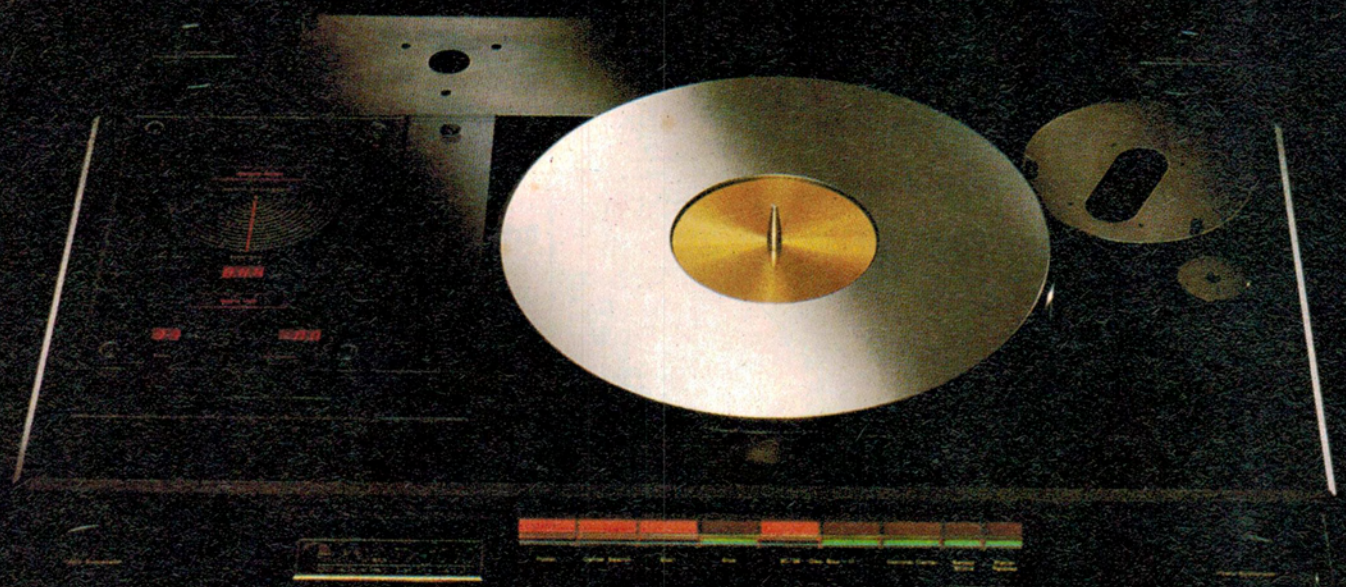
Nakamichi's 'computing turntable'



No matter what shape your record's in — to paraphrase an old advertising line — Nakamichi's new TX-1000 turntable computes the error and compensates!

IN THE APRIL 1980 issue of ETI we published a reader's letter discussing some of the problems that occur with discs and turntables. The reader, Robert Clark, presented calculations to show that any eccentricity in a disc's centre, or an oversized centre hole, would introduce a 'virtual wow' component of at least 0.05% RMS — quite clearly audible, irrespective of whether the turntable had a considerably lower wow figure or not. Recognising that record manufacture is not a 'perfect art', the problem remains as one of the last nagging imperfections to be tackled in an audio reproduction system. From research results produced by Nakamichi's engineers, it seems Mr Clark underestimated the magnitude of the problem.

Generally, the technology involved in producing records has improved dramaticaly since the first stereophonic recordings were released in 1958. We saw the remarkable four-channel recordings of the early 1970s, and today there are a multitude of non-limited (no compression) direct cut and digital master recordings that are all aimed at improving the final quality of reproduction.

The phono reproduction equipment itself has undergone drastic changes as well. There are many turntable systems available that provide some very fine engineering in terms of rotational accuracy, speed stability, functional control and tracking accuracy. As with tape reproduction equipment, however, in which the final quality of reproduction depends largely on how accurately the tape's characteristics are matched to those of the tape deck (bias, level, equalisation and azimuth, for example), the ultimate reproduction quality of any record/turntable combination depends on whether these two essential elements function together as a precision reproduction unit.

Nakamichi engineers, basing their approach on the above concept, began to search for a way to optimally integrate the turntable and record into one 'ideal' reproduction mechanism. The result is the Nakamichi TX-1000 Computing Turntable with a unique 'Absolute Centre Search' system that they claim completely eliminates sound quality degradation due to off-centre rotation of the record in relation to the turntable platter — perhaps the one remaining barrier to achieving optimum reproduction based on today's record technology.

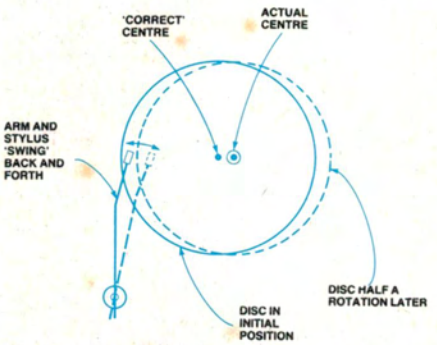
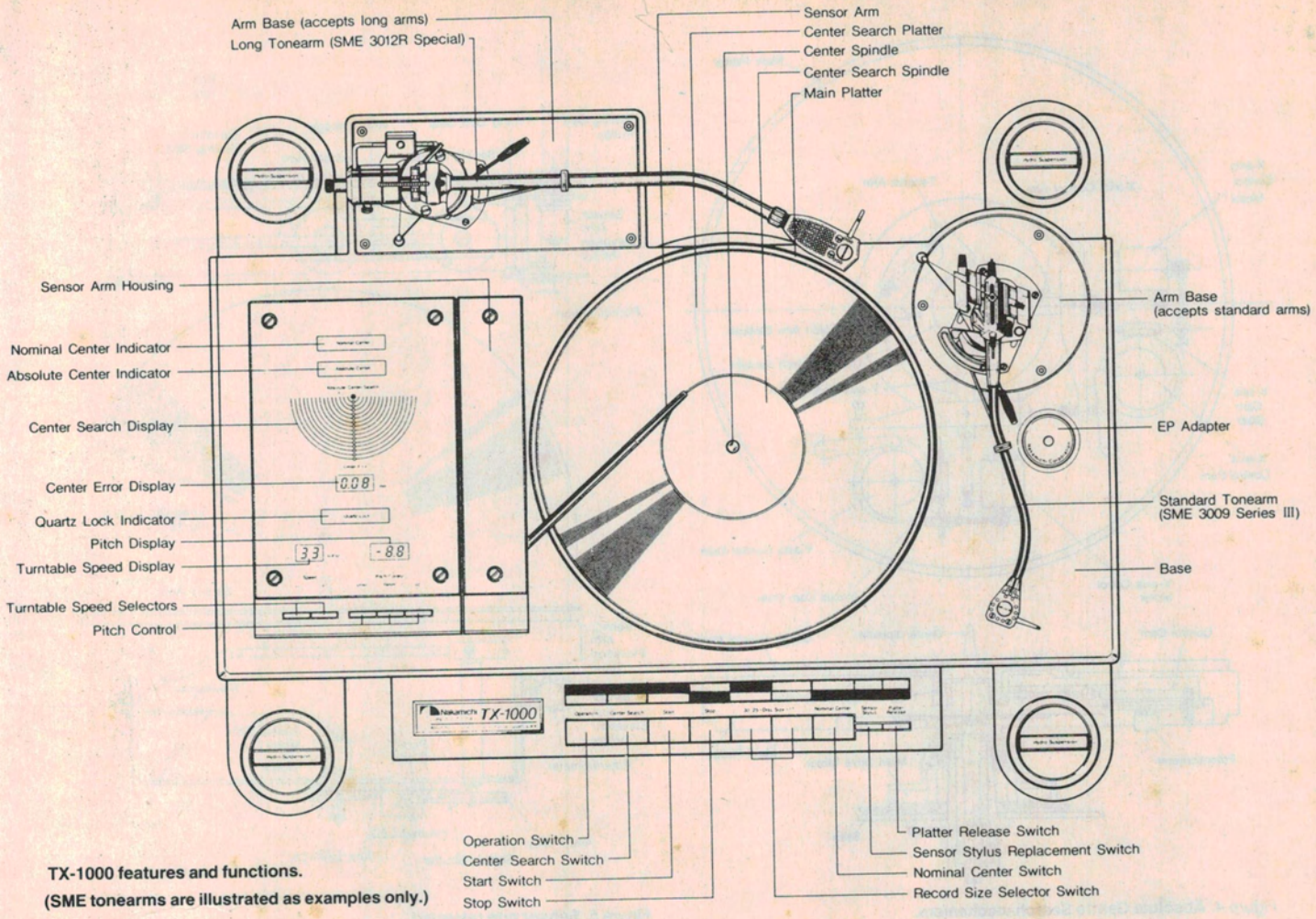


Figure 1. **A record with an off-centre hole introduces a wow component as it swings the arm and stylus back and forth.**

The problem, the solution

Wow and flutter can be reduced to negligible levels in the turntable by increasing the mass of the platter (that is, by making it larger and/or heavier). This technique does, in fact, achieve remarkably low wow and flutter levels in the turntable itself, but the real test of wow and flutter performance begins when a record is placed on the platter and the cartridge stylus lowered into its groove.

The standard diameter of record centre spindle holes is:



TX-1000 features and functions.
(SME tonearms are illustrated as examples only.)

$7.24^{+0.09}_{-0}$ mm (IEC standard 98A),

while the average diameter of turntable spindles varies from 7.05 to 7.15 mm. This means that, combining the smallest spindle diameter and largest allowable centre hole diameter, a spindle-to-record gap of as much as 0.28 mm is possible. This means a concentricity error of 0.14 mm. Add to this the maximum allowable record hole concentricity error of 0.2 mm (IEC 98A), and we end up with a total centre error of 0.34 mm. Even with a turntable that has *no* wow and flutter itself, the amount of wow and flutter created by this type of centre error is considerable, as shown in Figure 2.

The Nakamichi method of eliminating this effect is, with the record placed on the turntable, to relocate the platter spindle ('Centre Search Platter') so that the record's grooves are perfectly concentric in relation to the platter's axis of rotation. The true centre thus located is referred to as 'Absolute Centre'.

Referring to Figure 3, we can see that the TX-1000 drive motor and main platter form an integral unit, while a laterally moveable secondary platter ('Centre Search Platter') is located on top of the main platter. ▶

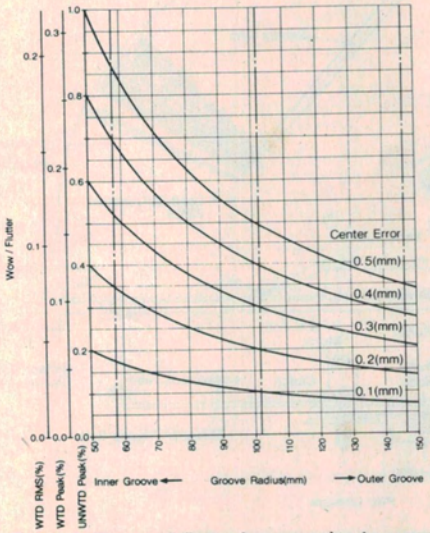


Figure 2. **Wow and flutter increase due to record centre error at various groove radii.**

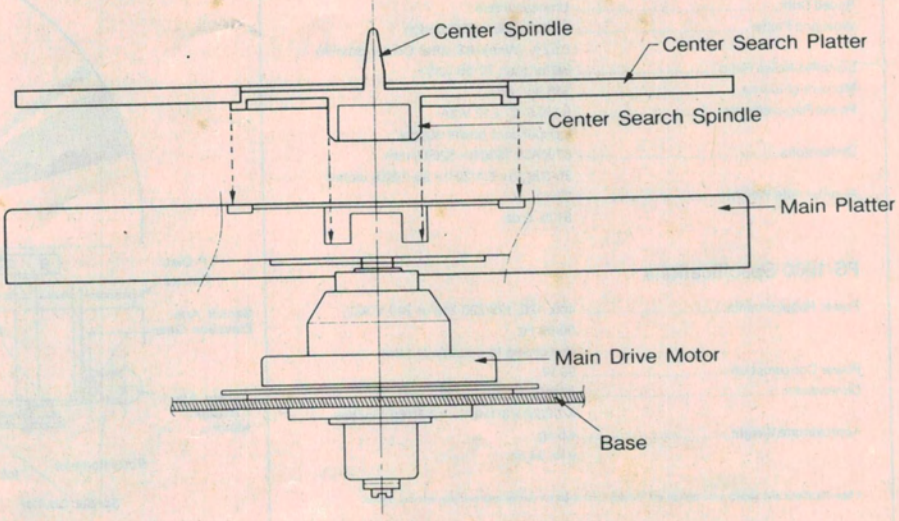


Figure 3. **Turntable construction.**

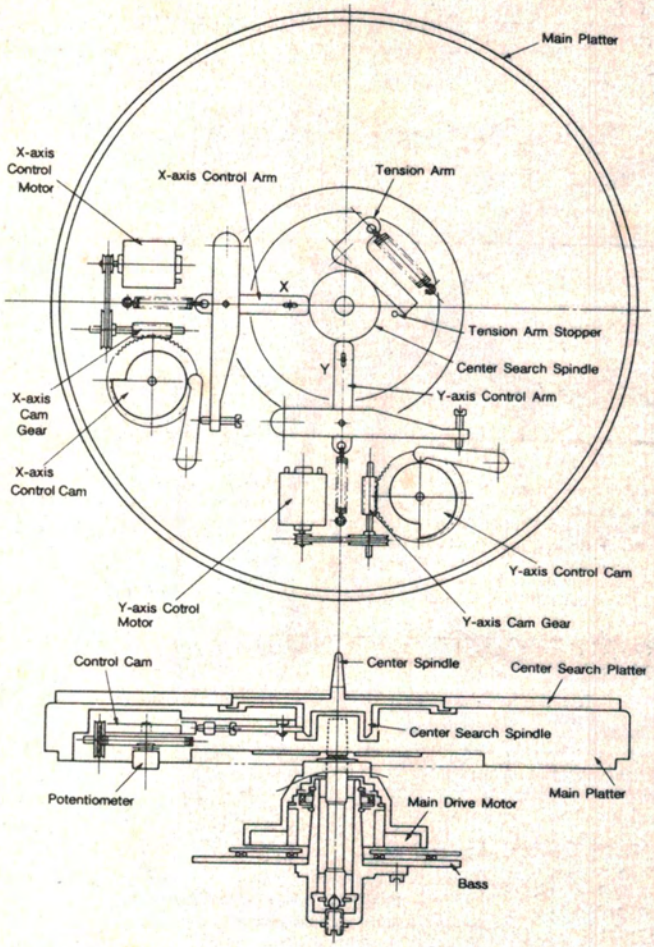


Figure 4. **Absolute Centre Search mechanism.**

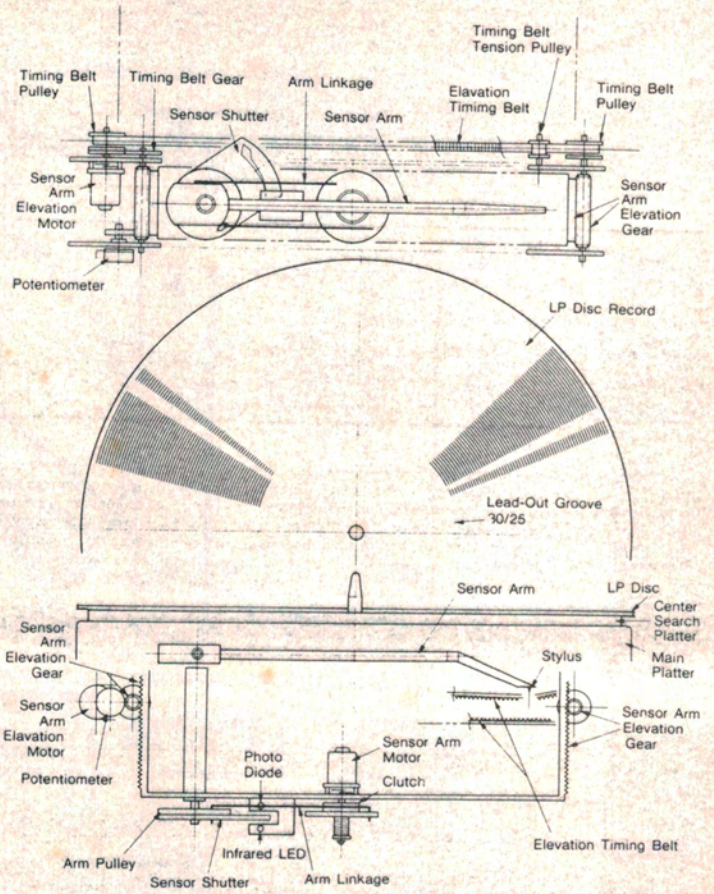


Figure 5. **Sensor arm retracted.**

TX-1000 Specifications

Drive System	Direct drive
Drive Motor	Quartz PLL DC, brushless, slotless, coreless, zero-cogging motor
Speeds	33-1/3 and 45 rpm
Pitch Control	PLL synthesizer, ±9.9% in 0.1% increments
Center Search Platter	Metallized glass (6 mm thick, 29 cm dia., 600 g)
Main Platter	Aluminum (31.5 mm thick, 30 cm dia., 4.5 kg)
Start-Up Time	Within 3/4 revolution
Speed Deviation	Unmeasurable
Speed Drift	Unmeasurable
Wow and Flutter	0.003% (Wrms/FG-direct) 0.02% (Wrms/JIS, after Center Search)
Signal-to-Noise Ratio	Better than 70 dB (JIS)
Moment of Inertia	585 kg · cm²
Power Requirements	5 V/0.5 A, ±12 V/3A independent power supply
Dimensions	670(W)×165(H)×520(D) mm 26-3/8(W)×6-1/2(H)×20-1/2(D) inches
Approximate Weight	37 kg 81 lb. 6 oz.

PS-1000 Specifications

Power Requirements	100, 120, 120/220-240 or 240 V AC; 50/60 Hz (According to country of sale)
Power Consumption	90 W
Dimensions	124(W)×82(H)×312(D) mm 4-7/8(W)×3-1/4(H)×12-5/16(D) inches
Approximate Weight	4.5 kg 9 lb. 14 oz.

• Specifications and appearance design are subject to change for further improvement without notice.

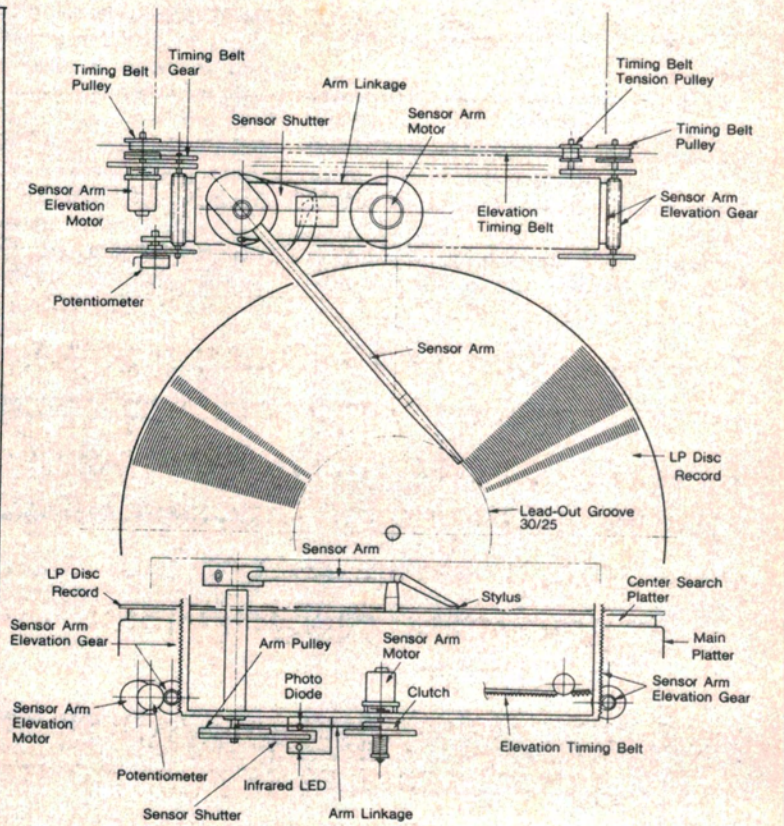


Figure 6. **Sensor arm in operation.**

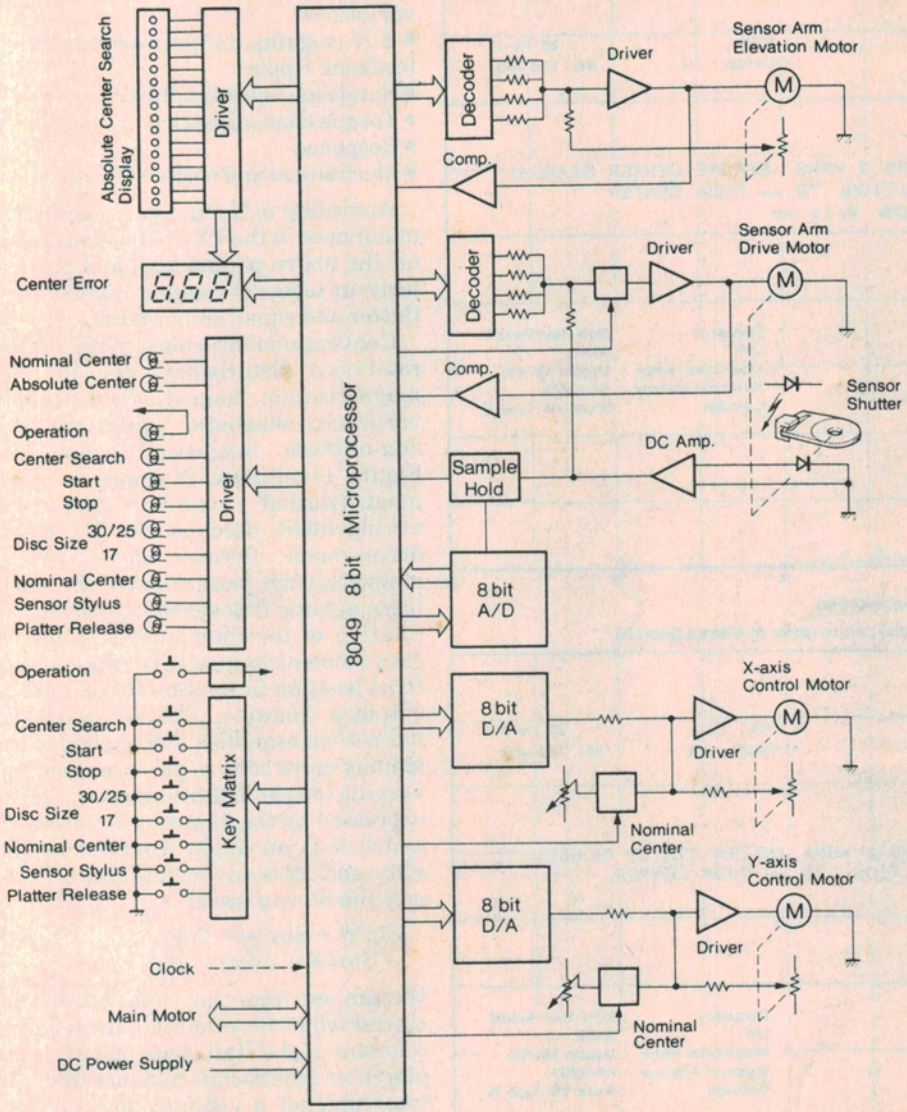


Figure 7. **Absolute Centre Search block diagram.**

As shown in Figure 4, the main platter houses motors and the control mechanism for accurately positioning the Centre Search Platter along two axes (X and Y), permitting relocation of the Centre Search Platter's spindle in relation to the main platter's axis of rotation.

Absolute Centre Search system operation

When the TX-1000 is initially turned on, the drive motor spindle and Centre Search Platter spindle are aligned along precisely the same axis ('Nominal Centre'). The record to be played is then placed on the platter, and the appropriate record size selected (300, 250 or 170 mm). Then, to initiate the Absolute Centre Search operation, the Centre Search button is pressed. This activates the sensor arm elevation motor, raising the sensor arm housing 50 mm. The sensor arm then swings out of the housing and across the record until its stylus is located above the record's final lead-out groove. The elevation mechanism lowers the sensor arm 16 mm, permitting the sensor arm stylus to trace the lead-out groove (refer to Figures 5 and 6).

Any movement of the sensor arm corresponding to record concentricity error is detected by a special infrared LED/shutter/photodiode system coupled to the sensor arm. The amount of concentricity error is thus converted to a dc voltage, which then undergoes analogue-to-digital conversion so it can be processed by the TX-1000's eight-bit microprocessor system. The microprocessor outputs the appropriate 'Centre Error' signal to the digital Centre Error display and to the X and Y axis centre correction motors. The X and Y axis motors, pulleys, belts, worm gears and control arms are thus activated so that the Centre Search Platter is moved into a relationship with the main platter axis such that the centre error is eliminated. This process of moving the Centre Search Platter to correspond with absolute centre is graphically displayed on the Absolute Centre Search LED display, and when absolute centre has been accurately located the Absolute Centre indicator lights. At the same time the sensor arm rises, returns to its housing, and finally recedes to its original position in the turntable base. Refer to the Absolute Centre Search system block diagram (Figure 7) and flowchart (Figure 8).

The above process precisely aligns the record's groove centre with the turntable's drive motor spindle axis (Absolute Centre), thereby achieving precise phono reproduction with an absolute minimum of wow and flutter. Wow and flutter spectral analyses made before and after Centre Search are shown in Figures 9 and 10 (overleaf).

Drive motor

The TX-1000 employs a brushless, coreless, slotless, Hall element direct-drive motor that is claimed to excel in the following critical sound reproduction parameters: ▶

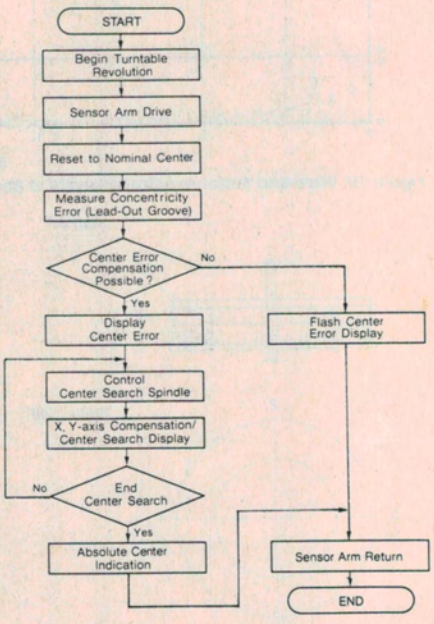


Figure 8. **Absolute Centre Search flowchart.**

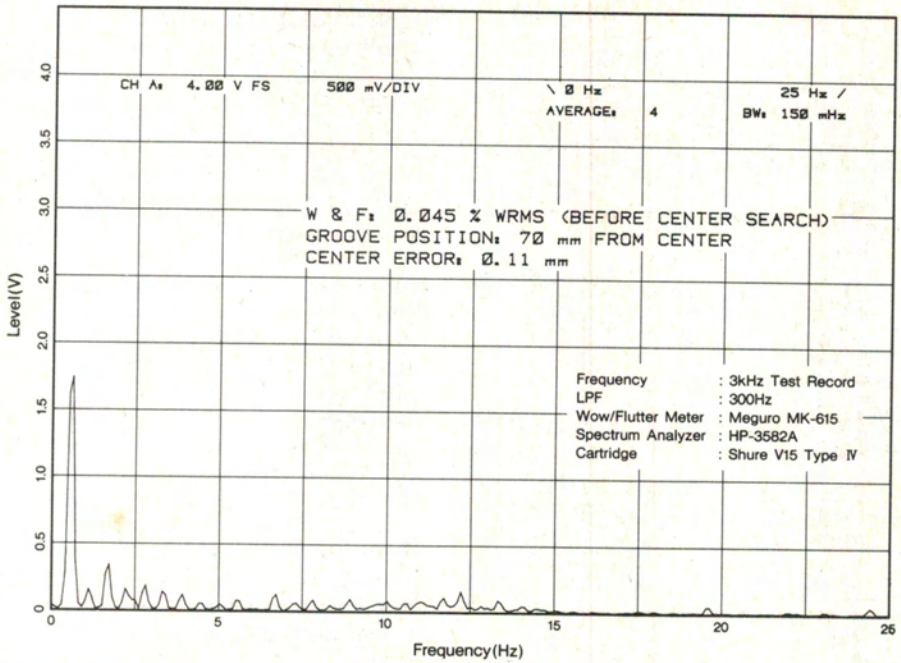


Figure 9. **Wow and flutter spectral analysis at nominal centre (prior to Centre Search).**

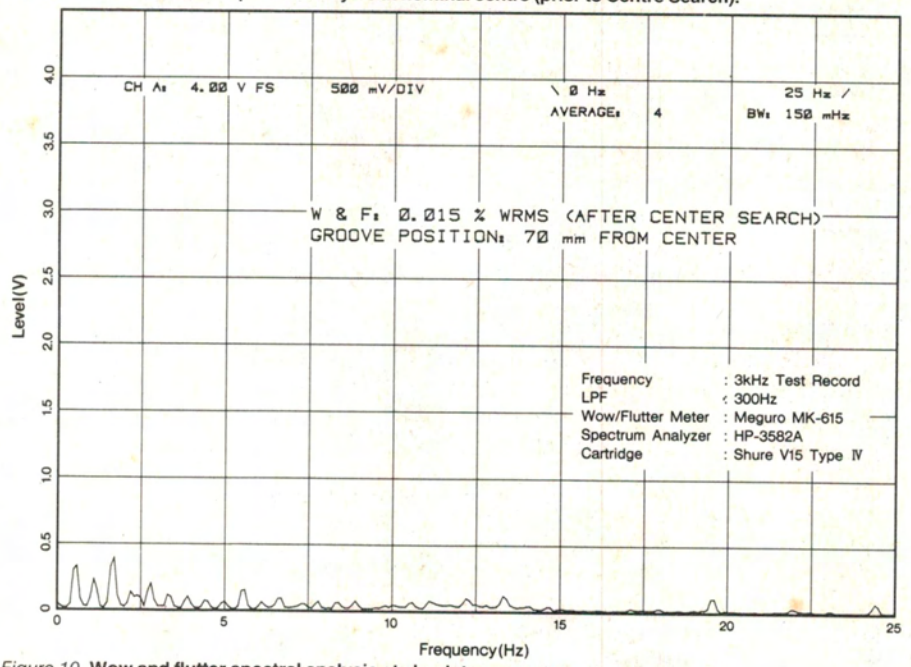


Figure 10. **Wow and flutter spectral analysis at absolute centre (after Centre Search).**

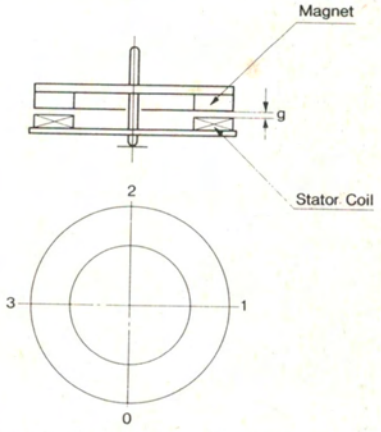


Figure 11. **Cross-section of conventional brushless motor.**

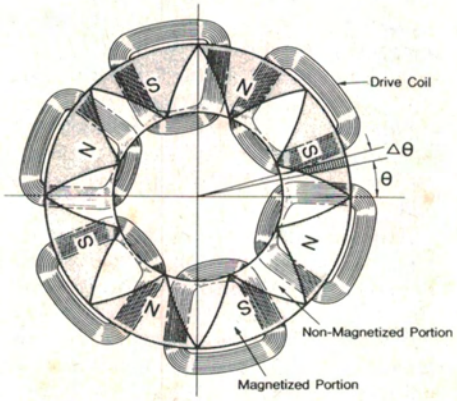


Figure 12. **Coil/rotor magnetisation pattern relationship.**

- Wow and flutter (cogging, torque variation)
- S/N (cogging, torque variation, servo feedback ripple)
- Rotational speed stability
- Torque characteristics
- Response
- Mechanical and electrical noise.

According to Nakamichi's claims, the motor used in the TX-1000 is superior in all the above parameters, and particularly in terms of cogging-related wow/flutter and signal-to-noise ratio.

Conventional brushless motors suffer rotational disturbances due to rotor magnetisation, magnetic field strength variation, magnetic saturation and non-uniform magnet/coil gaps (see Figure 11). Figure 12 shows the rotor magnetisation pattern and coil arrangement used in the TX-1000's drive motor. Because of the special magnetisation pattern used, the varying magnetic flux density generated by rotation of the rotor magnet causes a Hall element located in an appropriate fixed position in relation to the rotor to output a sinewave. This sinewave signal is then amplified and applied to the motor's drive coils to produce even, unvarying torque. This relationship can be expressed by the following equation, in which θ is an angle travelled by the rotor and $\Delta\theta$ is any instantaneous rotor position during travel:

$$\mathrm{Sin}^2\theta + \mathrm{Sin}^2(\theta + 2/3\pi) + \mathrm{Sin}^2(\theta + 4/3\pi) = 3/2$$

We can see from this equation that no matter what the value of θ, the result is constant. If the Hall element detector is placed an appropriate distance from the rotor magnet a virtually perfect sinewave output can be obtained. The result is that the cogging (stepped motor rotation) has been eliminated, while wow and flutter have been reduced to an absolute minimum. Figure 13 shows the construction of the main drive motor.

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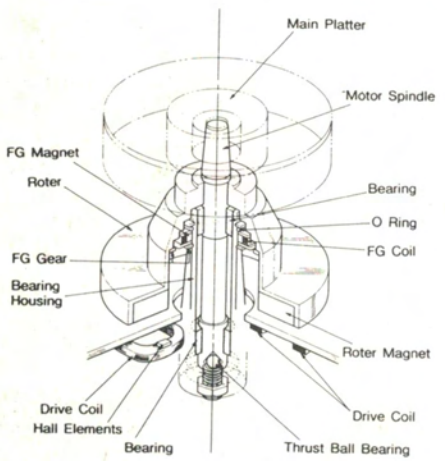

Figure 13. **Main drive motor construction.**

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Servo

The TX-1000 drive motor is controlled by a PLL synthesiser servo system. Employing a quartz crystal oscillator, VCO (voltage controlled oscillator) and phase comparator, this system maintains rotational speed accuracy as well as providing full 'quartz lock' (i.e: motor drive still crystal controlled) even when the pitch control (0.1% increments) is activated (refer to Figures 14 and 15).

Nominal Centre switch

Pressing this switch causes the Centre Search Platter spindle to be aligned with the motor spindle for operation as a conventional turntable system. The position feedback potentiometers connected to the X and Y axis control arms are factory set to permit virtually perfect 'nominal centring'. Once nominal centre has been located, the Nominal Centre indicator will light.

Sensor stylus replacement

Although replacement of the sensor arm stylus (diamond, two gram tracking pressure) should rarely be necessary, this function is provided in case replacement or cleaning do become necessary. Pressing the Sensor Stylus switch activates the sensor arm elevation motor, which raises the sensor arm housing and swings the sensor arm halfway out across the platter. In this position the stylus can easily be cleaned or replaced as necessary. Pressing the Sensor Stylus switch a second time causes the stylus arm and housing to return to its original position.

Platter Release

Pressing the Platter Release switch causes the X and Y axis control motors to rotate, decoupling the X and Y axis control arms from the Centre Search spindle. In this condition, the Centre Search Platter can be removed from the main platter. If, after replacing the Centre Search Platter on the the main platter, the Platter Release button is pressed a second time, the control arms are recoupled to the Centre Search Platter and nominal centre is located ready for normal operation.

Tonearm mounting

The TX-1000 can be fitted with two tonearms — one long and one normal or two of normal effective length — to provide maximum versatility for the advanced audiophile.

A number of optional tonearm bases that accept many of the most popular high-performance tonearms will be made available.

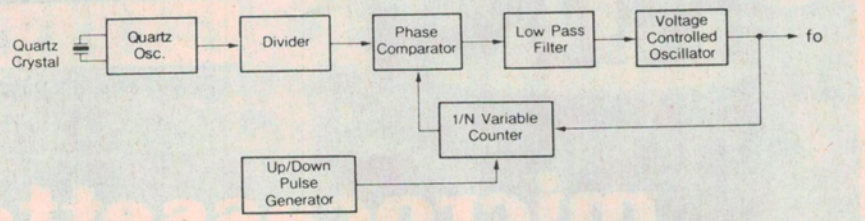

Figure 14. **PLL synthesiser circuit block diagram.**

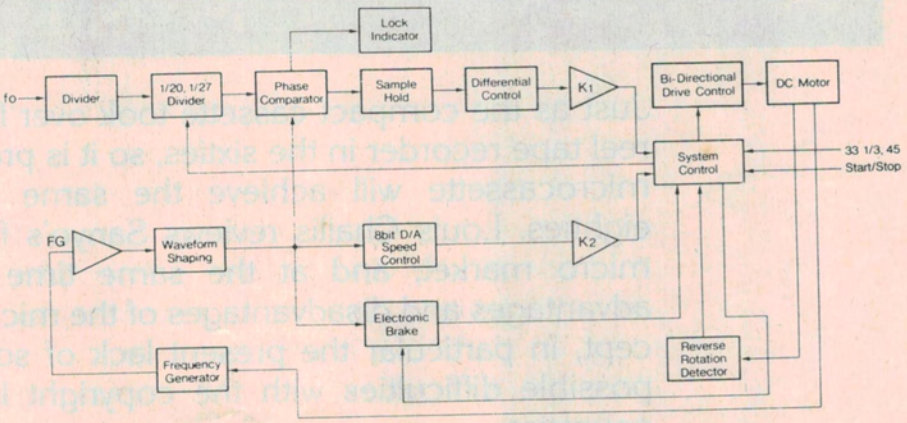

Figure 15. **Main drive motor servo system block diagram.**

Power supply

The TX-1000 power supply has been separated from the main turntable unit to maintain as high a signal-to-noise ratio as possible. All control operations including drive motor activation are carried out from the TX-1000 front panel, while the PS-1000 (power supply) panel features a power on/off switch, power-on LED and operation condition LEDs.

The power supply unit has been carefully shielded to minimise electromagnetic radiation. Nakamichi recommend that it be located as far as possible from the turntable unit for maximum performance.

Centre Search Platter

The TX-1000 Computing Turntable Centre Search Platter is formed of a special glass featuring high surface flatness and hardness that has been coated on both surfaces with a layer of metal. In addition to providing a completely flat surface, this metallised glass provides an effective ground path to drain off record static charges, according to Nakamichi.

The ultimate turntable? Only time and the acceptance of PCM digital disc systems will tell.

For the present, though, it certainly seems way ahead of whatever is in second place! ●