A BRIEF HISTORY OF CASSETTE DECKS

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Recently, I have accumulated a large amount of multi-faceted information related to audio cassette decks. Many of these materials are now available in primary sources, but individually they do not allow us to imagine the entire process of development of this technology. Only by understanding at what stage a particular model appeared can one objectively assess its capabilities and place in history. For this purpose, the proposed article was written.

1. FORMATION (1963-1972)

As you know, the compact cassette format was proposed by *Philips* in **1963** as a convenient medium for everyday use. The first serial tape recorder designed to work with a compact cassette becomes *Philips FL3300*. Its frequency responce was from 120 to 6000 Hz. At that time, such tape recorders had a portable design, battery power, as well as built-in power amplifiers and a speaker.

Fig. 1 – Philips FL3300. The first cassette recorder.

But at the same time, several more cassette formats are appearing on the market, providing higher recording quality. And in order to maintain its position, the compact cassette needed to establish itself in the market and improve the sound quality.

The way to success was a cooperation agreement between the developer of the format – the Dutch company *Philips* and the Japanese electronics manufacturer *Sony*, as well as the refusal of the former from royalties.

In **1966**, *Sony* released its first cassette recorder *TC-100*, which used the control buttons of the tape mechanism in the style of piano keys. Such buttons will later become classic and will be used by many manufacturers.

In the same year, *Matsushita* begins OEM production of *Philips* cassette recorders under the *National* brand (model *EL-3301T*).

Fig. 2 – Sony TC-100. The first cassette recorder with piano-style keys.

In **1967**, as a result of negotiations with *Philips*, the compact cassette format actually became open. In Japan, *Aiwa*, *Hitachi*, *Sanyo* and *Victor* companies are joining the production of cassette recorders.

In the same year, *Philips* released the first stereo cassette recorder *FL3312*. With minor changes, this model will be produced under the brand *Ampex Micro 85*.

Fig. 3 – Philips FL3312.
The first stereo cassette recorder.

At the same time, qualitative changes are taking place in the production technology of magnetic tape. *Agfa, Hitachi/Maxell, Sony* and *TDK* join the production of compact cassettes, in addition to *BASF*, which was originally engaged in their production. Low noise magnetic tapes with a reduced noise level appear, as well as compact cassettes with a recording duration of *120 minutes*. As a result, this format is gaining popularity and bypassing its competitors.

Fig. 4 – Sony TC-50.

In **1968**, Sony released the legendary professional voice recorder *TC-50*, successfully combining compact size, recording quality and reliability. At that time, portable devices are gaining popularity (see *Appendix 3*). This recorder could be operated with one hand. Serial samples of this model without any mods were included in the equipment of the astronauts of the *Apollo-7* spacecraft. Later, this recorder will be considered a prototype of *Walkman* cassette players.

At the same time, the Sony *TC-125* cassette deck is released, which can be considered the first stereo cassette deck. There was no built-in power amplifier, automatic adjustment of the recording level was used, and a simple filter was installed to reduce the tape noise. At that time, cassette decks had a horizontal body layout, imitating the usual forms of a vinyl record player. Expensive models were equipped with a transparent cover to protect against dust.

In the same year, *TDK* releases *Super Dynamic* cassettes with a claimed frequency responce of 30-20000 Hz. The magnetic particles in the coating of this tape had *smaller dimensions* and a more *uniform surface*. This made it possible to increase the number of particles per unit volume and, accordingly, increase the residual magnetization of the tape. Next year, *TDK Extra Dynamic (The Audiophile Tape)* cassettes will appear with a claimed frequency responce of 20-23000 Hz.

Fig. 5 – TDK Super Dynamic.

In **1969**, *Harman/Kardon* produced a *CAD-4* cassette deck with classic arrow indicators and manual adjustment of the record level.

In the same year, *Philips* released the first cassette deck *N2401* with a *changer N6711* for continuous playback of 6 compact cassettes. The changer also allowed the cassettes to be automatically turned over to perform the *auto reverse* function.

Fig. 6 – BASF Chromdioxid. The first Type II cassette.

But, despite the results obtained, the inverter of the compact cassette continued to treat this format as an inexpensive medium that does not pretend to high sound quality. As a result, the further development of cassette decks will be associated with other manufacturers.

In **1970**, *BASF* bought a license from *DuPont* for a new chemical compound and offered magnetic tapes based on *chromium dioxide* (CrO_2, *Type II*). In the future, *Sony* buys a license from *BASF* for the production of such tapes and receives the exclusive right to distribute them in Japan.

Magnetic tapes of the new type had a large *saturation output level (SOL)* at high frequencies, which allowed reducing the *equalization* in the recording-playback channel from the previously accepted *120 μs* to *70 μs*. This made it possible to reduce the noise level of tape recorders at medium and high frequencies.

However, the use of new magnetic tapes based on chromium dioxide caused increased wear of *permalloy heads*, which were used by most manufacturers at that time. As a result, expensive models of cassette decks are beginning to be equipped with *ferrite magnetic heads*, previously developed for reel-to-reel tape recorders.

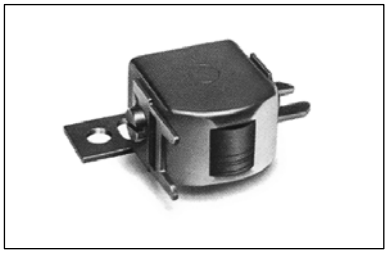


Fig. 7 – Ferrite head TEAC HD.

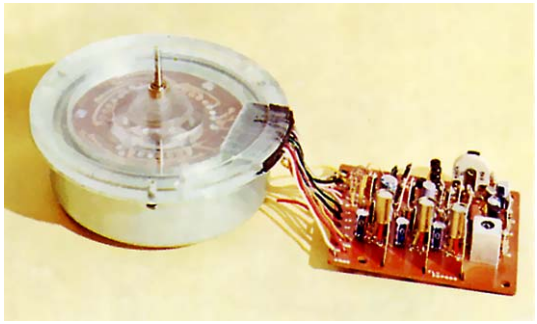


Fig. 8 – The first direct drive motor (Technics).

In the same year, the *Technics* produces the first cassette deck *RS-275U* with a *direct drive* capstan motor. This made it possible to get rid of the use of a belt and increase the stability of the movement of the magnetic tape. Previously, such a motor was developed by *Matsushita* specialists for use in vinyl players.

At the same time, a consumer version of the compander noise reduction system was presented, called *Dolby B* and allowed to increase the signal-to-noise ratio by 10 dB in the high frequency range.

Fig. 9 – Harman/Kardon CAD5. The first cassette deck with Dolby B.

After that, two *Advent 200* and *Harman/Kardon CAD5* cassette decks appear at once, in which the *Dolby B* system was used, and there was also the possibility of recording to CrO_2 magnetic tapes. Production of both models is located in Japan at the *Nakamichi* factory.

At the end of **1970**, sales of compact cassettes pre-recorded using the new *Dolby B* noise reduction system began.

In **1971**, *Sony* received a patent for a tape drive mechanism with *closed loop dual capstan*, and also introduced the first cassette deck (*TC-160)* equipped with such a mechanism. Then the *Sony TC-165* model appears – the first cassette deck with a *closed loop dual capstan and an auto reverse mechanism*.

In **1972**, *Tandberg* introduced the *TCD 300* cassette deck, equipped for the first time with a *three-motor* tape drive mechanism. Previously, this design has proven itself well in reel-to-reel tape recorders.

At the same time, *Akai* produces the *GXC-65D* cassette deck, equipped with an *Invert-o-Matic* mechanism with the cassette body turning over to perform the *auto-reverse* function. This model also uses the *ADR* (*Automatic Distortion Reduction*) system, which prevents overload of the magnetic tape by limiting the recording current at high frequencies. In the future, this system will be used in many *Akai's* cassette decks.

Since the beginning of the production of cassette decks, *Akai* has used its own *GX* heads in them, previously developed for video recorders. These heads used a ferrite core covered with *special glass*. Such heads had minimal wear and maintained an ideal working surface for a long time.

In the same year, *Philips* develops a *DNL* system (*Dynamic Noise Limiter*) that works only in playback mode and releases it as a separate unit *N6720* for connection to a tape recorder. This system could be used with previously made recordings and was used in cassette decks of various manufacturers. However, this system introduced noticeable distortions and ceased to be used after the widespread use of compander noise reduction systems.

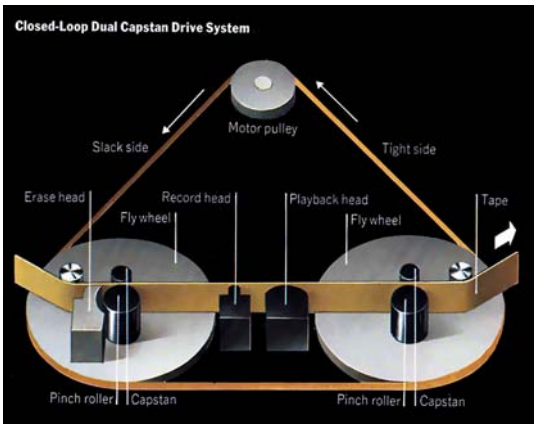


Fig. 10 – The first closed loop dual capstan cassette deck mechanism (Sony).

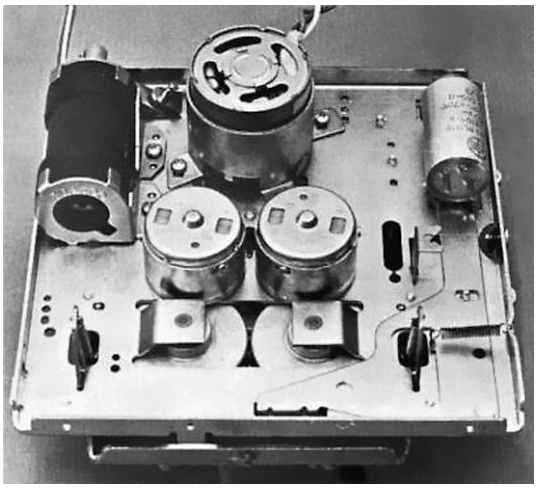


Fig. 11 – The first cassette deck mechanism with three motors (Tandberg).

Fig. 12 – Akai GXC-65D cassette deck with Invert-o-Matic mechanism.

2. DEVELOPMENT (1973-1977)

During this period, cassette decks become an equal component of the *Hi-Fi* system. With that, the best models acquire a vertical housing layout in order to even outwardly resemble a reel-to-reel tape recorder, which at that time was considered the reference standard of a high-quality sound source.

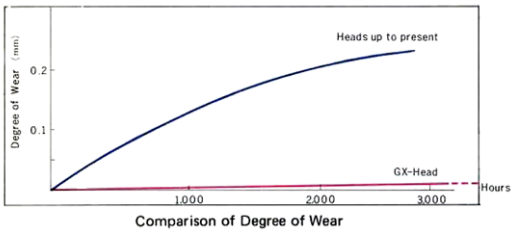


Fig. 13 – Comparison of wear of conventional magnetic heads and Akai GX.

In **1973**, *Nakamichi*, which had previously been engaged in the OEM production of tape recorders, entered the market under its own name. For the first time, the *Nakamichi 1000* cassette deck uses *three discrete heads* with the ability to calibrate the azimuth of the recording head. This model is becoming the most expensive on the market and sets new standards for the quality of recording on a compact cassette.

In the same year, *Sony* independently develops a double coated magnetic tape (*FeCr, Type III*), combining the advantages of the first two types of tapes. Later, *BASF* will also be engaged in the production of double coated tapes.

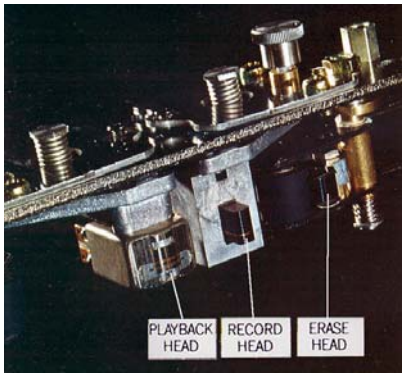
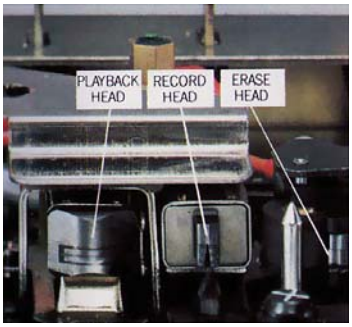
Fig. 14 – Sony Ferri Chrome. The first cassette with double coated tape (Type III).

At the same time, *Sony* is introducing the first cassette deck *TC-177SD* compatible with new *FeCr* tapes. This deck was also equipped with *three discrete heads*, but the ability to calibrate the azimuth of the recording head in it will appear only after the modernization carried out in **1975**.

In the same year, the *Lo-D D-4500* cassette deck appeared, released by the audio division of *Hitachi* and also equipped with *three heads*. But, unlike its competitors, it will be sold only in the domestic market of Japan. In this model, for the first time, the recording and playback heads were assembled into a single unit. This solution provides greater long-term stability of the structure, but imposes increased requirements on the production culture. In the future, such a combined head will be called a "*sandwich*" and will be used by most manufacturers.

Puc. 15 – Maxell UD XL II. The first cobalt-based Type II cassette (Epitaxial)

At the same time, the *Technics* produces a cassette deck *RS-279US*, equipped with *three discrete heads* and *direct drive motor*. However, the small third head in this model was used only for *monitoring* in recording mode. At the same time, the monitoring signal was not processed by the *Dolby* system. In playback mode, the signal came from a large universal head. Thus, this model cannot be considered a full-fledged three-head cassette deck. In the future, such auxiliary heads will be used for calibration in two-head decks, as well as for automatic search of music programs.

Table 1. The first cassette decks with three heads (1973)		
Nakamichi 1000		
Sony TC-177SD		
Lo-D D-4500		 *The first "sandwich" head*
Technics RS-279US		

Immediately after its appearance on the market, the *Dolby B* noise reduction system is gaining popularity and most manufacturers of cassette decks acquire a license to install it in their new models. However, *JVC* is developing its own system – *ANRS (Automatic Noise Reduction System)*, similar in characteristics to *Dolby B*. In **1973**, the *JVC CD-1668* cassette deck appeared equipped with this system for the first time.

At this time, there is a massive transition from the top loading of the cassette, adopted with the horizontal layout of the case, to the front loading, convenient for placing the cassette deck in a rack with equipment. Also, the widespread use of *electronic control* of the tape drive mechanism is beginning, which allows it to be protected from erroneous user actions, provides the possibility of automation and remote control.

Fig. 16 – Crystalloy head (Nakamichi).

In **1974**, *Nakamichi* develops magnetic heads from a new material called *Crystal Permalloy* (*Crystalloy*). The *Nakamichi 500* becomes the first cassette deck equipped with such a head. *Crystalloy* turned out to be a successful compromise between the sound quality characteristic of soft permalloy heads and the wear resistance of ferrite heads, which up to that time were equipped with almost all expensive models of cassette decks. The characteristic groove was intended to preserve the geometry of the working surface as the head wears out.

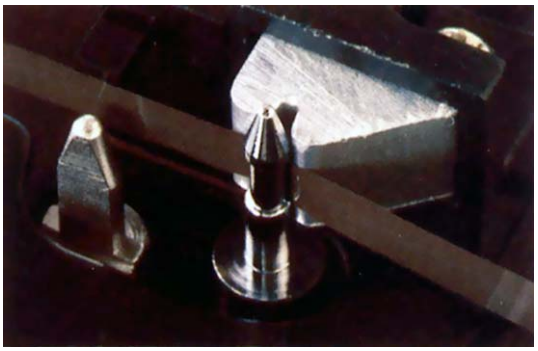


Fig. 17 – Back tension pin, combined with the tape guide (Hitachi D-3500).

In the same year, *Hitachi* released a simplified model with three heads, the *D-3500*, in which for the first time, instead of the second capstan, a special pin was used in the tape tensioning mechanism. This model cost half as much as the previous one and was already sold the worldwide. In the future, a similar tape tensioning design will be widely used by other manufacturers (*Closed Loop Single Capstan system*).

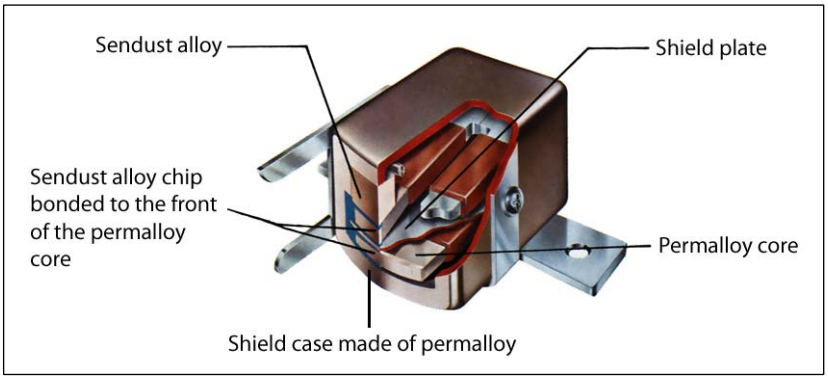


Fig. 18 – Sendust head (JVC SA).

In **1975**, *JVC* produced the cassette deck *CD-1669-2* with *Sendust* heads, which previously developed for use in professional equipment. At the same time, the core of the head was made of permalloy, and the tips were made of sendust. In the future, sendast magnetic heads (85% iron, 9.5% silicon and 5.5% aluminum) will be widely used.

Fig. 19 – Akai GXC-570D.

In the same year, the *Akai GXC-570D* cassette deck appeared, having a three-motor tape drive mechanism, a vertical housing layout and FWD/REW speed adjustment.

At those times, *TDK* is developing a new coating for magnetic tape *Super Avilyn (SA)* based on cobalt-doped iron. According to the main characteristics, such tapes turned out to be similar to *chromium dioxide*. As a result, *TDK* bypasses *Sony's* licensing restrictions on the production of *Type-II* magnetic tape. In the future, compact cassettes with cobalt-based magnetic tape will be widely distributed and will be produced by many Japanese companies.

Fig 20 – TEAC A-860.

In **1976**, the *TEAC A-860* cassette deck was released, which has a three-motor tape drive mechanism with direct drive of the reels and a vertical housing layout. For the first time, this model was equipped with a built-in *dbx II* compander and had the ability to adjust the equalization in recording and playback amplifiers. In addition, a microphone mixer with the ability to pan the signal was installed in it.

At that time, recording from a microphone at home is gaining popularity and many models of cassette decks are equipped with built-in microphone amplifiers and mixing panels. Later, in the **1980s**, microphone inputs would disappear from the front panels of most cassette decks.

At the same time, *Clarion* is developing the first *dual well* cassette deck *MD-8080A*. Unlike the *changers* that appeared earlier, this function will be successful and will become widespread in the future.

Fig. 21 – Technics RS-9900US.

In **1977**, the only *two-block* cassette deck *Technics RS-9900US* was released. The tape drive mechanism of this model was allocated in a separate unit, by analogy with two-block reel-to-reel tape recorders.

In the same year, *Pioneer* enters the market of cassette decks with three heads with the *CT-F1000* model. It used a two-motor belt drive mechanism with a closed loop dual capstan and three heads of its own production.

At the same time, *Aurex* is producing a *PC-4280* portable cassette deck with three heads, which used a tape drive mechanism with a *stabilizing roller*. It was assumed that such a roller provides the necessary tension of the tape and reduces parasitic amplitude modulation. *Sony* has also used this simple solution in its *TC-K80* cassette deck. However, the effectiveness of the stabilizing roller was insufficient and already in the updated *TC-K80II* model, the engineers abandoned this idea. Later, a similar design, called the *Dyna-Scrape Filter*, was used in *Sansui* cassette decks. Only instead of a roller, a *rotating shaft* was used in it.

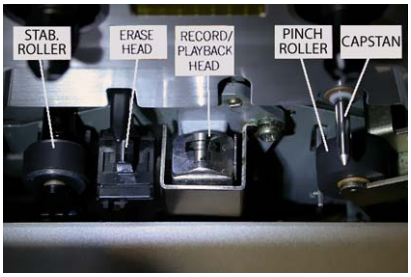


Fig. 22 – Stabilizing roller (Sony TC-K80).

Table 2. Top models of cassette decks with two heads	
 *Aurex PC-6030 (1975)*	 *Denon DR-750 (1977)*
 *Sansui SC-5100 (1977)*	 *Sony TC-K7 (1977)*
 *Victor KD-95 (1977)*	 *Yamaha TC-1000 (1978)*

At those times, several premium cassette decks with *two magnetic heads* are being developed. Among them are *Denon DR-750, JVC KD-95, Sansui SC5100, Sony TC-K7, Toshiba PC-6030* and *Yamaha TC-1000*. At the same time, the engineers deliberately refused to use three heads in the limited space of the compact cassette. The use of one universal head allows you to use a larger magnetic head. Such a head has a large and symmetrical surface of magnetic tape contact, which improves the frequency response of the playback amp at low frequencies and reduces parasitic amplitude modulation. Also, this eliminates the problem of combining the azimuths of the recording and playback heads.

Despite the use of one universal magnetic head, these models use separate recording and playback amplifiers, which makes it possible to simplify signal switching schemes and use the most rational circuit solutions.

Later, cassette decks with three heads replaced models with two heads in this market segment. But the idea of placing a large playback head has been preserved in *Tandberg* cassette decks and some other manufacturers using the placement of the recording head in a separate window of a compact cassette (see *Appendix 1*). Such a solution is possible, since for the recording and erasing heads, the surface of the magnetic tape contact is not crucial.

3. CLASSICS (1978-1983)

Fig. 23 – Luxman 5K50.

This period becomes the most favorable for the development of cassette decks. On the one hand, this is due to the beginning decline in demand for reel-to-reel tape recorders and the shutdown of the *Elcaset* project (see *Appendix 4*). On the other hand, attempts to create digital media have not yet led to the creation of a new competitive format. At those times, the efforts of most manufacturers are focused on the compact cassette. Thus, significant investments are directed to the development of this format, which leads to the creation of many new technical solutions and qualitative changes in the market of cassette decks.

In **1978**, *Luxman* entered the premium cassette deck market, introducing the *5K50* model. This cassette deck had a lot of innovative technical solutions and was produced at the *Alpine* factory.

Special *Luxman XM* cassettes were developed for this model, which allowed adjusting the azimuth and had a special sensor used to operate the tape counter in real time.

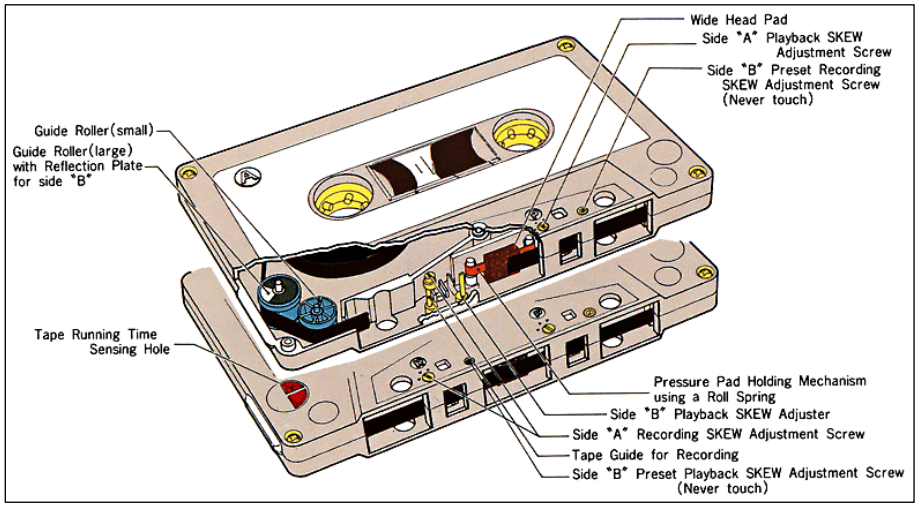


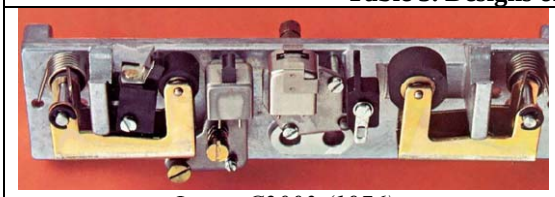
Fig. 24 – Luxman XM. Compact cassette with azimuth adjustment.

At the same time, *3M* developed a magnetic tape *Metafine* with metal particle deposition (*Metal, Type IV*). The novelty allowed to significantly expand the range of recorded frequencies, but required the modernization of existing models of cassette decks and the development of new magnetic heads. As a result, manufacturers are beginning to abandon the use of ferrite heads, since they could not provide high-quality recording on Type IV tape. Modified models of cassette decks compatible with Metal type tape and having the letter *M* in their name are rapidly appearing on the market. After this modernization, cassette decks are approaching the peak of their development.

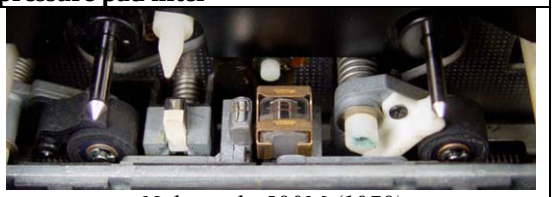
Puc. 25 – Scotch Metafine. The first type IV cassette.

In the same year, *Nakamichi* produces a *580M* cassette deck, which used a *pressure pad lifter*, which reduces modulation noise and wear of the heads. In the future, this solution will be used in all *Nakamichi* models, as well as in some *Alpine* and *Luxman* cassette decks. Previously, pressing the tape to the magnetic heads only due to the tension of the tape was known in reel-to-reel recorders. In cassette decks, this design was first used in the *Lenco C2003* in **1976**. Later, a similar solution in the form of *stickers* on magnetic head was used in *Sony* premium cassette decks, as well as in the *Pioneer CT-93*.

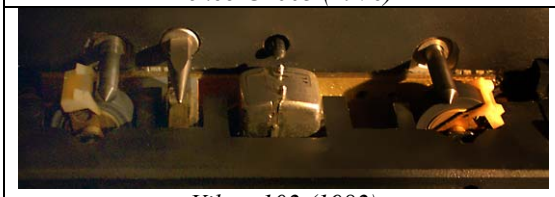
Table 3. Designs of pressure pad lifter



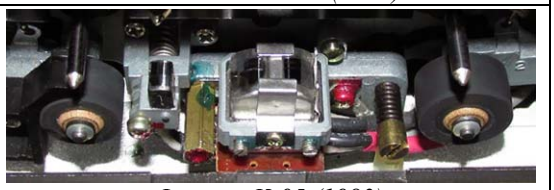
Lenco C2003 (1976)



Nakamichi 580M (1978)

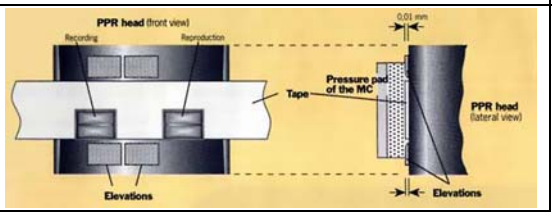


Vilma 102 (1982)



Luxman K-05 (1983)

Sony TC-K555ESA (1991)



The model *580* belonged to the *second generation* of *Nakamichi* cassette decks, which used a new *Silent Mechanism* (see *Apendix 2*), much smaller in weight and size. Switching modes in it was carried out using a *program drum*, instead of the previously used solenoids. This ensured fast, accurate, but at the same time quiet and smooth operation of the entire mechanism. Switching of operating modes was performed using microprocessor control.

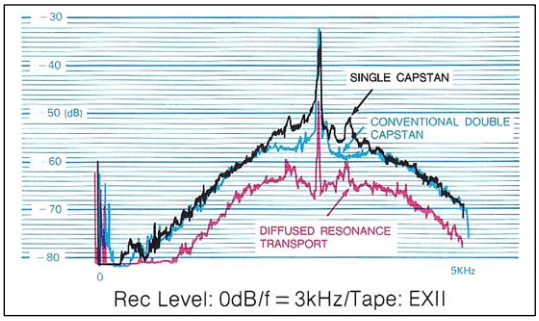


Fig. 26 – Modulation noise (Nakamichi Diffused Resonance Transport).

Also, in all models of the *second generation* of *Nakamichi* cassette decks, a closed loop dual capstan mechanism with *diffused resonance* was used. Such a mechanism has an asymmetric design, i.e. capstans of different diameters that rotate at different speeds, and, accordingly, have different resonant frequencies. This provides a blurring of the spectral density of the Wow & Flutter energy and a decrease in its absolute values. In the future, similar asymmetric mechanisms will be used in *Akai* and *Sony* cassette decks.

Fig. 27 – TEAC C-1mkII.

Fig. 28 – Replaceable calibration card TEAC CX-8.

At the same time, *TEAC* introduces the *C-1* cassette deck, which for the first time used a system of replaceable cards to calibrate the recording amplifier. This system was borrowed from professional equipment and was later used in other cassette decks of this company. Also, this model had a three-motor direct drive mechanism.

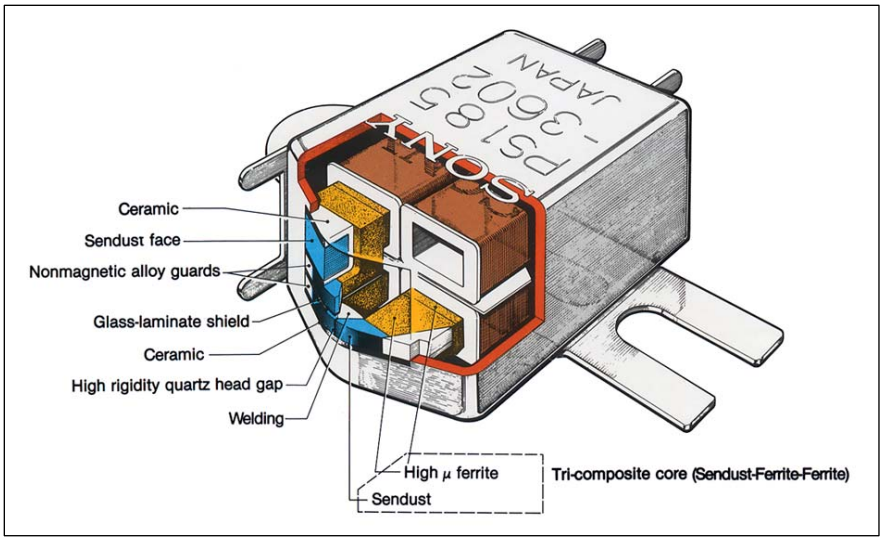


Fig. 29 – Sony S&F head.

In the same year, three companies at once produce cassette decks with quartz lock servo: *Luxman 5K50, Sony TC-K80* and *Technics RS-M85*. In the future, this technology will be used by other manufacturers, which will solve the issue of compatibility of records over time.

At the same time, the system of automatic search of music programs by pauses begins to be used. Initially, this function was developed as part of the *Elcaset* project, but in **1978**, the *Sony TC-K80* cassette deck entered the market, in which this system was used for the first time. Later this function will be widely used in various models.

In the *Sony TC-K80* for the first time users new *S&F* combined magnetic heads with a *sendust* tips and *ferrite* core. The heads of this design are considered one of the best and will be used in many cassette decks. They will also be selected for installation in the *Revox B710* and *Studer A710*.

Fig. 30 – Optonica RT-6905.

Some manufacturers used a special magnetic head to search for fragments of the recording. The most complex mechanism was implemented in the *Optonica RT-6905* cassette deck, which had a separate timer, programming and automatic control unit. However, such devices turned out to be too expensive, complex and redundant for most users.

Also in **1978**, *Tandberg* introduced the *TCD 340A* cassette deck equipped with the *Actilinear* system, which reduces distortion in the output stages of the recording amplifier and increases up to 20 dB more headroom. This result is achieved thanks to a special cascade in the recording amplifier, in which the recording current is mixed with the bias current. In the future, this system will be used in all *Tandberg* cassette decks.

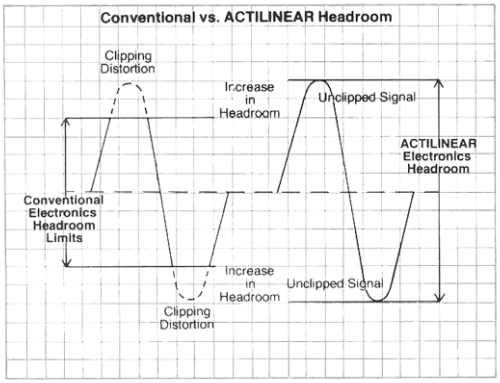


Fig. 31 – Actilinear system effect (Tandberg).

In the same year, *BIC* released the first *T-3* cassette deck with the ability to record at *double the tape speed*. Increasing the speed allows you to significantly improve many specifications. For example, the Wow & Flutter is halved. In the next few years, three more companies (*Dual, Marantz* and *TEAC*) will start producing cassette decks with double the tape speed. However, due to the incompatibility of such recordings with other models, increased consumption of magnetic tape and an increase in the parasitic amplitude modulation of the signal, they refused to use this function in the future.

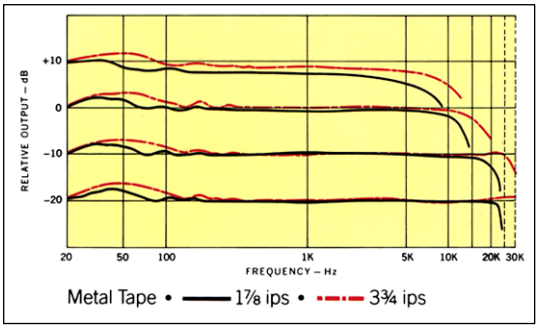


Fig. 32 – Doubling speed effect (BIC T-3).

In response to this, *Nakamichi* claims that the standard tape speed is quite enough and in **1979** it released the *680ZX* model, which had the ability to work at a speed twice as low as the standard one. This function was proposed to save tape consumption when recording programs with a limited frequency response. But even at a reduced speed, this cassette deck provided a frequency range from 10 to 15,000 Hz. Also, this cassette deck for the first time had the function of *automatically setting the azimuth* of the recording head. The whole setting process takes 2-3 seconds.

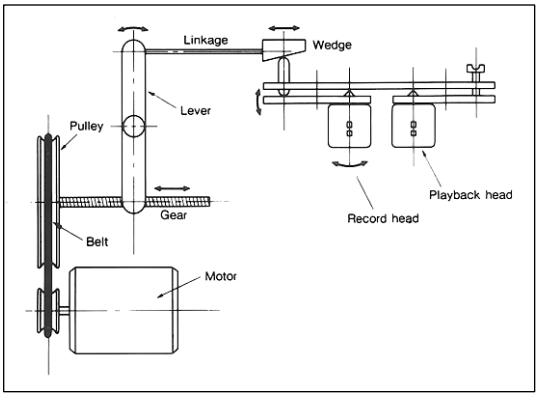


Fig. 33 – Automatic azimuth control (Nakamichi 680ZX).

Also in **1978**, *Sony* released the *TC-K88* cassette deck, for the first time equipped with a tape drive mechanism with *three direct drive motors (3 DD)*. Herewith, the drive of the capstan had *quartz lock servo*. All this was implemented very compactly and at the same time reliably. This model was sold as part of the *Esprit* series, which imposed serious restrictions on the height of the case. As a result, a unique mechanism with *horizontal loading of the cassette* was developed, which was extended from the case on a special tray. The horizontal position of the coils with the tape made it possible to further reduce the Wow & Flutter.

At those times, playback heads with special-shaped magnetic cores (*Aiwa V-cut* and *JVC X-cut*) are being developed to reduce the *Contour effect* at low frequencies. For the same purpose, *Hitachi*, *Nakamichi* and *Sony* are developing heads with a *hyperbolic shape* of the work surface that improves its contact with the tape.

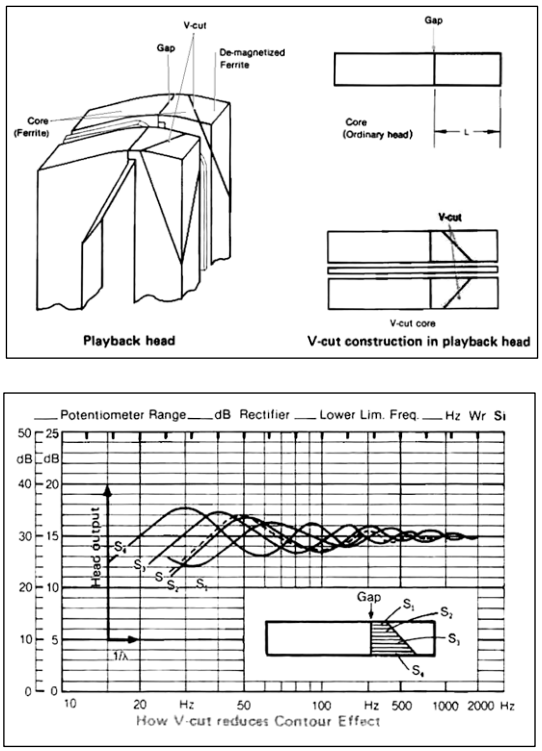


Fig. 34 – Aiwa V-cut playback head construction and reduces Contour Effect.

At the same time, *Tandberg* is developing the *DynEQ* system, which uses a new approach to recording high-frequency components of the signal at low tape speed. Herewith in order to prevent overloading of the tape at high frequencies, dynamic regulation (reduction) of the equalization in the recording amplifier occurs. For the first time, the *DynEQ* system was installed in the *TCD 440A* cassette deck and was later used in many models of the company. According to *Tandberg*, this system introduced less intermodulation distortion than the *Dolby HX* system that appeared simultaneously with it.

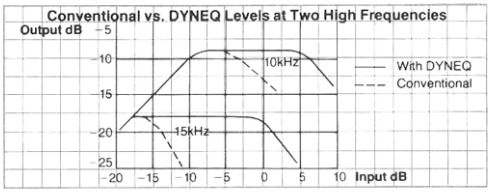


Fig. 35 – DynEQ system effect (Tandberg).

Table 4. The first cassette decks with automatic calibration system (1979)

JVC KD-A8

Hitachi D-5500

Onkyo TA-2080

Pioneer CT-A1

At those times, cassette decks appear which are standard equipped with *wireless remote controls*. The first such models are the *Aiwa AD-6900mkII* and *Hitachi D-5500*. Before that, the remote controls were wired and offered as an option.

Also in **1979**, three cassette decks with microprocessor calibration of the recording amplifier for any type of tape appeared at once: *JVC KD-A8*, *Hitachi D-5500* and *Pioneer CT-A1* (sold for export under the *Phase Linear 7000II* brand). Herewith, the sensitivity of the recording amplifier, recording equalization and the bias current were automatically set. Simple models were also available, in which only the bias current was automatically set: *TEAC A-430* and *Onkyo TA-2080*.

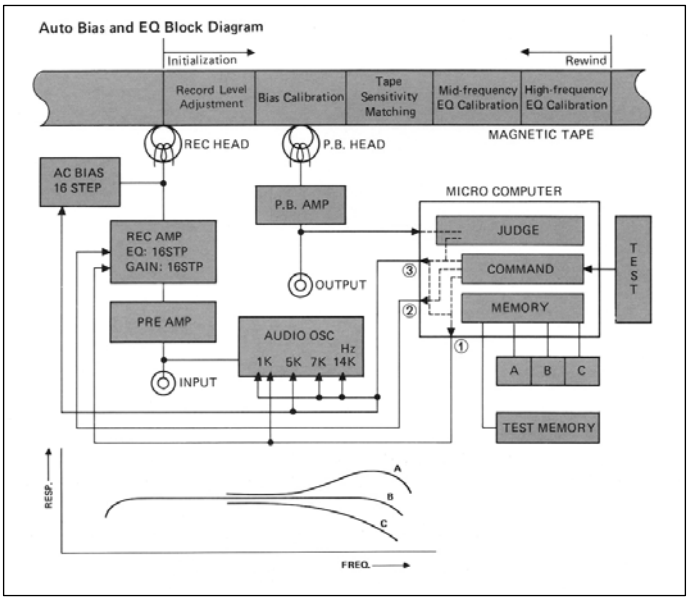


Fig. 36 – Auto calibration diagram (Hitachi).

However, in practice, the ideal result of auto calibration was not always obtained. As a result, on high-quality models of cassette decks, it becomes possible to manually adjust the results of the auto calibrator. A number of manufacturers do not use auto calibration system in premium cassette decks at all, reasonably believing that the ideal option can only be obtained manually. Other companies produce two top–end cassette decks at once – with auto and manual calibration, offering the buyer to choose the most suitable option independently.

But it is most advisable to use the auto calibration function in cassette decks with two heads, since it is very difficult to implement manual calibration in them in the absence of a monitoring mode.

At the same time, the widespread use of *microprocessor control* of the tape drive mechanism begins, which made it possible to automate many functions, as well as to realize the possibility of searching for music programs. The transition from mechanical tape counters to electronic ones is also beginning. With the advent of microprocessors, such counters will work in *real time* mode.

In the same year, *Hitachi* began using *titanium coating* on the surface of its magnetic heads. The titanium coating protected the magnetic gap from damage. In addition, such heads had a special design and provided a minimum distance between the working gaps of the recording and playback heads of 1.4 mm. For the first time, these heads were installed in the *D-5500* cassette deck. Later, *Hitasenrite* heads appeared which became the top of their model range and combined a sendust recording head and a ferrite playback head in one block. The working surface of such heads was also covered with titanium.

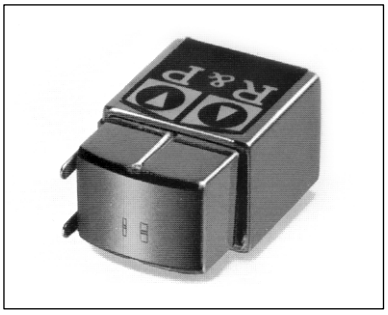


Fig. 37 – Magnetic head with titanium coating (Hitachi).

At the same time, the *Pioneer CT-F1250* cassette deck appears, in which all the achievements of the company for that period of time were collected. This model was sold only for export, since in the domestic market of Japan the top model of *Pioneer* was the *CT-A1* cassette deck.

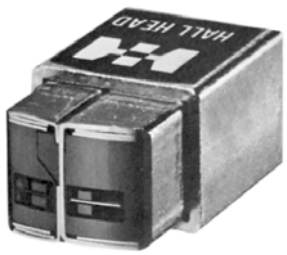
In the same year, the *Eumig FL-1000up* cassette deck appeared which used a unique tape drive mechanism with *optoelectronic control* of the speed of rotation of the capstan and *overrunning clutches*. These solutions were borrowed from the production of motion picture cameras, which this company was also engaged in.

Fig. 38 – Capstan with optoelectronic control (Eumig).

At the same time, *Hitachi* is developing a playback head based on the *Hall Effect* and installing it in the *D-7500* cassette deck. This technology allowed reducing the noise level during playback, but required special operating conditions. As a result, such heads often failed and were subsequently discontinued.

Table 5. Comparison of compander noise reduction systems

System	Developer	Year	Effect	Transfer characteristic	Number of processing lanes
Dolby A (Professional)	Dolby Lab. (UK)	1966	15 dB (>9 kHz) 10 dB (1 kHz)	Variable	4 (Section frequencies: 80 Hz, 3 kHz, 9 kHz)
Dolby B		1968	10 dB (>5 kHz) 5 dB (1 kHz)	Variable	1 (Sliding strip)
Dolby C		1981	20 dB (>1 kHz) 15 dB (500 Hz)	Variable	1 (Sliding strip)
Dolby SR (Professional)		1986	27 dB (>800 Hz) 19 dB (500 Hz)	Variable	2 (Sliding strip)
Dolby S		1990	24 dB (>2 kHz) 10 dB (100 Hz)	Variable	2 (Sliding strip)
dbx I (Professional)	dbx (USA)	1973	>30 dB	Linear (1:2)	Broadband
dbx II		1976	>30 dB	Linear (1:2)	Broadband
ANRS	JVC (Japan)	1972	10 dB (>5 kHz) 5 dB (1 kHz)	Variable	1 (Sliding strip)
Super ANRS		1975	10 dB (>5 kHz) 5 dB (1 kHz)	Variable	2 (Sliding strip)
ADRES	Toshiba (Japan)	1978	30 dB (10 kHz) 20 dB (1 kHz) 17 dB (100 Hz)	Variable (1:1.5)	Broadband
Super D	Sanyo (Japan)	1979	35-40 dB	Linear (1:2)	2 (Section frequency 4.8 kHz)
Lo-D Compander	Hitachi / NHK (Japan)	1979	>20 dB	Linear (1:1.5)	Broadband
Telcom C4 (Professional)	Telefunken (Germany)	1976	25-30 dB	Linear (1:1.5)	4 (Section frequencies: 215 Hz, 1.45 kHz, 4.8 kHz)
High-Com		1978	15-20 dB	Variable (1:2)	Broadband
High-Com II	Telefunken (Germany) / Nakamichi (Japan)	1979	20-25 dB	Variable (1:2)	2 (Section frequency 4.8 kHz)



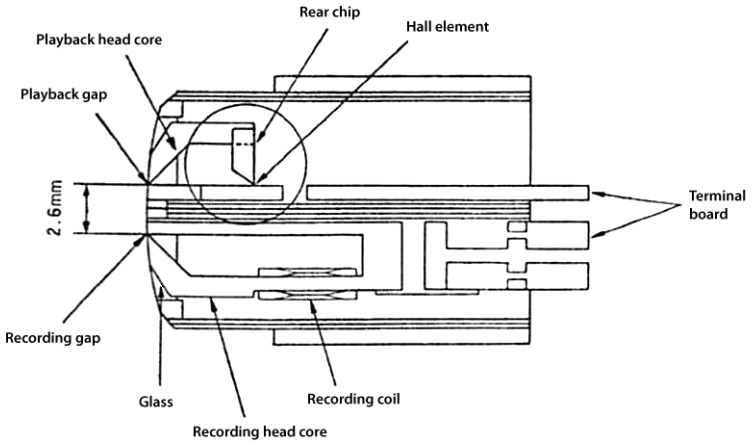


Fig. 39 – Magnetic head based on the Hall Effect (Hitachi).

In **1979**, *Akai* developed *Super GX* heads with improved magnetic flux characteristics and the ability to record on Metal tape. For cassette decks with two heads, *Twin Field Super GX* heads with *two gaps* have been developed, each of which is optimized for recording or playback. When using such heads, the only advantage of models with three heads is only the possibility of monitoring during recording.

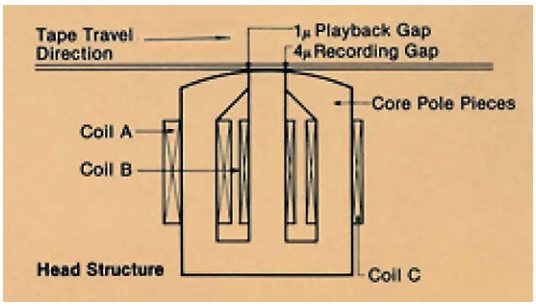


Fig. 40 – Twin Field Super GX head (Akai).

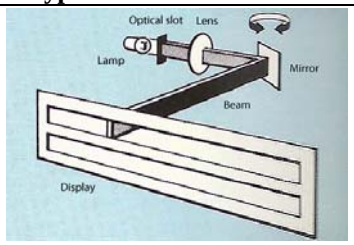
In the second half of the **1970s**, it became clear that, despite the improvement of magnetic media, it was impossible to obtain an acceptable signal-to-noise ratio from a compact cassette without using compander noise reduction systems. The *DNL* system proposed by *Philips* could not provide high-quality sound. The *Dolby B* system that existed at that time had noticeable drawbacks and required serious royalties from cassette deck manufacturers.

Against this background, the development of alternative noise reduction systems begins, among which are: *ADRES, ANRS, dbx* and *High-Com*. Of these, only the *ANRS* was compatible with *Dolby B*, but was based on the original developments of *JVC*. All other systems were incompatible with each other and were produced both built-in on cassette decks and in the form of separate external units that allowed them to be used with any equipment.

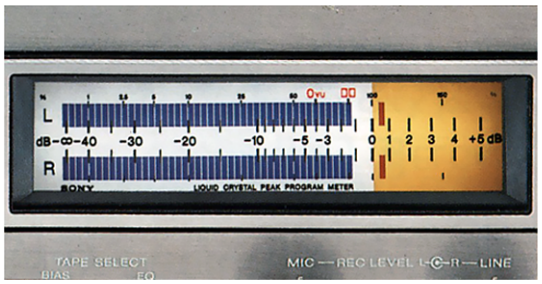
During this period of time, the appearance of cassette decks changes significantly. The number of controls is increasing. Mechanical toggle switches are replaced with electronic buttons, additional regulators appear. But the most significant changes are associated with the replacement of the *arrow level meters* with *LED*, and then with *fluorescent* ones.

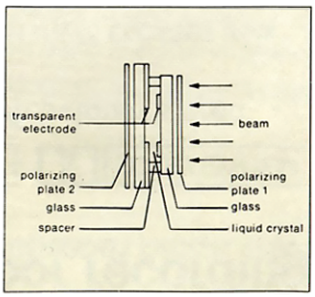
Table 6. New types of level meters

Two arrows (Aiwa)

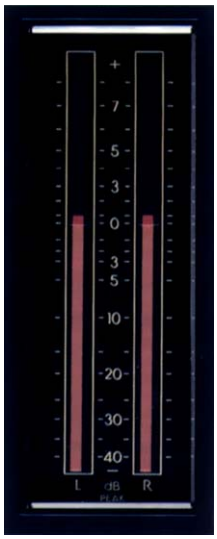


Mirror (Alpine, Sony)





Liquid crystal (Sony)



Plasma (Toshiba)

Due to the increasing complexity of electronics and the widespread use of new compander noise reduction systems, the requirements for signal level meters are increasing. *Arrow meters* show the average signal level and have great inertia, so in the early **1970s**, in addition to them, *LED* indicators of peak value appeared. Some manufacturers use the *VU/Peak* value switch for arrow meters instead. *Aiwa* uses meters with *two arrows* in the best models of cassette decks (one shows the VU level, the second shows the peak level). But then the *LED* meters almost completely displace the arrow ones. Herewith, the accuracy of their measurement is directly related to the number of *LEDs* in the line.

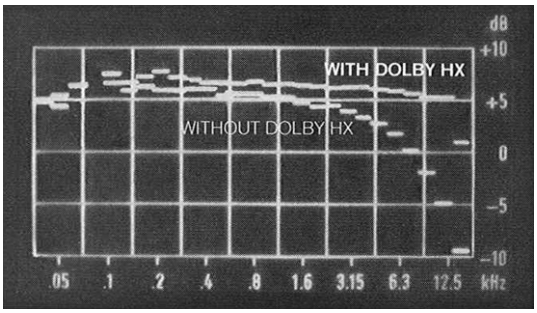


Fig. 41 – Dolby HX System effect.

Also in the late **1970s**, manufacturers began experimenting with the use of new types of meters. This is how *Sony* cassette decks with *liquid crystal*, *Toshiba* with *plasma* and *Alpine* with *mirror* meters appear. But in the end, they are all replaced by *fluorescent* meters, which turned out to be the most technologically advanced and convenient.

In **1979**, the *Dolby HX* dynamic control bias system was introduced, allowing expanding the range of recorded frequencies. In **1980**, the *Harman/Kardon HK705* cassette deck appeared, in which this system was used for the first time. However, this system introduced distortions into the recorded signal, while its actual efficiency was lower than stated.

Fig. 42 – TDK MA-R.

At the same time, *TDK* produces *MA-R* cassettes, which have become the de facto standard of professional quality. The cassette case was based on an aluminum alloy frame. The magnetic tape is created on *FINAVINX* metal particles. The *TDK MA-R* weighed twice as much as a regular compact cassette.

At the same time, experiments are being conducted to control the tension of the tape by adjusting the braking force on the supply reel. This solution was borrowed from reel-to-reel tape recorders and was first used in **1979** in the *TEAC C-3* cassette deck. The system was named *Mechanical Tension Servo System*. With a weak tension of the tape, the mechanical sensor, through a system of levers, slowed down the supply reel; with a strong tension, on the contrary, it weakened. But, unlike a reel-to-reel recorder, the space in a compact cassette for placing a tension sensor is very limited. As a result, the sensor stroke turned out to be small, and the whole design is too demanding to configure.

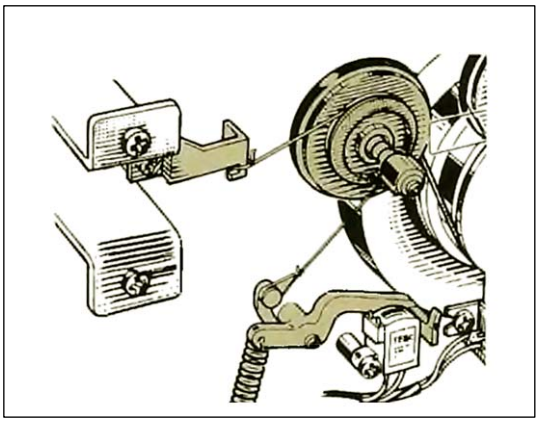


Fig. 43 – Mechanical Tension Servo System (TEAC).

Later, similar systems were used by other manufacturers: *Constant Tension System (Kenwood, 1980), Tension Servo Mechanism (Sansui, 1981), Tension Stabilizing Loop (JVC, 1982)*. However, all of them were an attempt to abandon the more expensive mechanism with closed loop dual capstan, but they turned out to be less effective and were not widely distributed.

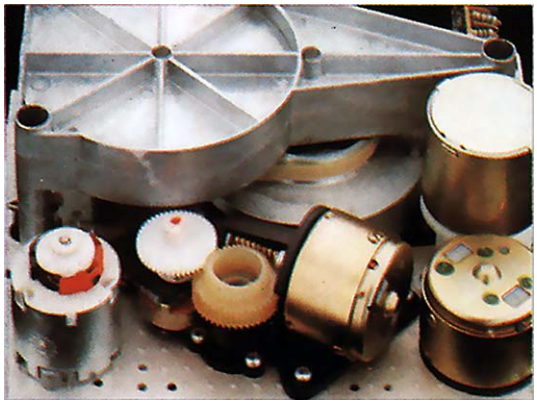


Fig. 44 – The first four-motor tape drive mechanism (Tandberg).

In **1980**, changes were made to the *IEC* standards, which finally approved the existing classification of magnetic tapes (see *Table 12*) and made it possible to equip cassette decks with their automatic recognition system. After that, almost all manufacturers refused to manually select the type of tape.

Fig. 45 – Nakamichi 1000ZXL.

Up to this point, some manufacturers (for example, *Nakamichi*) allowed the user to independently choose which EQ to use when recording. At the same time, it was possible to record tapes based on chromium dioxide (CrO_2) with *EQ* of *120 µs*, which further reduced the nonlinear distortion of the signal.

At the same time, *Tandberg* presents the first *TCD3004* cassette deck with a four-motor tape drive mechanism. Herewith, the fourth motor performed auxiliary functions, ensuring smooth movement of the block of heads and pressure rollers.

In the same year, *Nakamichi* released an updated version of its flagship model – *1000ZXL*, which was compatible with metal tapes and equipped with a microprocessor-based recording amplifier calibration system.

In **1981**, *Studer/Revox* entered the cassette deck market. This company had not previously recognized this format and was engaged in the production of exclusively reel-to-reel tape recorders. For the debut model *B710*, a unique tape drive mechanism with 4 direct drive motors was developed. Herewith, all motors were used to move the tape. This cassette deck was equipped with *Sony's* discrete heads. These heads had combined ferrite/sendust cores and were considered one of the best on the market. Later, a professional version of this deck is released – *A710*, equipped with balanced input and output, as well as a new *Dolby C* noise reduction system.

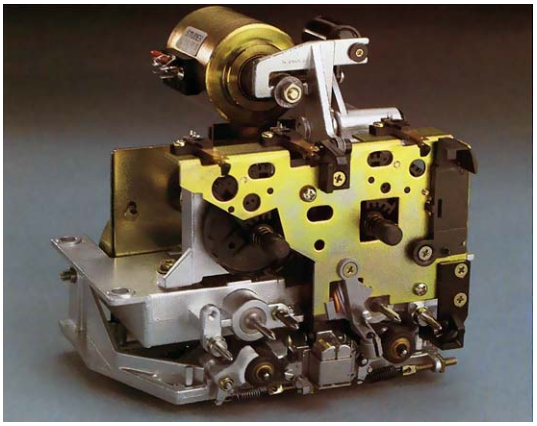


Fig. 46 – The first tape drive mechanism with four direct drive motors (Revox B710).

In the same year, *Sony* introduced the flagship model *TC-K777*, which used the best achievements in the field of magnetic sound recording. In **1983**, its updated version *TC-K777ES* will be released, which will receive a *Dolby C* noise reduction system and will become one of *Sony's* best cassette decks.

At the same time, the most expensive cassette deck in the entire history of their production appears – *Nakamichi 1000ZXL Limited*, worth $6000. Created on the basis of the *1000ZXL* model, this version was made to order and was distinguished by the presence of selected components, gilding of some parts, as well as a nameplate with the owner's name on the front panel.

Fig. 47 – Amorphous head (Technics).

In the same year, *Matsushita* specialists organized the production of a tape made of *amorphous metal*. The basis of the new material was an alloy of cobalt, silicon and barium. It turned out to be possible to obtain a thinner tape from the amorphous metal for the manufacture of head core plates.

Almost simultaneously, such heads are installed in the *Kenwood KX-900, Sony TC-FX77, TEAC V3RX* and *Technics RS-M275X* cassette decks. According to the totality of specifications, *amorphous heads* immediately occupy a leading position, but they turn out to be difficult to manufacture and, as a result, expensive.

Table 7. Materials for cassette deck heads

	Amorphous metal	Sendust	Permalloy	Ferrite
Initial permeability (1 kHz), μ	20,000-50,000	11,800-15,000	15,000-39,000	10,500
Magnetic flux density, Gs	8,000-11,500	8,500-10,000	6,600-8,100	4,500
Coercive force, Oe	0.012-0.02	0.007-0.025	0.012-0.03	0.03
Hardness, HV	850	480-500	110-200	680
Core thickness, μm	30	150	50-100	Monolith
Playback sensitivity (315 Hz), dB	-71	-71	-73	-73
Frequency response of playback at 14 kHz and 315 Hz, dB	+17	+15	+13	+15
Maximum output level (low frequency), dB	+4	+4	+2	0
Saturation output level (high frequency), dB	-1	-2	-4	-6
Harmonic distortion, %	1	1	2	5
Relative bias	1	2	2	0.85
Wear resistance, μm/hour	0.004	0.005	0.1	0.001
Number of plates in the stereo head core	12-16	2-3	4-7	Monolith

After that, leading manufacturers gradually replace *ferrite* and *sendust* heads with *amorphous* ones in the most expensive models of cassette decks. In cheaper models, magnetic heads made of *hard permalloy* continue to be used everywhere.

At the same time, *Pioneer* is developing *Ribbon Sendust* magnetic heads. When using this technology, it is possible to obtain a thin sendust tape for the manufacture of head cores. Using a thin tape, it is possible to assemble the core from a larger number of plates, which reduces eddy current losses in the head. For the first time such heads were used in the *CT-970* cassette deck. These heads will be used in the most expensive *Pioneer* models until **1985**, when they will be replaced with *amorphous* heads.

Fig. 48 – Ribbon Sendust head (Pioneer).

Also in **1981**, *Bang & Olufsen* specialists developed an improved version of the dynamic bias control system, the patent for which was immediately purchased by *Dolby*. In the same year, the *Bang&Olufsen Beocord 8002* cassette deck was released, for the first time equipped with this system, called *Dolby HX Pro*. In the future, this system will be widely used.

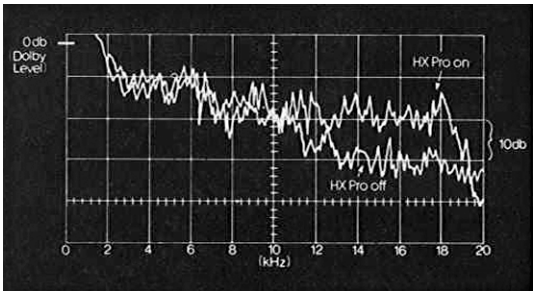


Fig. 49 – Dolby HX Pro system effect.

At the same time, a new *Dolby C* noise reduction system appeared which made it possible to improve the signal-to-noise ratio by 20 dB at high frequencies. The first cassette deck in which this system was used becomes *Sony TC-FX6C*. In addition, this system had an anti-saturation function, which made it possible to reduce signal distortion at high frequencies.

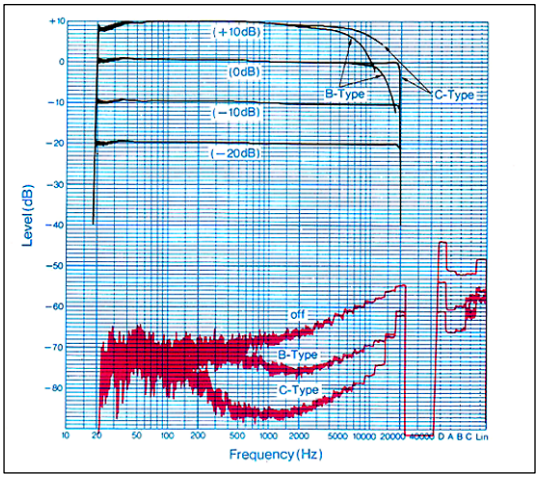


Fig. 50 – Dolby C system effect.

However, the use of the *Dolby C* system imposed additional requirements for the compatibility of recording and playback channels of various devices. In the **1970s**, many manufacturers of cassette decks allowed deviations from standard presets in their models in order to achieve their own, characteristic sound. These deviations fit into the tolerances of the old standard. But the growth of the pre-recorded cassette market and the advent of the *Dolby C* system led to the preparation of the updated *IEC 1981* standard, which established stricter tolerances. This forced manufacturers to make changes to the designs of their models and caused numerous discussions in the audio press of those years, since in some cases these changes led to incompatibility of new devices with previously recorded cassettes.

Also, when using the *Dolby C* system, calibration of the recording amp becomes almost a mandatory procedure (if you want to use different brands of magnetic tapes). It doesn't matter whether you use automatic or manual calibration; the main thing is to ensure an accurate signal level.

After the mass distribution of the *Dolby C* system in **1982**, all competing noise reduction systems, with the exception of *dbx*, refuse to participate in further struggle. By this time, the *Dolby* name is becoming so popular that its mere presence on the front panel of the cassette deck significantly increases its sales. The recording quality with precisely tuned equipment using the *Dolby C* system becomes acceptable for most users. Thus, it becomes more profitable for manufacturers to buy a license from *Dolby* than to invest in the development of their own systems.

In **1982**, the *Nakamichi Dragon* cassette deck appeared, for the first time equipped with a system for automatic azimuth correction of the playback head, called *N.A.A.C. (Nakamichi Auto Azimuth Correction)*. This model was also equipped with an auto-reverse system in playback mode and a closed loop dual capstan mechanism. At the same time, each capstan had its own direct drive motor. This model will become legendary, will undergo several upgrades and will be produced until **1993**.

At the same time, the *Nakamichi ZX-9* cassette deck appears which had advanced manual calibration capabilities, no auto-reverse and lower cost. It differed from the previous *ZX-7* model with a direct drive motor and a new playback amplifier.

In **1982**, at the Japanese Consumer Electronics Show, *Luxman* presented a prototype of the *X-3K* cassette deck with an *external tape loop*. This model marked a new direction in the development of cassette decks and turned them into a smaller version of a reel-to-reel tape recorder. This solution made it possible to bring the compact-cassette format to another qualitative level. However, at the same time, the main advantages of the format were lost – compactness, accessibility and ease of use. As a result, this model has remained a prototype, and further investments in the development of analog magnetic recording have been suspended.

Fig. 51 – Luxman X-3K.

The following year, **1983**, *Luxman*, instead of the declared revolutionary prototype, introduced cassette decks of the traditional designs: *K-05* and *K-04*. These models differed in the type of tape calibration systems (auto and manual) and collected the best achievements in the field of magnetic sound recording.

Fig. 52 – Luxman K-05.

In the same year, the *Pioneer CT-A9* cassette deck appeared, which is considered one of the best models of the company and, unlike all subsequent ones, has a *Reference Master* mechanism with direct drive and quartz lock servo. With minor changes, this model will be produced until **1988**.

At the same time, a *Marantz SD930* cassette deck appears also equipped with an automatic azimuth correction system for the playback head. This system was named *M.A.A.C. (Marantz Auto Azimuth Correction)* and implemented on the basis of a patent from *Philips*, who owned the *Marantz* at the time. Unlike the *Nakamichi* system, control of the playback head using a piezoelectric element was used here, and data from each recording track was used to generate the correction signal. However, the sound quality and technical equipment of this model were inferior to the *Nakamichi Dragon* and soon its production was discontinued.

Fig. 53 – Marantz SD930.

In the same year, the legendary *Tandberg TCD3014* cassette deck appeared which used traditional circuitry on discrete bipolar transistors. This model had an interesting sound and was produced with minor changes until the end of the **1990s**. In **1985**, professional models *TCD910* and *TCD911* were created on its basis.

Fig. 54 – Tandberg TCD3014.

At the same time, *TEAC* presents the *Z-7000* cassette deck, which becomes the most expensive model in the history of the company. This model used advanced microprocessor control and a tape drive mechanism with direct drive of the capstan and reels. The younger model *Z-6000* had the same equipment and differed only in manual calibration of the recording amplifier.

Table 8. Cassette decks with the lowest Wow & Flutter

 *Aiwa XK-009 (1988)*	 *Hitachi D-2200m (1982)*
 *JVC DD-9 (1981)*	 *Nakamichi Dragon (1982)*
 *Onkyo TA-2070 (1981)*	 *Pioneer CT-A9 (1983)*
 *Revox B710 (1981)*	 *Sony TC-K777 (1981)*
 *TEAC Z-7000 (1983)*	 *Yamaha K-2000 (1983)*

In the same year, *Yamaha* released the *K-2000* cassette deck equipped with a second erasing head installed after the playback head and allowing you to edit recordings in monitoring mode. Also in this model, for the first time, the frequency of the bias current of *200 kHz* was used to reduce intermodulation distortion.

During this period of time, the designs of tape drive mechanisms reach the peak of their development (see *Appendix 2*). In the best models of cassette decks, a weighted average Wow & Flutter of *0.02%* or lower. Such values were at the error level of the available measuring tapes and instruments. Further reduction of this coefficient made no practical sense and required disproportionately large expenses. In addition, to maintain the declared specifications, such mechanisms required careful periodic maintenance.

4. DECLINE (1984-1987)

In **1984**, sales of compact cassettes with pre-recorded programs exceeded sales of vinyl records for the first time. Cassette decks are mass-produced. But at the same time, the distribution of CDs and the advent of the era of digital audio technology begin. Against this background, the investments of leading manufacturers in the development of premium cassette decks are significantly reduced. This is noticeable by their model line at that time.

At the same time, the change of the base of electronic components is actively continuing. Discrete components are everywhere being replaced by microchips of varying degrees of integration. Mechanical switches and relays are replaced by electronic switches. Microprocessor control is widely used. The PCB mounting density increases and circuits design is simplified. Mass production dictates its own laws – there is a reduction in the cost of production. The overall dimensions and weight of the models are reduced, which indirectly confirms their simplification. Emerging novelties have nothing to do with sound quality and, as a rule, are of an auxiliary nature.

A striking example is the widespread fascination with the auto-reverse mechanism. The situation comes to the point that most manufacturers have all the top-models in the line of cassette decks equipped with a tape drive mechanism with auto-reverse. Herewith, higher-quality models with a one-way mechanism are in the background, and some manufacturers generally remove them from the premium segment.

There is a rejection of a number of important functions, for example, a full-fledged calibrator is replaced by a simplified version without a built-in oscillator, or in general there is only an adjustment of the bias by ear. There is also a rejection of expensive direct-drive motors and quartz lock servo. Dual well models are widely used, which are beginning to occupy a dominant position among some manufacturers.

Cost reduction leads to the unification of tape drive mechanisms. The resource of such mechanisms is noticeably reduced. The widespread use of plastic parts begins. Almost all manufacturers of cassette decks refuse to develop their own designs of tape drive mechanisms and purchase them from specialized suppliers. The most famous of them is the *Sankyo*. The same situation happens with magnetic heads. Almost all manufacturers are starting to use *Canon's* heads. The exceptions are several companies that have retained their own production of magnetic heads: *Akai, Alpine, JVC, Hitachi, Nakamichi* and *Sony*.

At the same time, the wages of workers in Europe remain much higher than in Japan. Accordingly, European manufacturers can no longer compete with Japanese in the medium and low price range. As a result, the production of cassette decks in Europe is sharply reduced.

During the heyday of the cassette deck, many random manufacturers appeared on the market, which did not bring anything new and only tried to make a profit. When the situation started to get complicated, they shut down their business and disappeared. At best, such companies have kept several cheap models in production, only to remain in advertising catalogs.

Fierce competition also forces *Nakamichi* to switch to the development of cheaper cassette decks. Models with a single-capstan mechanism reappear in its production program. There is a gradual transition to the release of cassette decks with a *third-generation* tape drive mechanism and simplified schematic. The service life of these models has been significantly reduced.

The main disadvantage of the *Nakamichi* mechanisms of the third generation is a small-diameter *idler*. After a few years of operation, it begins to slip and needs periodic replacement. *Nakamichi* recognized this mistake and released a set of gears to upgrade this mechanism. In general, most *Nakamichi* cassette decks with such a mechanism were inferior to second-generation models in terms of sound quality and functional equipment.

Fig. 55 – A set for tape drive upgrading (Nakamichi).

Nevertheless, even during this period, several effective solutions and interesting models appear.

In **1984**, *NAD* developed the *Play Trim* system, which improves the compatibility of recordings made on various equipment using *Dolby* systems. For the first time, the *Play Trim* was installed in the model *6155*. This simple system is used in playback mode and provides high-frequency level adjustment in front of the *Dolby* decoder. Herewith, it is possible to correct distortions caused by non-standard calibration of the recording amplifier, as well as partially compensate for errors in the installation of the azimuth of the magnetic head. Later, this system was also used in some *Yamaha* cassette decks.

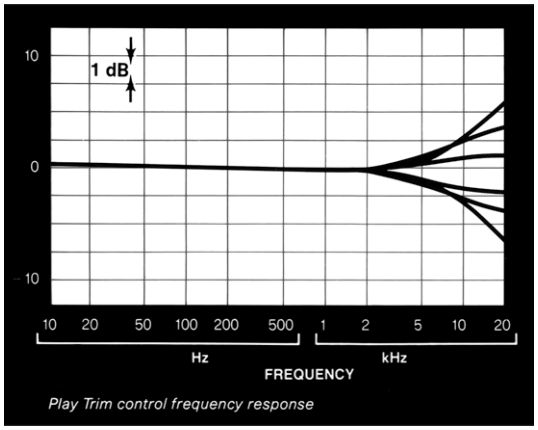


Fig. 56 – Play Trim system effect (NAD).

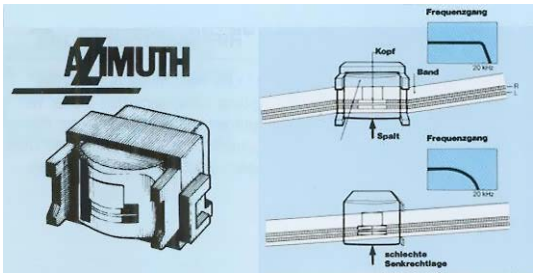


Fig. 57 – AzTech head (Philips).

In response to the advent of automatic azimuth adjustment systems for the playback head, *Philips* offers a simple way to stabilize the azimuth, which consists in installing two tape guides on one head. This system, called *AzTech*, of course, could not correct azimuth errors in records made on other equipment. But it made it possible to reduce errors that occur when the tape is unstable in simple tape mechanisms. This system was also used in some *Grundig* cassette decks. Later, a similar solution was used in digital tape recorders of the *S-DAT* format.

In the same year, auto-reverse cassette decks with direct drive of each capstan appeared: *Akai GX-R99* and *TEAC R-999X*. Herewith, the *Akai* has a closed loop dual capstan, and *TEAC* is a direct drive of each cassette reels. At those times, low front panels are becoming fashionable, which forces manufacturers to hide secondary controls on sliding panels (see *Table 9*).

Table 9. Top models of cassette decks with auto-reverse mechanism (1984)		
Akai GX-R99		
JVC TD-VR9		
TEAC R-999X		
Nakamichi RX-505		

At the same time, *Nakamichi* also creates fashionable auto-reverse cassette deck. In the new *RX* series, it was possible to completely eliminate the influence of auto-reverse on azimuth stability by using the *Uni-Directional Auto Reverse (UDAR)* cassette case flipping mechanism. Unfortunately, the beautiful external effect hid the rejection of important functions related to recording: the absence of an oscillator for calibration and a simplified level indicator.

In **1985**, *Nakamichi* released the *CR-7* model, which for the first time used manual azimuth adjustment of the playback head. This function, by simple means, ensured compatibility with recordings that were made on other equipment. The *CR-7* also becomes the first and only *Nakamichi* cassette deck, which was standard equipped with a wireless remote control and real time tape counter.

Fig. 58 – Nakamichi CR-7A.

Later, the azimuth adjustment function of the playback head was also used in *Nakamichi Cassette Deck 1, Nakamichi DR-1*, as well as in the *Tandberg TCD911* professional cassette deck.

After the release of the *CR-7* model, *Nakamichi* stopped investing in the development of this format and did not attempt to create new flagship models of cassette decks.

At the same time, *TEAC* is developing a system of electronic tape tension adjustment – *Hysteresis Tension Servo Control* and is releasing the *R-888X* cassette deck, equipped with such a system for the first time. Later, this mechanism will be used in other models of *TEAC* and *Tascam* cassette decks.

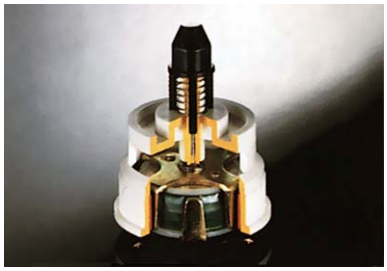
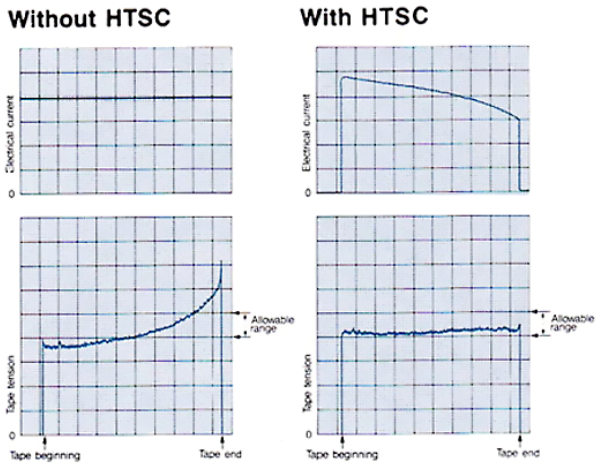


Fig. 59 – Hysteresis Tension Servo Control System (TEAC).



In the same year, the *Revox B215* cassette deck appeared which used a tape drive mechanism with *4 direct drive motors*, previously used in the *B710* model. Unlike the previous model, a complex system of microprocessor calibration of the recording amplifier was used here, as well as electronic switching of signals, which caused distortion of the analog signal. Later, based on this model, a professional *Studer A721* was created, which had analog recording level knobs.

Fig. 60 – Revox B215.

These models proved to be very successful, underwent several upgrades and became widespread. In the early **1990s**, the *H1* model was created based on the *B215* model. After that, Studer/Revox also stopped investing in the compact cassette format and almost all of its new models were clones of cassette decks from other manufacturers.

Fig. 61 – TDK MA-XG.

In **1986**, *TDK* produced *MA-XG* cassettes to replace the well-established *MA-R*. The coating of the magnetic tape was also based on *Finavinx* metal particles.

In the same year, *Sony* releases *Metal Master* compact cassettes with a *ceramic composite case*.

Fig. 62 – Sony Metal Master.

The appearance of higher-quality magnetic tapes allowed *Alpine* to produce *AL-81* (clone: *Luxman K-109*) and *AL-61* cassette decks with the ability to record metal type cassettes with an equalization of *50 µs*. This somewhat reduces the saturation output level of the tape, but allows you to further increase the signal-to-noise ratio on high frequencies by 3 dB. However, such records were not compatible with the *IEC-1981* standard and did not receive further distribution.

In **1987**, the *NAD* produced a *6300* cassette deck with three heads, a closed loop dual capstan and a direct drive mechanism. In this model, for the first time, *DynEQ* and *Dolby HX Pro* systems were used simultaneously to dramatic improvement in high-frequency saturation level. A proprietary *PlayTrim* system was used to adjust the signal in playback mode.

5. RENAISSANCE (1988-1994)

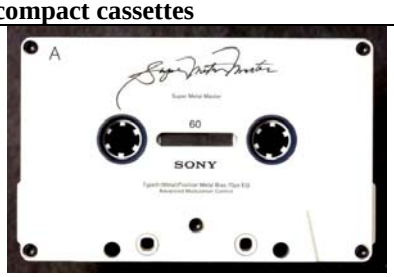
The ever-increasing advance of CDs is leading to a decline in the audio cassette market. However, CD players could not fully replace the cassette decks, because they did not support the recording function. In addition, over the past time, the quality of magnetic tapes has stepped far ahead. In many ways, this was facilitated by the widespread distribution of videotapes and technologies obtained during their development.

To boost demand in the compact cassette market, manufacturers are starting to offer new premium metal-coated magnetic tapes: *Maxell Metal Vertex, Sony Super Metal Master, TDK MA-XG* and *That's Suono*. These cassettes objectively become the best both in terms of technical specifications and in terms of manufacturing quality in the entire history of their production.

With the development of chemical technologies, the qualitative differences between types of magnetic tapes are gradually decreasing. The new *Type I* tapes are approaching the *Type IV* tapes in terms of frequency response and dynamic range. At the same time, they provide a lower harmonic distortion. The best low-noise tapes allow you to refuse noise reduction systems, eliminating the additional distortion they introduce.

Table 10. The best compact cassettes

Maxell Metal Vertex (1991)



Sony Super Metal Master (1993)

TDK MA-XG (1990)

That's Suono (1989)

By this time, sales of reel-to-reel tape recorders are declining to a minimum. Against the background of the continuing decline in demand, it becomes unprofitable for companies to support their production. *TEAC* lasted the longest in the market of household reel-to-reel tape recorders, which continued to sell them until the early **1990s**. The production of professional models continues, but this market is also beginning to shrink.

The *R-DAT* – digital magnetic recording format, proposed in **1987** by *Philips* and *Sony*, was originally intended as an alternative to analog cassette recorders. However, *DAT* equipment and cassettes proved to be too expensive for the average user. At that time, *DAT* tape recorders were considered a luxury and were distributed only in a professional environment.

At this time, electronics manufacturers offer a number of novelties that were designed to return the interest of demanding buyers to analog recording on a compact cassette. Many of them have been known for a long time, but were not put into production for economic reasons.

Others were borrowed from the fields of digital technology and video recording, which were better funded and developed faster. By this time, the development of flagship models of cassette decks is becoming unprofitable and is being undertaken more to demonstrate engineering skills and maintain the status of the company than to directly make a profit.

At the same time, there is a return to some important technical solutions that manufacturers abandoned during the decline. For example, models without auto-reverse come to the fore again, cascades on discrete transistors appear at the input of playback amplifiers, discrete recording and playback heads are used instead of sandwiches, and ceramic tape guides appear. Manufacturers are trying to use every opportunity to give the compact-cassette a second chance.

In the second half of the **1980s**, many manufacturers began to use oxygen-free copper (*OFC*) wires in the coils of magnetic heads, and then *LC-OFC* and *PC-OCC*, which have high chemical purity. In addition, *OFC* is cast and stretched in a special way, so that the length of the molecules increases tenfold. As a result, signal losses in such conductors are reduced.

At the same time, in premium models, copper plating of the body and chassis parts is beginning to be used. In addition to better shielding, this solution allows you to increase the protection of the housing from corrosion and improve the appearance. Such models look much more expensive, which was widely used as a marketing technique.

Also during this period, auxiliary functions are widely used, for example: wireless remote controls, a motorized cassette door and synchronization with a CD player.

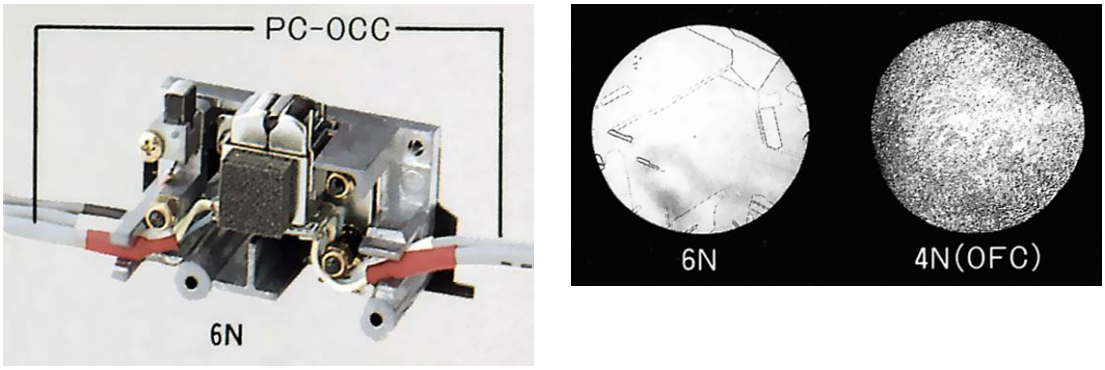


Fig. 63 – Magnetic head with coils made of oxygen-free copper 6N (99.99997) and a cross-section of wires with different metal purity (Aiwa).

In **1988**, the use of *cassette stabilizers* began. They were first used in the *Aiwa XK-009, A&D GX-Z9100, Pioneer CT-91* and *Victor TD-V721* models. These devices had different designs, but performed the same function – suppressed the vibrations of the cassette case, which cause parasitic amplitude modulation of the signal. Usually, this device was a rubberized plate, which, with the help of an electromagnet or an electric motor, is pressed with force against the cassette body. In the future, this solution will be used in other models.

Previously, to avoid uneven installation of the cassette and reduce vibrations, rigid fixation of the cassette body in an open cassette holder was used. This solution was used in many cassette decks in the early **1980s**, but it limited the front panel design options and was considered unacceptable in new models. In addition, it did not protect against possible resonances of the case when using cheap cassettes.

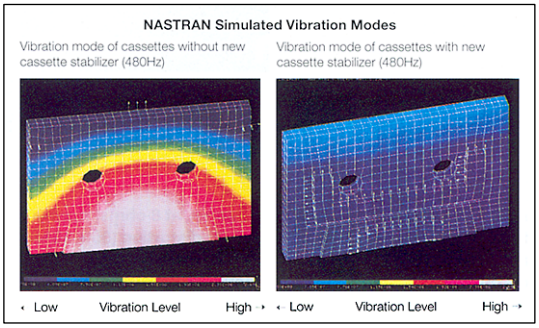


Fig. 64 – The cassette stabilizer effect (Pioneer).

The fight against vibrations at this time begins in all directions. Cases with wooden side panels reappear. *JVC* produces models with an anti-resonant wooden plate under the bottom, *Pioneer* uses elements of the housing with a honeycomb structure to increase rigidity, *Akai* and *Sony* use the separation of the housing by partitions into separate blocks to strengthen the structure and shield the nodes. At the same time, the widespread use of damping elements and antiresonance supports begins.

At the same time appear *Sony TC-K555ES* and *Yamaha KX-1200U* cassette decks with a high bias frequency of *210 kHz*. According to the developers, this solution allows to reduce intermodulation distortion and penetration of the signal with the bias frequency into the sound path. In the future, this solution will be used in other models.

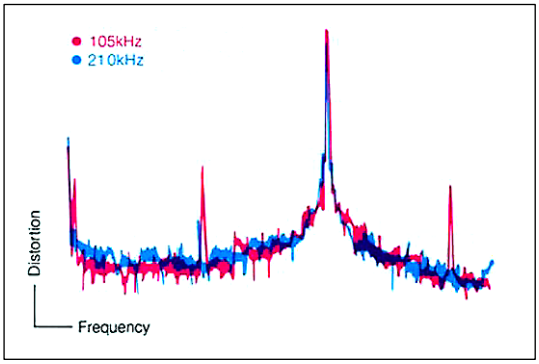


Fig. 65 – The high bias frequency effect (Sony).

In **1989**, a new *Dolby S* consumer noise reduction system was introduced developed on the basis of the professional *Dolby SR (Spectral Recording)* system, which appeared back in **1986**. The new system improves the signal-to-noise ratio at high frequencies by *28 dB*. Immediately, leading manufacturers of cassette decks present several prototypes for licensing. The most famous prototype was the *TEAC V-10000*, developed on the basis of the *V-9000* model. As early as next year, *Harman/Kardon* is releasing the first serial cassette deck *TD4800* equipped with a *Dolby S* system.

In the future, several flagship models of cassette decks equipped with the *Dolby S* system will appear on the market. However, the royalties for installing a new system are very significant. At the same time, investments in the development of cassette decks continue to decline. Thus, many manufacturers refuse to use this system for economic reasons.

Fig. 66 – Harman/Kardon TD4800.

In **1990**, *Sony* released the *TC-K555ESL* cassette deck, which uses a new *Lapis* tape drive mechanism with *sapphire capstan base* to increase durability. In the future, this solution will be used in almost all *Sony ES* series models.

In the same year, *A&D* released the *GX-Z9100EV* cassette deck with a playback amplifier built according to a balanced circuit on discrete *FET* transistors, without a common *Negative Feedback*. It also uses discrete recording and playback heads, which made it possible to adjust the azimuth more precisely. In the export version of this model (*Akai GX-95mkII*), the balanced playback amplifier was built on operational amplifiers. Unfortunately in the early **1990s**, *A&D* was experiencing financial difficulties and after that stopped developing new flagship models of cassette decks.

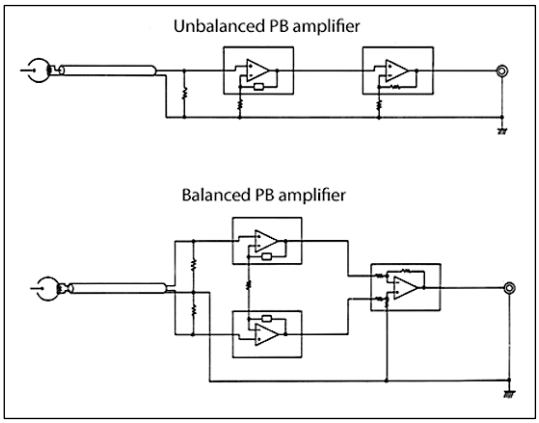


Fig. 67 – Balanced playback amplifier (Akai GX-95mkII).

In **1991**, the *Technics RS-B900* cassette deck, based on the *RS-B965* model, was released in limited edition for the domestic Japanese market. After that, *Technics* starts to the production of digital cassette decks of the *DCC* format and stops investing in analog cassette decks.

In **1992**, *Aiwa* released the *XK-S9000* cassette deck with an integrated *18-bit digital-to-analog converter* for direct connection to digital signal sources. This model was also equipped with a *Dolby S* noise reduction system. After that, *Aiwa* stops developing high-quality cassette decks.

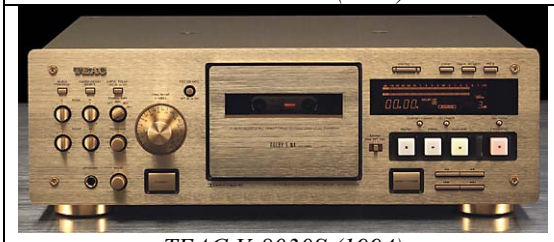
Table 11. The final flagships

A&D GX-Z9100EV (1990)

Technics RS-B900 (1991)

Aiwa XK-S9000 (1992)

Pioneer T-1100S (1992)



TEAC V-8030S (1994)

Sony TC-KA7ES (1994)

At those times, the *Pioneer CT-95* cassette deck appeared which the last flagship model of the company became. It used selected *FTA (Fine Tuned Amorphous)* magnetic heads and a new playback amplifier to reduce noise and expand the frequency responce. It also used the *class-A FET* buffer amp for record output.

In **1993**, *Tascam* produces a professional cassette deck *122mkIII*, equipped with direct drive motor, discrete heads and balanced input and output. This was the third version of the successful model proposed back in **1980**. After that, *Tascam* stops developing high-quality cassette decks.

Puc. 68 – Tascam 122mkIII.

At those time, leading manufacturers offer compact cassettes with multilayer tapes of all types. Various alloying additives that improve their characteristics are also widely used in new tapes. The successes achieved in the development of new magnetic coatings have caused the need to update the reference batches and bring them in line with modern technologies. In **1994**, the *International Electrotechnical Commission* published an updated standard that legitimized these changes.

Table 12. Classification of magnetic tapes

Type	Reference tape			Position	Description	Time constant, μs
	Manufacturer	Batch	Year			
IEC I	BASF (Germany)	R723DG	1979	Ferric / Normal	γ-Fe_2O_3 (gamma ferric oxide tapes)	120+3180
		Y348M	1994			
IEC II	BASF (Germany)	S4592A	1981	Chrome / High	CrO_2 (chromium dioxide) / Co-γ- Fe_2O_3 (ferricobalt tapes)	70+3180
		U564W	1986			
IEC III	Sony (Japan)	CS301	1979	FeCr / Ferro Chrome	γ- Fe_2O_3+CrO_2 (double-layer ferrichrome tapes)	70+3180
IEC IV	TDK (Japan)	E912HB	1981	Metal	Fe (metal pigment tapes)	70+3180
		MJ507A	1994			

In **1994**, *TEAC* released the *V-8030S* cassette deck, which had a completely updated appearance, reminiscent of professional models. However, compared to the previous *V-8000S*, its scheme was noticeably simplified, and production was moved from Japan to Taiwan. After that, *TEAC* also stops developing high-quality cassette decks.

In the same year, *Sony* releases the *TC-KA7ES* cassette deck, resuming production of the *7th series* models, which was discontinued back in **1986**. All the best technical solutions in the field of magnetic sound recording were concentrated in this cassette deck. To reduce noise in the playback amplifier, parallel connecting of discrete *FET* transistors was used. Selected magnetic heads were also installed here, with *6N* purity copper wire coils, the housings of which were gilded to improve the shielding effect. The recording amplifier used manual three-point calibration. This model can be considered the last flagship cassette deck. In the domestic market of Japan, it was sold until **2003** and with the cessation of its sales, the era of high-quality cassette decks ends.

Against the background of declining interest in cassette decks in Europe, the differences between models intended for the domestic market of Japan and those supplied for export are reaching their maximum. For example, the top model *Sony TC-KA6ES*, which was produced for export to Europe, belonged to a completely different class of equipment than the Japanese *TC-KA7ES*. Despite the external similarity, the quality of components, technologies used and design solutions differ dramatically.

6. EPILOGUE (1995-2010…)

After **1994**, the production of cassette decks continues to decline. Despite the presence of several flagship models, the design of most cassette decks is simplified as much as possible. Many manufacturers are reducing production or moving it to China, Taiwan and Malaysia. The quality of the materials and components used is noticeably reduced. Cheap permalloy magnetic heads are used almost everywhere.

The audio recording market is being captured by new digital formats that are rapidly replacing each other: *DC, MD, CD-R, DVD-Audio* and *SACD*. Compact cassettes are given the role of a cheap medium intended for undemanding listeners. At the same time, the opinion of the absolute superiority of digital signal sources is imposed on buyers.

In the second half of the **1990s**, the mass closure of the production of compact cassettes began. First of all, it affected the most expensive and high-quality models. Many surviving factories are sold to Korean and Turkish companies that simplify technology and reduce product quality.

Articles about magnetic sound recording disappear from the pages of the audio press. The use of cassette decks is becoming archaic and unpopular. The situation is aggravated by a general decline in interest in the *Hi-Fi* industry and a decline in production. The mass buyer goes first to the field of home theaters, and then to computer equipment. But some events in the market of cassette decks still continue to happen.

In **1995**, a professional cassette deck *Denon DN-790R* was released equipped with a closed loop dual capstan mechanism, amorphous heads and *Dolby S* system. After that, *Denon* stops developing high-quality cassette decks.

After the closure of the production of *DCC* recorders in **1996**, the *Technics* produces *RS-AZ7* cassette deck with *magnetic resistive* playback head. This technology was developed for the digital compact cassette (*DCC*) and allowed to reduce the noise during playback. However, the design of this model was simplified as much as possible and did not allow realizing all the possibilities of the new technology. In the future, the *Technics* stops the development of cassette decks.

In the same year, *JVC* introduced a compact-sized *TD-SD1* cassette deck, in which all the company's achievements were concentrated. This model had amorphous heads, manual calibration and a direct drive closed loop dual capstan mechanism. After that, *JVC* stops developing cassette decks.

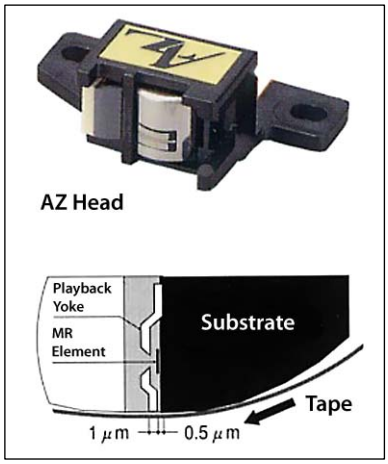


Fig. 69 – AZ magnetic resistive head (Technics).

Fig. 70 – JVC TD-SD1.

In **1997**, *Pioneer* released the *CT-S670D* hybrid cassette deck, which had a built-in *20-bit ADC/DAC* and carried out signal processing in digital form. An algorithm of a *digital noise reduction* system was developed for it, which works only during playback (similar to the previously used *DNL* filters). When using this system together with *Dolby NR*, it was possible to obtain a signal-to-noise ratio of *90 dB*. However, with the formal improvement of a number of technical specifications, this model had all the disadvantages inherent in digital signal sources and represented a transitional stage on the way to fully digital sound recording.

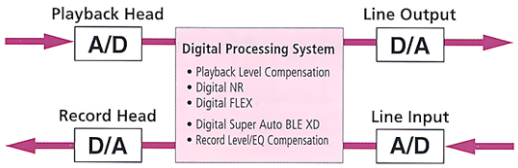
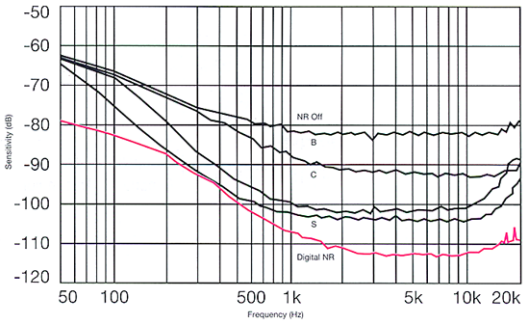


Fig. 71 – Digital NR (Pioneer).



In **1999**, *Nakamichi* resumed production of cassette decks and released the *DR-10* model. However, they did not offer anything new – this cassette deck was a simplified version of the previous *DR-2* model and was assembled in Malaysia. *Nakamichi* has not invested in the development of magnetic recording for a long time and in the **1990s** tried only to stay afloat. Production of this model will continue until the company's bankruptcy in **2002**.

In the early **2000s**, the market for compact cassettes continues to shrink and only a few manufacturers remain on it: *Maxell, Sony, SKC* and *TDK*. At the same time, only the cheapest models remain in their catalogs. The remnants of previously released high-quality cassettes are sold out in stores.

At those times, Japan remains the only market where high-quality cassette decks continue to be sold. Only here it was still possible to find interesting models and recording media, but they are gradually being discontinued and disappear from sale. The remnants of goods are sold at discounted prices. However, *A-Bex* and *TEAC* companies continue to manufacture all types of *test tapes* and *templates*.

Starting from the second half of the **2000s**, it is possible to purchase a high-quality cassette deck only on the secondary market. But manufacturers still provide service centers with original spare parts. At the same time, consumer interest in this device is reduced to a minimum. Herewith, it was possible to buy a used cassette deck inexpensively and, replacing worn parts in it, restore it to its original condition.

In the **2010s**, official service centers are running out of spare parts and consumables. The production of test tapes necessary for the correct adjustment of cassette decks is stopped. But, unlike modern digital gadget, analog equipment remains maintainable.

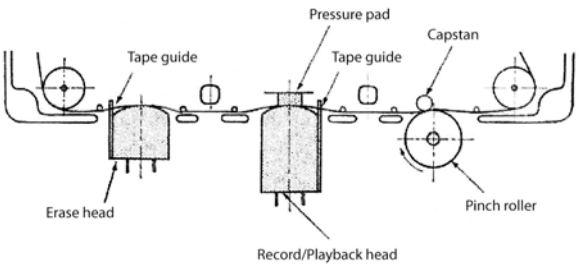
At the end of the **2010s**, prices on the secondary market for well-known models of cassette decks begin to rise. At the same time, the interest of audiophiles and collectors to cassette decks and magnetic recording in general is returning. On this wave, several companies appear that are engaged in professional restoration of analog tape recorders. In Germany, Switzerland and the USA the development and production of premium reel-to-reel tape recorders is resumed. And there is every reason to believe that the history does not end there…

APPENDIX 1. LOCATION OF MAGNETIC HEADS

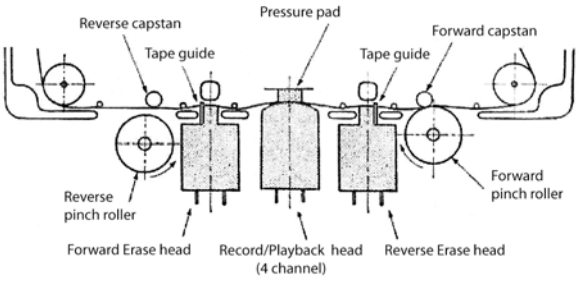
It is customary to classify tape recorders, first of all, by the number of magnetic heads. But in cassette decks, the location of the heads in the free windows of the cassette is also important. For two-head cassette decks, there is a standard location (*2*) and its variants for auto-reverse mechanisms: with a four-channel universal head (*2R*) and with a rotating block of heads (*2RR*). The design with a rotating block of heads became more widespread, since it allowed using a cheaper head, excluding two erasing heads and simplifying signal switching. However, such a design could not provide accurate alignment of the universal head for both directions of the tape movement and long-term stability of its position.

Also, models of cassette decks were created that had the auto-reverse function only in playback mode. Recording in such models was performed in one direction of the tape movement, which made it possible to simplify the design and reduce the number of magnetic heads.

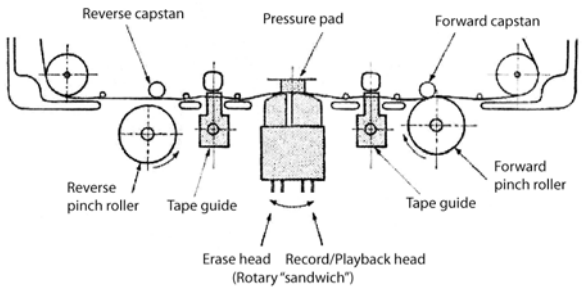
Table A1. Cassette decks with two heads



2 – Standard design



2R – Reverse design with four-channel universal head (3 heads)



2RR – Reverse design with rotating heads

The placement of three independent magnetic heads led to the appearance of non-standard locations. *Sony* in **1972** received a patent for a tape drive mechanism with closed loop dual capstans and auto-reverse, in which several such designs were proposed at once. It also patented the design of the erasing head, located in the holder of the pinch roller and combined with a tape guide.

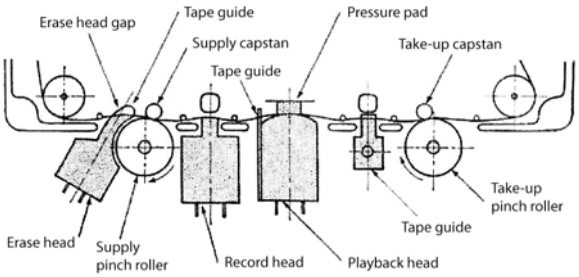
Initially, the design *(3a)* was proposed, which allows the use of a playback head of the largest possible size, which allows improving the sound quality. In **1973**, such a design was adopted by *Nakamichi*. However, there is a significant distance between the recording and playback heads, which leads to additional errors in the azimuth setting.

Later, design (*3b*) was adopted as the optimal. In the *second generation* of cassette decks, *Nakamichi* is also switching to this design. The disadvantage of this solution is the need to place two magnetic heads at once in one cassette window, which forces engineers to use a smaller playback head.

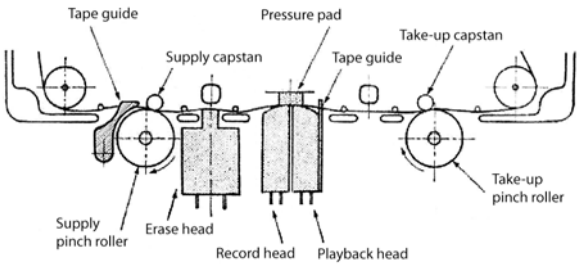
The design (*3c*) proposed by *Technics* was not widely used and soon fell out of use.

In single capstan mechanisms, a variant with a full-size erasure head (*3d*) was used.

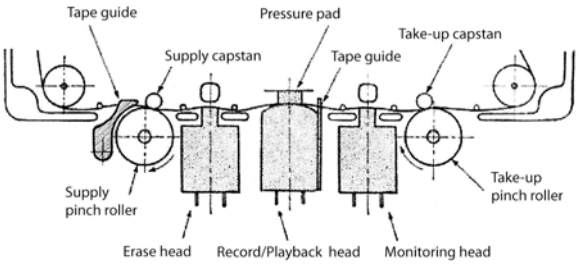
Table A2. Cassette decks with three heads



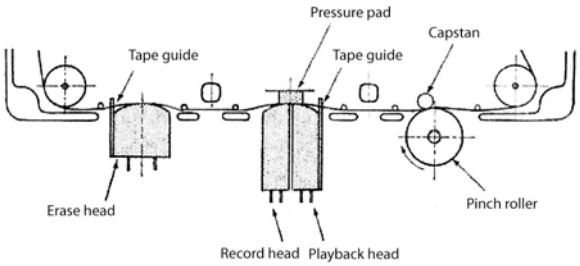
3a – Design with a large playback head



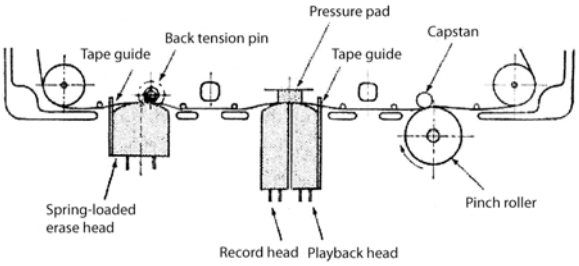
3b – Design with a compact playback head



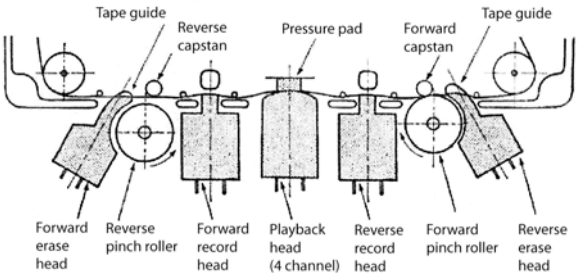
3c – Design with a monitoring head



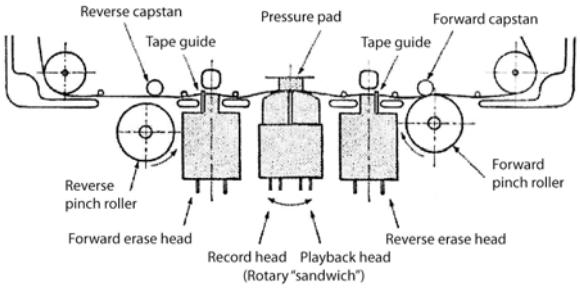
3d – Design with a single capstan



3e – Design with a closed loop and single capstan



3R – Reverse design with four-channel playback head (5 heads)



3RR – Reverse design with rotating heads (4 heads)

A number of models used a simplified mechanism with a *closed loop single capstan* (*3e*). In it, the magnetic tape is pressed by a spring-loaded erasing head to a special *back tension pin* located at the site of the supply capstan.

For tape drive mechanisms with reverse, in the same *Sony* patent of **1972**, a design with a stationary four-channel playback head, two recording heads and two erasing heads (*3R*) was proposed. However, this design turned out to be too complicated and was almost never used in

this form. In some models, a simplified version of this design was used, having a reverse mode only in playback mode.

The optimal solution for tape drive mechanisms with reverse is the placement of two rotating magnetic heads in the central window of the cassette (*3RR*). Herewith, two erasing heads were used.

Some cassette decks (for example, *Akai GX-R99* and *Nakamichi Dragon*) used a more complex version of the *3R* and *3RR* reversible designs with a *closed loop dual capstan* mechanisms. In these models, unlike the above designs, the capstans rotate in one direction.

Also, in some cassette decks, auxiliary heads were used, performing service functions (searching for music programs by pauses and monitoring the calibration signal). Sometimes, instead of such heads, the free windows of the compact cassette were used to place tape sensors that monitor the movement of the magnetic tape or its tension.

APPENDIX 2. DESIGNS OF THE TAPE TRANSPORT MECHANISM

Throughout the entire period of the existence of cassette decks, the designs of tape drive mechanisms were constantly changing. Classification of such mechanisms is usually carried out according to the number of motors used and the type of drives of the capstans and reels.

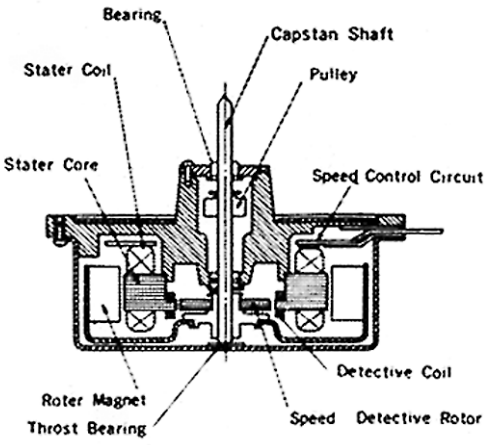


Fig. A2-1 – Slotted direct drive motor (Technics RS-279US).

The first cassette recorders used one common motor, which drove the capstan and the reel through the belts. At the same time, a *DC motor* was used, which was convenient in portable models. In desktop decks, large *AC motors* borrowed from reel-to-reel tape recorders were used. A feedback sensor was used to stabilize the rotation speed. However, this design had a high Wow & Flutter due to the influence of the cassette reels on the capstan.

When trying to raise the level of cassette technology to *Hi-Fi standards*, this drawback becomes obvious and in **1970** the *Technics* uses a *direct drive motor (DD)* in the *RS-275* cassette deck. Here, a brushless low-speed DC motor was used to drive the capstan. At the same time, a second motor was used to rewind and fast forward the tape.

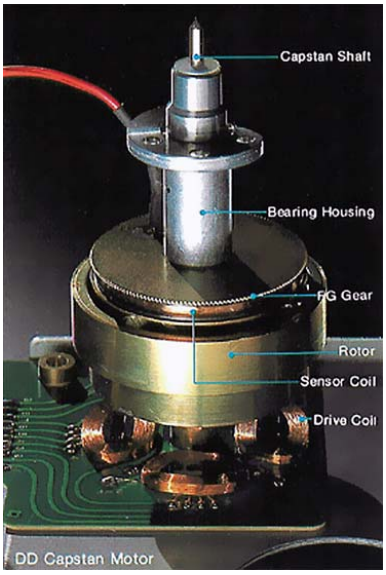


Fig. A2-2 – Slotless direct drive motor (Nakamichi ZX-9).

The use of a low-speed motor for direct drive of the capstan allows eliminating additional structural elements, increasing the stability of the tape movement, as well as reducing noise and vibration. In simpler versions of the two motors mechanism, the drive of the capstan was carried out from the collector motor through the belt.

The first brushless motors had *slot stators*. In this case, the coils are wound around the teeth of the stator. However, this design creates an uneven torque, which causes high-frequency Wow & Flutter. These high-frequency fluctuations are not reflected by the weighted average Wow & Flutter, but they worsen the sound quality.

A further development of this design is the use of a *brushless and slotless (BSL)* motor with *quartz lock servo*. In a slotless motor, the stator does not have a metal core and teeth, which provides a more uniform torque. Quartz lock servo allows you to maintain a stable speed of the tape with an accuracy of 0.2%. For the first time such a motor was used in **1978** in the *Sony TC-K80* cassette deck.

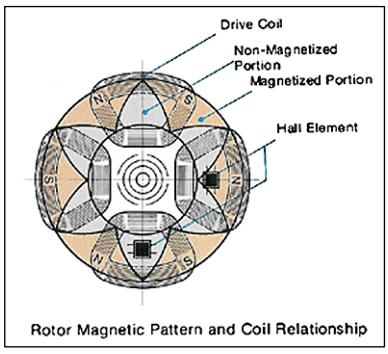


Fig. A2-3 – Rotor magnetic pattern (Nakamichi ZX-9).

For additional torque stabilization in *Nakamichi Super Linear Torque* motors, the magnetization of the rotor in the form of a star was used.

However, the increasing demands on the stability of the tape movement and competition are forcing manufacturers to develop new designs. Moreover, there were already ready-made solutions used in reel-to-reel tape recorders. So, in **1972**, the *Tandberg* used a *three-motor* tape drive mechanism with separate motors to drive the capstan and each cassette reel. This solution turns out to be very successful and is beginning to be used by some other manufacturers.

Fig. A2-4 – Slotless direct drive motor (Sony TC-K80).

Later, there is an option with the use of direct drive motors for the capstan and reels (*3DD*). For the first time such a mechanism was used in **1979** in the *Sony TC-K88* cassette deck.

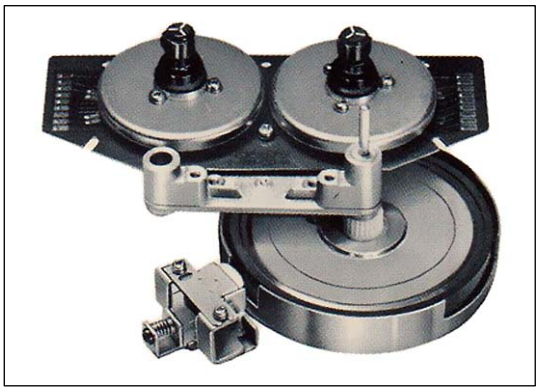


Fig. A2-5 – Tape drive mechanism with three direct drive motors (Sony TC-K88).

Each of the mechanisms discussed above can be used both with single capstan (*open loop*), as well as with dual (*closed loop*). The closed loop design provides better performance, but is more critical to the accuracy of manufacturing parts and is less stable in operation. In this regard, some manufacturers in the second half of the **1970s** used simplified versions instead of the supply capstan: a *special pin* for tensioning the tape (pressing it against the erasing head) or an *inertial roller*. There have also been attempts to use a *tape tension adjustment* system with a feedback sensor. But all of them turned out to be less effective than a closed loop dual capstan.

The top of evolution is a tape transport mechanism with a closed loop dual capstan and four direct drive motors *(4DD)*. Herewith, each of the capstans and each reels are driven by a separate motor. In the presence of *quartz lock servo*, this design also provides better reliability and long-term stability. However, such a mechanism turns out to be expensive and very few cassette decks were released with it.

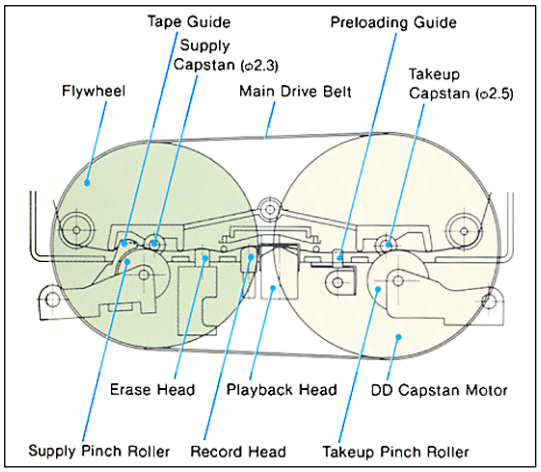


Fig. A2-6 – Asymmetrical tape drive mechanism with diffused resonances (Nakamichi).

At the end of the **1970s**, *asymmetrical tape transport* mechanisms appeared, having capstans, flywheels and pinch rollers of different diameters. The rotation speed of these parts in such mechanisms is slightly different, which allows you to get rid of resonant phenomena and further Wow & Flutter reduce.

In the early **1980s**, manufacturers of cassette decks began to use *Silent* tape drive mechanisms. In such designs, the movement of magnetic heads and pinch rollers is carried out not by solenoids (as was done earlier), but by a program drum driven by a capstan or by a service motor. In addition to a quieter mode switching, such a mechanism ensures smooth movement of the head unit, which increases the long-term stability of the parameters.

Subsequently, marketers used the presence of such an auxiliary motor in advertising materials. Herewith, the popular two motor tape drive mechanism with a service motor (used only for switching operating modes) was presented as a three motor.

Later, separate service motors were also used to drive the cassette door and other service functions. Thus, cassette decks with 4, 5 and even 6 motors appeared. But this is only a publicity stunt, since such motors are not related to the movement of the tape and have no effect on Wow & Flutter.

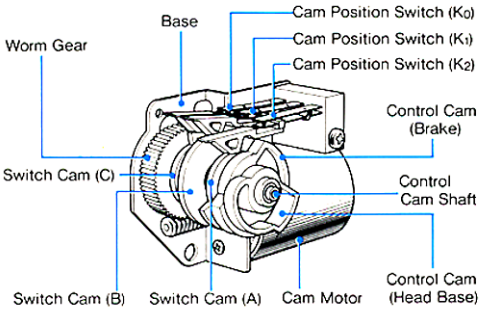


Fig. A2-7 – Service motor with cam drive (Nakamichi).

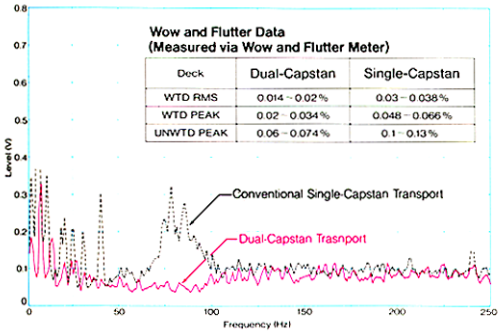


Fig. A2-8 – Comparison of the Wow & Flutter spectrum of mechanisms with single and dual capstans (Nakamichi).

APPENDIX 3. PORTABLE MODELS

In the early **1970s**, field sound recording became popular. And the compact cassette turned out to be a very convenient medium for this. This direction is most widespread in Japan. In addition, portable cassette recorders are beginning to be actively used in professional reporting.

In **1971**, *Uher* produced the first portable stereo cassette deck *CR-124*, equipped with a tape drive mechanism with auto-reverse.

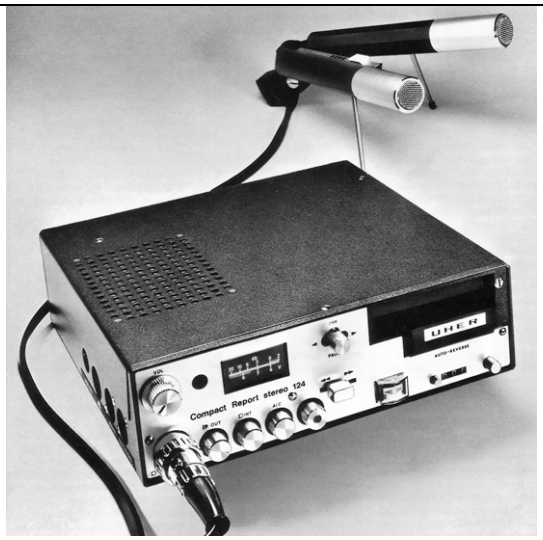
In **1973**, *Sony* released a portable stereo cassette deck *TC-152SD*, which received the nickname *Cassette Densuke* in Japan. This model provided high recording quality, had a fairly compact size and could be used in a stationary cassette deck mode.

In **1974**, *Nakamichi* developed a portable model *550* with the ability to calibrate the recording amplifier.

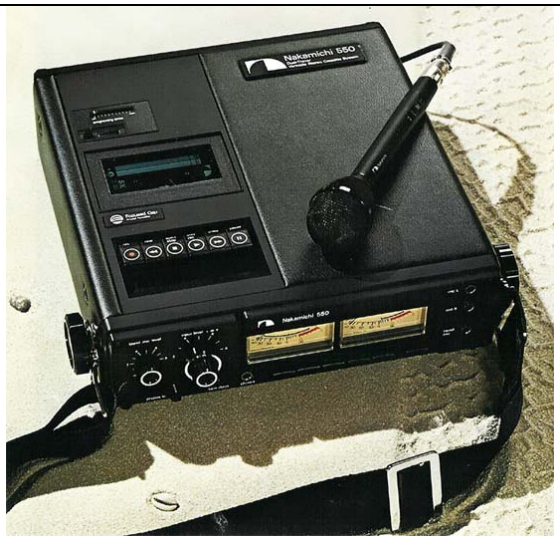
In **1976**, two portable models with a *direct drive motor* appeared at once: *Sony TC-164SD* and *TEAC PC-10*.

In **1977**, portable models with *3 heads* appeared: *Lo-D D-150, Technics RS-686DS* and *Aurex PC-4280*. Herewith, the *Lo-D D-150* model becomes the first and only portable cassette deck with a *closed loop dual capstan* mechanism, and the *Aurex PC-4280* model used a *stabilizing roller* on a ruby bearing.

Table A2. Portable cassette recorders



Uher 124 (1971)



Nakamichi 550 (1974)

Sony TC-152SD (1973)

Sony TC-164SD (1976)

TEAC PC-10 (1976)

Lo-D D-150 (1977)

Technics RS-686DS (1977)

Aurex PC-4280 (1977)

Sony TC-D5 (1978)

Sony WM-D6 (1982)

Uher CR-160AV (1984)

Marantz PMD430 (1984)

Sony also continues to develop this direction and the *TC-D5* model, released in **1978**, becomes the standard of a reporter's tape recorder. Various versions of this device will be produced for more than 25 years. The manufacturing quality and reliability of this cassette recorder proved to be out of competition. This model used a unique system with a rubberized metal disc as the drive of the capstan.

In the early **1980s**, interest in field sound recording was declining and further development of this direction was associated with the creation of a compact *Walkman* player by *Sony* in **1979** and the development of recording models based on it. The most successful of them is the *WM-D6*, which went through several upgrades and was produced from **1982** to **2002**. Despite the really pocket size and light weight, this recorder had excellent equipment and provided

high-quality recording in any conditions. The *WM-D6C* version, which appeared in **1984**, becomes the first portable model equipped with a *Dolby C* noise reduction system.

The *Uher CR-160* cassette recorder, which was produced at the same time, had much larger dimensions and weight and could not directly compete with the compact models mentioned above.

After that, the only competitor of *Sony* in the market of professional cassette recorders was only the *Marantz PMD430*, which had *three heads*, was equipped with a *dbx II* noise reduction system and was produced from **1984** to **2003**.

APPENDIX 4. ELCASET

It is necessary to consider the history of the compact cassette taking into account the influence of other competing formats. And if *DC International* and *8-track cartridges* have finally become a thing of the past, then the *Unisette* format developed by *BASF* in **1974** was taken as the basis for the new *Elcaset* format proposed by *Sony, TEAC* and *Matsushita*. Using the tape width of 6.35 mm familiar to reel-to-reel tape recorders and the tape speed of 9.53 cm/s, this format offered incomparably better sound quality. And this quality was achieved without using the tricks that manufacturers of compact cassette decks had to go to. In addition, the *Elcaset* format made it possible to completely isolate the tape movement path from the cassette body, which excluded its influence on Wow & Flutter and opened up more opportunities for the engineers of the tape drive mechanism.

In **1976**, prototypes of *Elcaset* decks were presented, and then the first serial samples appeared. Later, *Aiwa* and *JVC* announce joining this project. But *Sony* will have the widest model range, including a portable recorder with direct drive. Its models will also be produced under other brands: *Hitachi D-9000* (based on *Sony EL-7*), *Mediatech M950* (*Sony EL-5*) and *Wega E-4590* (*Sony EL-7*).

Table A4. Elcaset deck

Sony EL-7 (1976)

Teac AL-700 (1976)

Technics RS-7500US (1977)

JVC LD-777 (1977)

However, by this time, advances in the development of compact cassette recorders had significantly reduced the gap between them and the capabilities of the *Elcaset* format. As a result, the mass consumer preferred a more convenient and widespread compact cassette format, and those who needed better recording quality continued to use the reel-to-reel tape recorders. In addition, there was practically no market for pre-recorded music programs on the *Elcaset* medium.

Thus, in **1979**, it was decided that the further development of this format was unprofitable and the production of *Elcaset* decks was discontinued. After that, the companies involved in this project focused all their efforts on the format compact cassettes, which served as an additional incentive for its development. For example, while participating in the *Elcaset* project, *Sony* did not develop cassette decks with 3 heads and a closed loop dual capstan, so as not to create internal competition. Although previously such models were in its production program. And after the closure of the *Elcaset* project, the *TC-K75* cassette deck immediately appears.

Fig. A4-1 – Sony EL-D8.
The only portable Elcaset deck.

APPENDIX 5. NAKAMICHI PHENOMENON

Among the manufacturers of cassette deck, one company can be singled out, which has become legendary and has earned the right to go down in history thanks to this format. Despite the fact that *Nakamichi* had existed since **1948**, engaged in the manufacture of electronic components and *OEM* production of tape recorders, it gained real fame only in **1973**, after it bet on a compact cassette.

The beginning of the **1970s** was an ideal time for the development of cassette technology. On the one hand, there was an interest of the mass consumer in a convenient small-sized recording medium. On the other hand, by this time there is a technical opportunity to provide a recording quality on a compact cassette that meets the standards of *Hi-Fi* equipment.

Engaged in the *OEM* production of cassette decks for *Advent* and *harman/kardon* companies, *Nakamichi* understands that success in the development of new magnetic tapes in combination with the *Dolby B* noise reduction system can bring a compact cassette to a new qualitative level. With all the necessary technologies at its disposal, *Nakamichi* begins production of cassette decks under its own name.

At the same time, from the very beginning, a bet was placed on models of the highest price range. It was in this segment that it was possible to offer cassette decks, which differed sharply in quality from all existing ones on the market. And the bet on quality turned out to be correct. Throughout the entire production period, *Nakamichi* cassette decks occupied the upper price range and maintained the legend of their exclusivity.

But behind this legend were real achievements and years of hard work. First of all, it is work in all promising areas and exceptional attention to detail. Starting from the development of unique magnetic heads and ending with the creation of their own standards and test tapes. All this was provided by a research center that dealt with theoretical and applied issues of magnetic recording. In **1977**, its own concert hall was opened in which recordings of classical music phonograms were made.

New developments really went in all directions: own super linear torque direct drive motors, recording amplifier equalization, a reference level of tape magnetization, a noise reduction system (together with *Telefunken*), a calibration system and even its own "correct" azimuth. In the future, some of these developments had to be abandoned (due to the tightening of international standards and the emergence of new competing systems). As a result, the difference in the sound of *Nakamichi* models and other cassette decks begins to shrink.

However, the real masterpiece are the *Cristalloy* heads and the asymmetrical tape drive mechanism with diffused resonances. An important feature of *Nakamichi* cassette decks is a unique mount base for discrete magnetic heads with independent adjustment and stoppers. This system is used in all models and provides critical parameter stability and extensive adjustment capability. At the same time, *Nakamichi's* basic circuit solutions are quite ordinary. This fact proves once again that the main contribution to the sound of cassette decks is made by magnetic heads and recording equalization.

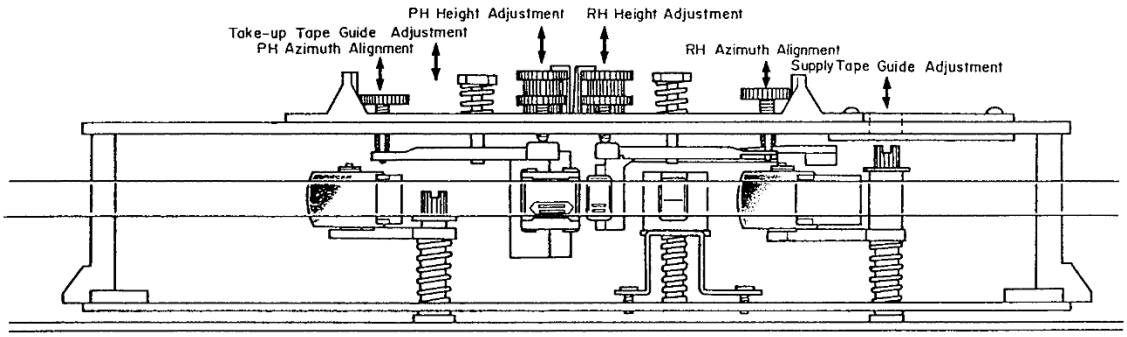


Fig. A5-1 – Head mount base.

Nakamichi has always offered an extremely technocratic approach. The front panels of their cassette decks were replete with various controls and knobs, offering the user more options for customization. For example, many models had independent switches type of tape and *EQ*. With the seeming inconvenience, this made it possible to record CrO_2 tapes with a *EQ* of *120 µs* and get an additional margin for overload capacity. Advertising brochures are also very detailed and full of technical details, which fundamentally distinguished them from most competitors.

In total, it is customary to distinguish three generations of *Nakamichi* tape drive mechanisms and, accordingly, cassette decks (only models with three heads are listed below):

First generation (massive, maximally reliable and durable mechanism with a minimum number of plastic parts, electromagnetic control, hydraulic compensators, powerful motors):

- 1000 Tri Tracer (1973-1977)
- 1000II (1977-1980)
- 700 Tri Tracer (1973-1977)
- 700II (1977-1980)

Second generation ("silent" mechanism with motor driven cam, significantly smaller weight and dimensions, *Cristalloy* heads, asymmetric design, tape pad lifter, direct drive is possible):

- 680ZX (1979-1980)
- 680 (1979-1981)
- 670ZX (1979-1980)
- 660ZX (1979-1981)
- 582Z (1979-1981)
- 582 (1979-1981)
- 581 (1979-1981)
- 482Z (1979-1982)
- 482 (1979-1982)
- 481 (1979-1981)
- 1000ZXL (1980-1984)
- 700ZXL (1980-1982)
- 682ZX (1980-1981)
- 1000ZXL Limited (1981-1984)
- 700ZXE (1981-1982)
- 681ZX (1981-1982)
- 581Z (1981-1982)
- 481Z (1981-1982)
- ZX-7 (1981-1984)
- LX-5 (1981-1984)
- Dragon (1982-1993)
- ZX-9 (1982-1985)
- RX-505 (1984-1993)

Third generation (a simplified version of the "silent" mechanism, an abundance of plastic parts, reduced service life, a new generation of *Cristalloy* heads, asymmetric design, tape pad lifter, direct drive is possible, manufactured by *Sankyo*):

- BX-300 (1984-1987)
- MR-1 (1986-1994)
- CR-7 (1986-1993)
- CR-5 (1986-1990)
- CR-4 (1987-1990)
- CR-3 (1987-1990)
- Cassette Deck 1 (1990-1992)
- Cassette Deck 1.5 (1991-1992)
- DR-1 (1992-1996)
- DR-2 (1992-1996)
- DR-10 (1999-2002)

Nakamichi was the first to offer many innovative solutions and massively implemented them into its products (3 heads, azimuth calibration, *Cristalloy* heads, asymmetric mechanism, *NAAC*). But even when they were not the first in the development of technologies, they became leaders in their application (dual capstan, discrete heads, tape pad lifter, *UDAR*). *Nakamichi's* technological advantage persisted until the **mid-1980s**. And this confirms the fact that even after the termination of investments, they remained among the leaders for another 10 years, using only old developments and a well-deserved reputation.

Unfortunately, in the **mid-1980s**, the company decided to focus on digital technology and stopped research in the field of analog magnetic recording. Promising technical solutions appearing at that time (*Dolby HX Pro*, *Dolby S*, cassette stabilizer, high frequency bias etc.) are not used in new models. Moreover, their model range is noticeably simplified. And this contradicts the original principles of the company – to be in the foreground and use all available opportunities. As a result, competitors are starting to catch up and unconditional leadership has been lost.

An attempt to transfer success to the field of actively developing digital technology also failed. Competition in the audio market is intensifying at those time. Many companies are moving their production facilities to Malaysia and Taiwan. As a result of reduced demand, in **1996** *Nakamichi* discontinued the production of cassette decks and switched to the production of equipment for home theaters. However, high-quality *Nakamichi* cassette decks are still favorites in the secondary audio equipment market.

APPENDIX 6. SOME STATISTICS

Below is a table that allows you to compare manufacturers of cassette decks by the presence of key functions in their products. The cells indicate the number of models equipped with this function. The information is collected from the description of *1318 models* produced from **1970** to **2000** and included in the Handbook of Cassette decks.

Manufacturer	Discrete 3 head	Azimuth adjust.	3 direct drive	Two speed	dbx	Dolby S	Portable	Elcaset	Total
Aiwa (Japan)	-	1	-	-	3	4	-	-	53
Akai (Japan)	3		-	-	10	-	-	-	78
Alpine (Japan)	-	-	-	-	-	-	-	-	19
Arcam (UK)	-	-	-	-	-	1	-	-	1
ASC (Germany)	-	-	4	-	-	-	-	-	4
B&O (Denmark)	-	-	-	-	-	-	-	-	16
BIC (USA)	-	-	-	5	-	-	-	-	5
Braun (Germany)	-	-	-	1	-	-	-	-	7
Denon (Japan)	-	-	-	-	-	2	-	-	52
Dual (Germany)	-	-	-	3	-	-	-	-	24
Eumig (Austria)	-	-	-	-	-	-	-	-	2
Grundig Germany)	-	-	-	-	-	-	-	-	14
harman/kardon (USA)	-	-	-	-	-	3	-	-	26
Hitachi (Japan)	-	-	-	-	-	-	1	1	52
JVC (Japan)	10	-	-	-	-	-	4	1	72
Kenwood (Japan)	-	-	-	-	-	5	-	-	44
Kyocera (Japan)	-	-	-	-	-	-	-	-	4
Lenco (Switzerland)	1	-	-	-	-	-	-	-	1
Luxman (Japan)	3	2	-	-	4	-	-	-	30
Marantz (USA / Japan)	3	1	-	10	12	1	4	-	66
Mayak (USSR)	-	-	-	-	-	-	-	-	4
Mitsubishi (Japan)	1	1	-	-	-	-	-	-	16
NAD (Canada)	-	-	-	-	-	-	-	-	13
Nakamichi (Japan)	39	21	-	2	-	-	3	-	64
NEAL (UK)	-	-	-	-	-	-	-	-	7
Onkyo (Japan)	-	-	-	-	1	3	-	-	45
Philips (Holland)	-	-	-	-	-	-	2	-	27
Pioneer (Japan)	-	-	6	-	3	14	-	-	79
Revox (Switzerland)	2	-	8	-	-	-	-	-	13
Sansui (Japan)	-	-	-	-	1	-	-	-	29
Sharp (Japan)	-	-	-	-	-	-	-	-	19
Sony (Japan)	19	1	2	1	-	20	12	5	122
Tandberg (Norway)	7	8	-	-	-	-	-	-	14
Tascam (Japan)	2	-	-	2	-	-	-	-	13
TEAC (Japan)	3	-	3	3	28	6	1	1	93
Technics (Japan)	3	-	-	-	17	-	2	2	83
Telefunken (Germany)	-	-	-	1	-	-	-	-	7
Thorens (Germany)	-	-	-	-	-	-	-	-	1
Toshiba (Japan)	1	1	-	-	-	-	1	-	18
Uher (Germany)	-	-	-	1	-	-	6	-	20
Vector Research (USA)	-	-	-	-	-	-	-	-	6
Vilma (USSR)	-	-	-	-	-	-	-	-	7
Wega (USSR)	-	-	1	-	-	-	-	-	1
Yamaha (Japan)	-	-	-	-	14	3	-	-	46
	97	**36**	**24**	**29**	**93**	**62**	**36**	**10**	**1318**

The distribution of cassette decks by the countries in which the manufacturing companies were registered can be represented from the following diagram:

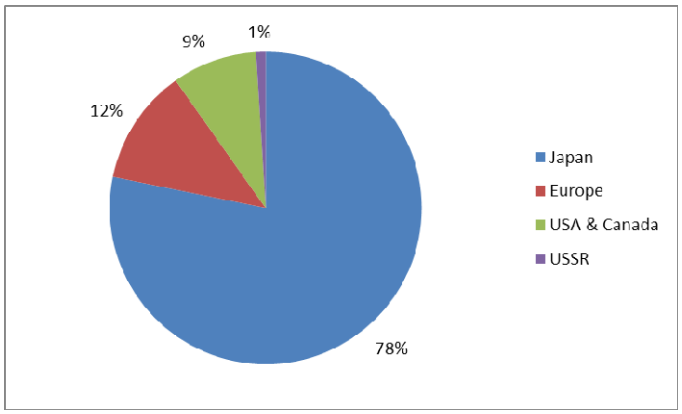


Fig. A6-1 – Geography of production of cassette decks.

It was also planned to include in this section a selection of models that fall into the *TOP-10* according to the main specifications (frequency response, Wow & Flutter, signal-to-noise ratio, weight and price). But this idea had to be abandoned, since the available data are of an advertising nature and was obtained at different times on different magnetic tapes. In addition, the measurement methods used in different countries differ.

Therefore, for a real rating, it is necessary to perform an objective comparison of all models under the same conditions. At the same time, all devices must be adjustment on the same equipment and be in perfect technical condition. It is almost impossible to implement all this in today's conditions, and it makes no sense to use disparate data.

In addition, cassette decks that have the best data on any indicator have already been noted in this article. At the same time, the real assessment of the sound quality cannot be determined by the main specifications and still remains very subjective. This factor becomes especially noticeable when it comes to analog audio technology. For more information, see my article The Apology of Magnetic Recording.

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