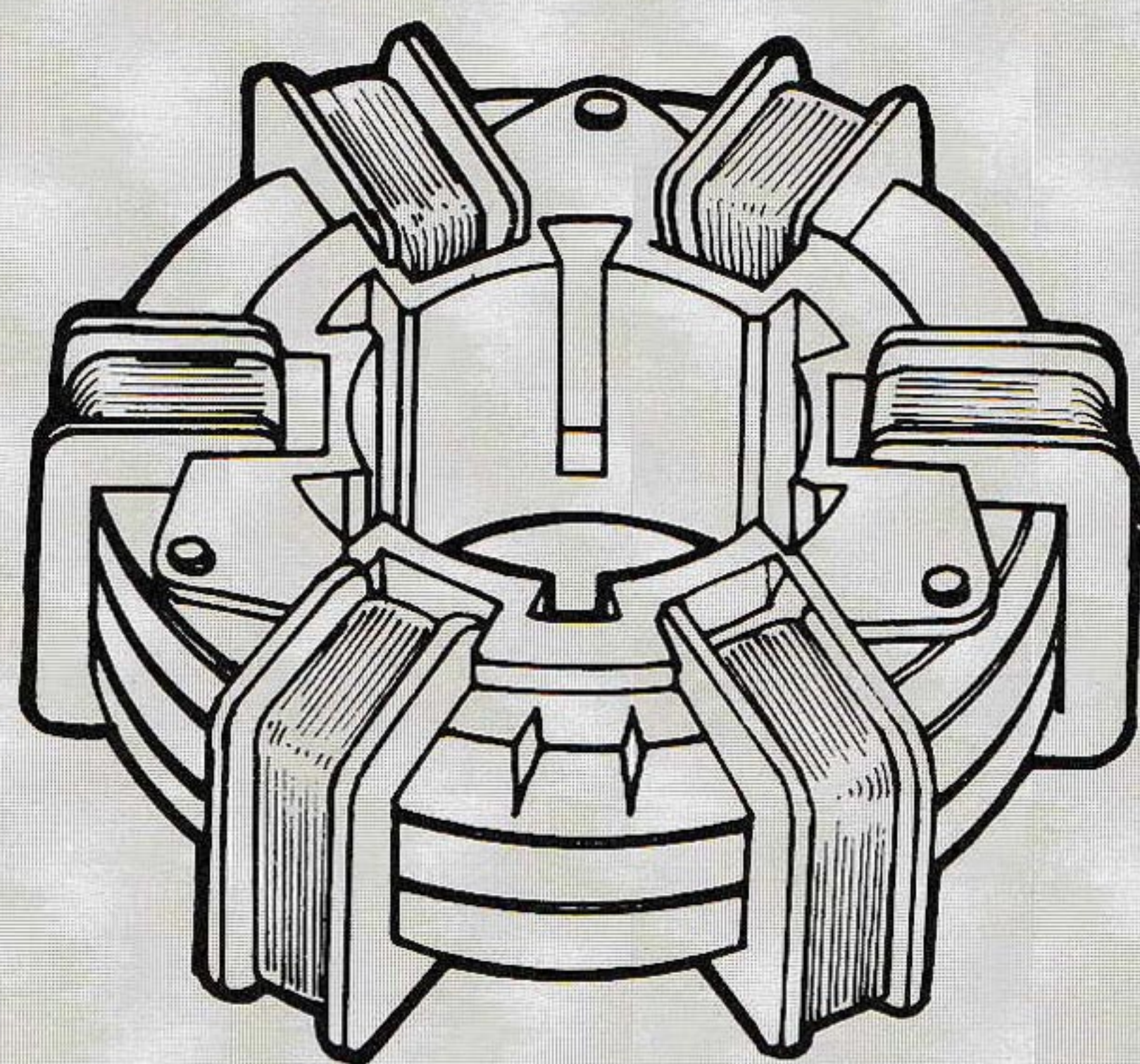


Fig. 5 Slotless stator

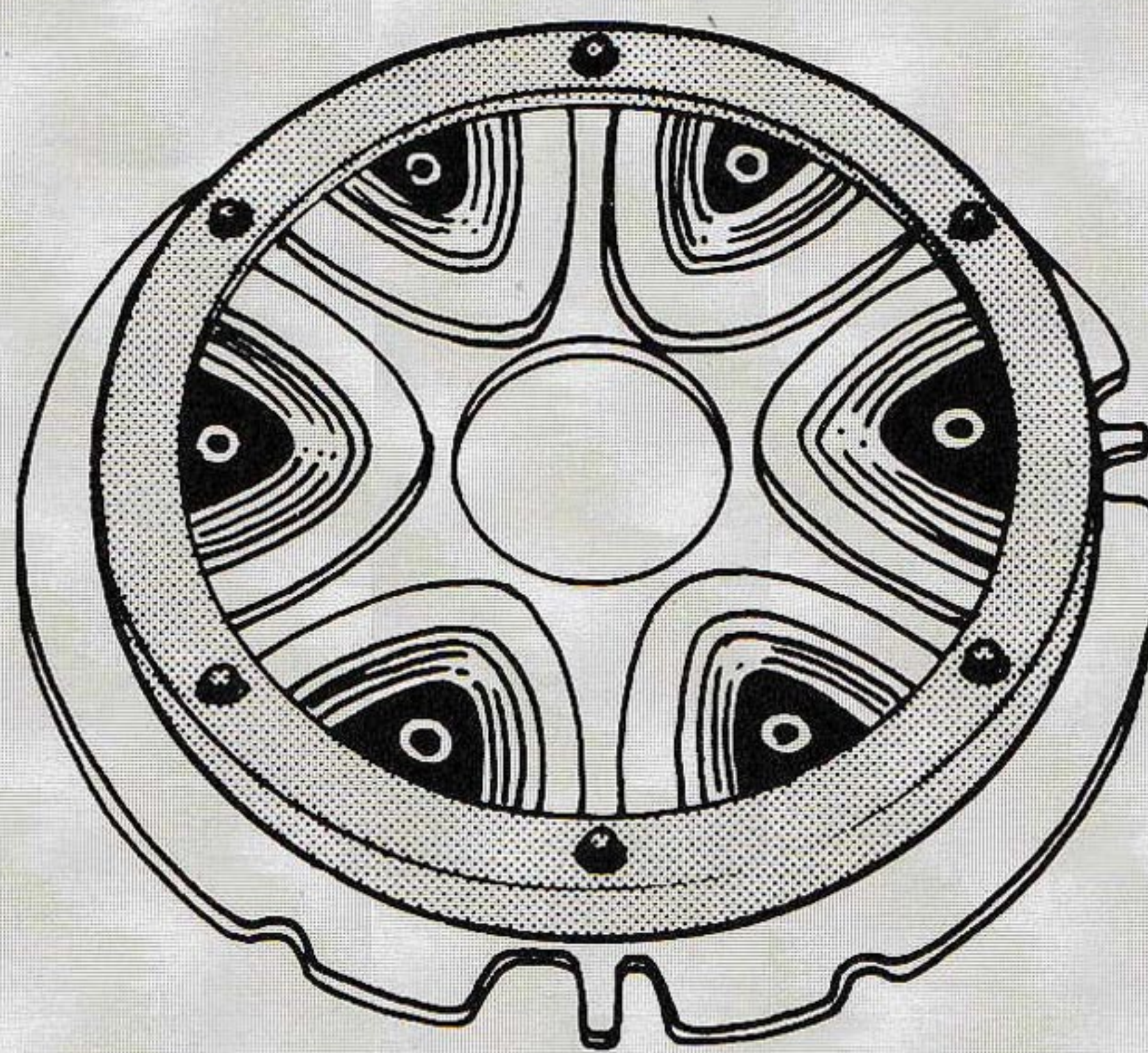


Fig. 6 Coreless stator

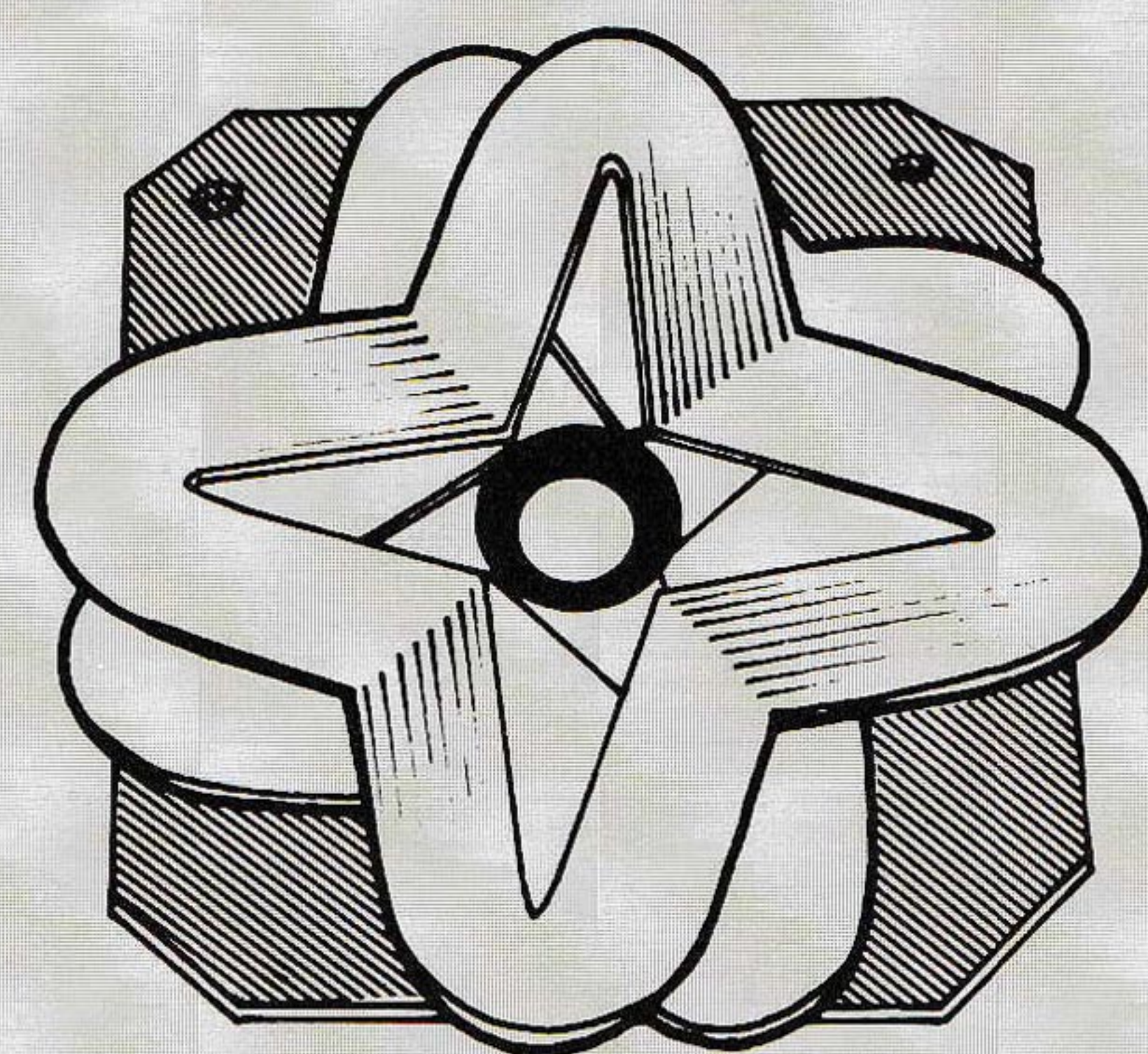


Fig. 7 Uni-torque stator

phase control systems can also be integrated into DC motors relatively simply. The “cogging” problem, due to inter-action between rotors and stators, was the only serious drawback in the initial stages, but even this has been largely overcome by the skillful arrangement of magnets, and by increasing the moment of inertia of the turntable platter.

In the development of Technics direct drive motors, emphasis has always been placed on motor efficiency, thereby making the DC motor a natural choice for all direct drive turntables manufactured by Technics.

Although there is little difference between the 5 stator shapes listed in the above chart as far as their rumble and wow & flutter ratings are concerned, the obtainable torque in the slotless and coreless (ring-shaped stators) and uni-torque types is not very great (approx. 350g.cm). They also suffer from a certain amount of “torque ripple” (i.e. the torque generated by the motor is not constant). But the torque obtained in the hetero-polar type (where the number of rotor and stator poles are different) employed in the Technics SL-1300MK2, is a powerful 1.5kg.cm.

Speed Control Systems

All control systems employed to maintain constant rotational speed consist of the following major

stages:— (a) rotational speed (rpm) fluctuation detector and voltage converter stage, (b) reference voltage comparator stage, and (c) torque generator stage. That is, speed control systems are a type of feedback circuit.

In other words, speed control is performed by the interaction of this feedback with the moment of inertia of the turntable.

In such control systems, stability over long periods of time is essential. To prevent any form of drift, Technics direct drive motor control systems are equipped with differential amplifiers and temperature compensating circuits mounted in one-chip ICs.

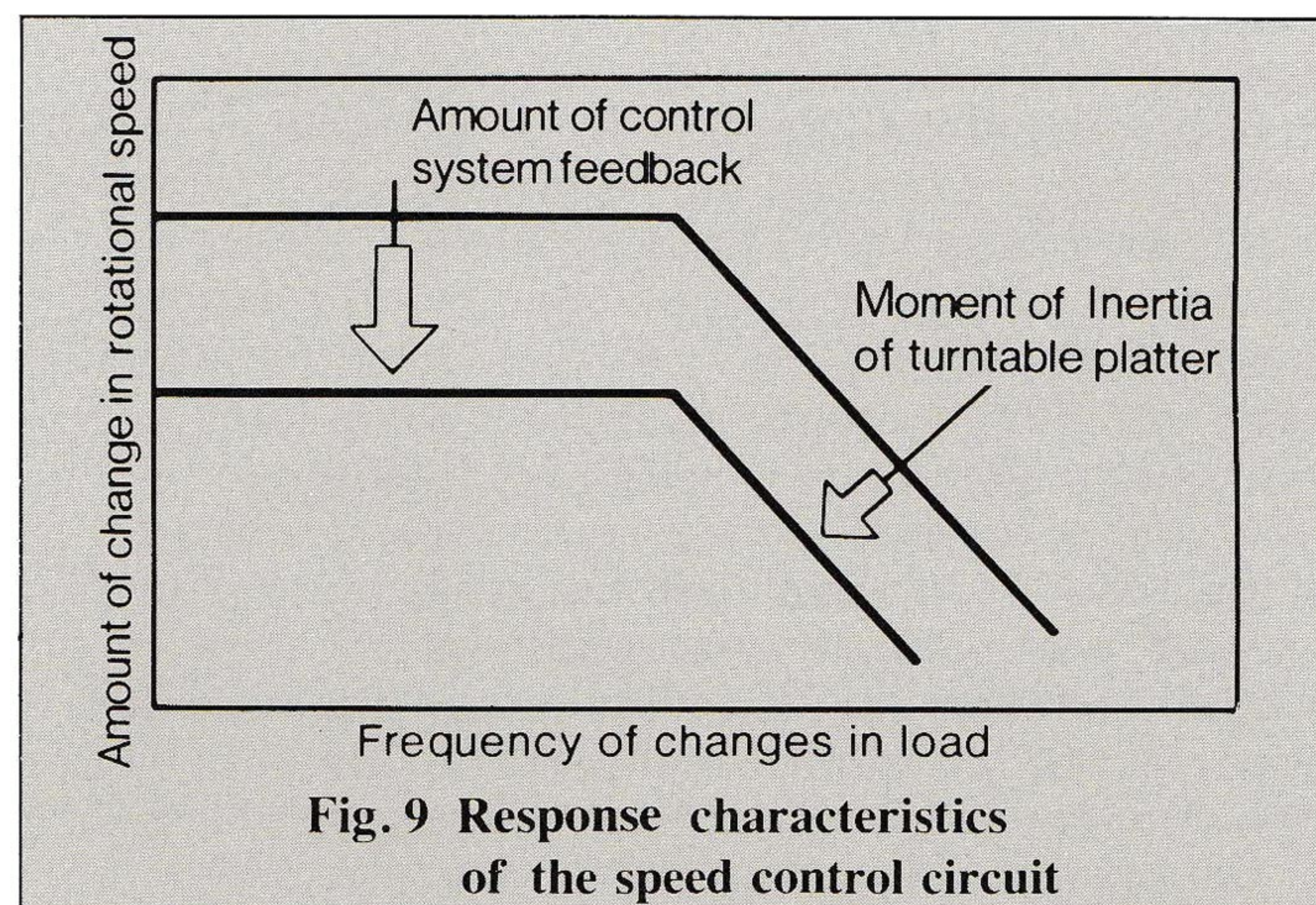


Fig. 9 Response characteristics of the speed control circuit

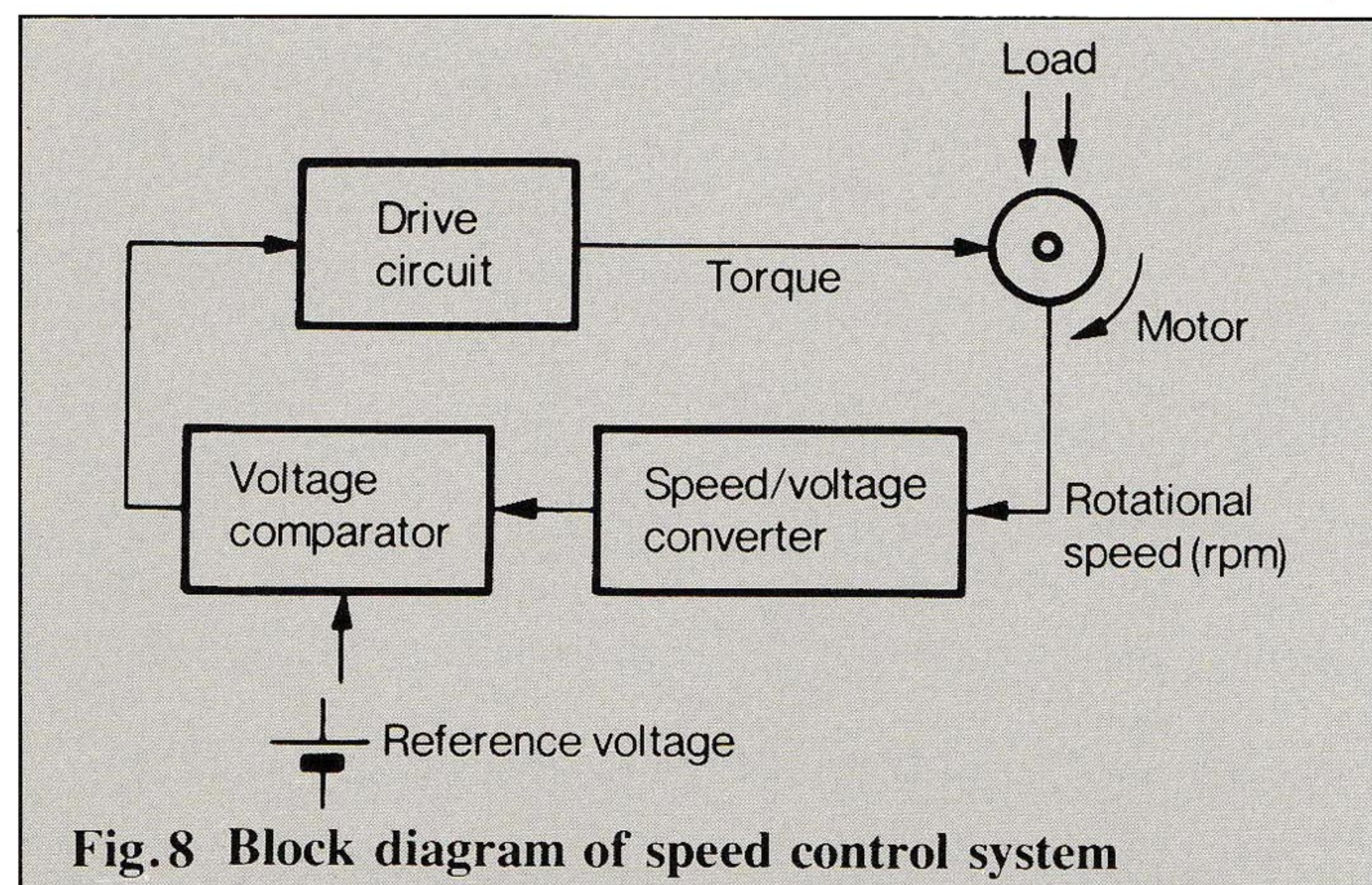
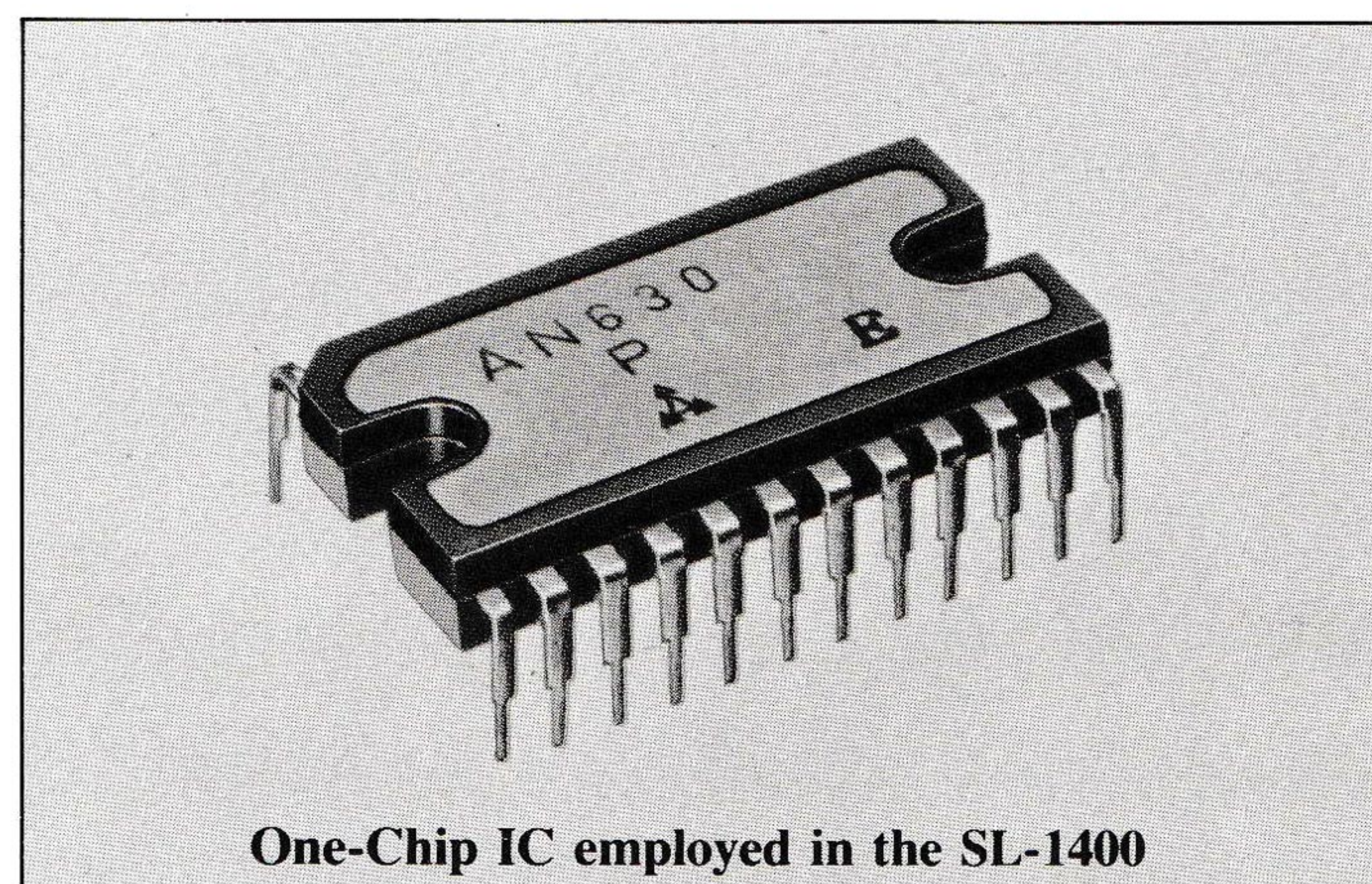


Fig. 8 Block diagram of speed control system



One-Chip IC employed in the SL-1400

Quartz Locked Phase Control Systems

With the additional help of a phase control system, speed deviations are almost “obliterated”, the accuracy attained being of the order of $\pm 0.002\%$ (or a maximum of a mere 0.036 seconds during 30 minutes of record play). In effect, the motor rotational speed is “locked” to a reference frequency originating in a quartz oscillator (one of the most accurate oscillators employed in electronic circuits). Or to be a little more specific, the frequency of the output signals from the motor rpm detector is compared with the reference frequency. Any difference in phase is immediately fed back to the motor, thereby assuring an rpm stability equal to the stability of the quartz oscillator itself.

However, as the following diagram shows, the main role of the quartz locked phase control system lies in the realm of fine speed control. It will only be effective when supported by an excellent speed control system.

Speed Change Detection Methods

The two major detection methods are the back electromotive force method (where changes in rpm are converted directly into voltages) and the frequency generator (FG) method (where rpm changes are first converted into frequencies before being converted into voltages).

The widely used FG method employs a variety of different means to detect the changes in rotational speed. For example, the magnetic pulse method which employs a recording head to detect any changes in the rate of magnetic pulses generated as a coat of magnetic material is passed in front of the head. If, however, the magnetic layer should happen to peel off, serious problems will arise. A more reliable method is typified by the push-pull gear method (employed in the SL-1300MK2) where any changes in speed are immediately detected by the two sets of opposing (but not contacting) gears.

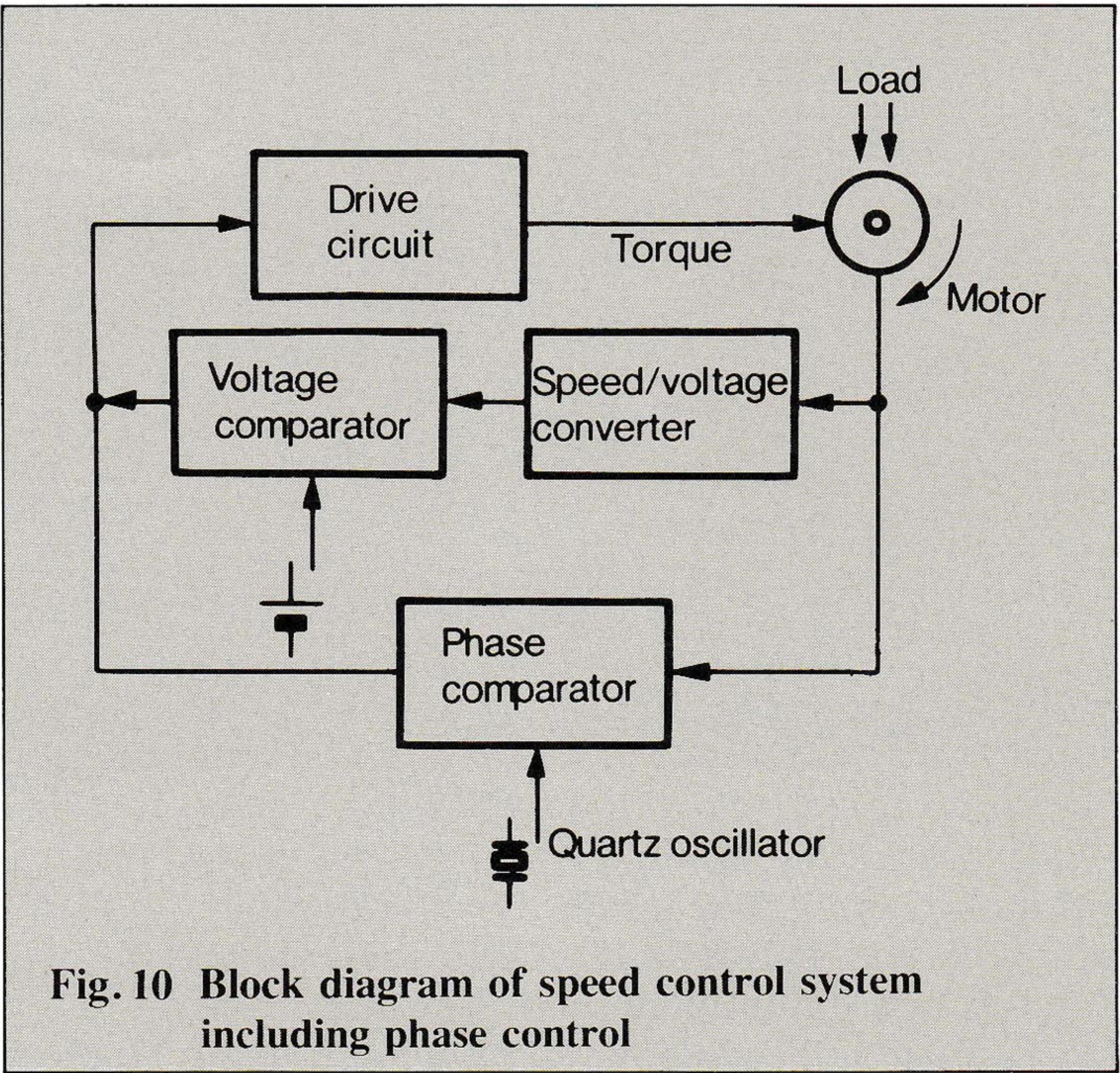


Fig. 10 Block diagram of speed control system including phase control

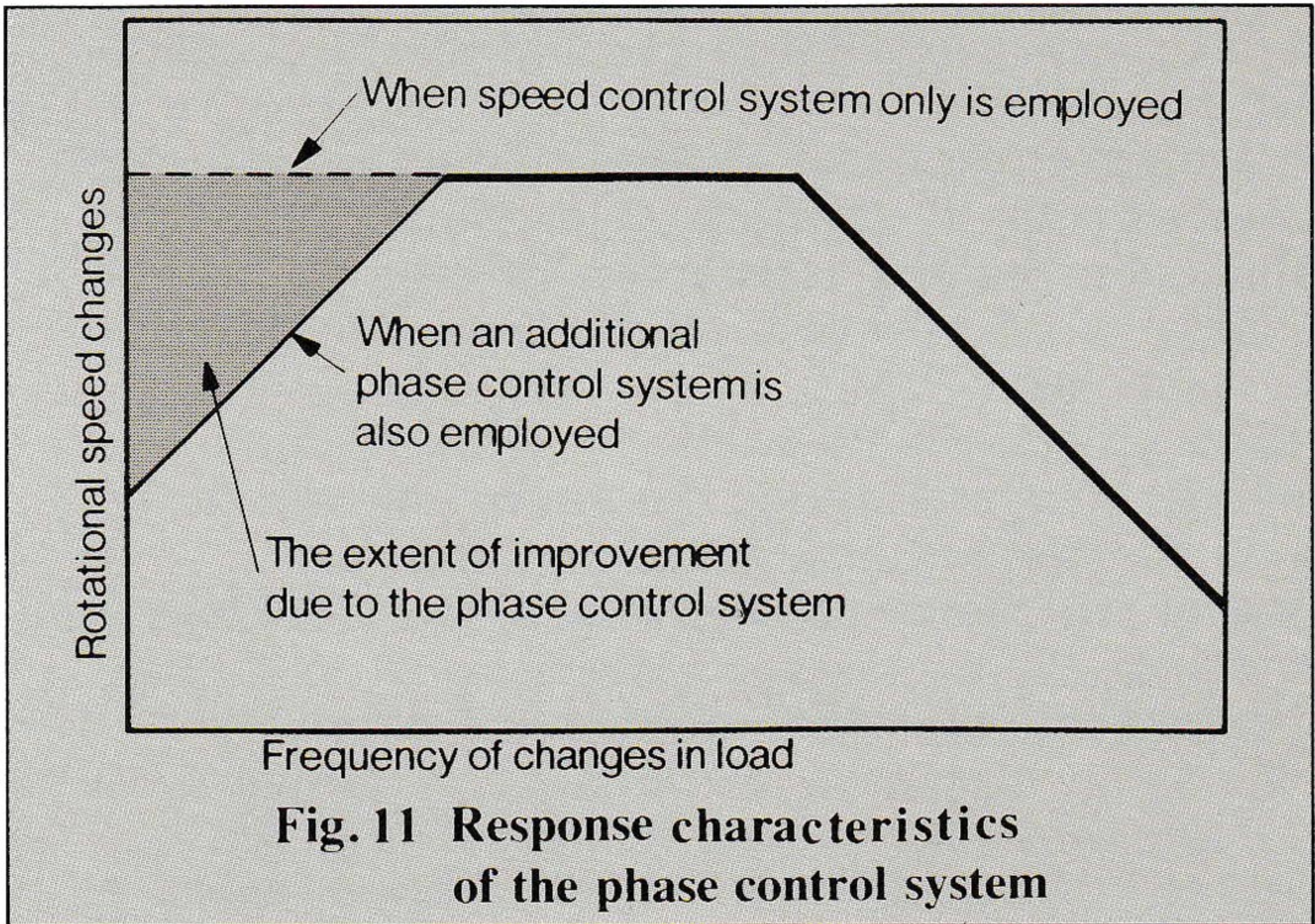


Fig. 11 Response characteristics of the phase control system

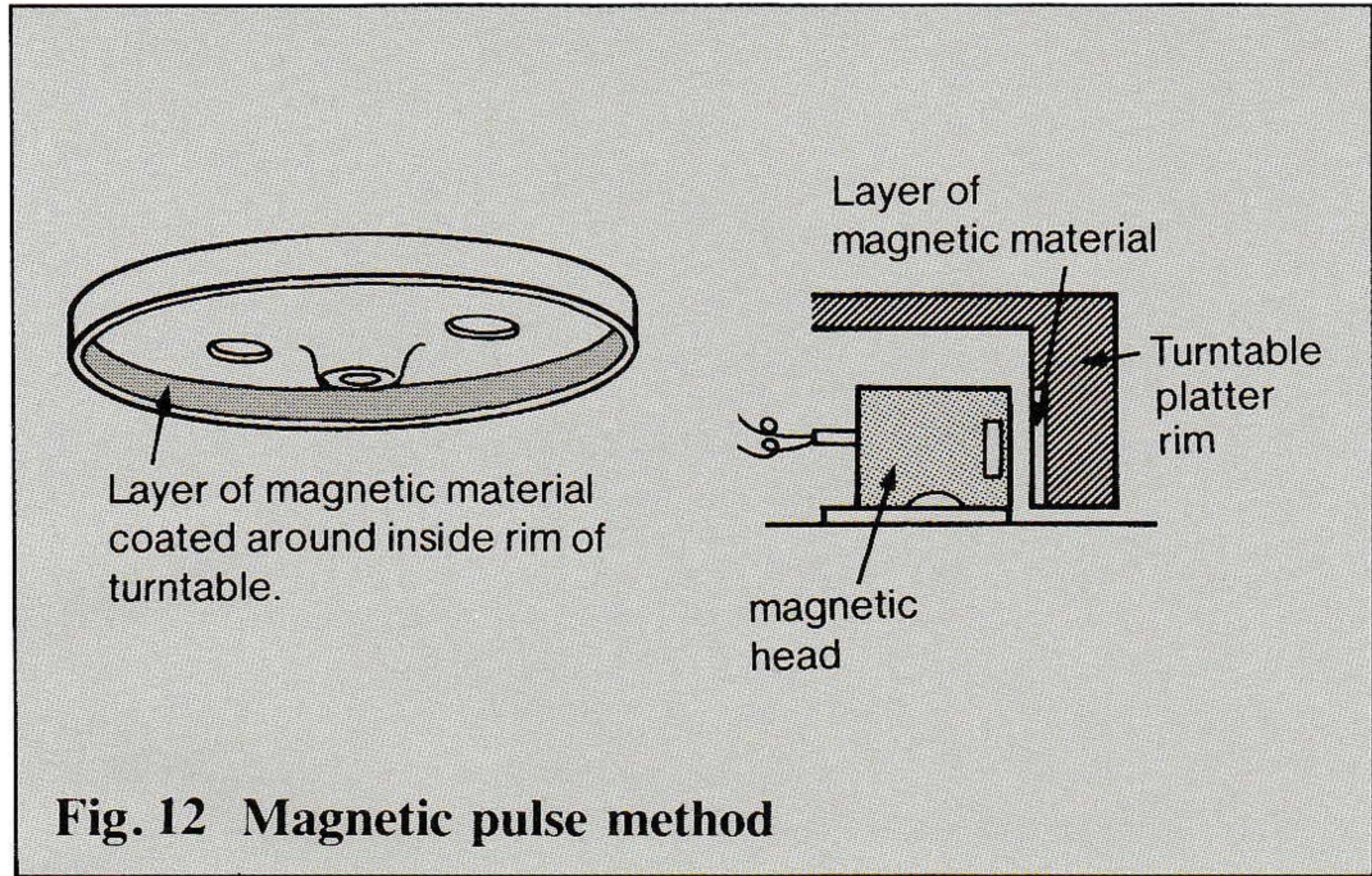


Fig. 12 Magnetic pulse method

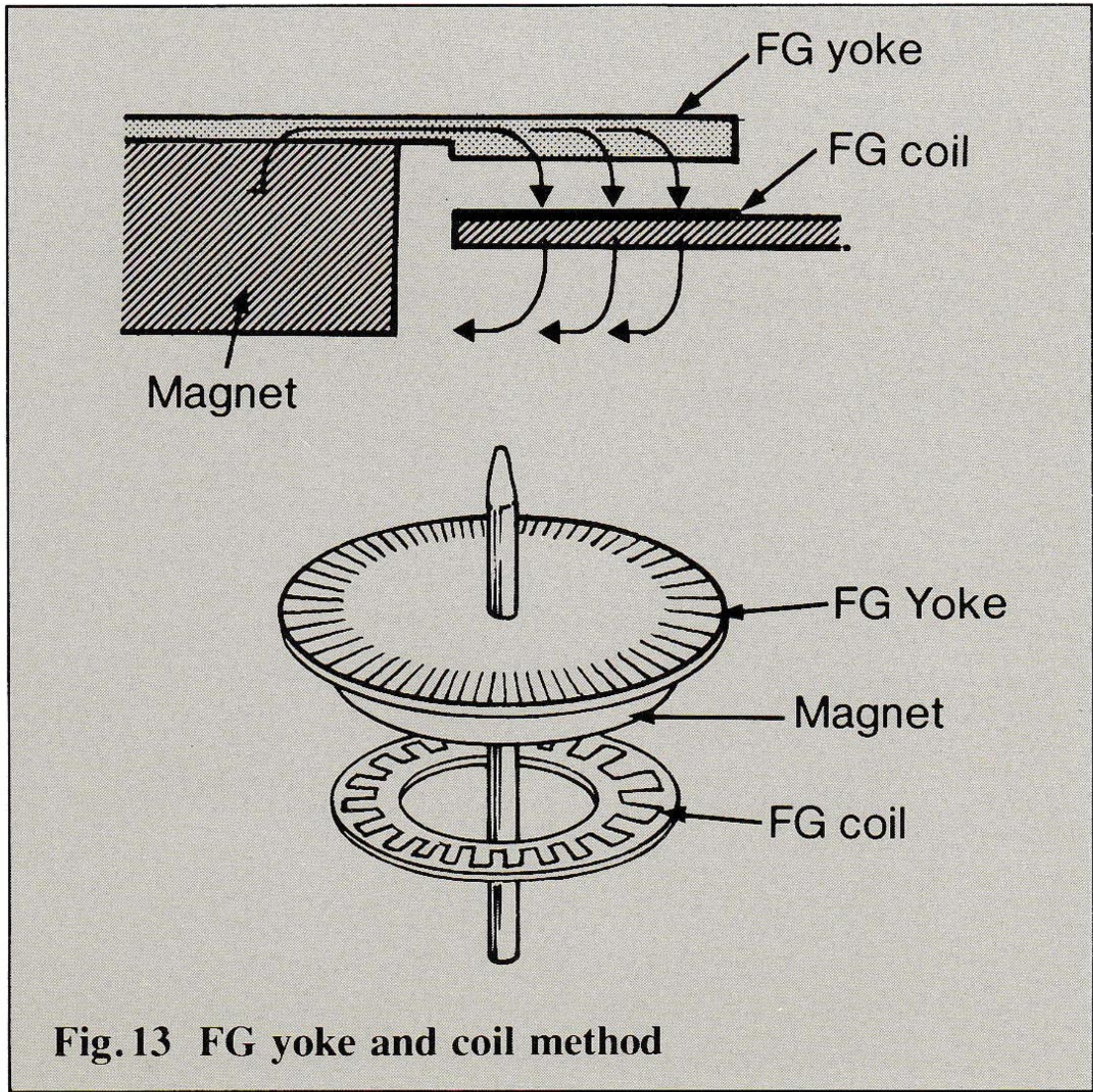


Fig. 13 FG yoke and coil method

3 Seven Essential Features for High Grade Direct Drive Turntables

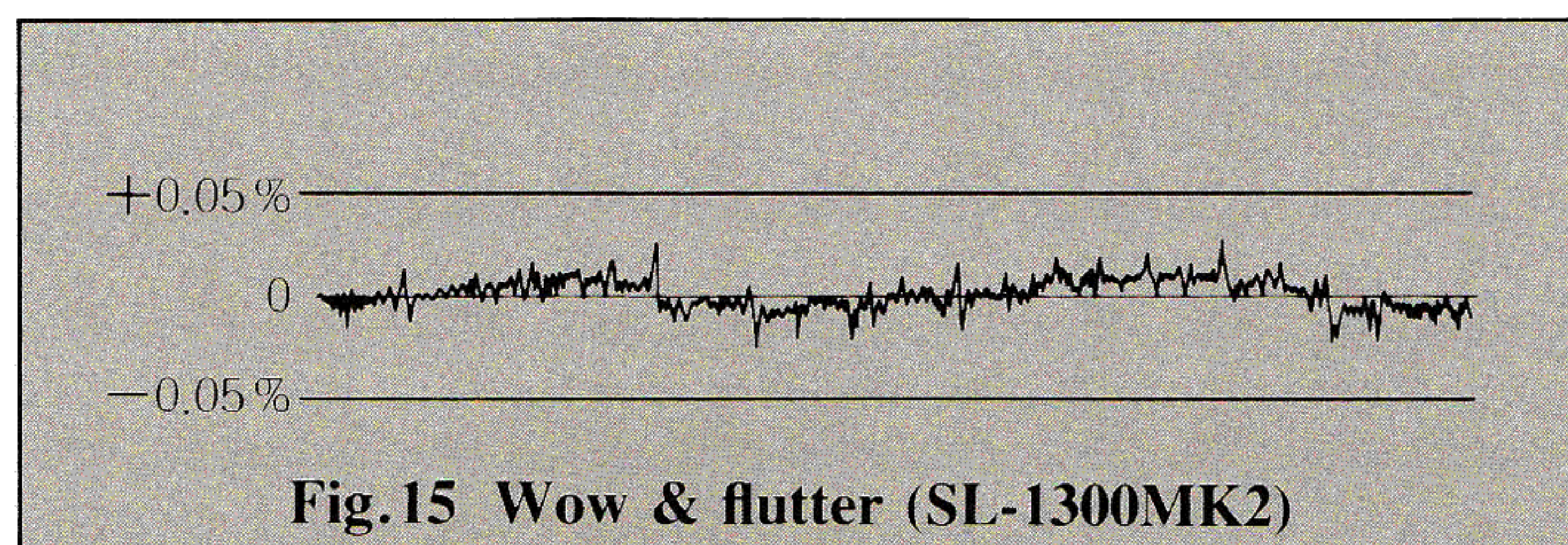
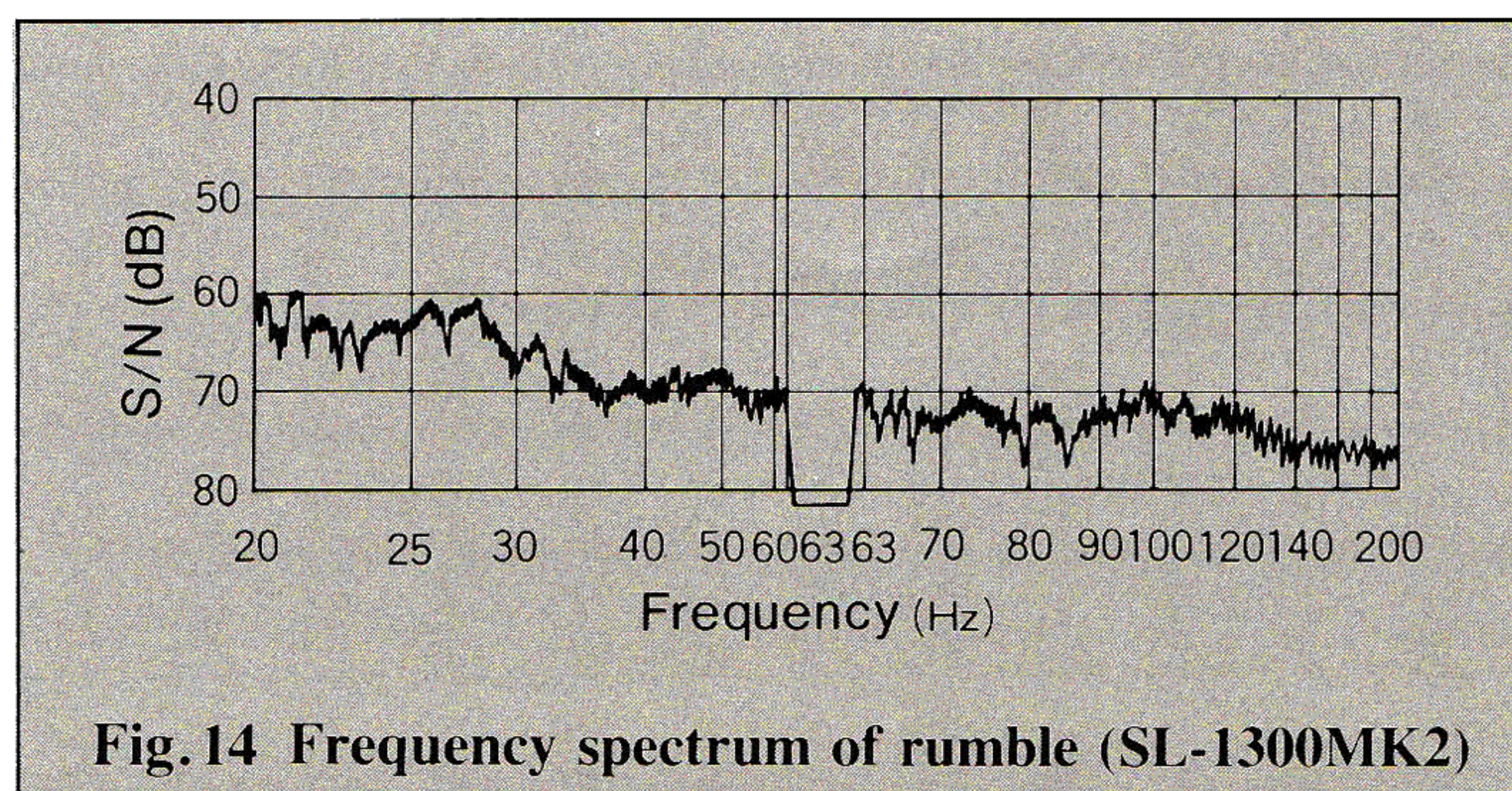
When considering the merits and demerits of the various direct drive turntables available, it is important to consider the overall performance of the turntable, not just one or two of the more prominent features. That is, even features not apparently directly related to the direct drive system (such as tonearm and acoustic properties) must also be examined to gain a balanced overall picture.

1. Rumble and Wow & Flutter

Ever since the arrival of the SP-10, these two highly symptomatic ratings have been improved by such an extent that today they tend to lose their former significance. However, it is important to note the exact conditions under which the ratings were measured. Some manufacturers employ a glass disc instead of a record to measure rumble, and a magnetic plate and recording head to measure wow and flutter (i.e. no record, cartridge, or even tonearm). Such results would naturally appear to be better than those measured under real conditions.

But since the role of the turntable is to play phonograph records, Technics has consistently measured rumble and wow & flutter under real conditions, employing record, cartridge, and tonearm etc. of the turntable under test.

The results: SL-1300MK2 Rumble – 73 dB (DIN 45539B) W & F 0.025% WRMS

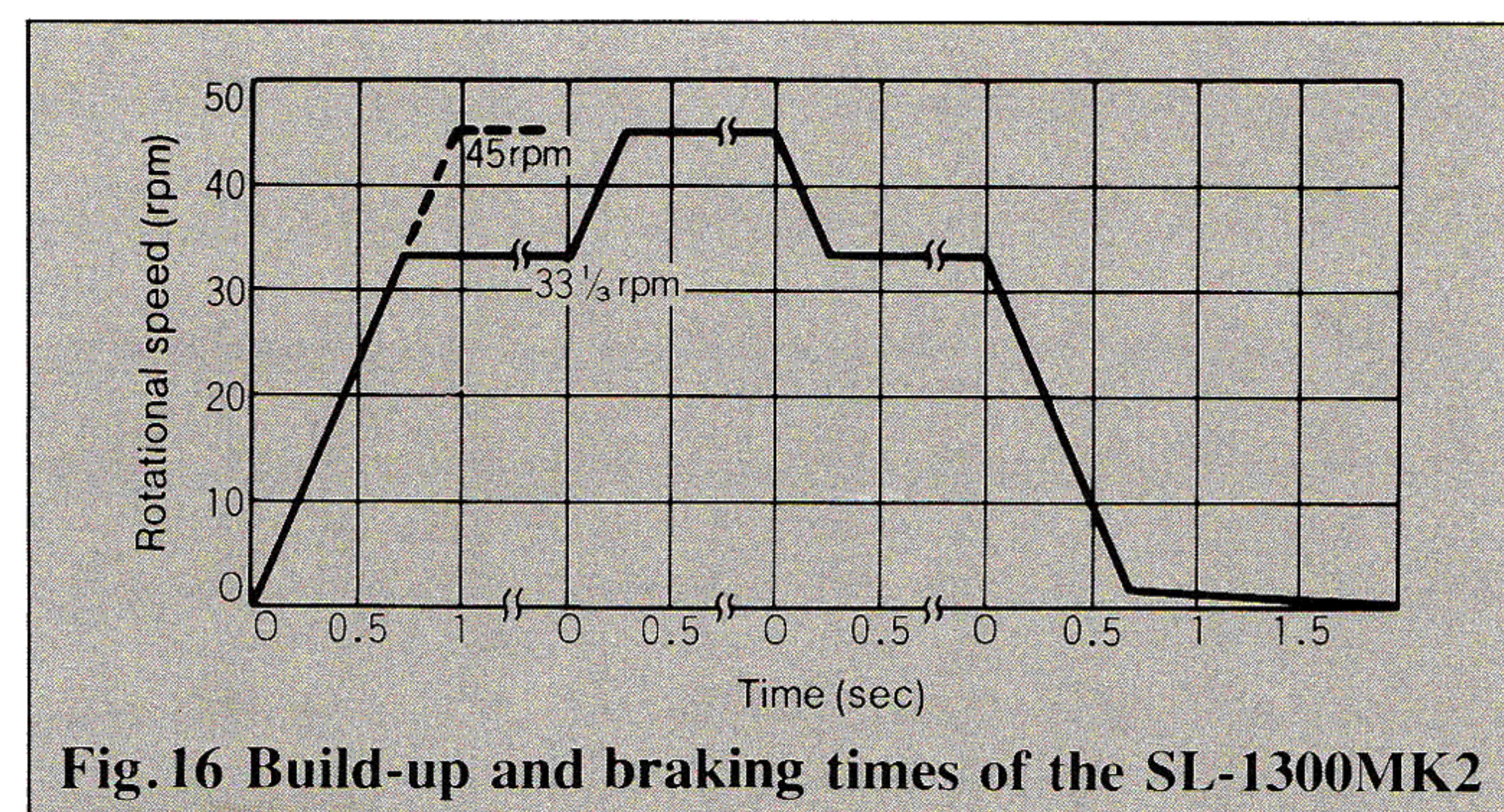


2. Build-up Time

One of the greatest differences between direct drive turntables may be seen in the type of motor drive employed, and the resultant torque and build-up time. That is, systems unable to create a large torque have to reduce the weight of the turntable platter in order to reach the specified rpm within a relatively short period. But lightweight platters (i.e. platters of small moment of inertia) are more easily influenced by external forces, and tend to be less stable. On the other hand, too heavy a turntable platter results in longer build-up and braking times, as well as exerting an excessively high pressure on the central spindle shaft bearing (which will naturally reduce its operational life).

The clue is to design a motor capable of generating high torque to drive a platter of suitable moment of inertia (and weight). The optimum design parameters employed in the Technics SL-1300MK2 are as follows:—

Torque:	1.5 kg·cm.
Weight of Platter:	2.5 kg.
Moment of Inertia:	340 kg·cm²
Build-up Time:	0.7 sec.
(Required to reach constant rpm)	(1/4 of a rotation) (at 33-1/3 rpm)
Electronic brake:	bi-directional drive

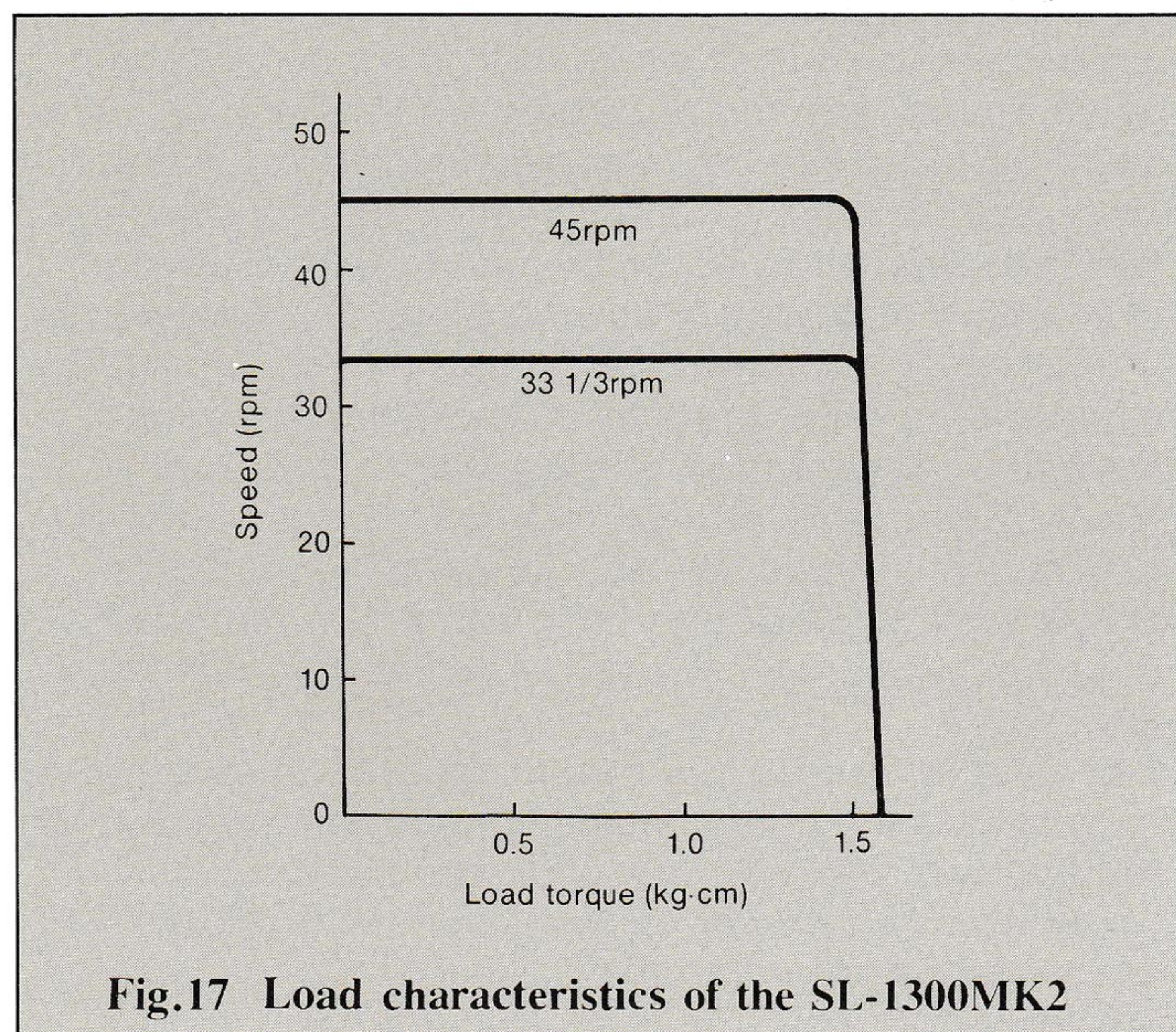


3. Performance under Varying Loads

Total tracking force is a measure of a turntable's ability to maintain constant rotational speeds under various load conditions, such as when record cleaners and brushes are used during play. And since tracking force will also vary according to the downward pressure of the cartridge employed, a high grade turntable design must include all these considerations.

In the SL-1300MK2, there is no change in speed (or effect on the quality of sound) even for loads as high as 1.5 kg·cm. This corresponds to a tracking force of 300 g at the outer edge of the record.

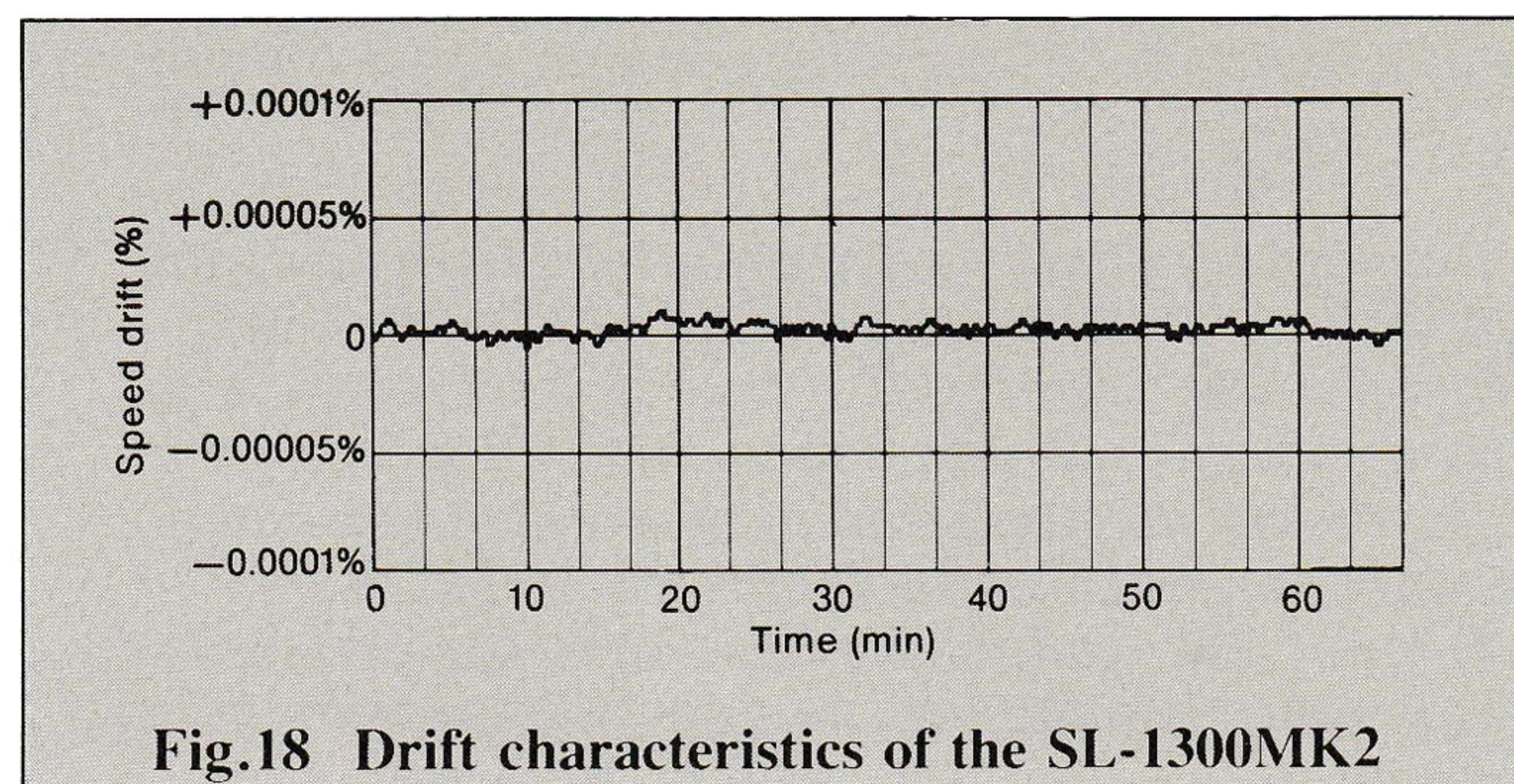
It is also necessary for high grade turntables to be capable of maintaining constant speed when the turntable platter is inadvertently touched by the hand during play. The SL-1300MK2 achieves this stability by employing a sufficiently high AC gain in the servo control loop.



4. Drift

The effects of time and temperature, etc. on the performance of the speed control system must be kept to an absolute minimum. The differential amplifier and temperature compensation circuits reduce drift to $\pm 0.02\%$ even without the assistance of the phase control system. When the

motor rpms are also locked to the quartz oscillator frequency, drift is further reduced to an insignificant $\pm 0.002\%$, or no more than ± 0.036 secs. during the 30 minutes required to play one side of a record.



5. Pitch Control

As will be seen later, the pitch control feature in the SL-1300MK2 has been developed to a very high degree of sophistication. Musical pitch has been standardized at the international level to A=440 Hz (although some slight variations may be found between different orchestras). During the manufacture of phonograph records, there are a number of stages where pitch may suffer slight changes. People of acute hearing (especially musicians) with so-called "absolute pitch" are capable of detecting such changes, and will certainly appreciate the degree of precision to which this pitch control can be adjusted. The range of control will also be appreciated by many audio enthusiasts, permitting pitch to be adjusted by well over a half tone in either direction. But where this pitch control is really unique is in the quartz control at each pitch control step. Other turntables employing a quartz locked phase control cut the quartz oscillator out once the pitch control is



employed (subsequently depending on the accuracy of less stable oscillators such as CR oscillators). In a few turntables, this problem has been partly overcome by varying the quartz frequency divider factors, but the resultant pitch control range is very limited (about 440 Hz $\pm$ 6 Hz). In marked comparison, the pitch control in the SL-1300MK2 includes the following features.

Range: $\pm$ 9.9% (in increments of 0.1%, plus digital display)

**+5.9%
-5.6% } corresponding to a half tone.**

6. Repression of Acoustic Feedback

The performance of a turntable may be seriously affected, depending on how well it is able to prevent extraneous vibration caused by sound waves sent back to the turntable, either via the floor, or through the air (assuming that the turntable has already been placed on a firm support, and located away from corners of the listening room where sound wave energy tends to concentrate).

The double isolated suspension system (described in greater detail later on) employed in the SL-1300MK2 makes this turntable virtually feedback-proof.

7. Tonearm Performance

No matter how well other systems in the turntable may be designed, no genuine hi-fi turntable can be considered complete without a high grade tonearm. The overall superiority of one tonearm over another is determined by a number of different factors, not merely by its shape (S-shaped or J-shaped) or weight, etc.

The more important factors include (a) sensitive horizontal and vertical movement (i.e. pivot construction), (b) rigidity (in order to suppress partial resonance), (c) optimum effective mass designed to restrict low frequency resonance when cartridges of varying compliance are employed, (d) good lateral balance, (e) minimal tracking

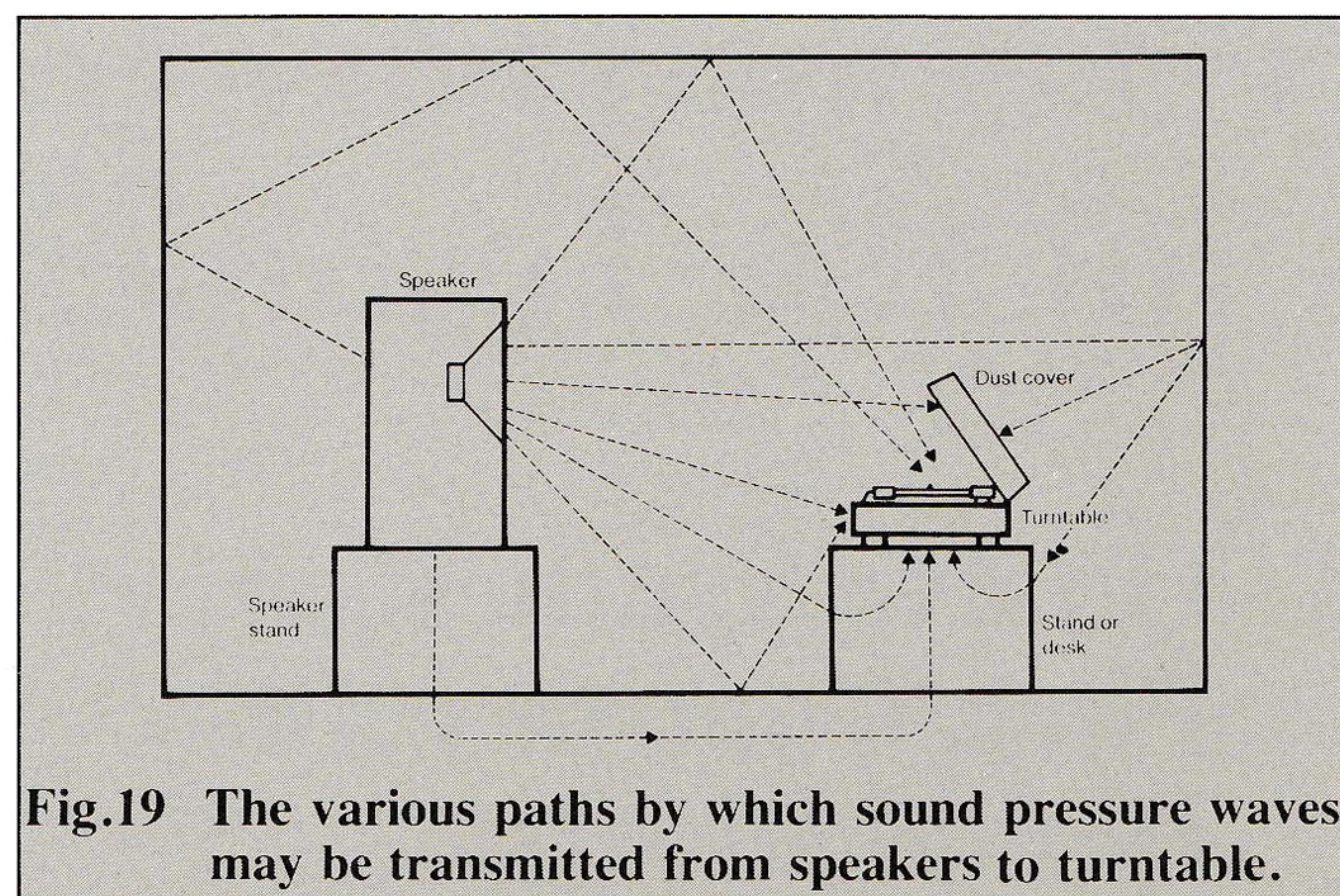
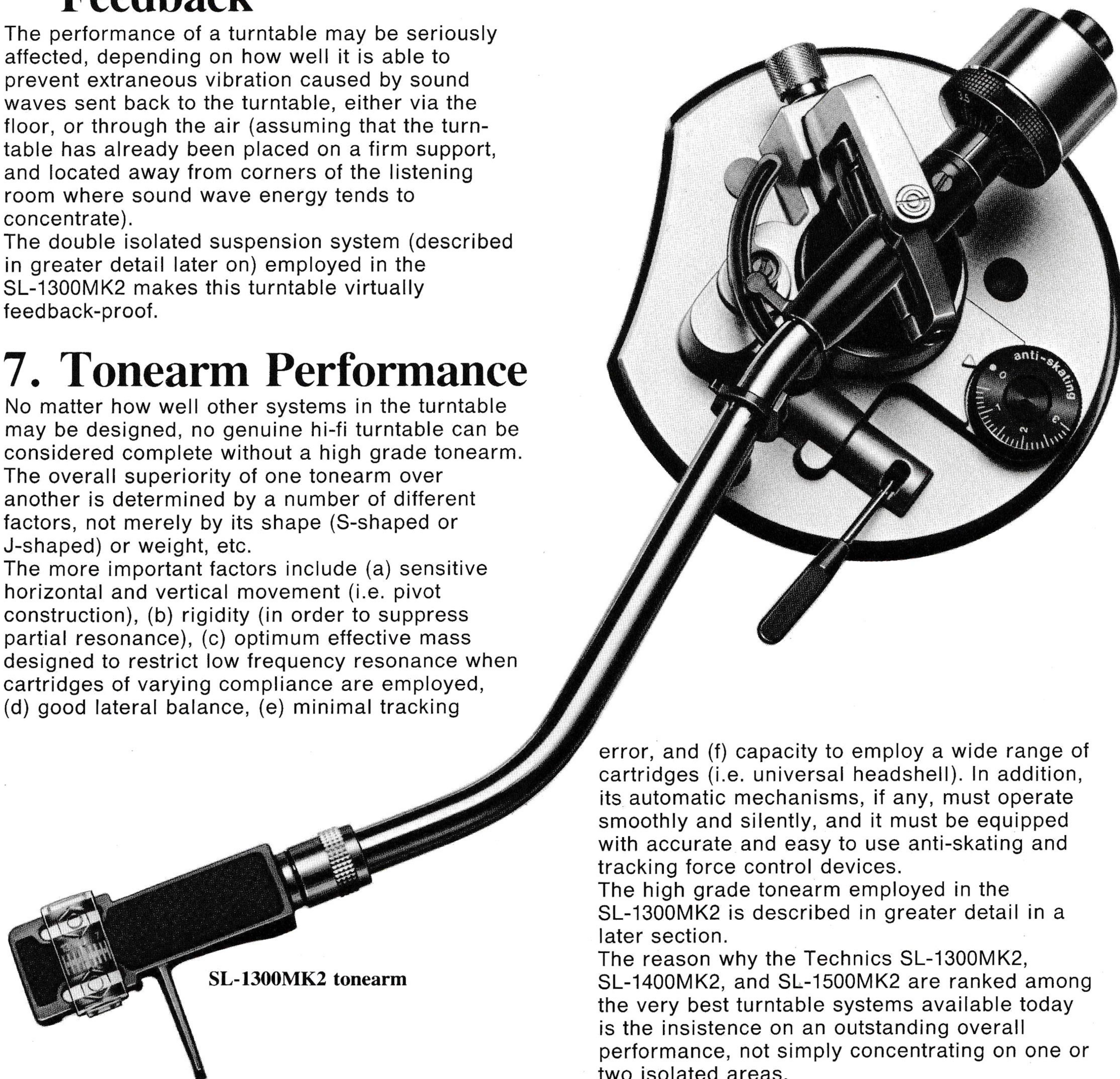


Fig.19 The various paths by which sound pressure waves may be transmitted from speakers to turntable.



SL-1300MK2 tonearm

error, and (f) capacity to employ a wide range of cartridges (i.e. universal headshell). In addition, its automatic mechanisms, if any, must operate smoothly and silently, and it must be equipped with accurate and easy to use anti-skating and tracking force control devices.

The high grade tonearm employed in the SL-1300MK2 is described in greater detail in a later section.

The reason why the Technics SL-1300MK2, SL-1400MK2, and SL-1500MK2 are ranked among the very best turntable systems available today is the insistence on an outstanding overall performance, not simply concentrating on one or two isolated areas.

4 Major Drive and Control Features of the Technics SL-1300MK2

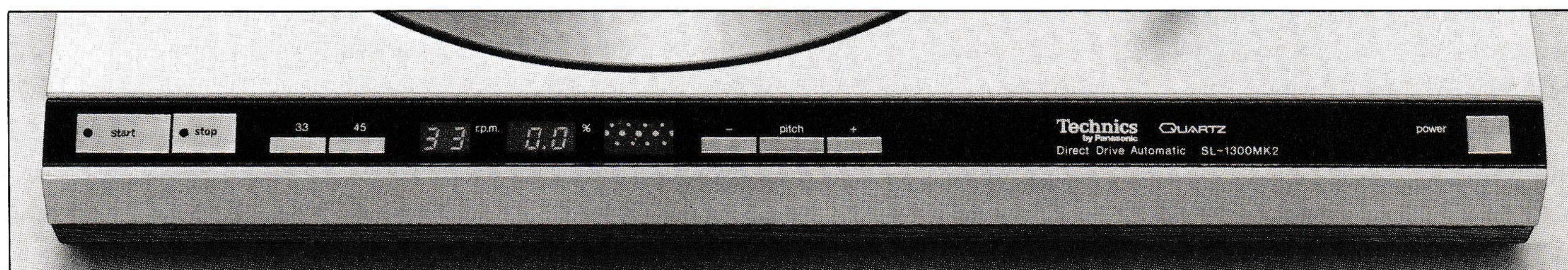
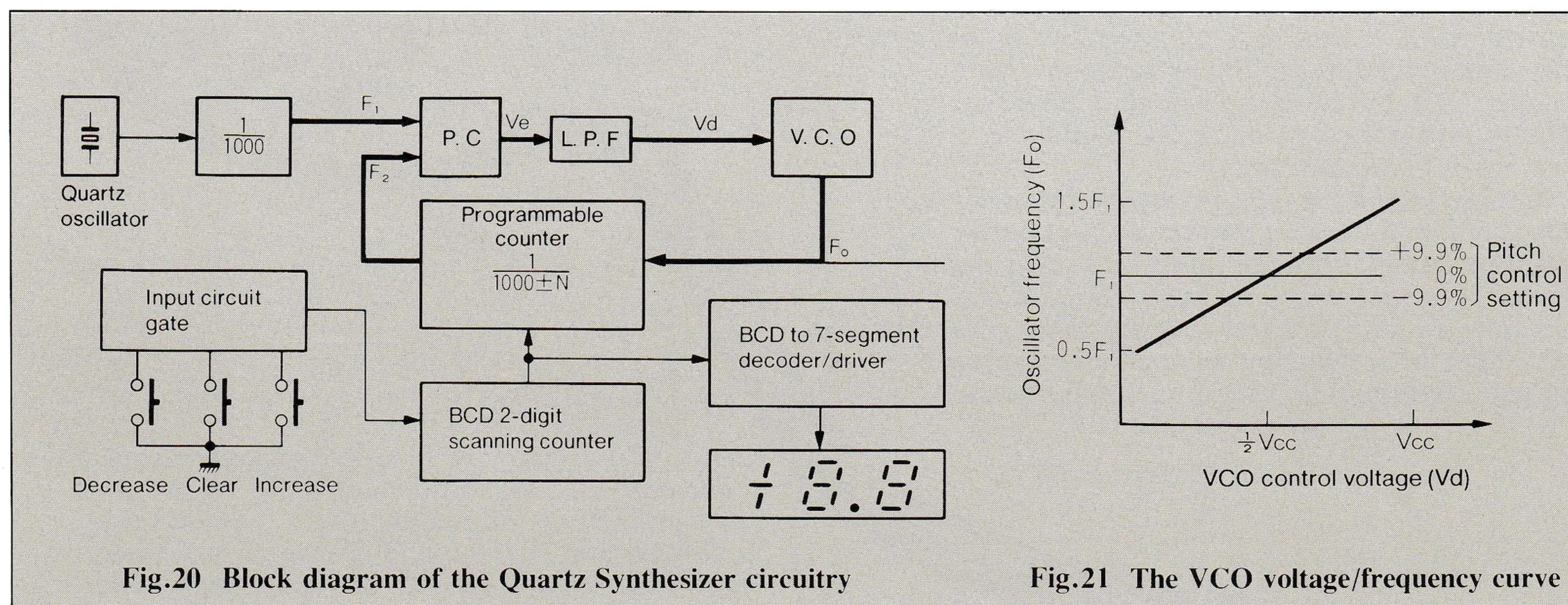
1. Quartz Synthesizer Pitch Control with Digital Display

Unlike other quartz locked phase control systems (which are automatically cut out when the pitch control is employed), the unique quartz synthesizer pitch control featured in the SL-1300MK2 is designed with quartz locked accuracy at all pitch control settings. With this unique system, pitch may be varied by up to $\pm 9.9\%$ in increments/decrements of 0.1% per step. Records may be "tuned" accurately to the piano or other musical instruments of relatively accurate and constant pitch, or deliberately decreased in pitch (by -5.6% , or a half tone) to facilitate choral studies. Likewise, an increase by a half tone ($+5.9\%$) can add unexpected interest to a variety of musical renditions. An important application in professional work such as broadcasting is the ability to fit a given tune into a given time slot or to record a 32-minute disc onto a 30-minute tape. Pitch will of course change, but there are cases where time

conformity is of overriding importance. In other words, the pitch control in the SL-1300MK2 is in effect a "play adjuster", in addition to being a pitch correction device.

The operating principle is outlined in the following block diagram. In order to vary pitch in steps of 0.1% , the frequency of the quartz oscillator is divided by $1/1000$ (frequency F_1). The phases of the two AC input signals (F_1 and F_2) are compared in the phase comparator (PC), with the difference in phase being converted into a voltage output (V_e). This voltage is passed through a low-pass filter (LPF) where it forms the control voltage V_d which is then applied to the voltage-controlled oscillator (VCO). V_d is converted into a frequency signal (F_0) according to the relation described by the curve in Fig. 21. F_0 is divided in the programmable counter by $1/1000+N$, where N is the pitch control setting (expressed as an integer).

When $F_2=F_1$, the pitch control setting frequency is "locked" to the quartz oscillator (divided) frequency, thereby attaining the same level of precision and stability as the quartz oscillator itself. When the pitch is increased by 5.9% for example, the programmable counter simply divides F_0 into $1/1059$.

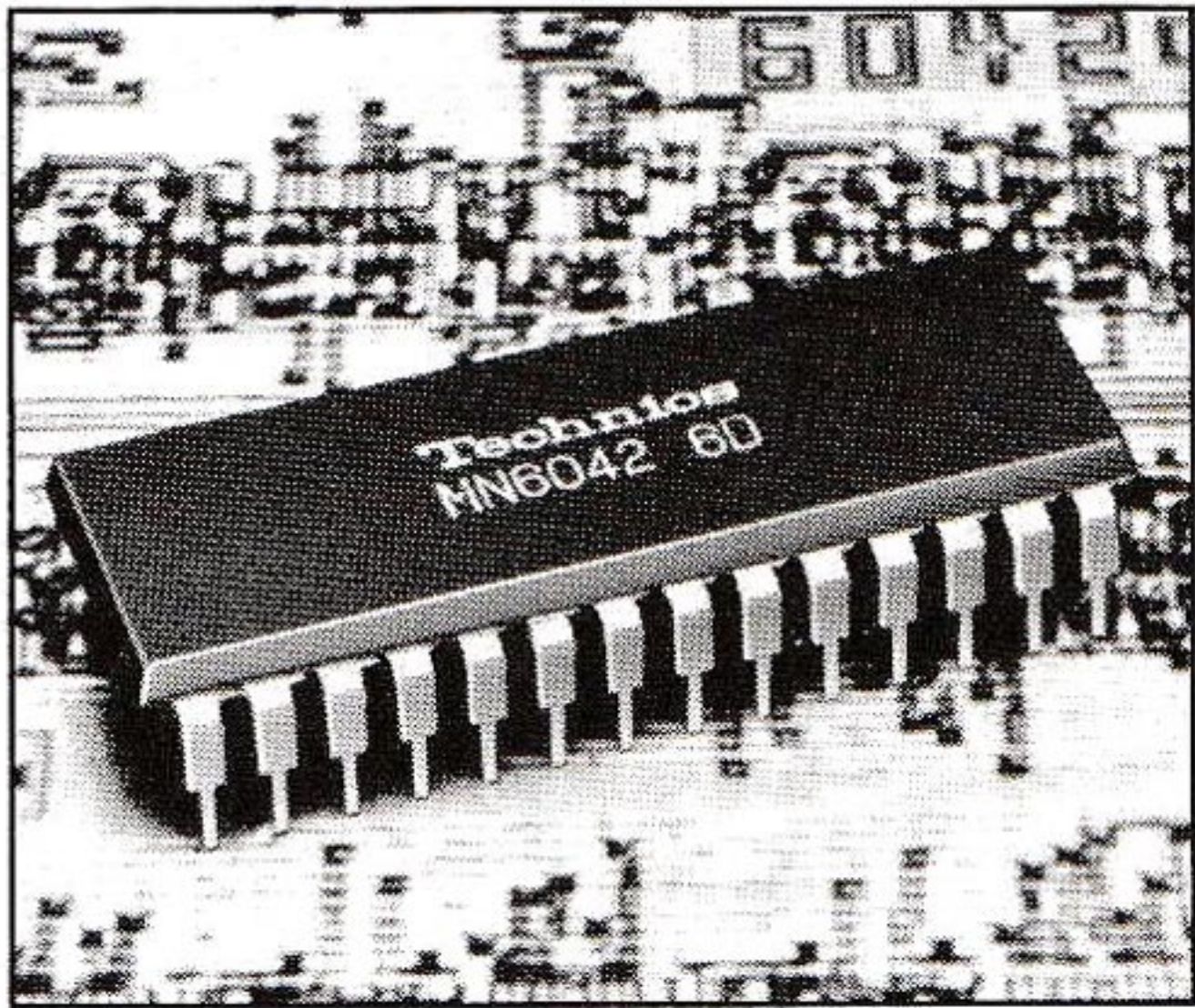


2. Quartz Phase Control Servo System

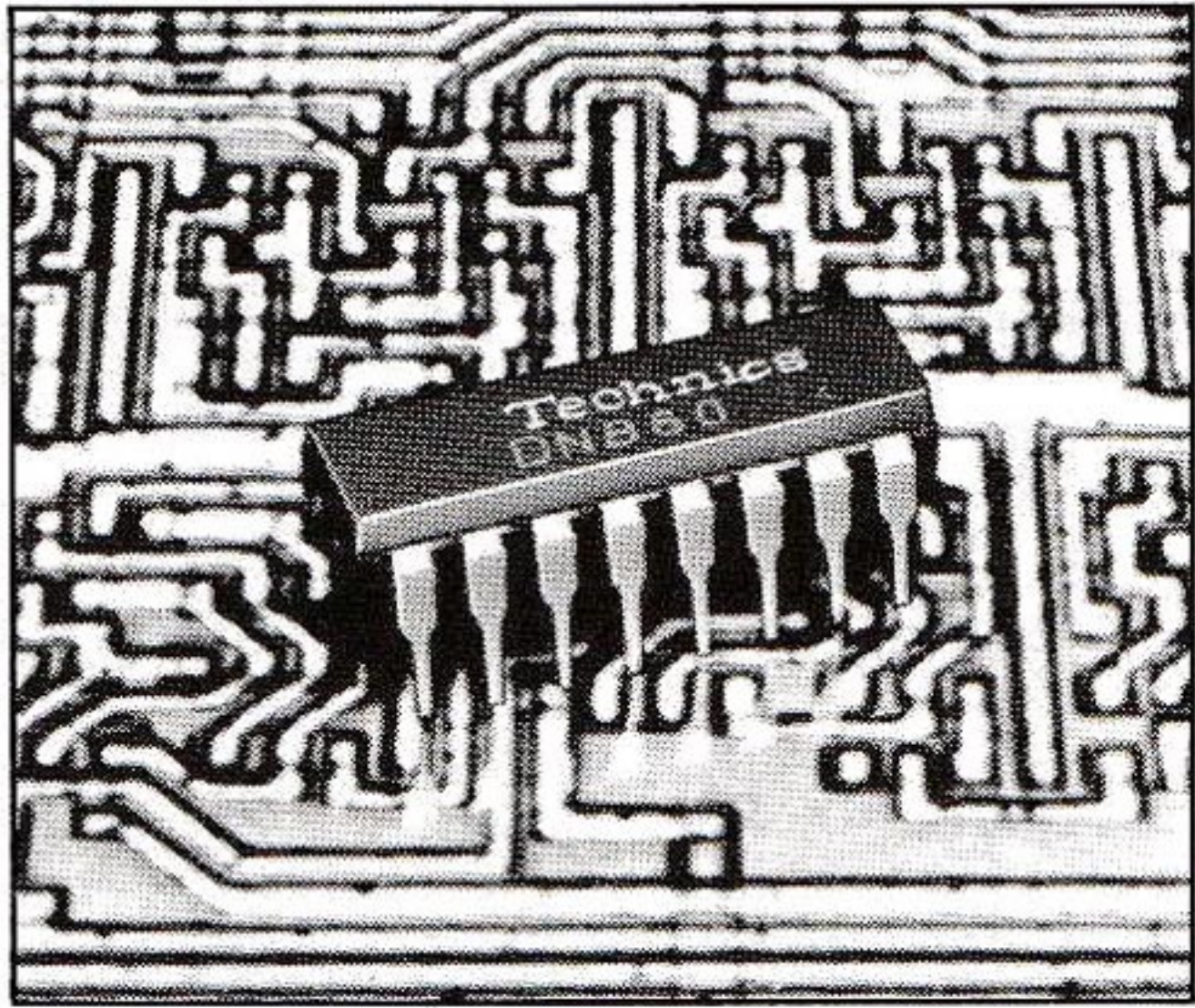
As can be seen in the following block diagram, the principal circuit components in this phase control system are incorporated into four unique ICs. MN6042 is a CMOS LSI housing the quartz synthesizer pitch control described above, DN860 contains the quartz oscillator and an I²L•ECL equipped frequency divider, AN660 is a bi-polar IC designed for phase and speed control via sample hold circuits, and AN640 is designed for three-phase full-wave bi-directional drive. These four ICs correspond to over 3,000 independent circuit components, and contribute greatly to the high degree of precision and reliability of this direct drive turntable.

When the start button is pushed on, the motor commences to rotate due to the signal from the start logic circuit. The FG output signal, whose frequency is directly proportional to the actual rotational speed, is passed through a band-pass filter (BPF), shaped by a Schmitt trigger, and converted into a DC voltage in the sample hold circuit. When the motor rpms approach the designated speed, the phase control circuit is activated, resulting in a very rapid and smooth

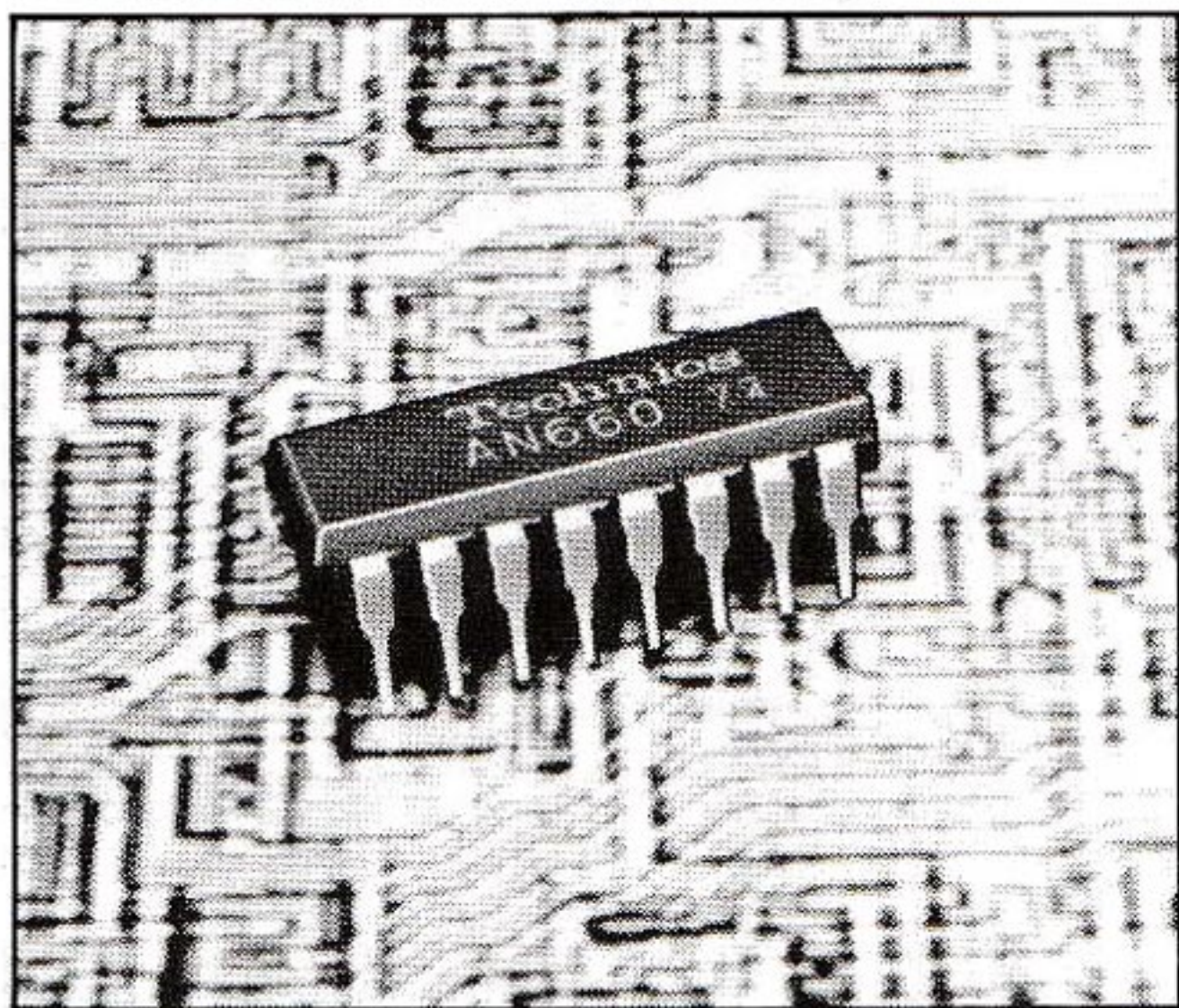
attainment of the exact rotational speed. There is no overshooting or undershooting as has been common in other phase control systems. Once the designated speed has been attained, the PC output is mixed with the F-V converter output to form a control voltage ER, which is applied to the input of AN640, and compared with the reference voltage Es. This results in command signals for forward/reverse rotation being applied to the motor.



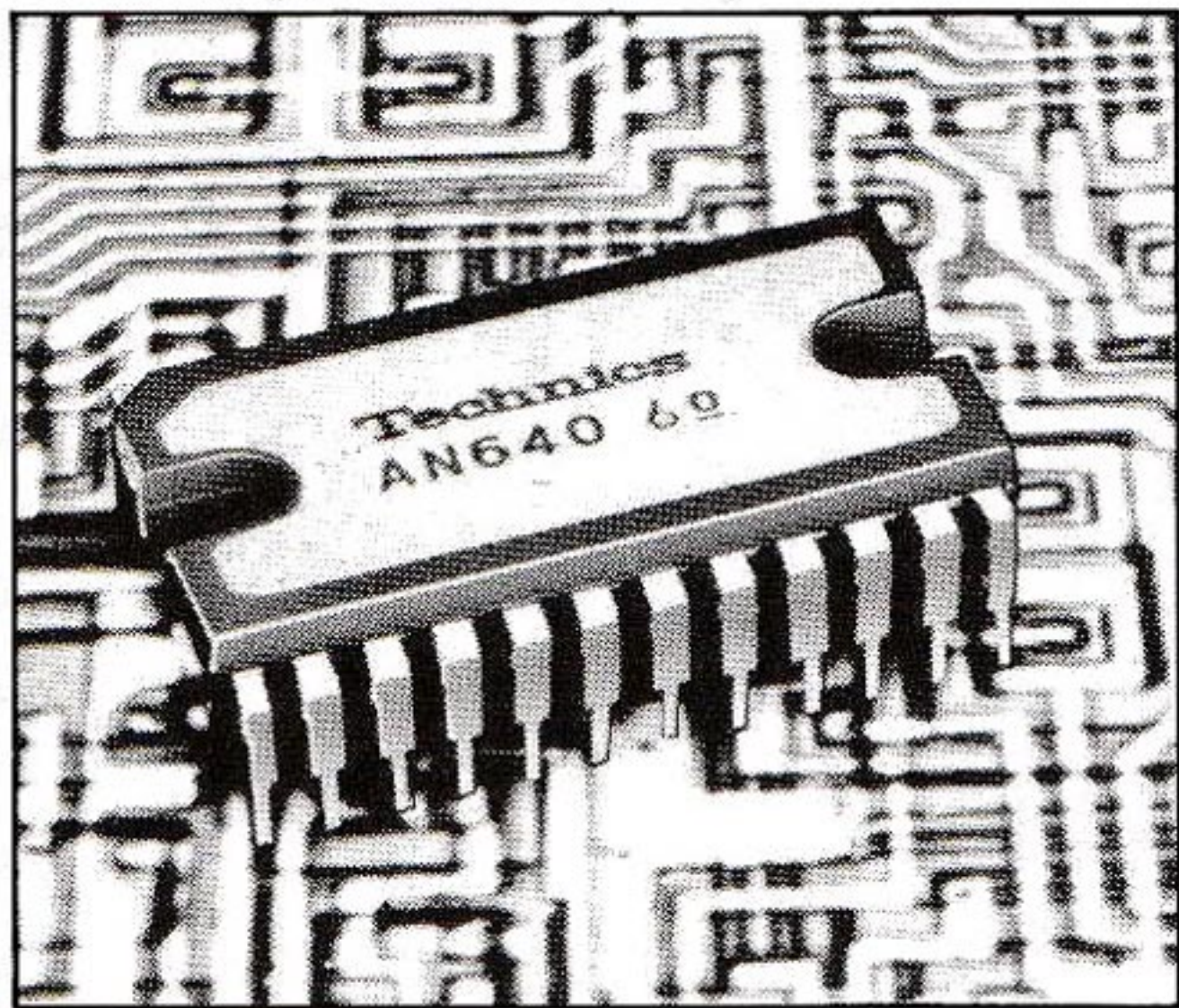
MN6042 (1856 elements)



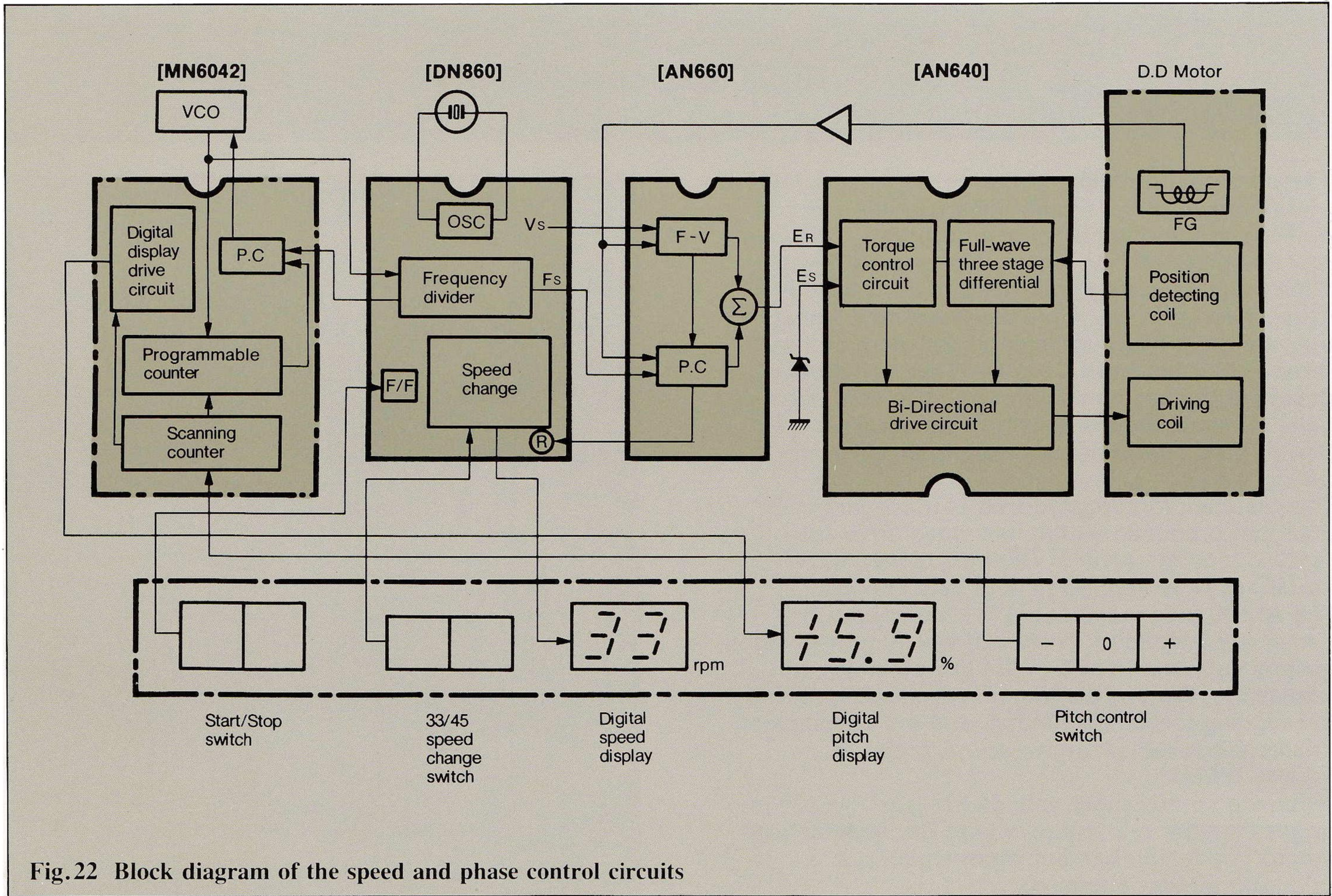
DN860 (380 elements)



AN660 (427 elements)



AN640 (340 elements)



3. Hetero-Polar Motor and Full-Wave Bi-Directional Drive Circuit

The highly effective hetero-polar direct drive motor is now incorporated into almost all Technics direct drive turntables. The SL-1300MK2 features a 16-pole 12-slot structure. This 4:3 magnet pole to stator slot ratio has been found to be ideal for high torque high efficiency direct drive motors.

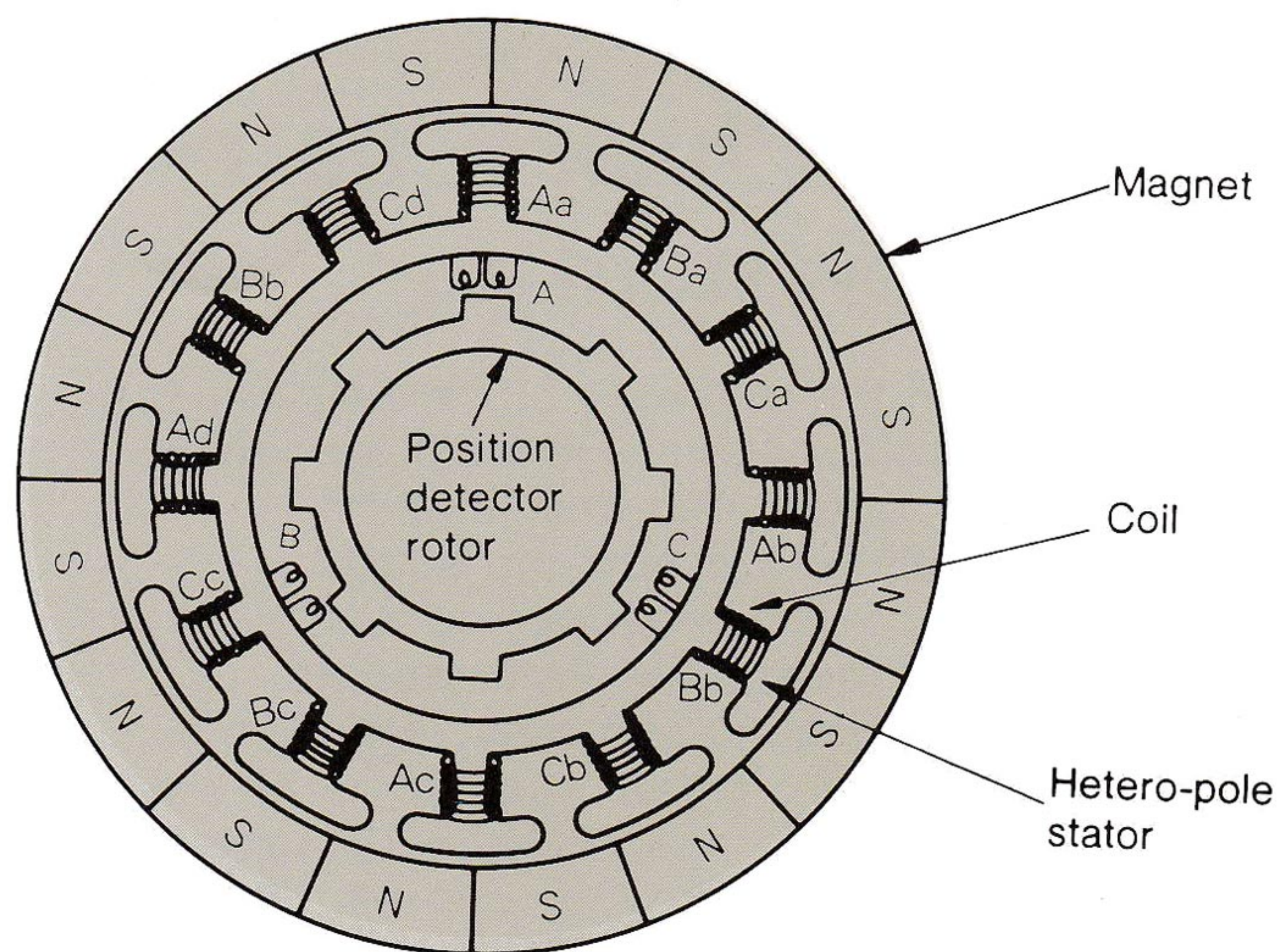
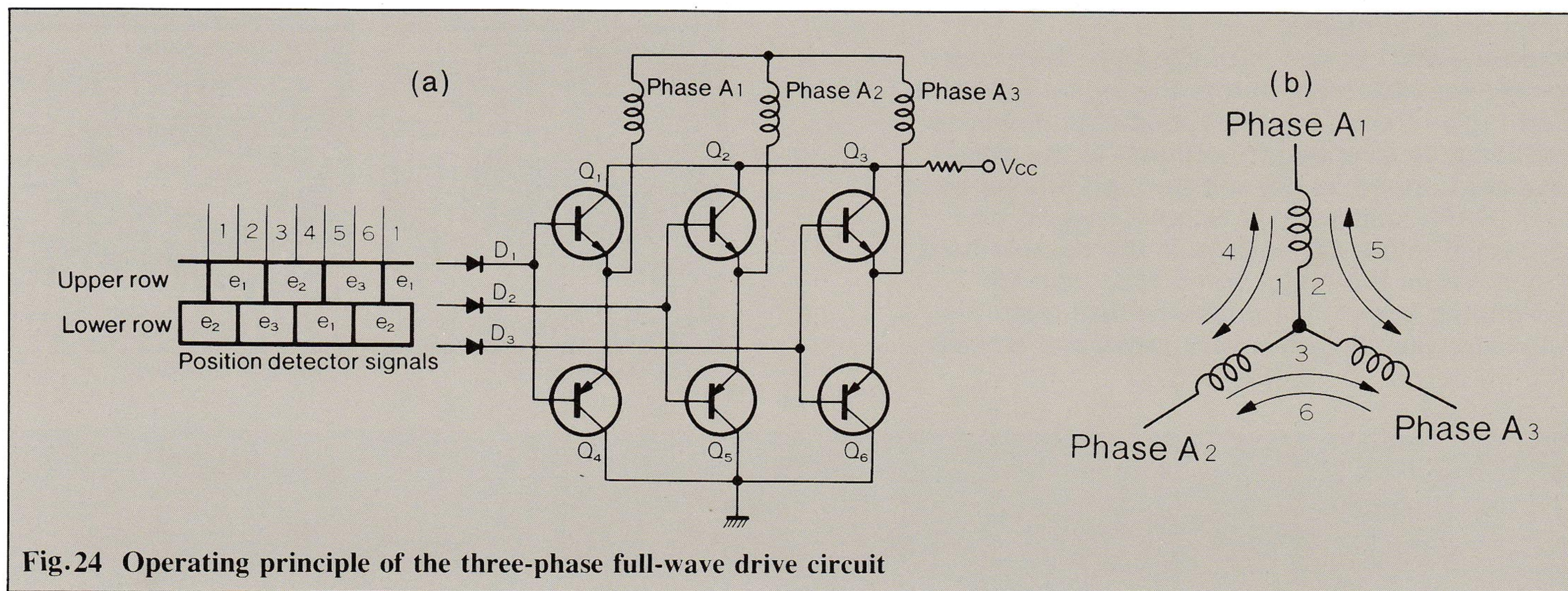


Fig.23 Outline of the Hetero-Polar direct drive motor



The operating principle of the three-phase full-wave bi-directional drive circuit of the IC AN640 is outlined in the diagram above. (Fig. 24). The upper row position detector signals activate the 3-stage differential switching consisting of the three NPN transistors Q_1 to Q_3 , while the lower row signals activate the 3-stage switching consisting of the three PNP transistors Q_4 to Q_6 . This switching is designed to pass current through two sets of drive coils in the sequence shown in the diagram (section (b)), an operation requiring highly precise timing.

The resultant torque produced is much smoother than that produced by the half-wave drive (see Fig.25), and the level is $\sqrt{2}$ times higher when equal power is applied to both sets of coils. The AN640 also includes an hFE compensatory circuit (developed by Technics) which compensates for any variation in hFE of the three differential transistors, thereby playing a very significant role in reducing torque fluctuation, and the consequent attainment of the ultra-low wow & flutter of 0.025% WRMS.

When the control input voltage E_R (see Fig. 22) is larger than the reference voltage E_S , an acceleration torque is applied, but when smaller, a retarding torque is applied.

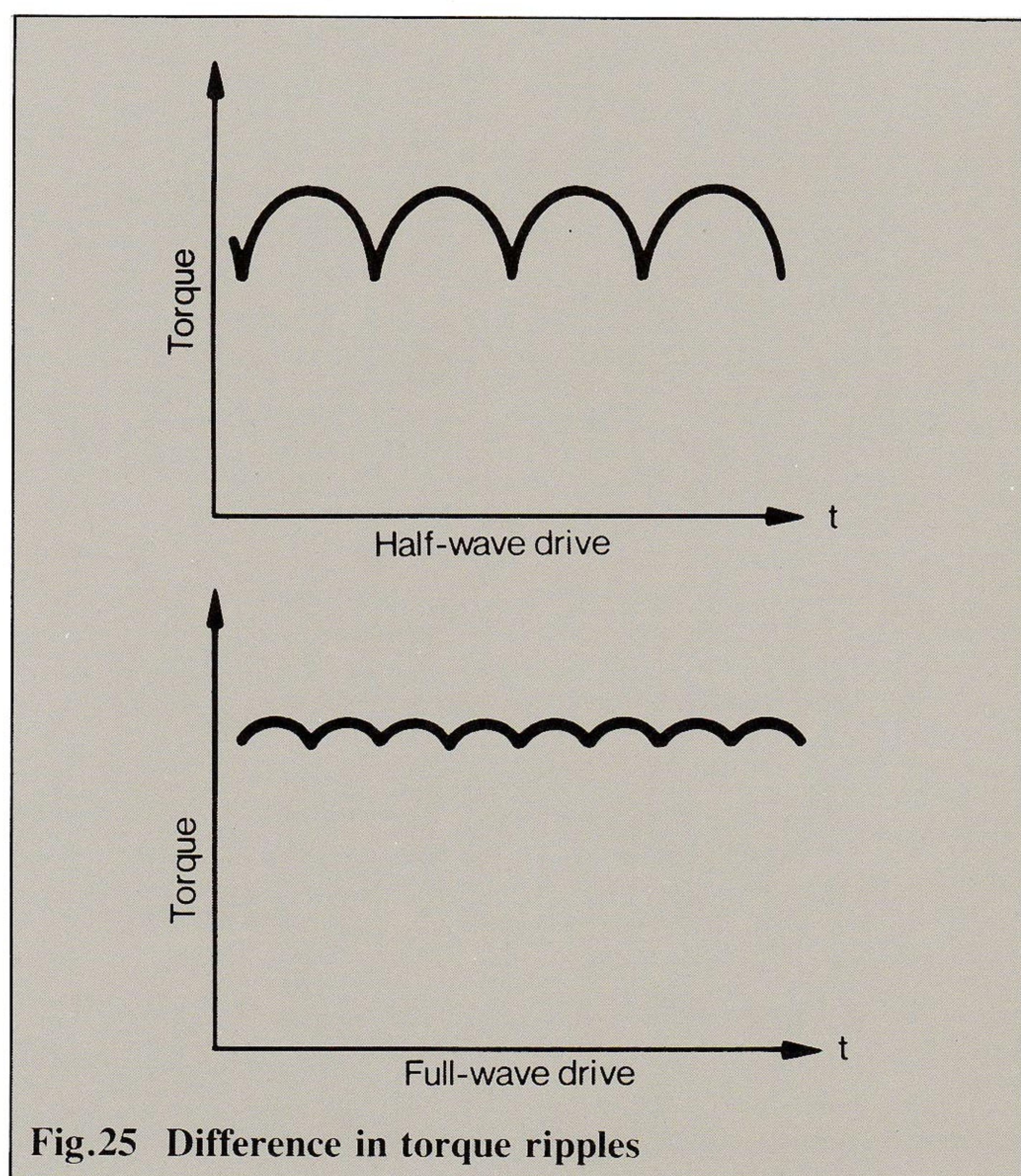


Fig.25 Difference in torque ripples

4. Turntable Structure and Integrated FG Servo Mechanism

Another unique feature employed in the SL-1300MK2 is the turntable platter and rotor precision—machined in a single structural unit. The FG servo mechanism consists of two annular gears (with 91 teeth each) mounted opposed to each other (but not in contact) around the central spindle shaft. The changes in reluctance between outer and inner gears are detected by a pair of coils to produce 91 pulses per full rotation. The coils and magnets are arranged so that their interaction cancels induction hum. The significance of this integrated structure is the fact that the resultant detection signal is an averaged value. Any slight eccentricity tendencies, or pitch variations between outer and inner gears are therefore minimized for even greater accuracy in the FG control system.

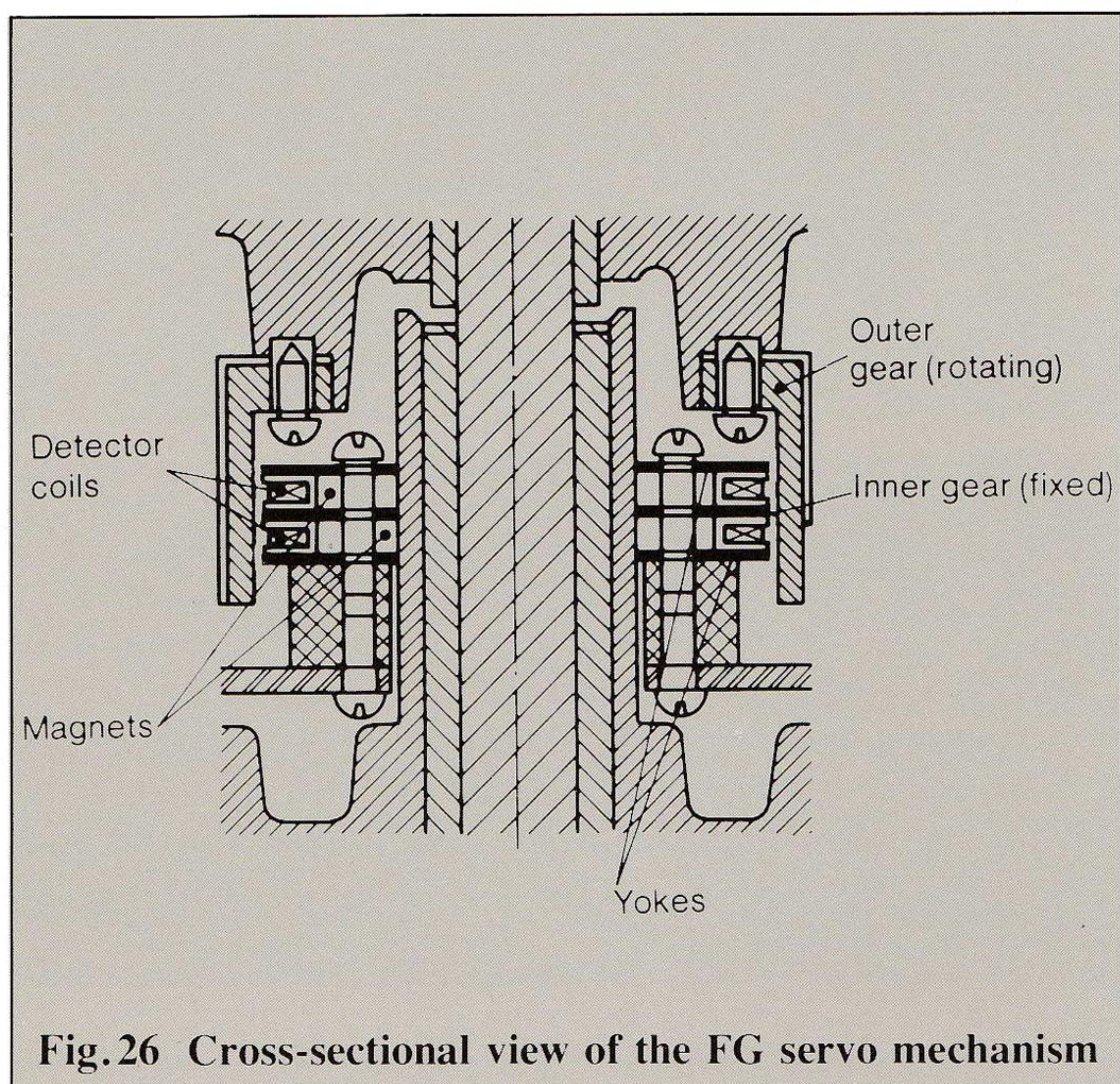
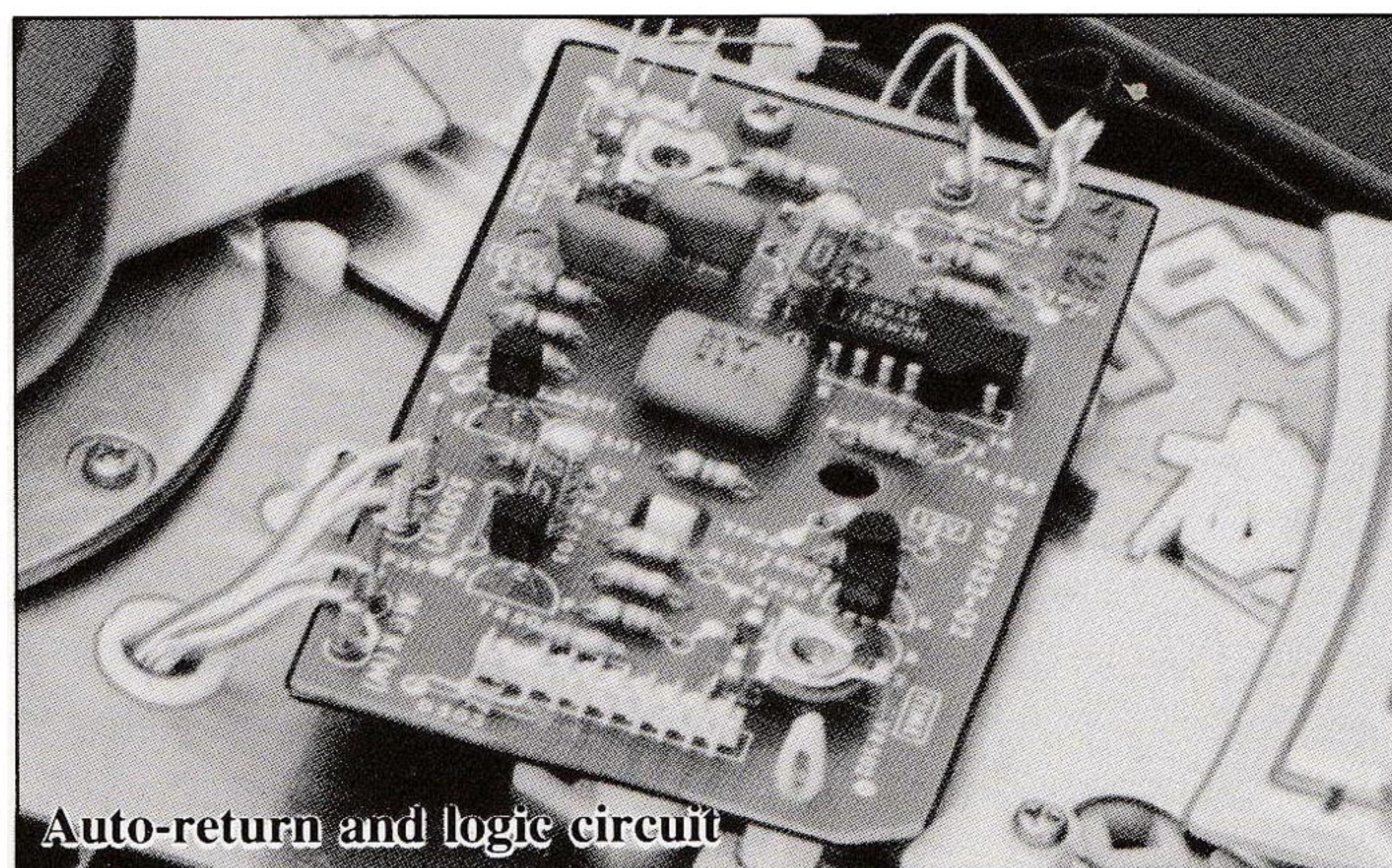


Fig.26 Cross-sectional view of the FG servo mechanism

5. Auto-Return Mechanism and Logic Circuit

Unlike mechanical end-of-record detector systems, the LED/photo transistor electronic detector system in the SL-1300MK2 ensures exceptional accuracy and stability from start to finish in this automatic operation. When the tonearm is still tracing the music grooves, the amount of advancement towards the center of the record is very small, and the period of the photo transistor output waveform relatively long. Therefore, the output level of the sawtooth wave generator circuit is well above the fixed reference level, and no detector pulse will be produced. But once the tonearm enters the lead-out groove, the amount of lateral advancement suddenly increases, thereby reducing the period of the output waveform, and decreasing the sawtooth output level below the fixed reference level, resulting in the generation of a detector pulse. The pulse signal then activates a timer circuit, and a plunger drive circuit to set the auto-return mechanism into motion.

An added feature in the SL-1300MK2 is a special return detector switch which may be turned off when the user prefers to maintain manual control of the tonearm.



Auto-return and logic circuit

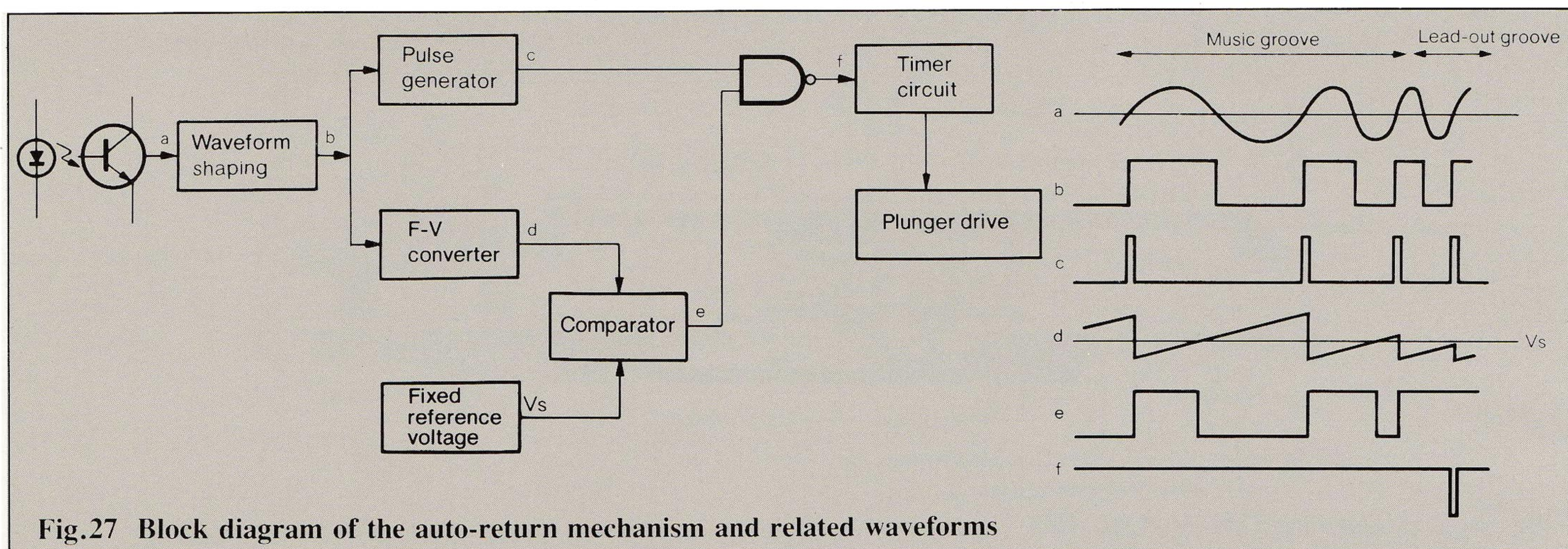


Fig.27 Block diagram of the auto-return mechanism and related waveforms

5 Suppression of Acoustic Feedback in the SL-1300MK2

With Technics exclusive “floating” structure, specially developed turntable base materials, and computer designed isolators, the SL-1300MK2 is almost completely free from acoustic feedback.

a) Double Isolated Suspension System

The direct drive motor (including turntable platter) and the tonearm assembly (including auto-return mechanism) are mounted into the molded main base made of glass fiber (blended with other anti-resonant materials). This complete assembly is then separated from the diecast turntable base by the 2nd isolator suspension system consisting of special elastic material and tuned metal springs. The turntable base is in turn rested upon the felt padded 1st isolator system.

Acoustic feedback through the floor and the air may cause the dust cover and shelf to vibrate, but practically none of this vibration will get through to the turntable due to the double isolated suspension system.

b) Component Design Based on Vibration Analysis

The design of all major components of this turntable is aimed at the reduction of vibration and ease of handling. The tonearm base for example is manufactured from heavy diecast zinc, and the platter itself weighs 2.5 kg. Even the rubber mat is designed to deaden vibration and ensure intimate contact with the record. Also facilitates easier handling when removing the records.

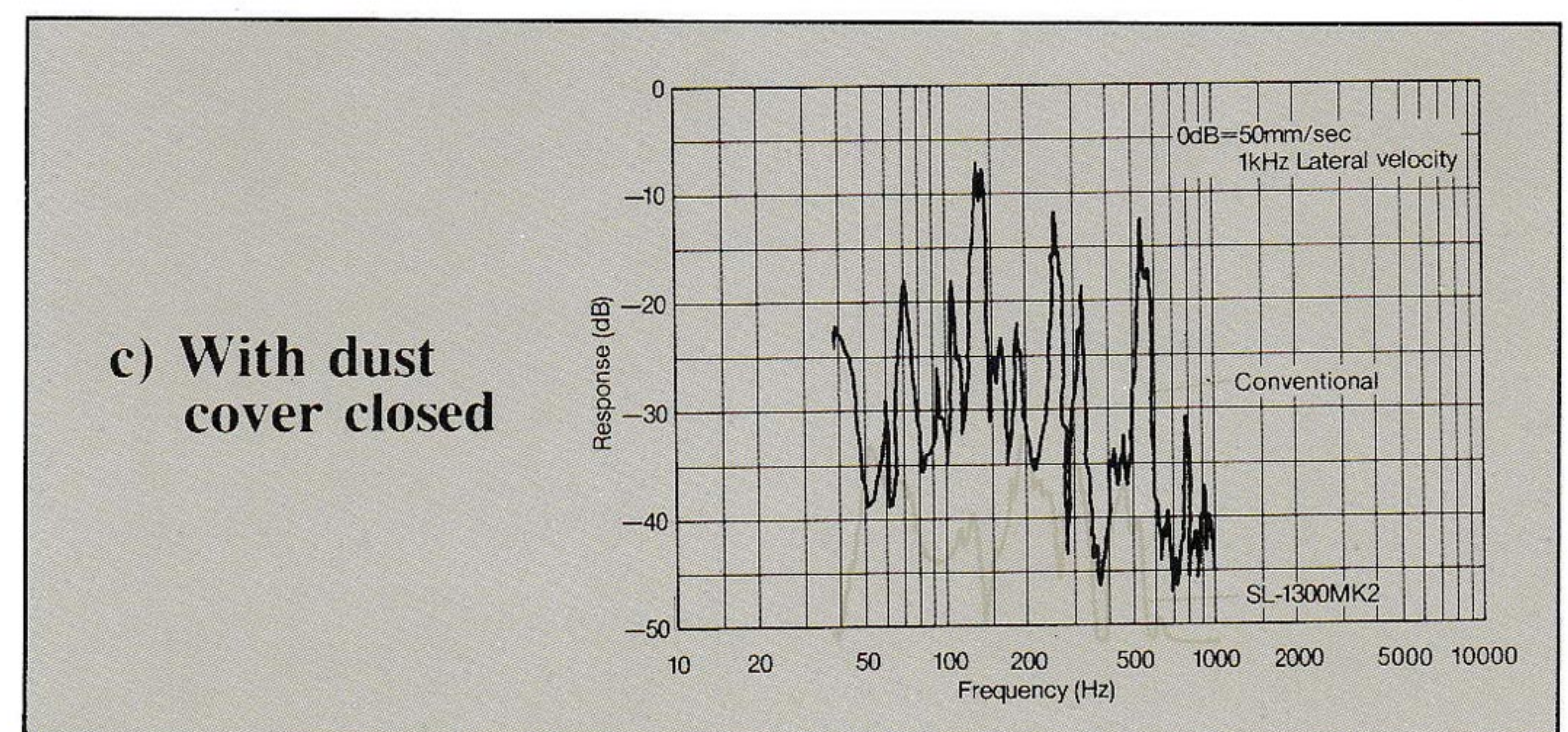
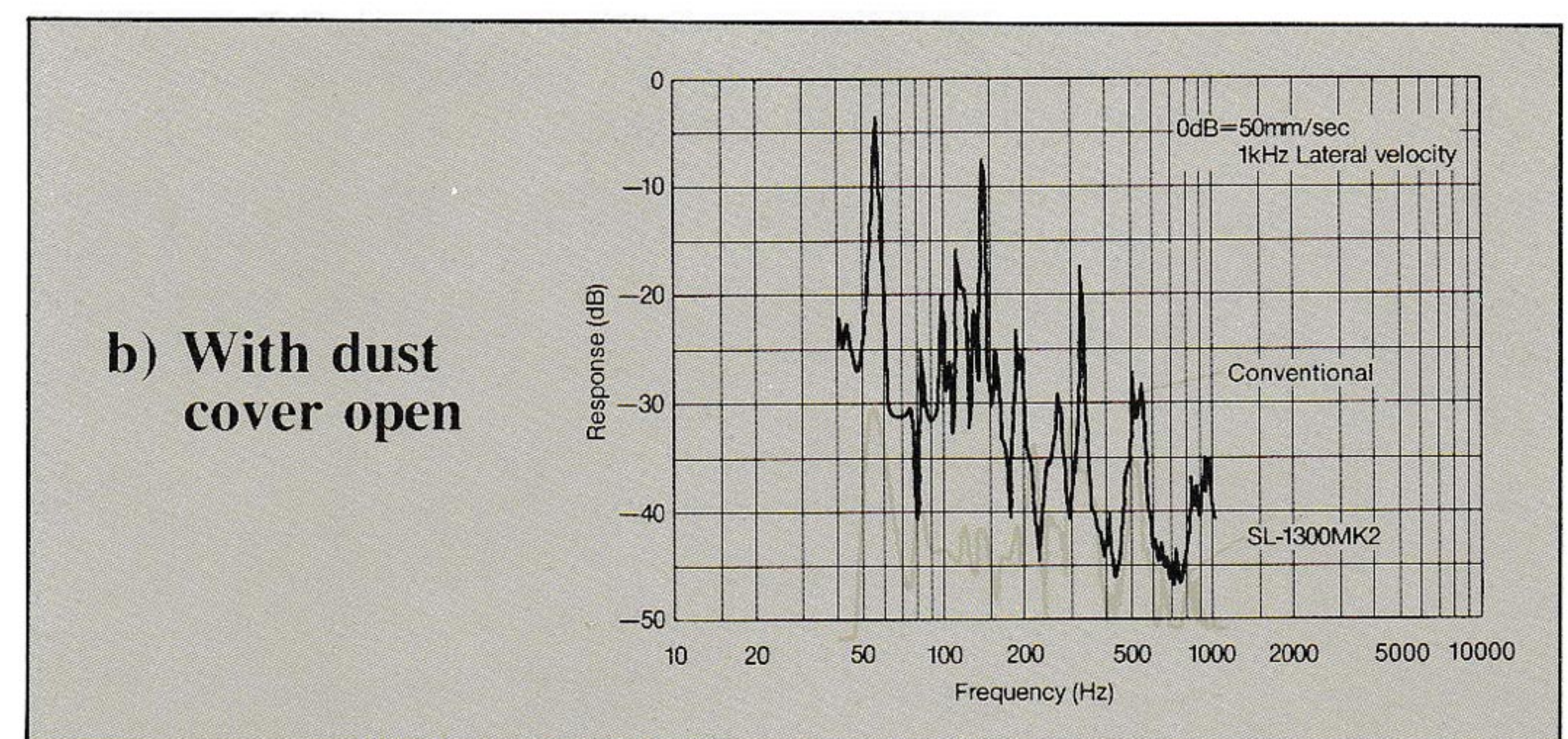
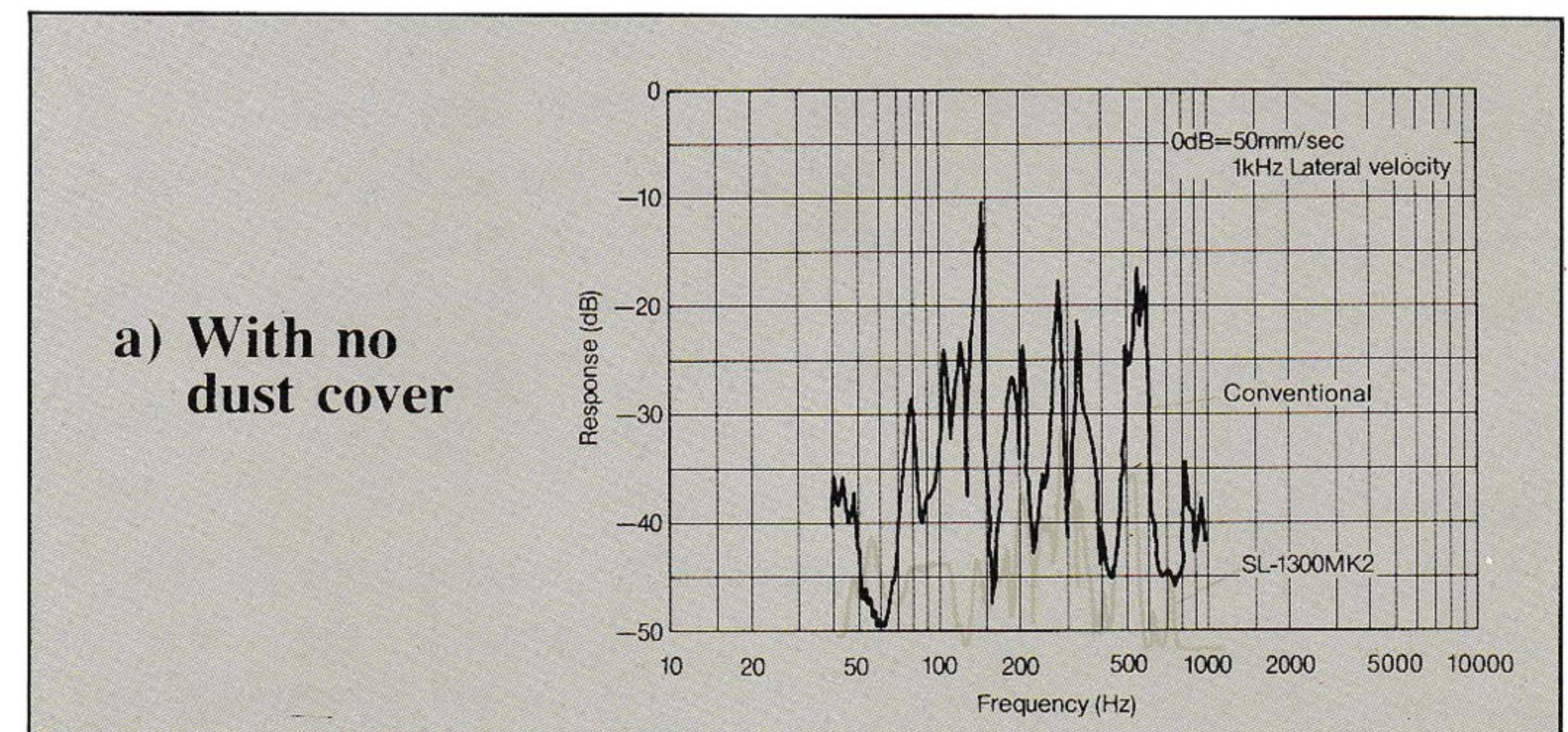
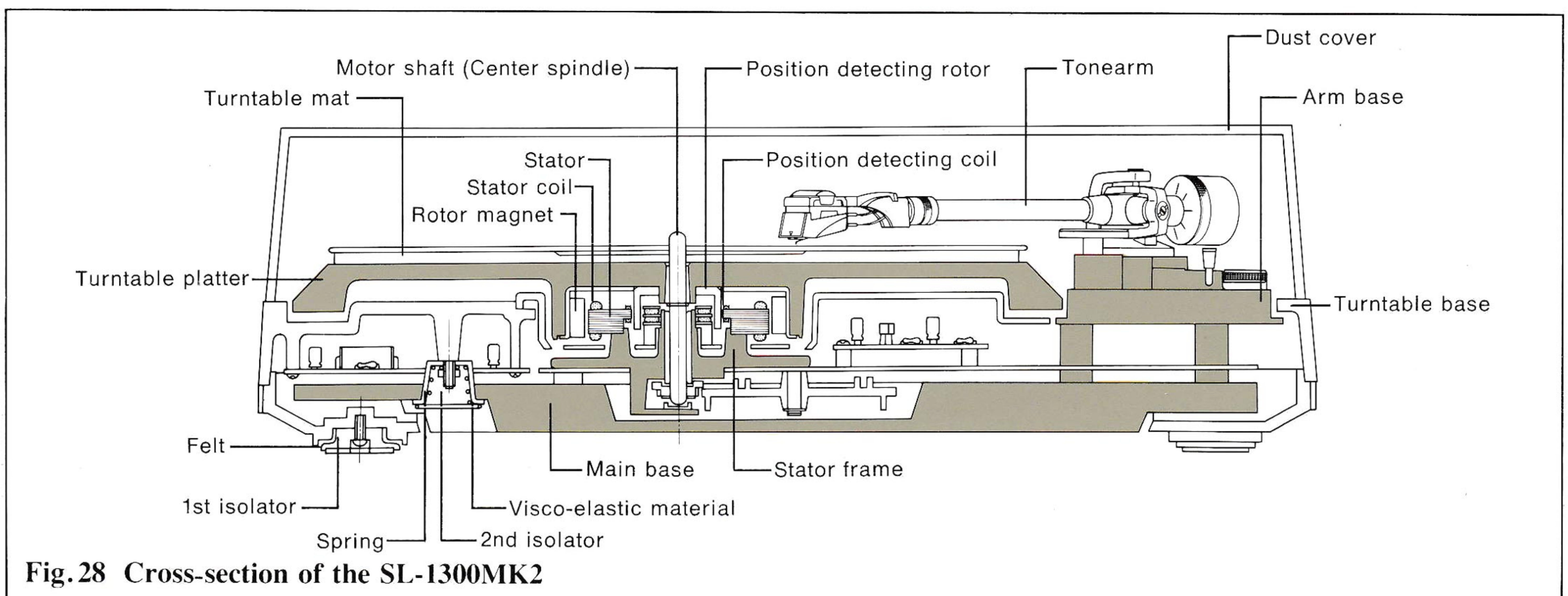


Fig.29 Vibration analysis of floating system vs. non floating system



6 High Performance, Sophisticated Tonearm

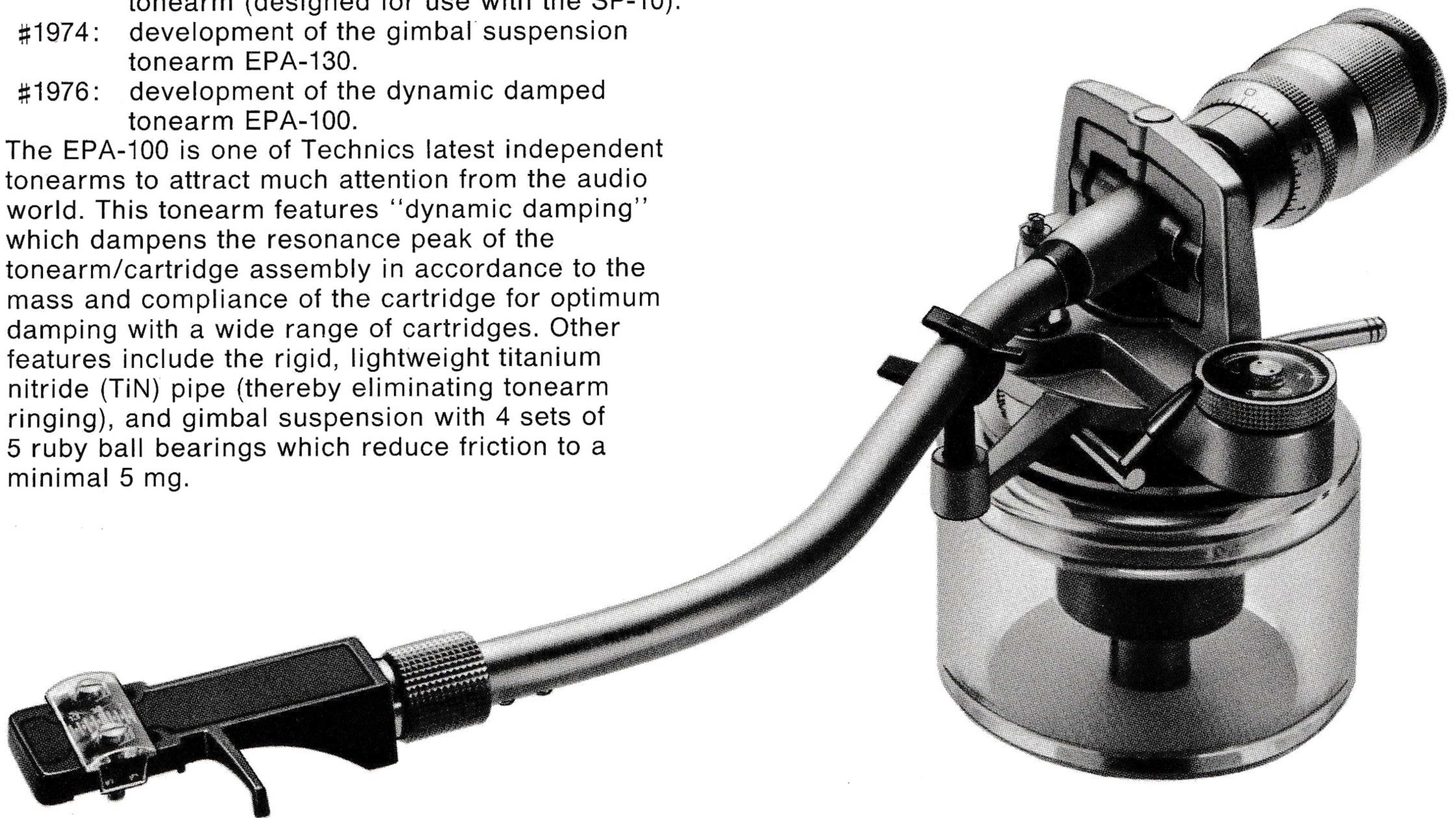
Technics has been manufacturing high grade tonearms for more than 40 years, the first tonearm appearing way back in 1934 (called a pick-up in those days). The following chart outlines the more recent history of hi-fi tonearms produced by Technics:—

- #1954: the first hi-fi magnetic pick-up.
- #1958: integrated pick-up with MM cartridge for LP records.
- #1959: MM pick-up for stereo records.
- #1966: linear tracking tonearm (with mechanical servo control).
- #1970: development of the EPA-99 high grade tonearm (designed for use with the SP-10).
- #1974: development of the gimbal suspension tonearm EPA-130.
- #1976: development of the dynamic damped tonearm EPA-100.

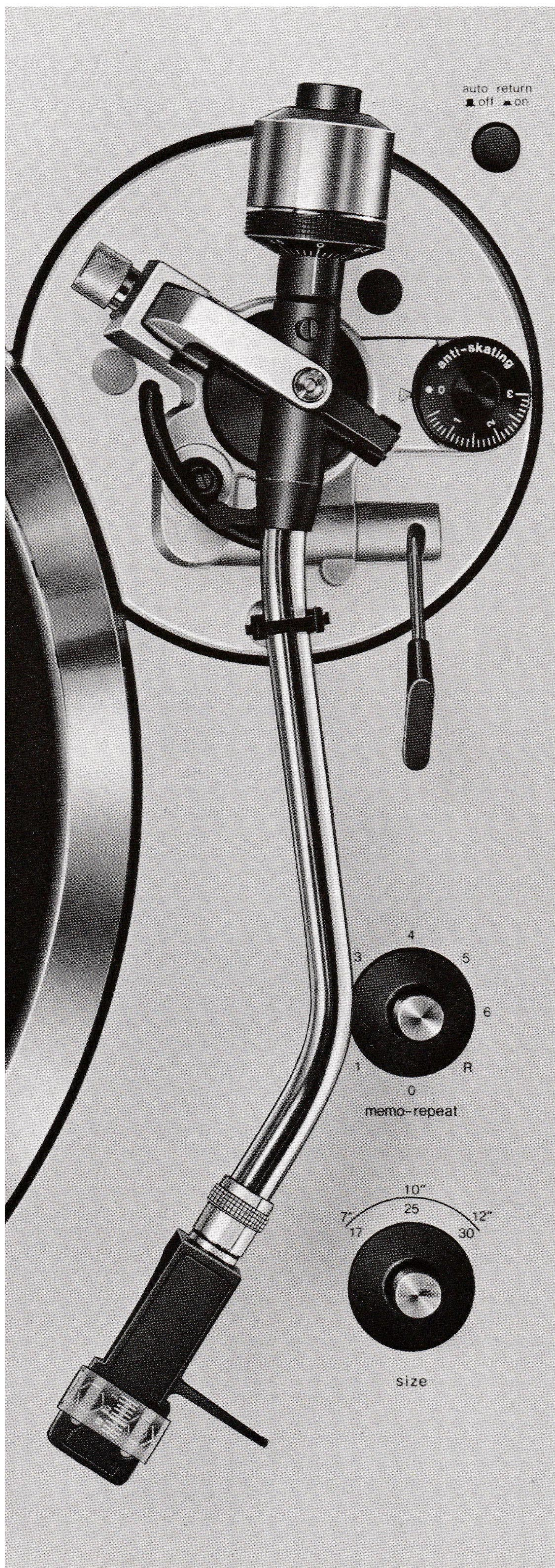
The EPA-100 is one of Technics latest independent tonearms to attract much attention from the audio world. This tonearm features “dynamic damping” which dampens the resonance peak of the tonearm/cartridge assembly in accordance to the mass and compliance of the cartridge for optimum damping with a wide range of cartridges. Other features include the rigid, lightweight titanium nitride (TiN) pipe (thereby eliminating tonearm ringing), and gimbal suspension with 4 sets of 5 ruby ball bearings which reduce friction to a minimal 5 mg.

The tonearm employed in the SL-1300MK2 is designed for “total performance”. That is, no one feature, effective mass for example, is promoted at the expense of any other important features such as rigidity and anti-vibration characteristics. It is also a very versatile universal type of tonearm, capable of optimum performance with many different cartridges.

Compared to this, it is an easy task to produce a high performance tonearm for a specified cartridge. But such a design concept will curtail the possibility of using advanced cartridges developed in the future.



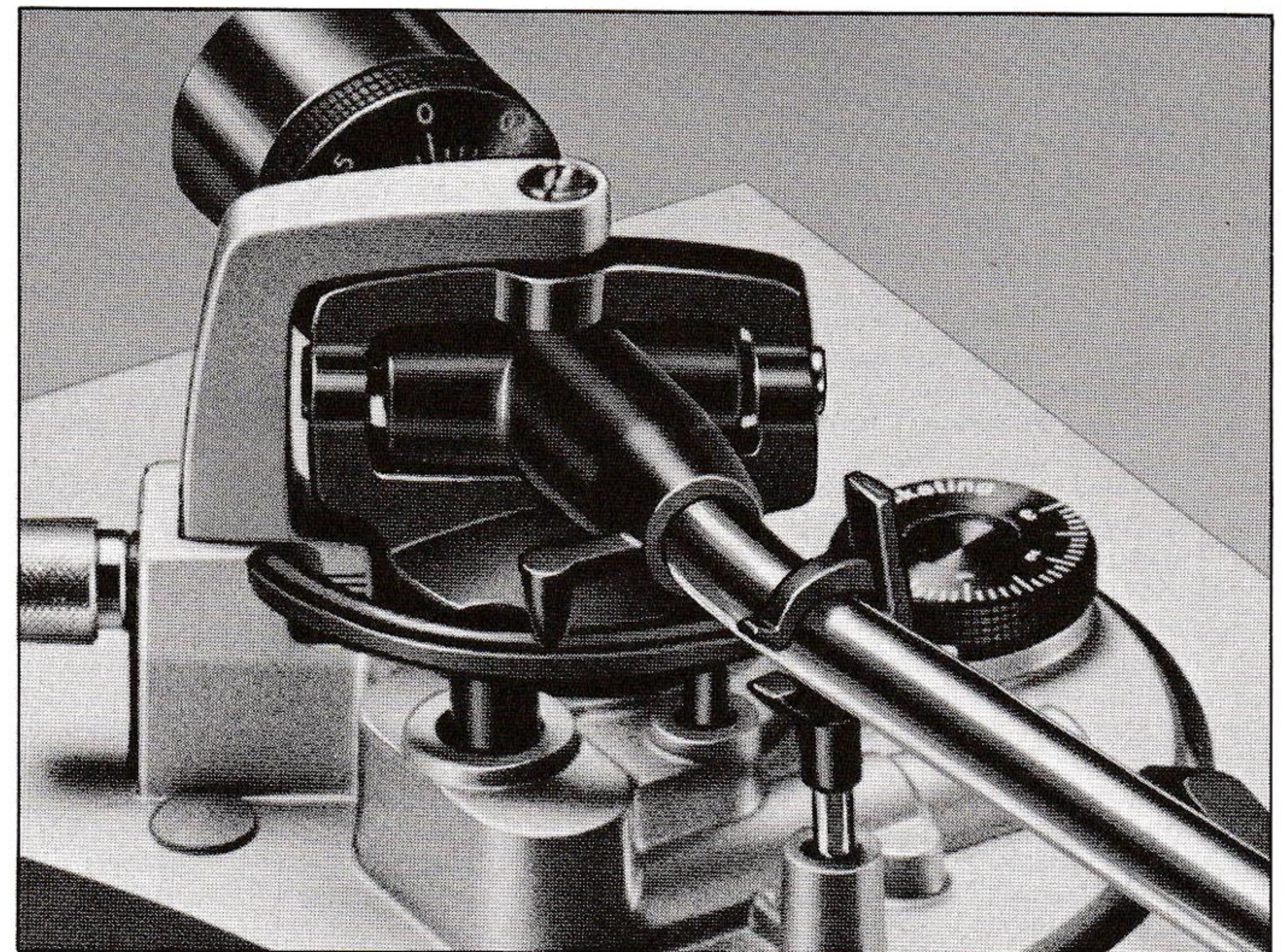
EPA-100



Major features of the SL-1300MK2 tonearm are:

1. Low friction gimbal suspension pivot bearing

With the ball bearings employed in this 30 mm gimbal suspension machined (in Technics' own factories) to an accuracy of $\pm 0.5\mu$, lateral and perpendicular friction factors have both been reduced to a mere 7 mg (maximum).



2. Rigid Aluminum Alloy Pipe Tonearm and Headshell

All perceptible partial vibrations are suppressed by this extremely rigid pipe tonearm mounted in the precision machined "vibration insensitive" zinc diecast tonearm base. The rigid, light-weight diecast headshell is resonance-dampened with vibration absorbing material.

3. Optimum Effective Mass for Stable Use with High Compliance Cartridge

Recent attention has been paid to the importance of the tonearm's effective mass and cartridge compliance in determination of low frequency resonance of the tonearm. If this resonance is located in the 0.5 to 6 Hz range, there is a strong tendency for record noise (such as record warpage) to accentuate the resonance, resulting in cross-modulation distortion and "pumping" of the woofer unit. In extreme cases, the cartridge will fail to faithfully trace the record groove. Resonance in the 15 Hz and over range, on the other hand, will effect the lower range audio signals. Thus the optimum resonance frequency is said to be around 10 Hz.

As the resonance frequency of the cartridge/tonearm assembly is given by the following equation,

$$f_0 = \frac{1}{2\pi\sqrt{MC}}$$

where M is the effective mass and C is the compliance of the stylus

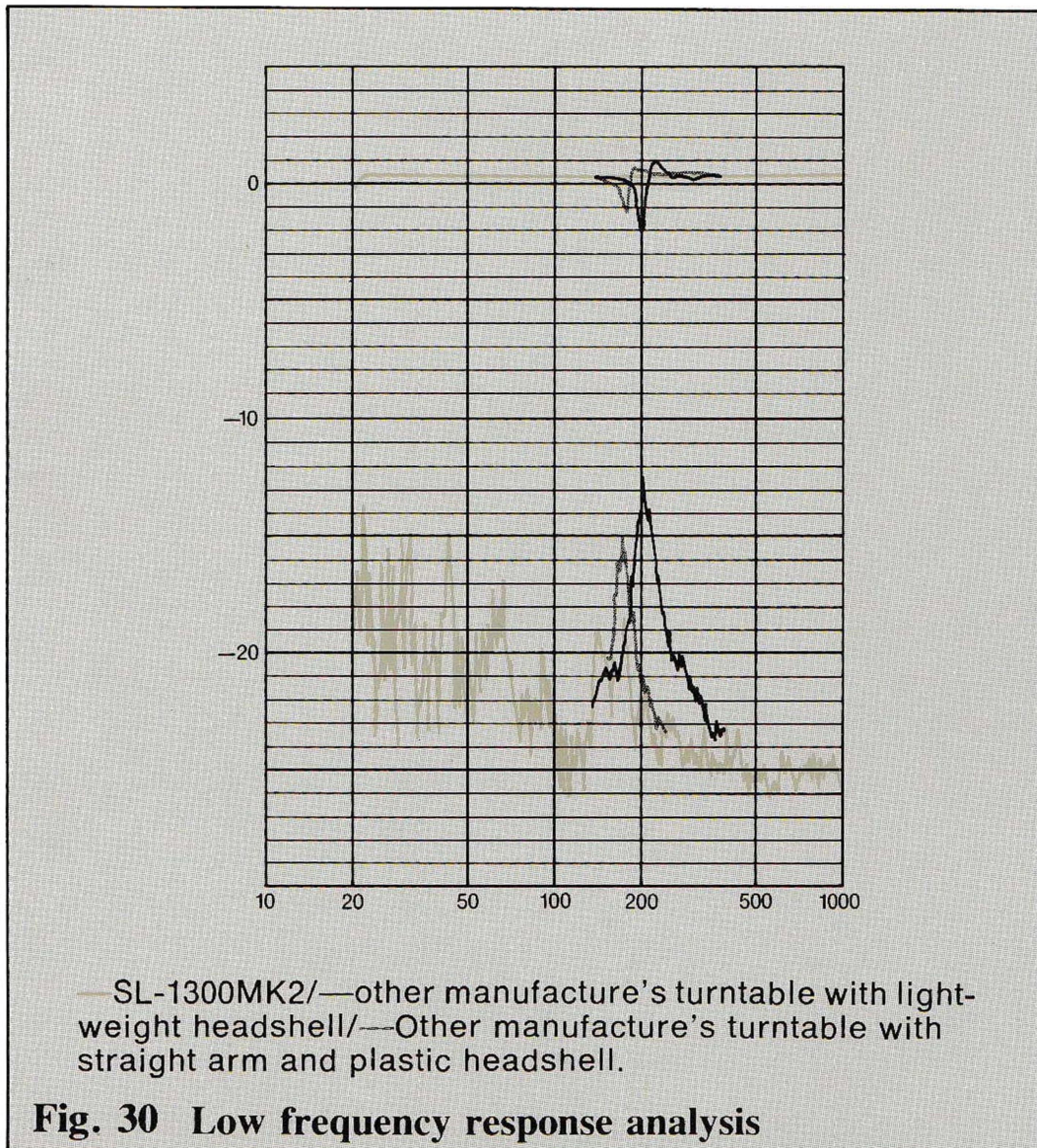
the higher the compliance or the bigger the effective mass, the lower the f_0 and vice versa.

This means that a combination of high compliance cartridge and high effective mass tonearm gives too low a f_0 ; at the other extreme, a combination of low compliance cartridge, such as MC type, and extremely low effective mass tonearm will give too high a f_0 .

Pursuing only the aim of lower effective mass gives rise to a loss of rigidity. Thus the use of excessively thin, light-weight headshells or headshells made of light but not rigid material results in inferior transient characteristics and tends to produce notches in frequency response.

(See fig. 30)

The effective mass of the SL-1300MK2 tonearm is 22 g with a cartridge weighing 6.5 g at 1.25 g tracking force. This is neither too high nor too low for a high performance universal tonearm. This figure is applicable where using the 9.5 g headshell supplied. Of course, use of a lightweight headshell with holes may reduce the SL-1300MK2 tonearm's effective mass, we don't recommend the use of such a headshell if it is not rigid enough to avoid unwanted partial vibrations.



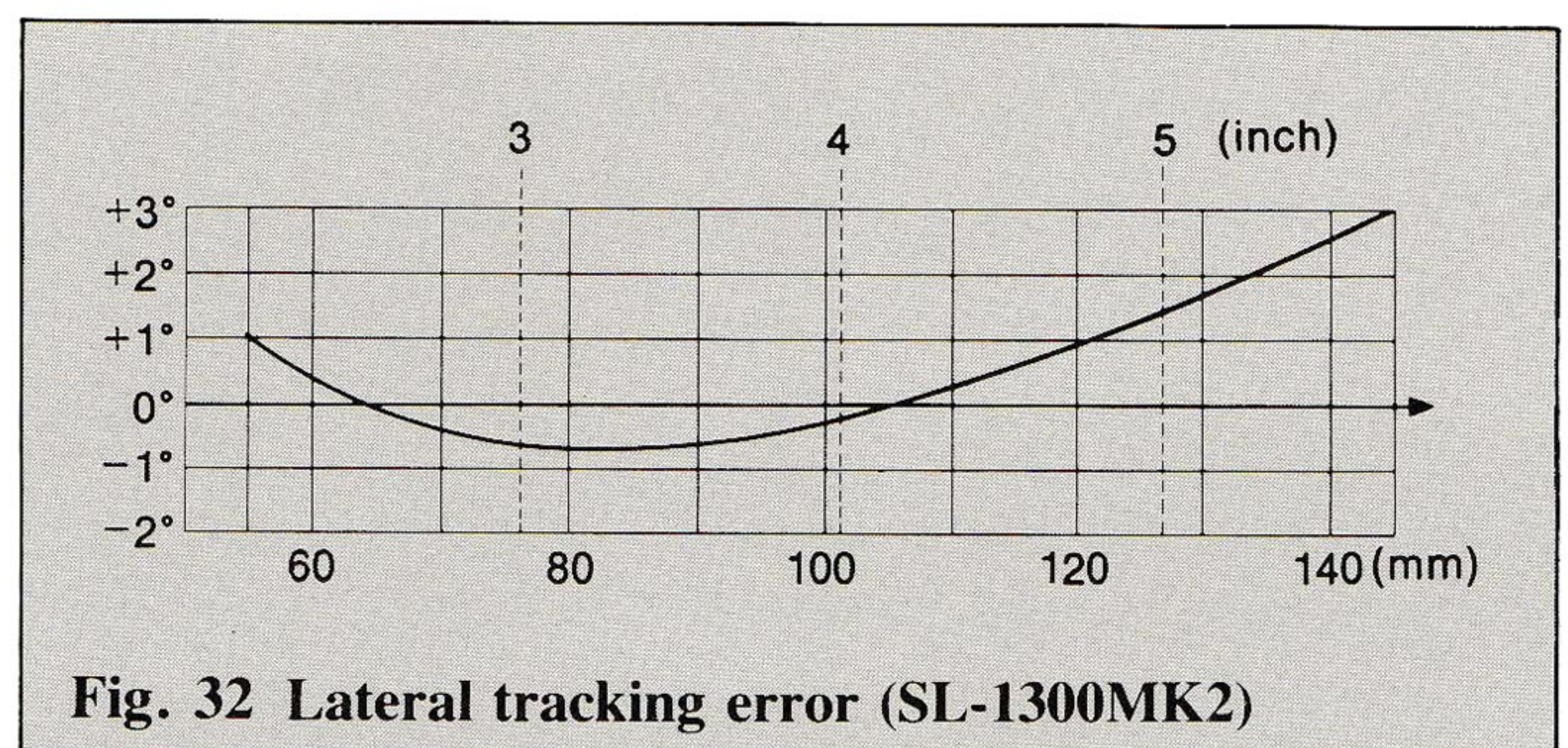
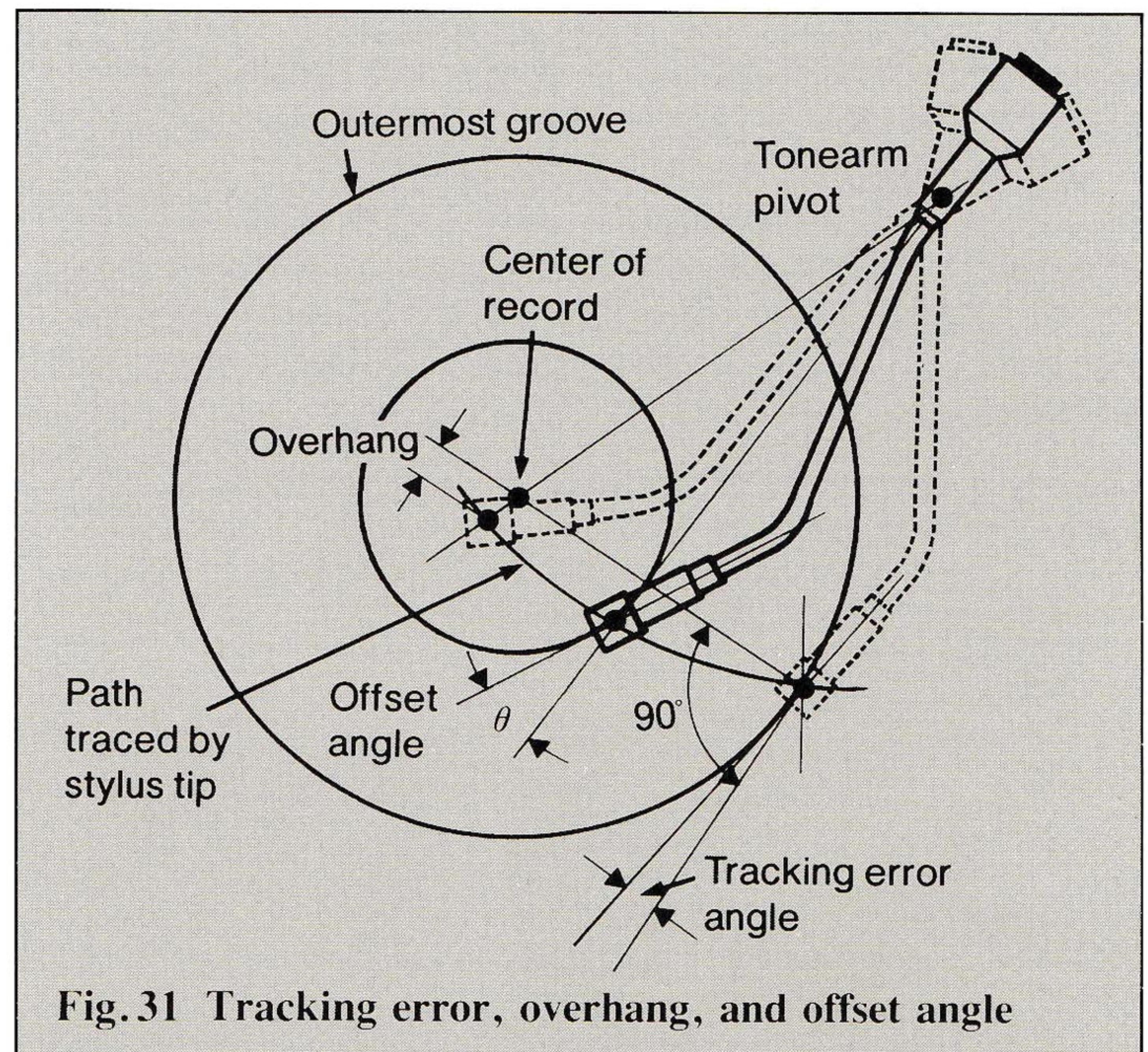
4. Optimum lateral balance and small tracking error

Lateral balance, or the weight distribution of the tonearm around an axis joining the tip of the stylus to the tonearm pivot (as seen from above) presents a problem in some J-shaped tonearms. But

Technics' expertise in tonearm manufacture has achieved excellent lateral balance in this S-shaped tonearm. Tracking error is also unavoidable, but by adopting an relatively long effective arm length (230 mm) and optimum offset angle, tracking error in the SL-1300MK2 has been reduced to a minimum ($+3^\circ$ at the outside of the record, and $+1^\circ$ at the inside).

Although it is possible to make this rating appear smaller by expressing the error in "per inch", the problem involves no more than the effective length and offset angle.

Correction of the vertical tracking error is effected with the use of arm locking screw permitting a 6 mm height adjustment to accommodate all cartridge sizes.



5. Simple universal headshell design

With the universal 4-pin headshell employed in this tonearm, cartridge replacement has been reduced to a very simple task indeed. Overhang adjustments (for different cartridges) has also been simplified considerably. Furthermore, the high precision spring action in the anti-skating adjustment also ensures optimum play conditions with almost any kind of cartridge.

Straight Arm Versus S-Shaped Arm

When comparing the relative advantages and disadvantages of straight tonearms and S-shaped tonearms, it is important to keep in mind the overall performance of both types, and not just one or two differences.

For good reason, Technics has consistently preferred S-shaped tonearms. The so-called advantages claimed for straight line tonearms are not really as significant as they may first appear to be. A closer look at some of these claims will show why.

Claim(a) The effective mass of a straight line tonearm is smaller than an S-shaped tonearm of the same effective length (assuming that materials and diameter etc. are also the same).

However, this advantage is very slight. The effective mass of the whole tonearm is smaller by no more than 0.5%, and this affects the resonance frequency by no more than 0.2%. Hardly a real advantage.

Claim(b) The lateral balance in a straight line tonearm is better.

One of the features of Technics S-shaped tonearms is the excellent lateral balance. Unlike J-shaped tonearms, a well designed S-shaped tonearm does not require a lateral balancer, putting it on par with well designed straight line tonearms. In other words, it is a problem of engineering precision more than anything else.

Claim(c) S-shaped tonearms lack high rigidity. This is simply not true. In fact, this is a problem faced by designers of straight line tonearms, many of which employ plastic headshells in an attempt to reduce effective tonearm mass. Many straight line tonearms also suffer from partial vibration in the cartridge mount region.

Claim(d) S-shaped tonearm machining precision is not as good as in straight line tonearms. This too is simply not true. Although straight lines would appear easier to manufacture, the real difference lies in the different standard of machining precision achieved by the respective manufacturers.

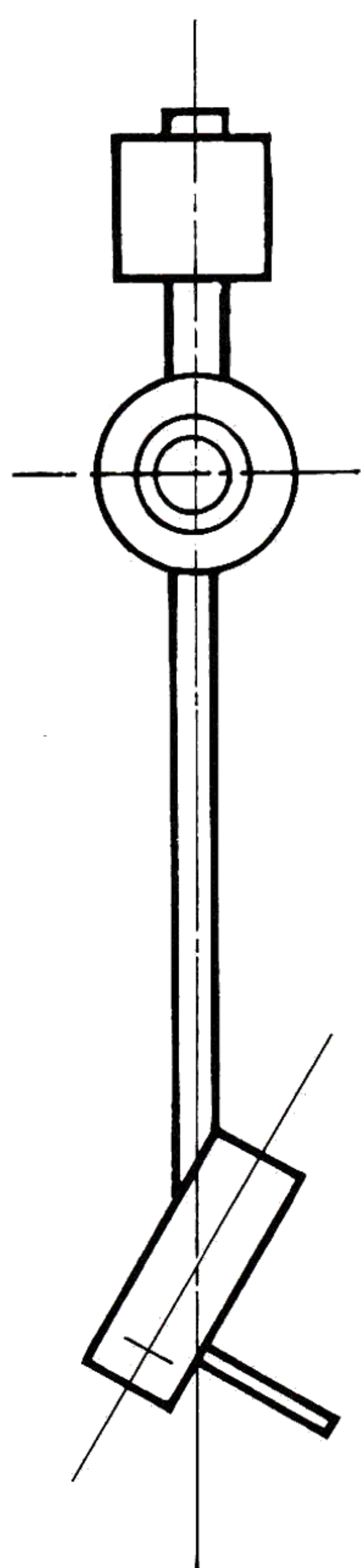


Fig. 33 Straight arm

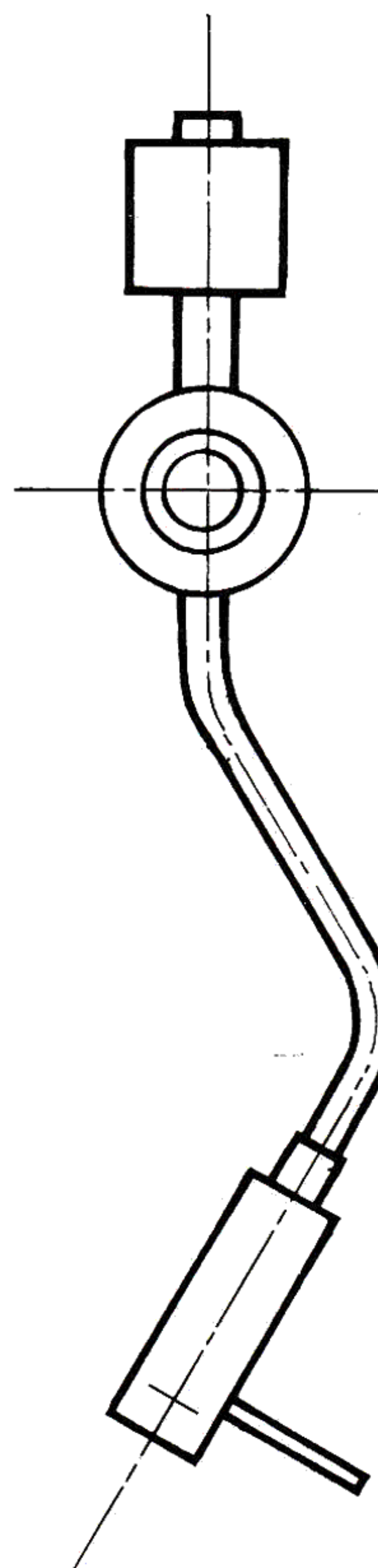


Fig. 34 S-shaped arm

How to Read and Evaluate Technical Specifications

TURNTABLE SECTION

Type	Quartz-phase-locked control direct drive semi-automatic turntable
Motor	Ultra-low-speed brushless DC motor
Turntable platter	Aluminum diecast, diameter 13" (33 cm), weight 5.5 lb. (2.5 kg) <u>moment of inertia</u> 116 lb·in ² (340 kg·cm ²)
Turntable speeds	33⅓ and 45 rpm
<u>Pitch controls</u>	Quartz synthesizer pitch control ±9.9% range digital pitch readout
<u>Starting torque</u>	1.3 lb·in (1.5 kg·cm)
<u>Speed fluctuation due to load torque</u>	0% within 1.3 lb·in (1.5 kg·cm)
<u>Speed drift</u>	Within ±0.002%
<u>Wow and flutter</u>	0.025% WRMS (JIS C5521) ±0.035% weighted zero to peak (DIN 45507)
<u>Rumble</u>	−50 dB (DIN 45539A) −73 dB (DIN 45539B)

TONEARM SECTION

Type	Universal "S" shaped tubular arm, static-balanced type, with anti-skating force control device, oil-damped cueing device in both directions
<u>Effective length</u>	9-1/16" (230 mm)
<u>Overhang</u>	19/32" (15 mm)
<u>Tracking error angle</u>	+1° at the inner groove of record +3° at the outer groove of record
<u>Friction</u>	7 mg (lateral, vertical)
<u>Effective mass</u>	22 g (with a cartridge weighing 6.5 g at 1.25 g tracking force)
<u>Offset angle</u>	21.5°
<u>Tonearm height adjustment</u>	6 mm
<u>Adjustable tracking force</u>	0~3 g
<u>Headshell weight</u>	9.5 g
<u>Cartridge weight range</u>	5~11 g

GENERAL

<u>Power consumption</u>	13 W
<u>Power supply</u>	AC 110 V/120 V/220 V/240 V, 50/60 Hz
<u>Dimensions (H×W×D)</u>	5-45/64"×17-45/64"×15-7/64" (14.5×45.3×38.4 cm)
<u>Weight</u>	26.0 lb. (11.8 kg)

Turntable Section

Moment of inertia

Moment of inertia is a measure of speed-smoothing flywheel effect of the turntable platter. The larger the figure, the more resistant to the effects of varying loads and howling. But if the platter is made too heavy in weight, it will cause longer build-up and braking times, and excessive wear on the bearings. To avoid these problems, a good combination of suitable amount of moment of inertia and excellent servo control system is particularly desirable for optimum performance.

Pitch controls

Pitch controls have the subjective effect of raising or lowering the pitch of a record being played since they actually alter the rotational speed of the motor. In turntables subject to speed drift, such controls may be used to bring it back to proper rotational speed with the aid of a stroboscope. They are especially helpful when a musical instrument is to be played along with a record of slightly different pitch. (Expressed in percentage, +5.9% or −5.6% corresponds to a half tone.) In professional applications they are used for fitting a musical selection into a limited time slot (when accurate pitch is not of overriding importance).

Starting torque

Starting torque is a maximum load torque with which the motor can start and get up to constant speed. It is measured in lb·in (or kilogram·centimeter) in the case of turntables and has a direct relationship with build-up time; the higher the starting torque, the faster the turntable comes to full speed. High starting torque allows the use of a heavier turntable platter having a greater flywheel effect and more resistance to howling.

Speed fluctuation due to load torque

This gives an idea of how outside forces such as the tracking force or a record cleaning device will affect the rotational speed of the turntable. A turntable with insufficient torque will slow down or even stop altogether when the load is increased. The rating achieved in the SL-1300MK2 (0% within 1.3 lb·in) means that there is no change in speed even for a tracking force of 300g at the outer edge of the record.

Speed drift

Speed drift, also called speed accuracy, describes the amount of deviation from the standard rotational speed

over a set period of time, usually thirty minutes. Speed drift may be caused by variations in power supply voltage and the effects of temperature and humidity on circuit element performance. However, with the adoption of a good servo control system, a differential amplifier, and temperature compensating circuits, speed drift can be reduced to negligible levels. Naturally, the smaller the figures, the better.

Wow and flutter

Although wow and flutter may also be thought of as a measure of rotational speed accuracy, it refers more to the specific effects on the reproduced sound caused by momentary or regular speed fluctuations. Wow is a slow repetitive speed variation (one cycle per rotation, for example) which may be heard as a slight raising and lowering of pitch during playback. Flutter is a higher frequency quivering that may become particularly noticeable on a single long-held note. In terms of the output signal, wow and flutter has the effect of frequency modulation and for this reason may significantly degrade fidelity to the point of blurring the distinction between musical instruments. Expressed as a percentage, smaller figures are better with a maximum of about 0.15% (WRMS) for high fidelity performance. The human ear cannot detect wow and flutter below 0.1%.

WRMS

Abbreviation for Weighted Root Mean Square. RMS represents the effective amplitude of an AC voltage waveform that corresponds to the DC current or voltage which in any given load would produce the same power dissipation. The term "Weighted" means a kind of filter is employed in measurement to take into account human hearing characteristics.

DIN

Abbreviation for Deutsche Industrie Normen. This German industrial standard specifies very many different industrial manufactures and is internationally accepted as the measurement standards of audio equipment.

Rumble

Rumble is a measure of the amount of low pitched noise the turntable produces. It is expressed in decibels (dB) as a negative figure and is actually the ratio between a standard signal and the noise. Thus, exactly the same information is often listed as the signal to noise ratio (S/N) in which case the figure is a positive number. Rumble, along with wow and flutter are the two most important specifications dealing with turntable performance. Since the phono output signal is so much lower than that of other sound sources (tape deck, tuner), noise or rumble reduction becomes of all the more critical importance.

Rumble specifications vary considerably according to the measurement procedure employed. For example, DIN A figures are a measure of turntable noise alone; DIN B figures are a result of measurement under conditions that take into account human hearing characteristics. To get a realistic picture of turntable performance it is necessary to compare the two figures.

Tonearm Section

Static-balance and dynamic-balance

In order to provide the correct amount of tracking force for the cartridge, tonearms must have some sort of balancing device. A static-balanced tonearm employs an adjustable counter-weight alone to balance the weight of the cartridge and tonearm whereas a dynamic-balanced type uses a spring to exert downward force on the cartridge which in turn is balanced by a counterweight. The latter type allows the use of a lighter weight tonearm and is little affected by horizontal imbalance in the total system. However, due to the characteristics of the spring, dynamic-balanced tonearms are unsuitable for high compliance cartridges.

Anti-skating force

Ideally the center-line of the cartridge should always be tangential to the record grooves since this is the way the record was cut. The amount that the cartridge deviates from this ideal is called the tracking error angle and it is to correct this error that an offset angle is designed into the tonearm-cartridge combination. However, due to this offset angle, when the stylus is in the record groove, the frictional drag tends to pull the stylus towards the center of the record. This inside force, or skating force must be cancelled in order for the stylus to accurately trace both sides of the record groove and thus minimize distortion. For this purpose, various types of anti-skating force devices are employed. Skating force increases in proportion to tracking force.

Effective length

This refers to the distance from the tonearm pivot to the stylus measured in a straight line. In order to minimize tracking error angle over as much of the record surface as possible, the effective length is made a bit longer than the distance from the center hole of the record to the pivot. This extra length is called overhang. Actually, the longer the effective length, the less the tracking error angle but such factors as the corresponding increase in effective mass and the limitations of space must be taken into consideration.

Overhang

As mentioned above, overhang is the distance that the effective length extends beyond the center spindle of the turntable. It is one means (besides the offset angle) of maintaining a minimum tracking error angle over the widest possible area of the record surface. Since cartridge-stylus combinations have different dimensions, overhang must usually be readjusted when a new cartridge is installed. For easy readjustment the SL-1300MK2 headshell is equipped with a precisely calibrated sliding scale.

Tracking error angle

This is the angle describing the difference between a true tangent to the grooves of the record and the actual center line of the cartridge. To prevent distortion, this lateral tracking error angle must be kept to a minimum over as much of the record surface as possible since the record itself was cut at a perfect tangent. Although a linear tracking arm does not have this problem, all other cartridge-tonearm combinations are designed with an offset angle for the purpose of correcting the tracking error angle. In this way tracking error angle can be reduced to zero at two locations on the record surface. In the case of the SL-1300MK2, tracking error angle is $+1^\circ$ at the inner groove and $+3^\circ$ at the outer groove thanks to the relatively long effective arm length (9-1/16") and optimum offset angle. However, all of the precise design calculations of the manufacturer will come to nothing if the cartridge is not properly installed.

Friction

This is the pivot friction occurring at the tonearm support. The tonearm must be able to move freely both vertically and horizontally in order to accurately trace the record grooves. Various types of pivoting and suspension systems are employed for this purpose. In the SL-1300MK2, the tonearm pivot employs a gimbal suspension system with four bearings each containing five miniature balls finished to an accuracy of $\pm 0.5\mu$ with the result that maximum friction in either direction is reduced to 7 mg (0.007g).

Effective mass

This is the moving mass of the tonearm-cartridge combination as looked at from the point of view of the stylus. Since the resonance frequency of the tonearm-cartridge assembly is determined by the combined factors of cartridge compliance and effective mass, the two must be carefully matched. (The higher the compliance or the bigger the effective mass, the lower the resonance frequency and vice versa.) The resonance frequency (f_0) should be below the audible frequency range yet above the most common record warp frequencies. The optimum f_0 is around 10 Hz with 0.5 to 6 Hz causing cross-modulation distortion and pumping of the woofer and an f_0 of 15 Hz and over affecting the lower range of the audio frequency spectrum. Thus, in a universal tonearm the effective mass must be carefully chosen since cartridges of varying compliances and weight will be employed. If the effective mass is made too low there is a danger of the f_0 entering the audible frequency range. Furthermore, lightweight tonearms tend to exhibit partial vibrations due to insufficient rigidity. Some manufacturers have tried to reduce effective mass by using lightweight plastic headshells but this results in inferior transient response and tends to produce notches in frequency response along with partial vibration. Effective mass is ordinarily measured in grams, and includes the mass contributed by a specific cartridge and the tracking force employed.

Offset angle

The offset angle is the angle between a straight line drawn from the stylus to the pivot and the center-line of the cartridge. As is the case with overhang, the offset angle is designed to minimize tracking error angle. The need for an offset angle is the reason for the bend occurring in all tonearms (with the exception of linear tracking arms).

It is interesting to note in this respect that if the effective length of the tonearm were infinite, the offset angle could be reduced to zero.

As mentioned above, the offset angle creates the problem of skating or inside force which must in turn be corrected for by an anti-skating force device.

Tonearm height adjustment

Tonearm height adjustment capability is a necessity in universal tonearms where it is assumed that a variety of cartridges having different dimensions may be attached. This is because the correct vertical tracking angle designed into the cartridge is based on the top of the cartridge being used horizontally. The SL-1300MK2 has an adjustable range of 6 mm thus allowing cartridges measuring 15 to 21 mm in height to be used.

Tracking force

Tonearms are equipped with a counterweight that is adjustable to provide the correct downward force on the stylus for optimum performance. The tracking force is higher for low compliance cartridges and vice versa. Furthermore, the tracking force must be increased to the cartridge manufacturer's maximum allowable value when playing records cut at high levels or when the ambient temperature is extremely low. It must also be increased if the turntable is used in a place where external vibrations might cause the stylus to jump out of the groove. Of course, if tracking force is increased too much, it will cause excessive wear on both the record and the stylus itself.

Naturally, when tracking force is increased, the skating force also increases and must be compensated for.

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