PIONEER

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BASIC LASER DISC TECHNOLOGY GUIDE

PIONEER Electronics has long been a leader in Laser Optical technology and maintains that position to this day. Since the introduction of the first Laser Disc player in 1979 to the current line of Combination Laser Disc players PIONEER continues its technical advances to provide the best in state-of-the-art consumer electronics.

This Laser Disc guide will acquaint you with the history and manufacturing methods of laser technology as well as a basic background of the optical and servo systems that control hardware operations. The Pioneer Technical Seminar series will address model specific laser design, troubleshooting and service techniques.

PIONEER VIDEO DISC HISTORY

1979 - PIONEER produces it's first Laser Disc player, model PR-7820. Introduced by DISCOVISION, a joint venture between PIONEER, IBM and MCA, the initial uses were for corporate training, as sales tools and in educational centers.

1980 - PIONEER introduces its first consumer player, VP-1000. Two competing video disc systems, the Capacitance Electronic Disc (CED) and Video High Density (VHD) are also on the market, though these used capacitive stylus systems rather than laser optics.

1982 - PIONEER's second generation of Laser Disc players contain electronics of reduced size and complexity. Commercial video games using the player are introduced.

1984 - The first PIONEER Laser Disc player with a solid state laser, model LD-700, is sold. Model CLD-900 is the first PIONEER consumer model that plays both Compact Discs and Laser Discs. The first PIONEER Compact Disc players, both home and car, are produced.

1987 - Continued improvements such as reduced laser pick-up size are found in PIONEER Laser Disc players. CLD-1010 combination player is the first to play Compact Discs with Video (CDV's).

1988 - Model LD-W1 is the first PIONEER that will play both sides of two Laser Discs continuously._ The new Opto-Electric IC laser pickup is introduced. CLD-3030 will play all LD and CD formats.

1989 - The CLD-1070 is the first combination player priced under $600. CLD-3070 and 2070 have Alpha-Turn mechanism, allowing play of both sides of a Laser Disc without removing the disc from the player.

VIDEO DISC SYSTEM

A Video Disc system is comprised of laser-optical video discs (Laser Discs) and a video disc player. Combined with a TV set or monitor TV and an audio system it provides audio/visual programs of the highest quality possible including digital sound comparable to Compact Disc.

Laser Disc

The laser optical video disc is an 8" or 12" plastic disc that contains encoded video, audio and control information on one or both sides. The information is recorded by a laser beam in the form of spirally aligned rows of microscopic indentations or pits starting from the inner track and terminating at the outer track. The disc provides a superb picture and stereo sound almost indefinitely due to the lack of wear from the non-contact laser optic playback system. Fine diameter laser beams allow high density recording of audio/video signals on the order of 140 billion pits per side (Fig. 1 and 2).

There are three Laser Disc formats: Constant Angular Velocity(CAV); Constant Linear Velocity (CLV); Constant Angular Acceleration (CAA), which is now normally referred to as a CLV disc as well. More on these later.

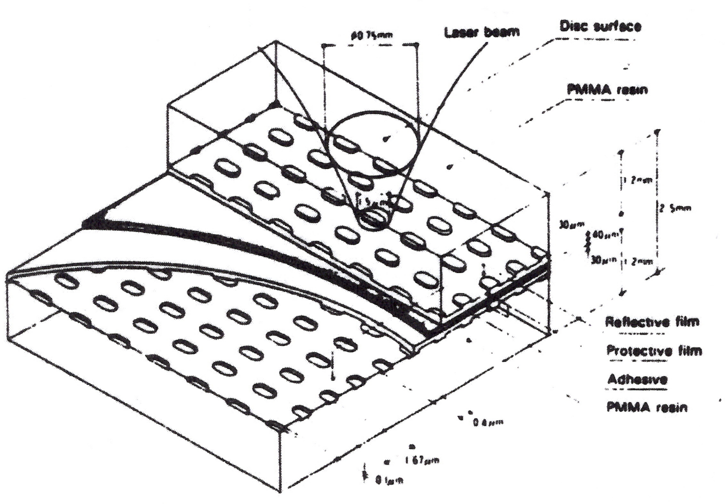
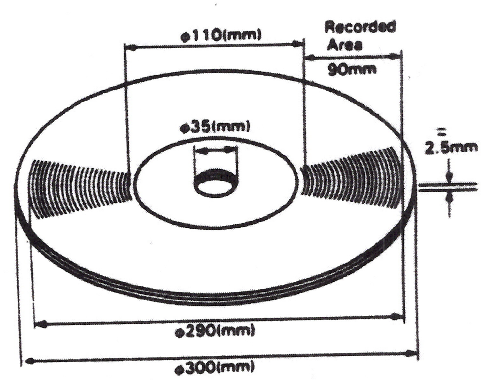


Fig. 1 Cross-section of Laser Disc



Diameter	300mm
Thickness	2.5mm
Revolution (CAV)	1800rpm
Linear velocity (CLV)	About 11m/sec
Track pitch	1.67μm
Up/down fluttering	±1.025mm max
Fluttering acceleration	10G max
Eccentricity	80μm max
Track meandering	2G max

Fig. 2 Laser Disc Specifications

Laser Disc Player

Employing a solid state diode laser, the player projects the laser beam onto the rotating disc. When the light is focused on the non-pitted areas of the disc nearly all of the light is reflected back through the lens. Laser light that hits the raised pits of the disc is nearly all diffracted away from the lens.

This variation in brightness is transformed to electronic signals that are divided into the video, audio and control signals. These signals are processed and finally converted into picture and sound. Control signals are required because the the player must compensate for eccentricities or flaws that exist within nearly every disc. These include uneven center holes, disc warp and uneven track-to-track spacing. These flaws require servo mechanisms within the player to adjust and read tracks accurately. These servos will be discussed in detail later in the manual.

Elements of a Laser Disc Player (Fig. 3)

- An optical pickup
- Six servo systems
- A time base corrector
- Demodulator circuits to reproduce original sound and picture
- Microprocessor control of servo and other logic systems
- A power supply circuit to supply voltages to all assemblies
- Mechanical blocks to drive and house the system

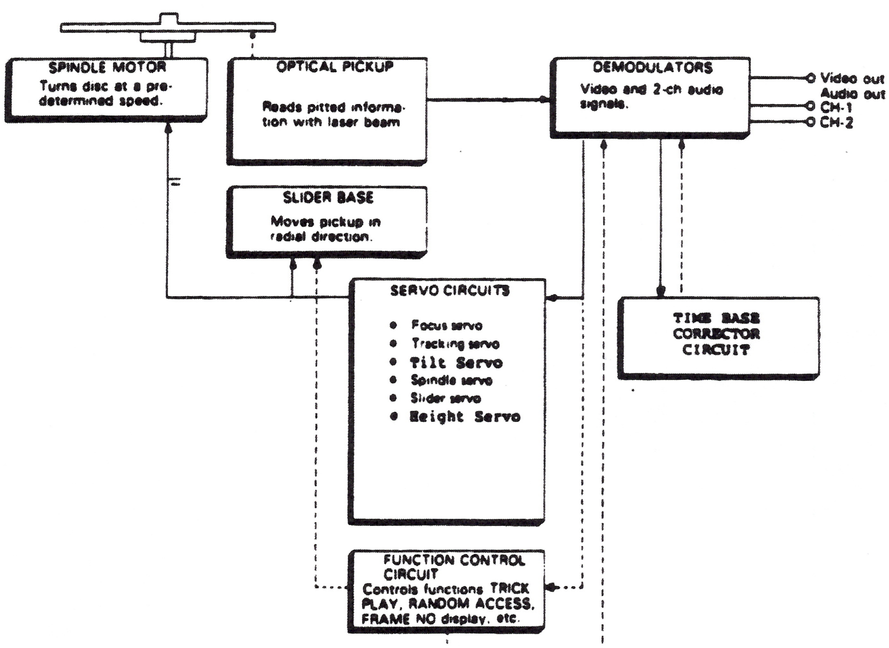


Fig. 3 LD Player Block Diagram

LASER DISC MANUFACTURING

Signal Processing

The video and analog audio signals from movie film or professional videotape undergo independent frequency modulation. The center frequency of the modulated video signal is 8.5 MHz with frequency deviation of ± 1.7MHz. The modulated analog audio signals are 2.3MHz (Channel 1) and 2.8MHz (Channel 2) with frequency deviation of ± 100KHz. Fig. 4 shows the frequency spectrum of a Laser Disc with analog audio.

In 1984 a technique was devised for adding two channels of digital audio to Laser Discs while retaining the two existing analog channels. Fig. 5 illustrates the frequency spectrum of a Laser Disc signal that contains digital audio. The area between 0-2MHz where the 2nd sideband was located previously has been reallocated to carry the digital audio signals.

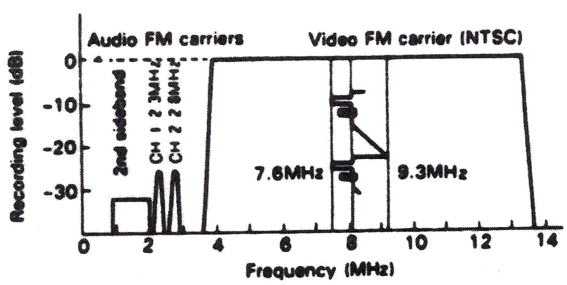


Fig. 4 Freq. Spectrum of Laser Disc without Digital Audio

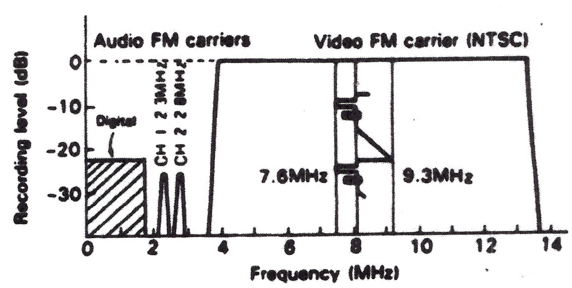


Fig. 5 Freq. Spectrum of Laser Disc with Digital Audio

The frequency modulated signals are mixed with the digital audio and are amplitude limited and shaped into squarewaves. The frequency variation of the pulses and that of the duty factor represent video information and audio information respectively.

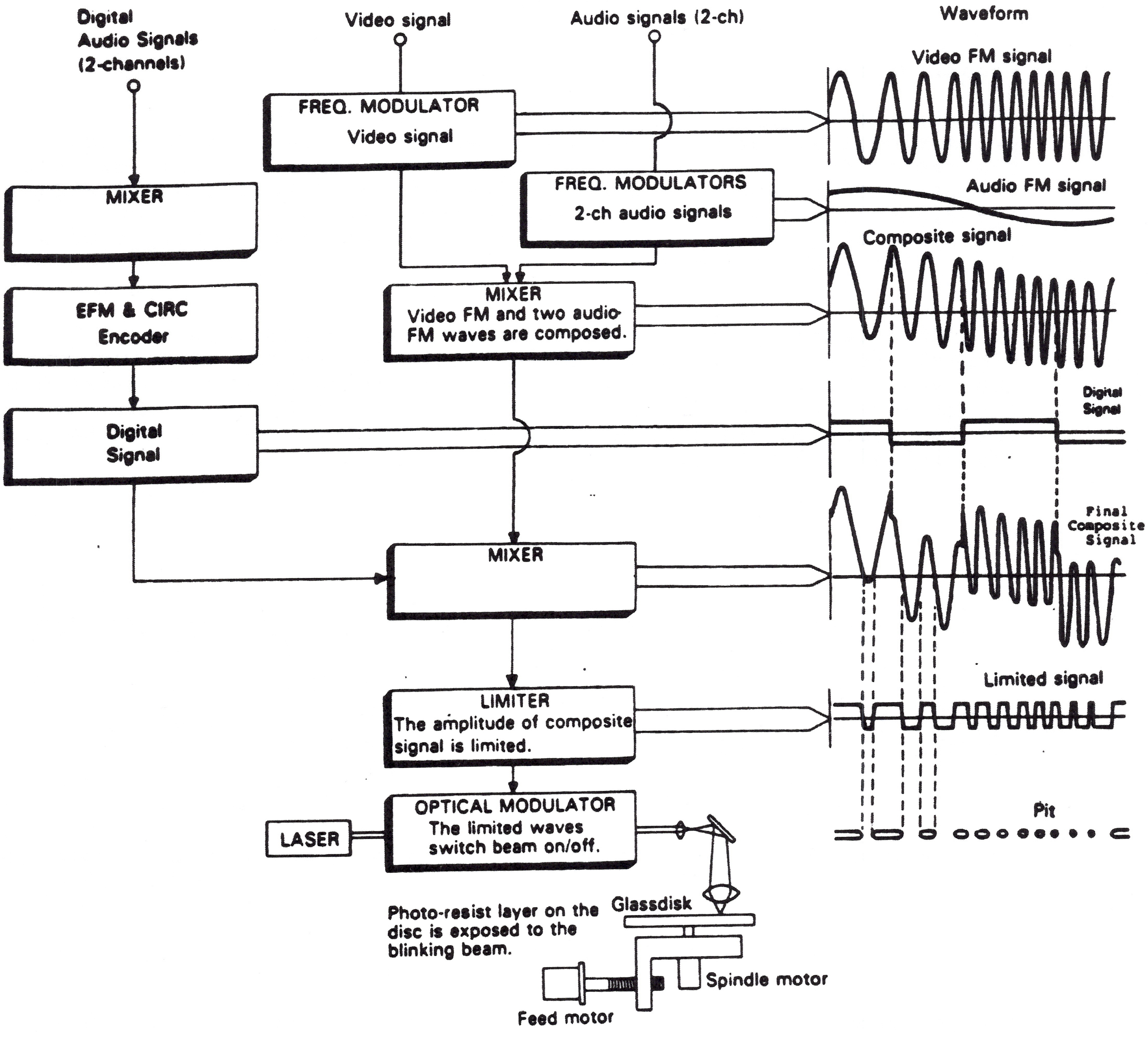


Fig. 6 Laser Disc Signal Processing

Mastering

During the mastering and replication of Laser Discs the need for cleanliness is paramount. The pit diameter of 0.4µm means that any speck of dust that contaminates a disc could render it useless. Therefore clean rooms are employed in all phases of Laser Disc manufacturing to insure the highest quality level.

The Laser Disc mastering process begins with a glass disc that is 35cm in diameter and 1cm in thickness that is precisely polished, washed supersonically and evenly coated with photoresist (a compound that is light sensitive). This disc is loaded on a real time disc cutter. The squarewaves of the composite signal are applied to an optical modulator which switches the high powered mastering laser beam on and off. The modulated beam is projected onto the disc photoresist layer 55mm off the disc center and outward in a spiral pattern. Track-to-track spacing or pitch is 1.67 um.

The photoresist layer is developed to reveal the pits caused by laser exposure. A thin layer of nickel is deposited on the glass mastering disc to allow conduction during plating, which takes several hours. The metal stamper is then separated from the glass master and inspected for quality by playing the disc (Fig. 7).

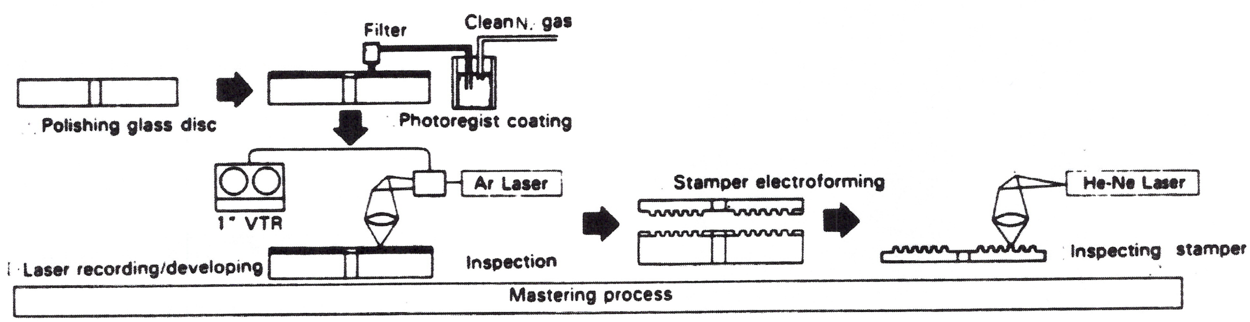
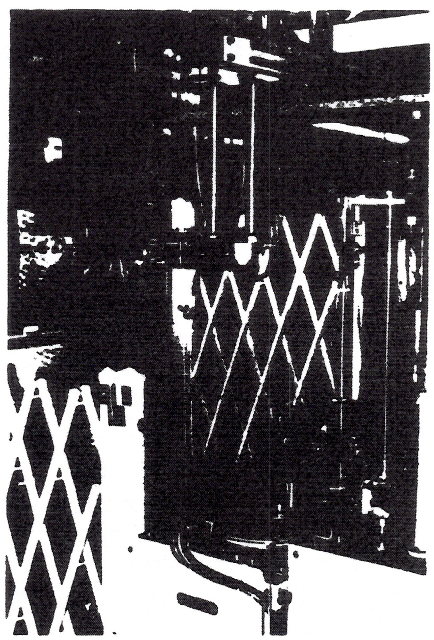


Fig. 7 Laser Disc Mastering

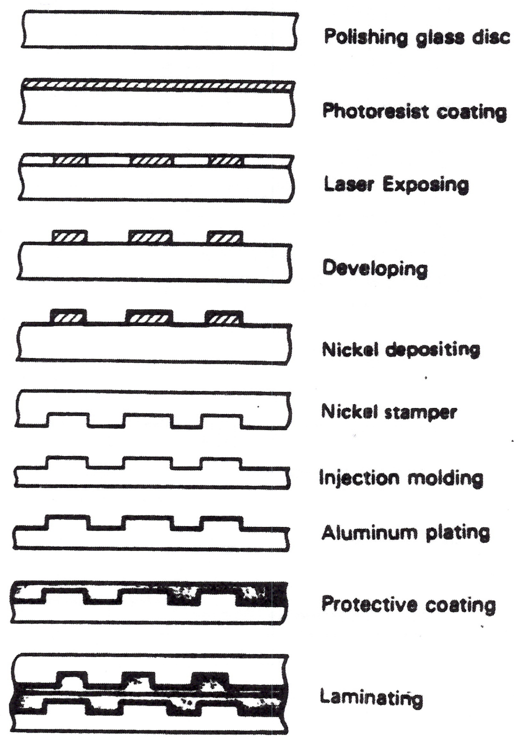
Replication

The stamper is conveyed to a replicating line and installed on an injection molding machine. Discs are produced by injecting melted transparent acrylic resin (PMMA) into a metal mold and allowing it to cool till set. Sides 1 and 2 of a Laser Disc are molded separately.

The transparent molded disc is then sent to the aluminum vapor depositing line where a reflective aluminum film is applied to the pitted surface of the disc. Protective resin is coated on the pitted aluminum surface (Fig. 8). The dynamic weights of Sides 1 and 2 are measured and the discs are precisely trimmed. Both sides are then laminated together with the recorded surface inside, the heavy area of Side 1 matched with the light area of Side 2 to assist in cancelling dynamic imbalances. The completed discs are checked again for dust or scratches, packaged and boxed for shipment.



Injection molder



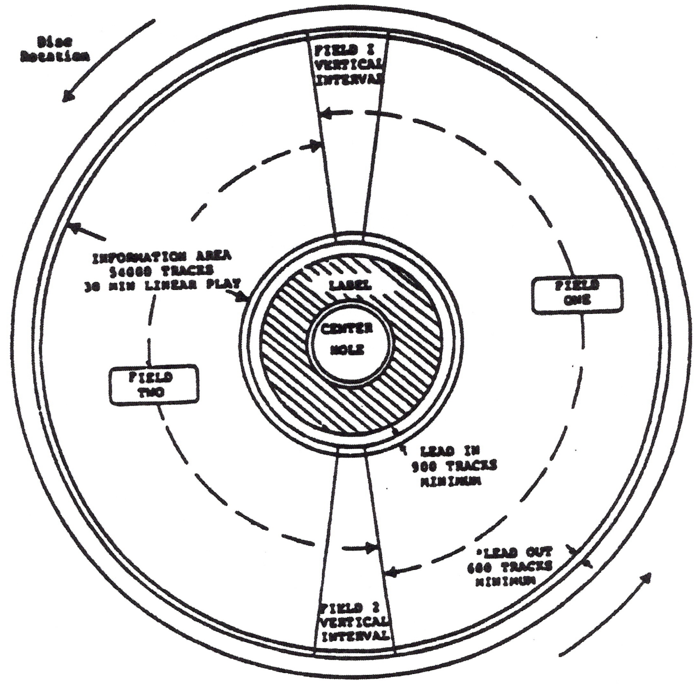
Manufacturing steps of LD

Fig. 8 Laser Disc Replication and Mastering

LASER DISC FORMATS

CAV (Standard Play) Disc

The CAV (Constant Angular Velocity) disc is played at a constant rotation speed of 1800 rpm. Each single rotation contains the information of one still picture consisting of two fields with a total of 54,000 frames per disc side. Each of these frames is assigned a number from 1 to 54,000 and separate chapter numbers are encoded on the discs. Horizontal blanking and synchronizing signals are aligned into two narrow radial stripes on the disk. The vertical blanking and synchronizing signals, as well as control signals, are contained in the two wide stripes lying opposite each other (Fig. 9). With one picture per revolution of the disc random access and trick play such as Still, Step and Multiple-Speed play is possible. Maximum playing time is 30 minutes per side.



*LEADOUT OCCURS AT THE END OF PRODUCTION MATERIAL

Fig. 9 Constant Angular Velocity (CAV) Information Layout

CLV (Constant Linear Velocity) Disc

A constant linear velocity of 11m/sec with constant relative pit speed can be achieved by a gradual slowing of the rotation speed from 1800rpm to 600rpm as the track radius increases (recall that the disc is played from the inside out). At this speed one frame is recorded on the innermost track with three frames on the outermost (Fig. 10). A CLV disc therefore has twice as much information and twice the playing time as a CAV disc (up to one hour per side). Though this format is preferable for movies due to it's extended playing time, trick play is difficult and requires digital video memory circuitry.

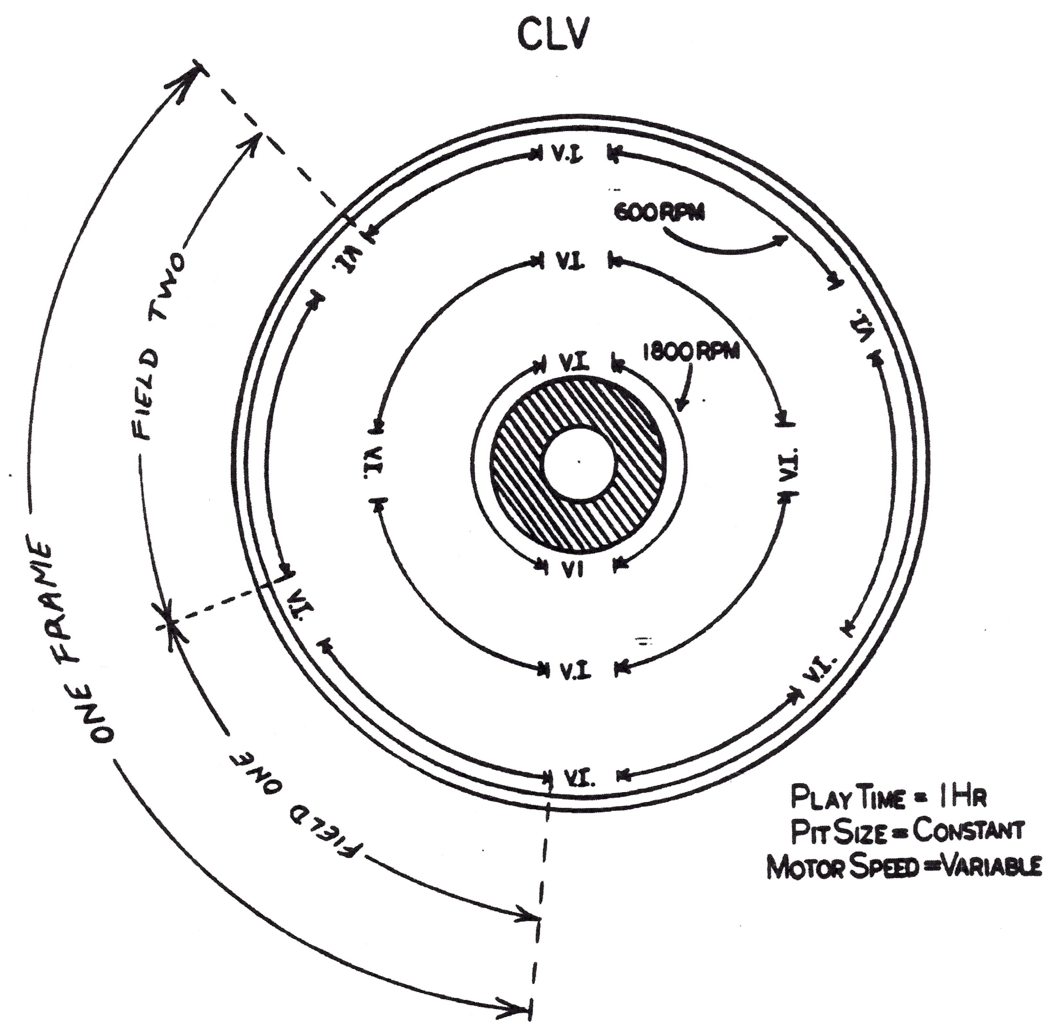


Fig. 10 Constant Linear Velocity (CLV) Data Layout

CAA (Constant Angular Acceleration) Disc

One serious problem that effected early CLV discs was interference between adjacent tracks that resulted in crosstalk, appearing as a greyish vertical line through the video. Due to imperfections in the disc like warping, incorrect centering or uneven track-to-track spacing the beam can sometimes read information from an adjacent track. If while reading the video of the correct track some of the horizontal sync pulse of the adjacent track is read as well, crosstal will result (Fig. 11).

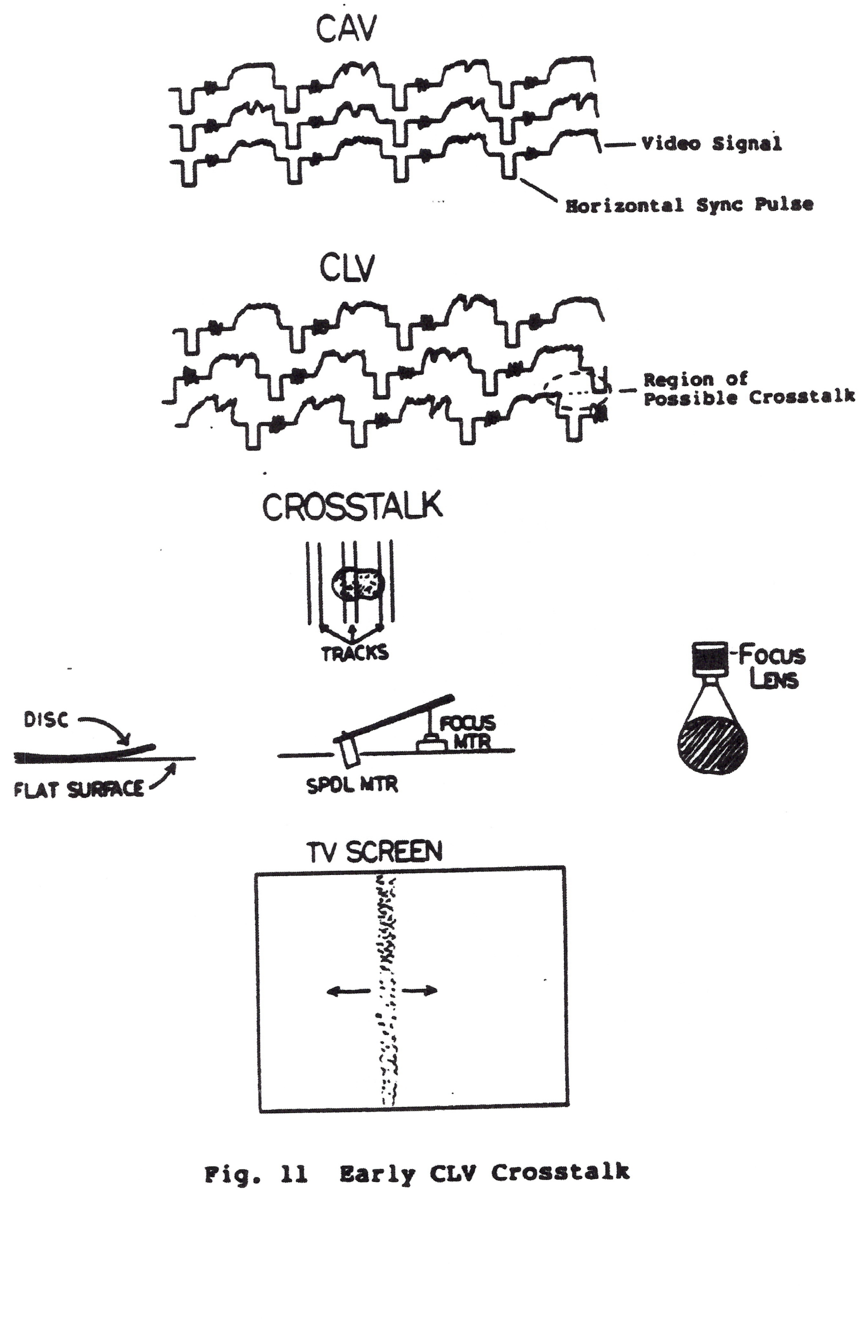
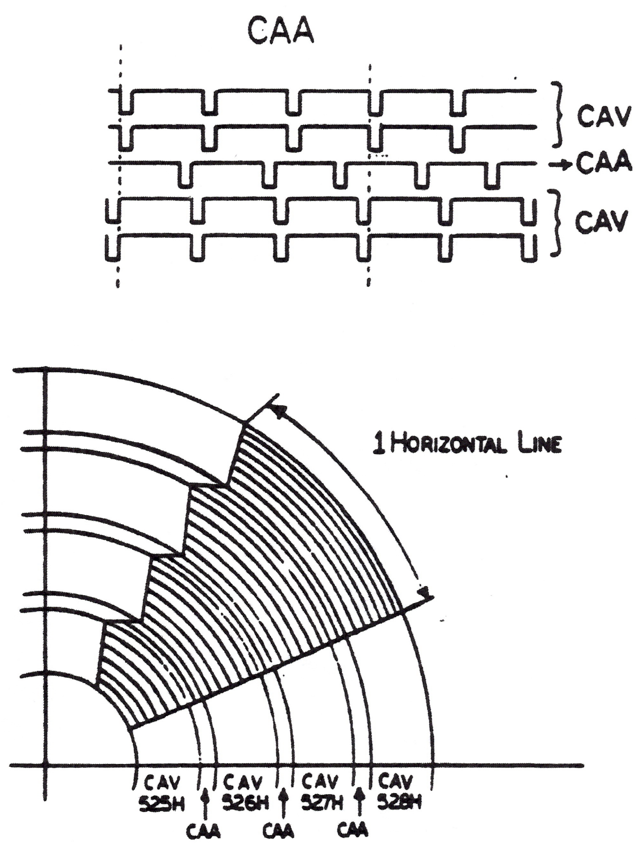


Fig. 11 Early CLV Crosstalk

To alleviate this problem the CAA disc was developed, combining strong points of the CAV and CLV formats. During CAA play the spindle rotates at a constant 1800rpm for as many tracks as possible Then, the speed shifts down to the next slower rate and again plays as many tracks as possible at that speed. This process continues throughout disc play untill the outer region has completed play at the final speed of 600 rpm. These step changes in speed allow the horizontal sync pulses to be aligned between tracks and mitigate the problem of crosstalk. Though technically they are CAA discs, they are now generally referred to as CLV discs due to the one hour per side playing time.



Disc Radious	H-Sync	CAV Time	CAA Time
56mm (inside)	532	1.241 Sec.	1.11 Sec.
100mm (midway)	951	3.862 Sec.	0.348 Sec.
144mm (outside)	1369	5.894 Sec.	0.168 Sec.

Total no. of CAV Sections = 855

Fig. 12 Constant Angular Acceleration (CAA)

OPTICAL PICKUP ASSEMBLY

The purpose of the optical pickup assembly is to produce the beam, divide it into three beams, shape them for optimum data retrieval and to maintain beam focus and direction on the information tracks of the disc. The pickup then receives the modulated, reflected beams and projects them onto a photo diode array for conversion to electrical outputs. These are the main system inputs for the various servos that maintain accurate tracking as well as actual playback RF.

HeNe System - 1979 to 1983

In the early generations of Laser Disc players the entire pickup assembly was large and cumbersome. Let's follow the beam path of an early model (Fig. 13).

- Helium-Neon gas within a tube is electrically excited (900 Volts startup, 1100 Volts operating) to produce a laser beam of 1mm diameter and 1mW with a 632.8nm wavelength.
- Beam direction is turned 180° by the 1st and 2nd fixed mirror.
- The beam passes through a grating lens that divides it into three linearly aligned beams. The center beam reads data (audio, video and control signals) while the side beams aid in tracking. The

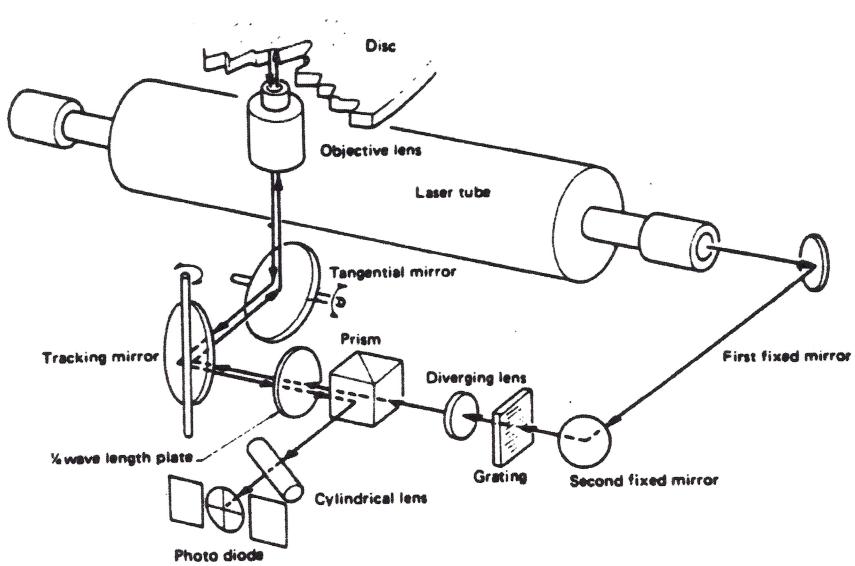


Fig. 13 HeNe Laser Pickup Assembly

center beam contains 50% of the energy with each side beam receiving 20%. The remaining 10% is distributed among other higher order side beams created by the grating but suppressed by the system.

- Beam passes through diverging lens which separates the beams and makes them parallel to one and other.

- The beam next enters a prism which has been aligned to allow horizontally polarized light (such as the beam) to pass through while refracting vertically polarized light by 90°.

- As the beam passes through the 1/4-wavelength plate it's polarization is changed from horizontal to circular.

- The tracking mirror alters the beams direction so it will track accurately. Though this mirror is no longer a part of pickup assemblies the tracking servo is still found in the system and will be discussed later.

- The tangential mirror advances or retards the beam as it reads the information. This is done to compensate for a disc that is revolving too slow or fast with respect to the reference clock. Current models employ an electrical time base corrector in place of the tangential mirror.

- Passing through the objective lens the beam is focused to a diameter of 1.5μm for reading the recorded information on the disc. The lens can move up and down relative to the disc to maintain focus and is controlled by the focus servo.

- After the beam is projected on the disc the reflected portion returns through the objective lens, off the tangential and tracking mirrors and back through the 1/4 wavelength plate.

- Returning through the 1/4 wavelength plate the laser beam's polarization is changed from circular to vertical. This vertical polarization is what makes the beam turn 90° as it passes through the prism again.

- The beam then passes through the cylindrical lens as part of the astigmatic focusing scheme. If objective lens focus is incorrect an elliptical rather than circular spot will be produced on Photo Diode B which senses deformity and generates control signals to correct the lens focus.

Solid State Laser Pickup Design

The basic function of optical pickups has not changed since the early models yet the actual construction of the pickup continues to improve. Current models are substantially reduced in size and now use semiconductor diodes to produce the laser beam. The grating lens remains. As before, these optical components generate a single laser beam that is split into three.

Rather than pass through a prism the beam now enters a half mirror. The properties of the half mirror are such that typically 50% of the light is reflected and 50% will pass through. Because of this loss factor the half mirror could previously only be used in compact disc designs since the carrier-to-noise ratio for CD is much less than LD due to the smaller bandwidth. Only after the OEIC was developed could the half mirror be used in an LD pickup (Fig. 14).

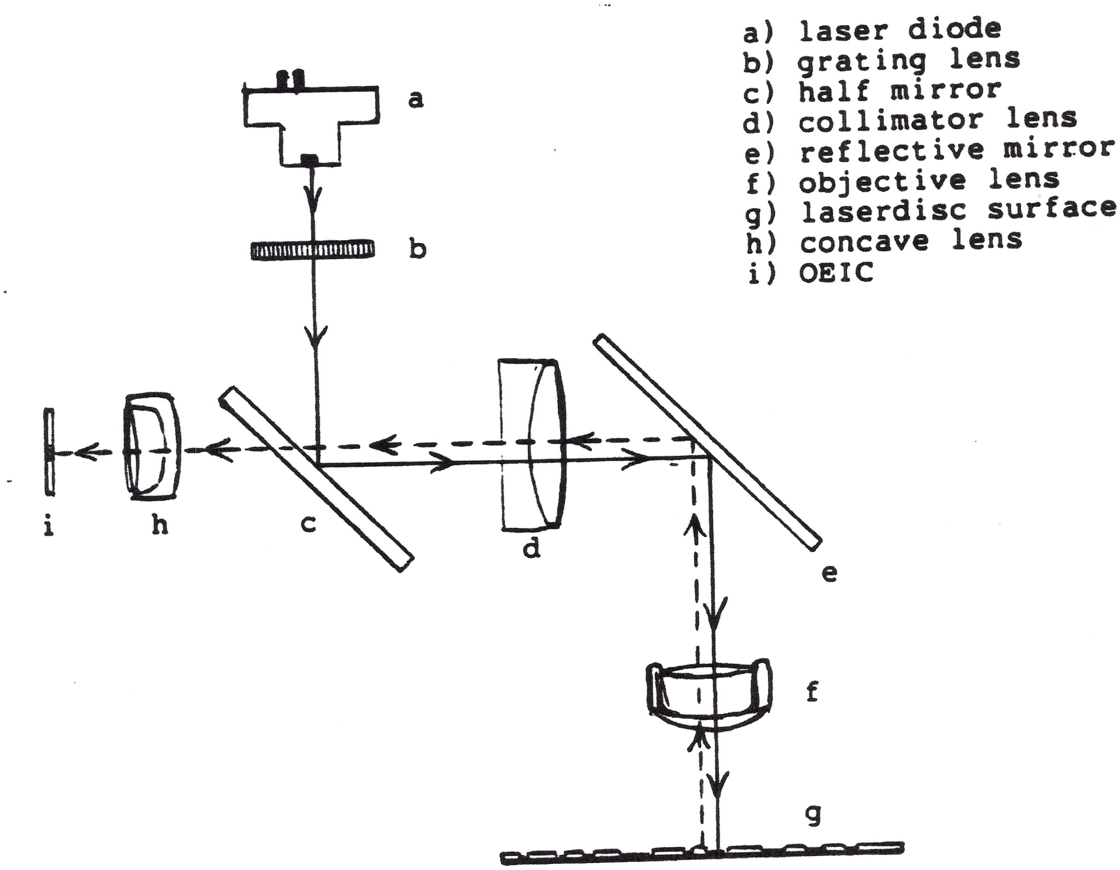


Fig. 14 Solid State Laser Pickup Assembly

From the half mirror the beams are passed through the collimator lens for reshaping the beams from diverging and elliptical to parallel and circular. Next the beams are redirected toward the objective lens by bouncing off the reflective mirror.

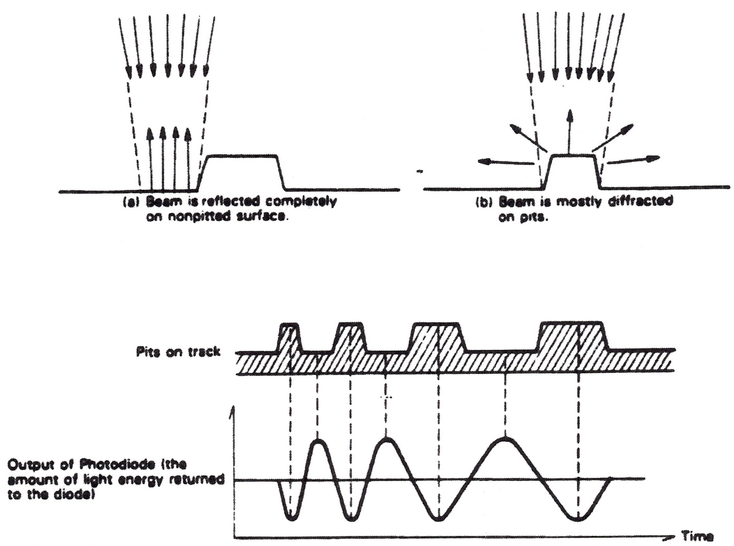


Fig. 15 Laser Reflection Off Disc Pits and Transduction to Electronic Signals

The objective lens then focuses the beam on the disc surface and the reflected portion returns back through the objective lens as in previous systems (Fig. 15). The beam is then bounced from the reflective lens toward the half mirror where 50% of the light is passed to the concave lens with the balance reflecting back to the laser diode. Since light passing through a half mirror acquires an astigmatic component, the concave lens can, together with the half mirror, develop the complete astigmatic focusing function.

Finally the beam arrives at the photo diode array, now incorporated within the OEIC .

OEIC

The OEIC or Opto-Electric IC was developed to permit the changes that are present in the current pickup design. This device contains both the standard photo diode array as in previous pickups and the head amplifier that was previously external to the pickup (Fig. 16). The combination of the two stages not only permits overall size reduction but allows the use of the half mirror by compensating for it's deficiencies.

The OEIC performs three key functions within the unit: transduction of the returned laser light to electronic signals for playback of the recorded information; objective lens focus control by detecting improper distancing of the lens to the disc; control of beam tracking by detection of imbalances in the return level of the two side beams adjacent to the data retrieval beam.

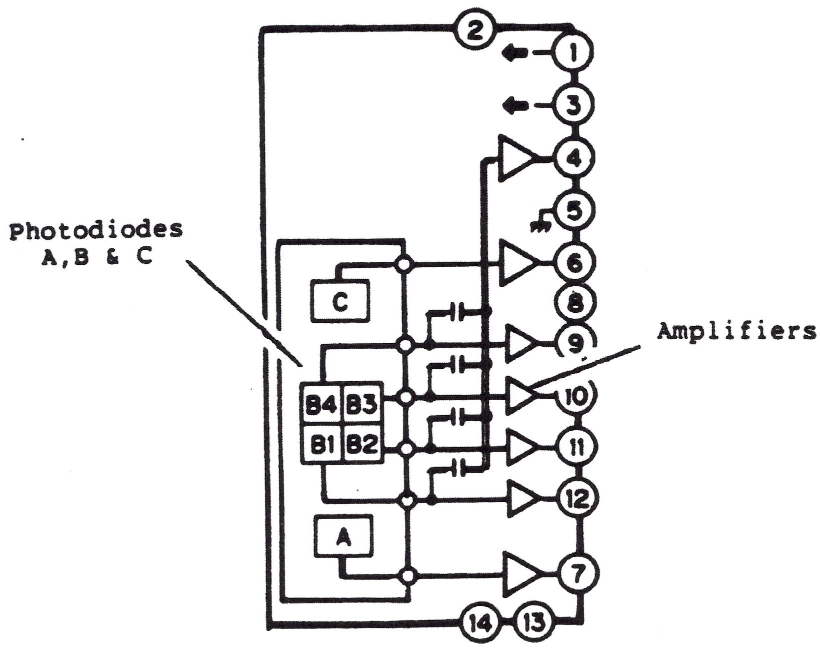


Fig. 16 OEIC Schematic

SERVO SYSTEMS

When Laser Discs are manufactured the tolerances and quality control are kept as rigorous as possible. Nonetheless there are eccentricities in the disc that could effect playback if they were were not compensated for by the player. These include incorrect distance from the disc surface to the objective lens, inability to keep the beam on the correct track because of improper track alignment, a pickup that is not perpendicular to the disc because of disc warp and a playback signal that is reproduced at a varying rate due to improper disc speed. All these anomalies are compensated for in the player by several servo systems. In addition there is a Time Base Corrector to compensate for data sync fluctuation during playback.

Focus Servo

Every disc has to some degree an uneven and warped surface which, when rotating between 600rpm and 1800rpm, causes slight up and down fluttering of the disc. The players objective lens must move up and down as well to maintain the optimum distance from the disc and focus the beam on the signal plane (information surface).

The concave lens and half mirror found in the optical pickup assembly provide the astigmatic focus of the returned laser beam. Exiting the concave lens the data retrieval beam reaches the four segment array Photodiode B. When the disc distance is optimum for beam focus the returned beam is circular and equally lights the four segments of diode B. When the the disc moves too close to the objective lens the returned beam is vertically elliptical rather than circular, and when the disc is too distant from the lens the beam is horizontally elliptical (Fig. 17).

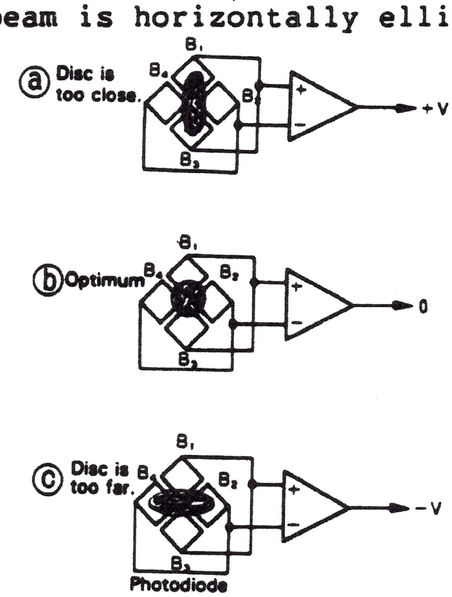


Fig. 17 Focus Servo Detection at Photodiode B

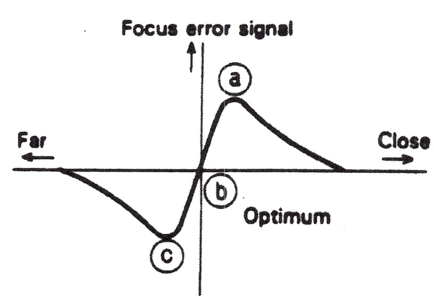


Fig. 18 Output of Photodiode B Differential Amplifier

The differential amplifier, connected to the four segments, performs the following calculation and produces a differential or error voltage proportional to the focal deviation (Fig. 18).

$$\text{Focus error} = (B1+B3) - (B2+B4)$$

The error voltage is applied to the objective lens focus coil (similar to the voice coil in a loudspeaker) and moves the lens up and down to maintain proper focus (Fig. 19).

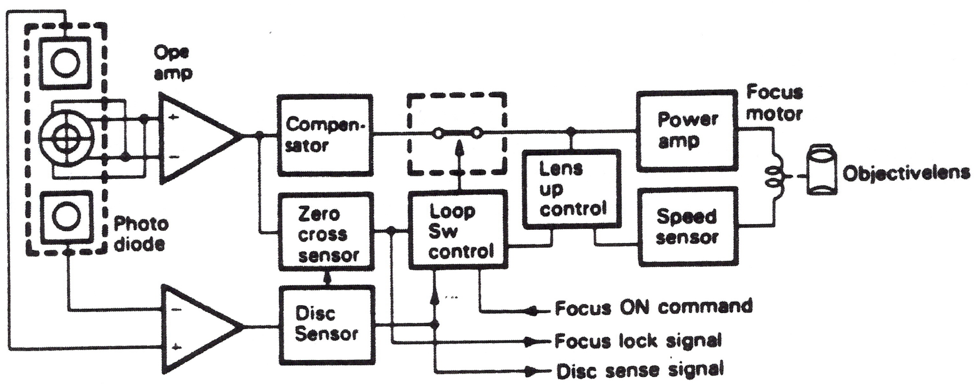


Fig. 19 Focus Servo Circuit Block Diagram

Tracking Servo

Every disc and disc clamp are eccentric to some extent and the signal track can meander during play. The tracking servo system is used to keep the data retrieval beam on track during disc play. It was stated earlier that the grating lens splits the laser beam into three beams that are kept parallel to one and other throughout the pickup system. When the beams are projected on the disc surface one of the tracking beams is ahead of the center data retrieval beam and the other tracking beam is trailing the center beam (Fig. 20).

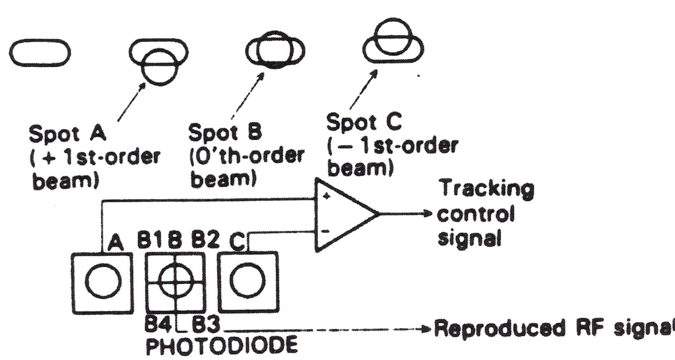


Fig. 20 Tracking Beams and Photodiode Array

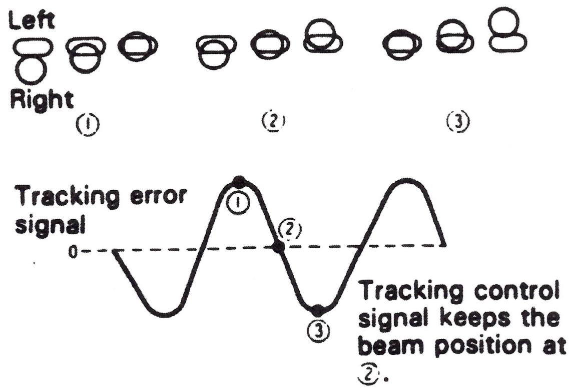


Fig. 21 Tracking Error Signal

The two side beams are configured slightly off center relative to the center beam, the leading beam (A) is off center to the left and the trailing beam (C) is off centered right (Fig. 21). When beam B is tracking properly (centered) both A & C will be partially reflected t an equal degree which is detected by Photodiodes A & C respectively. If beam B begins to deviate slightly from center, one side beam will become more reflective and the other side beam less reflective, resulting in a voltage difference between Photodiodes A & C.

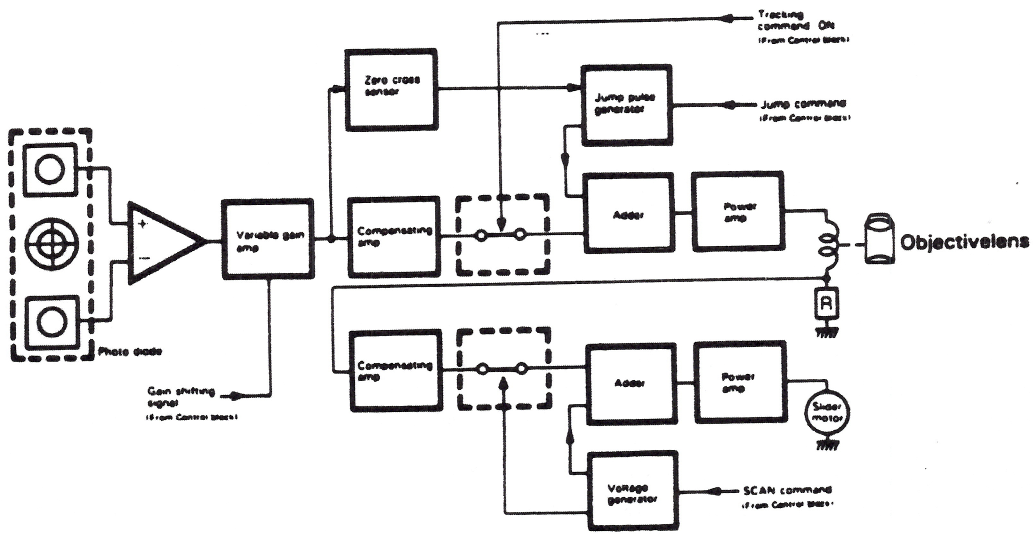


Fig. 22 Tracking Servo Circuit Block Diagram

This voltage difference is then sent to the tracking coil within the pickup assembly that radially shifts the objective lens position to maintain correct tracking. When the center beam traces the track the error voltage is 0. If the track veers leftward (A-C) becomes positive because A is brighter than C, and if the track veers rightward (A-C) becomes negative since C is now brighter than A.

Slider Servo

The slider servo system contained in laserdisc players can be thought of as an extension of the tracking servo previously described. The tracking servo compensates for unevenness in the track path but since the tracks are continually spiralling outward as the disc plays there is a point at which the tracking servo is at the end of its operating range. When this point is reached the DC component of the tracking drive return line activates the slider motor to move the entire pickup assembly to a point where the tracking servo returns to the center of its operating range (Fig. 23).

The slider servo is also used to accelerate the slider, both forward reverse, for search and scan operations. During high speed movement the tracking loop is opened except to read address (time) data. Forced acceleration the slider prohibits closed-loop tracking.

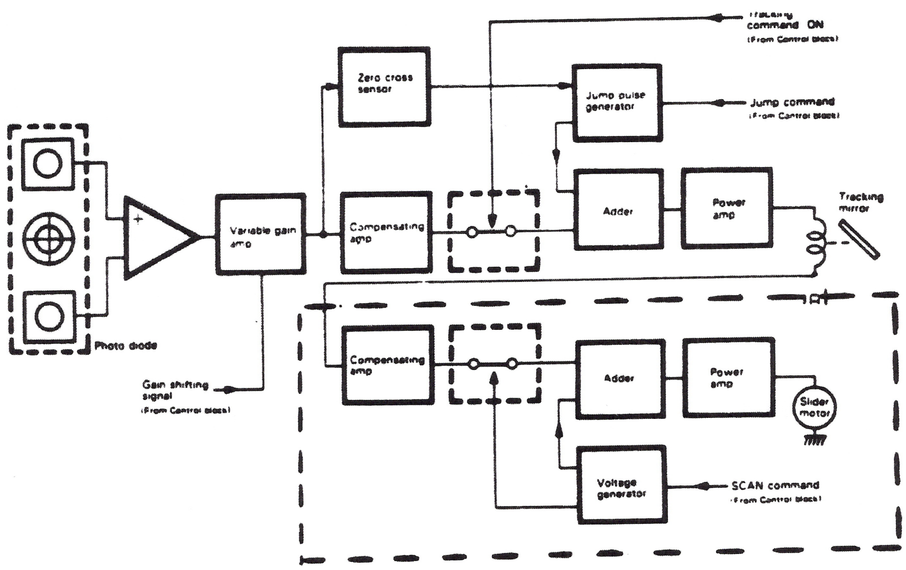


Fig. 23 Slider Servo Block Diagram

Spindle Servo

The spindle servo system is required to keep the spindle motor rotating at a constant 1800rpm for CAV discs or the predetermined linear speed of 11m/sec (1800rpm to 600rpm) for CLV discs. When the focus and tracking servos are locked the audio and video signals are read. The horizontal sync signal is separated from the playback video and then compared to the horizontal sync reference clock. The difference between the two becomes the drive to the spindle servo circuit (Fig. 24).

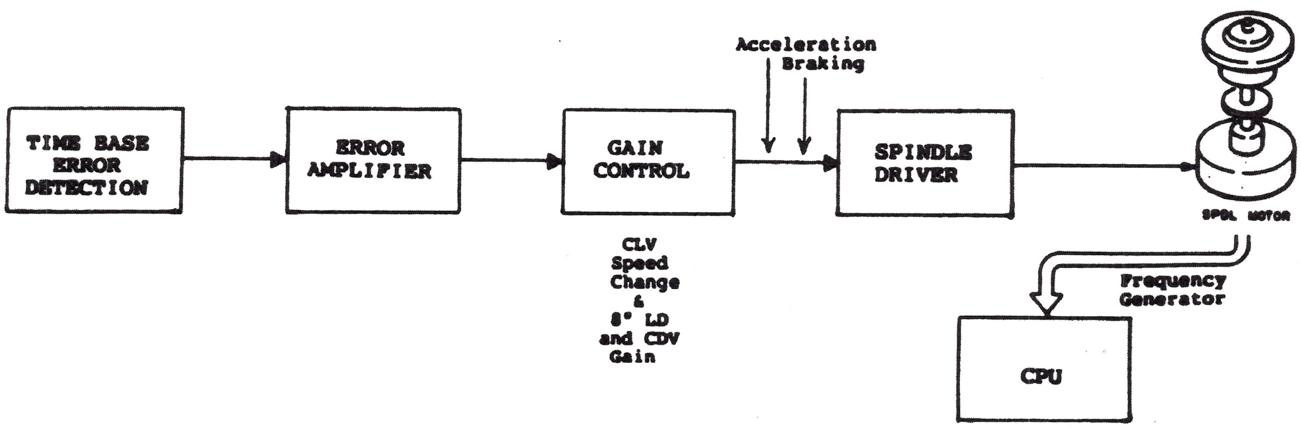


Fig. 24 Spindle Servo Block Diagram

Tilt Servo

When the laser beam is focused on the disc plane a 90° read angle is ideal. The disc, made of plastic, may be warped by its weight, heat or external forces and therefore may not always be perpendicular to the pickup beam. A beam that is not perpendicular to the disc surface may read a portion of adjoining tracks resulting in cross-talk.

The Tilt Servo responds to the detection of disc warp by the tilt sensor located on the pickup. Positioned adjacent to the objective lens (Fig. 25), the sensor provides detection as close as possible to the current playback point on the disc. The sensor consists of an LE with two photo detectors on either side, aligned with the direction of pickup movement. If no warp is present the reflected input to each photo detector results in equal output. When warp is sensed the photo detector outputs are unequal and a DC error results (Fig. 26).

In models that use the Alpha-Turn mechanism for two side play, the optical pickup assembly responds to this error by engaging the tilt motor to maintain a position perpendicular to the disc surface. In earlier models that contain the Constant Linear Tilt Servo the entire slider carriage would tilt to achieve the 90° read angle. This can no longer be used in Alpha-Turn units due to the need for the pickup assembly to rotate within the carriage, requiring that the carriage remained fixed.

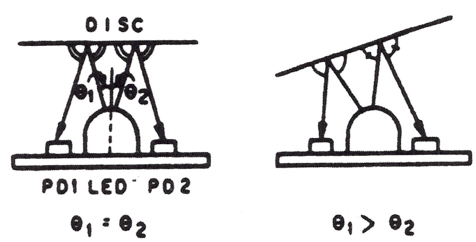


Fig. 25 Tilt Sensor Operation

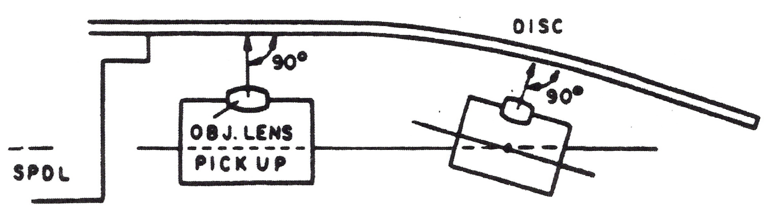


Fig. 26 Laser Pickup Tilt

TIME BASE CORRECTOR

In any disc there is a certain amount of inherant eccentricity due to the inability of the manufacturing process to precisely place the center hole at the exact center of the disc. During play the disc tracks can be said to be traveling in an elliptical path rather than a circular one relative to the pickup beam. This effects the speed of the information read off the disc so at one section the information will be traveling faster than at the opposing section. Though this difference is small, it is large enough to effect the sychronization of the video signal and can result in a picture that jitters and has poor color. The condition is known as time base error and is compensated for in the player by the Time Base Corrector circuit (Fig. 27).

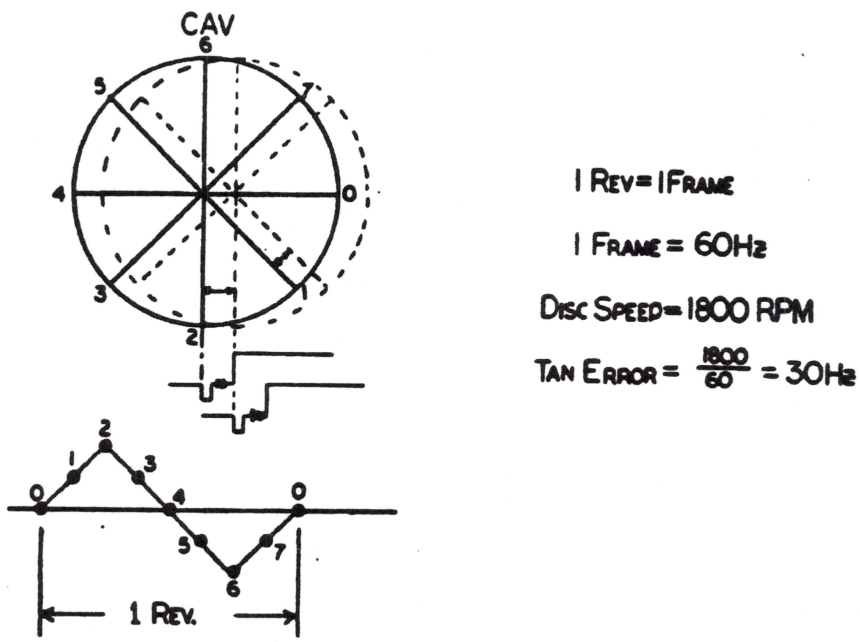


Fig. 27 Time Base Error

In earlier models the condition was known as Tangential Error and was corrected by the Tangential mirror. A phase comparator compared phase of the color burst signal, after separation from the video signal, with the reference clock subcarrier. The resulting voltage difference was applied to the Tangential mirror transducer to turn the mirror, retarding the beam when the track speed was slower and advancing it when faster.

In recent models this correction is achieved electronically. As the RF playback signal is retrieved off the disc it undergoes demodulation and is sent to the playback sync extraction circuits. There, both the horizontal sync pulse and chroma phase components of the video signal are compared to the reference clock frequencies of 3.58 MHz (sync) and 15.73 KHz (chroma) that are generated by the fixed reference oscillator. The sum of the differences in each signal compared to its reference (frequency error and phase error) is the time base error of the playback signal.

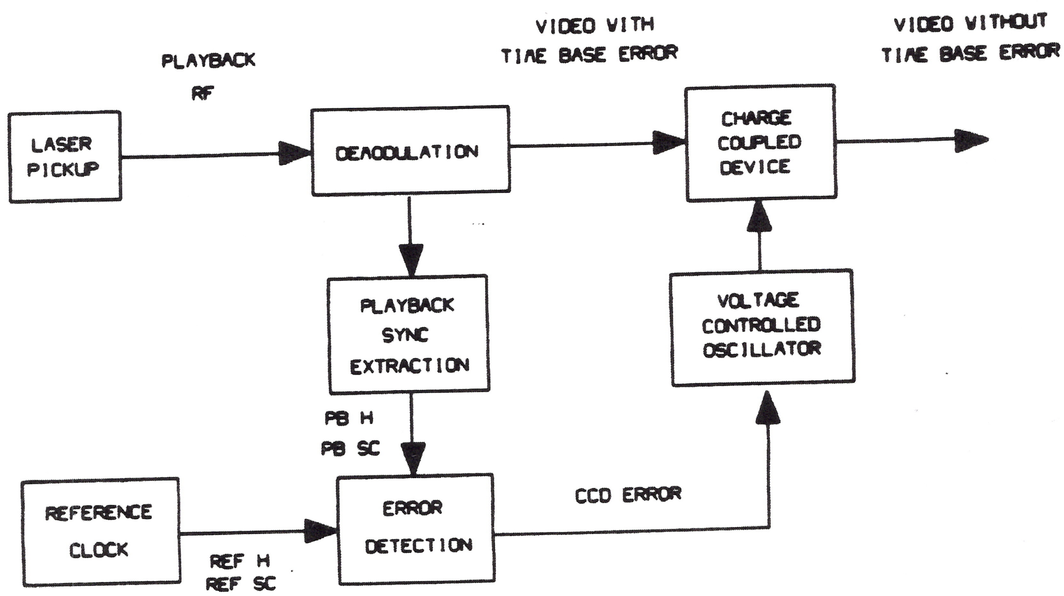


Fig. 28 Time Base Corrector Block Diagram

As the video signal travels through the Charge Coupled Device (CCD), which funtions as a delay line, the combined error regulates the CCD Control Oscillator that controls the amount of delay the CCD will apply to the video signal (Fig. 28). This effectively advances the playback rate at that point during one disc rotation when the track speed is slower, as well as retarding the playback rate at another point during the same disc rotation when track speed is faster than reference.