The RCA CED VideoDisc System—An Overview

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Abstract—This paper describes the various parts of the RCA CED VideoDisc system. First, the disc is described, including its manufacture and processing. This is followed by a description of the stylus and the player and its operation. Included is a brief discussion of the stereo CED system as well as a comparison of parameters for the 525 line/60 Hz and 625/50 Hz systems.

1. Introduction

Prerecorded video discs give to viewers the ability to see and hear what they want, when they want it. With it, we decide our own programming material—adventure, science fiction, comedy, mystery, drama, sports, information, and inspiration. The RCA CED (capacitance electronic disc) VideoDisc system was introduced to the American market on March 22, 1981, through more than 5,000 dealers. The players carried a suggested list price of $499.95, and discs, from a selection of 100 titles, were available at an average price of about $20. RCA's disc manufacturing plant has been expanded to support production of 3 million discs in 1981, with an ever increasing variety of program material, and will continue its expansion to produce 10 million discs in 1982.

Briefly, the RCA SelectaVision VideoDisc system comprises a disc on which television signals have been prerecorded and a player that converts these signals into a form suitable for input to television sets. Installation is simple and rapid with only three connections required, one to connect the player to the power line, the second to connect the player to the antenna terminals of the TV set; and the third to reconnect the antenna to the VideoDisc player. When the player is off, antenna signals are fed through it to the television set. Turning the player on replaces the antenna signal with signals from the disc on either channel 3 or 4, at the discretion of the owner, to avoid possible interference from other television signals in the area.

The disc is housed in a protective sleeve, or caddy. Inserting the caddy into the player and then extracting it automatically places the disc on the player turntable, ready for play. After play, the empty caddy is reinserted into the player, retrieving the disc for storage. Each disc will play up to 1 hour on each side, depending on the length of the recorded program.

This paper briefly describes the RCA CED VideoDisc system, giving an overview of its various parts and indicating advances in the system planned for the future.

2. The Disc

Information is embossed on the disc as frequency-modulated vertical undulations in a 140° "V" shaped spiral groove. A small section of the disc is shown in Fig. 1. The signal pattern is initially recorded on a copper surface that is replicated by several successive nickel electro-forming

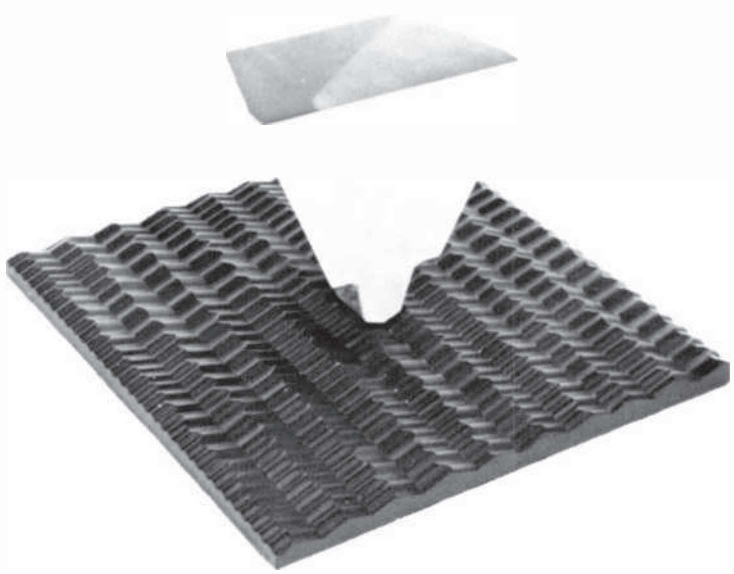

Fig. 1—Disc-stylus Model. A diamond stylus rides in a "V" shaped groove on the disc.

operations to produce stampers. These stampers are mounted in a multi-ton compression molding press on which discs of conductive carbon loaded polyvinyl chloride are molded.

The disc plays back at 450 revolutions per minute, and the signals from the disc vary from 4.3 MHz at sync tip to 6.3 MHz at peak white. The discs are 30.2 centimeters in diameter, and 1.9 millimeters in thickness, about the same dimensions as an audio LP record.

2.1 Disc Mastering and Replication

The various steps in making a master recording and producing a finished disc are shown in Fig. 2.

The major parts of the electromechanical recorder used in mastering are shown in Fig. 3. A smoothly turning, seismically isolated, precision turntable is accurately locked to the signal source. A piezoelectric cutterhead (Fig. 4) is mounted on a sturdy arm with a translation mechanism that radially moves the cutterhead a distance of one centimeter every 3793 rotations of the turntable. On the turntable is a flat aluminum substrate on which has been deposited a grainless electrolytic copper. Before recording, the copper surface is carefully machined flat on a jig borer.

The diamond stylus used to record on the master has a V shape that corresponds to the desired cross section of the finished groove. The stylus

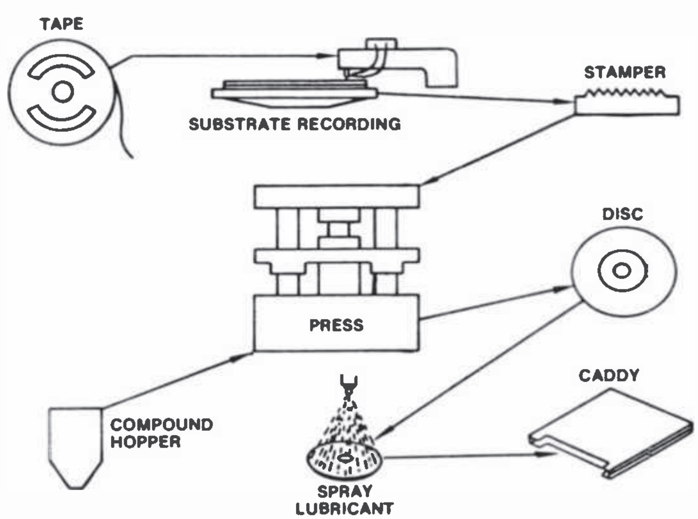

Fig. 2—Disc manufacturing overview.

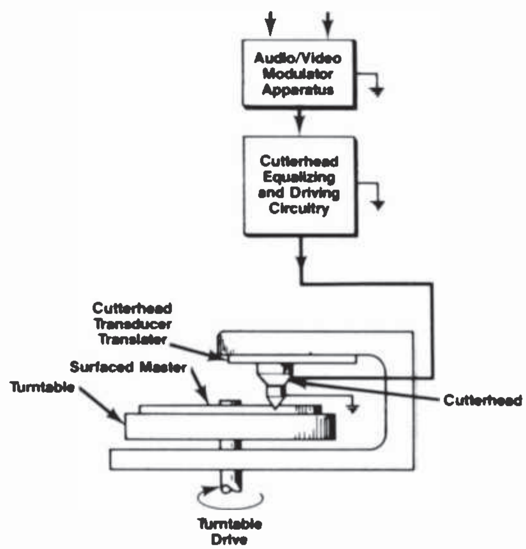

Fig. 3—Simplified schematic diagram of an electromechanical recorder.

cuts the groove (about 4000 Å deep) and the signal modulation (about 850 Å deep) at the same time. The cut is deeper than the groove, so that the groove depth is controlled by the shape of the recording stylus tip and the amount of translation between turns. The amplitude of the signal recorded is determined by the vertical motion of the stylus tip. Recording is done at half-real-time rate to achieve more consistent performance and longer life of the cutterhead. The dynamic stress on the bond to the

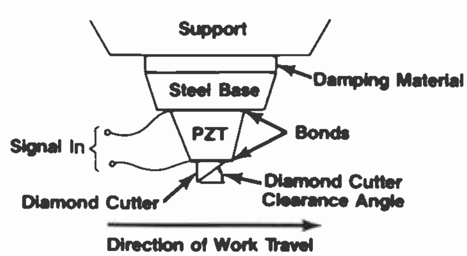

Fig. 4—Schematic of an electromechanical cutterhead.

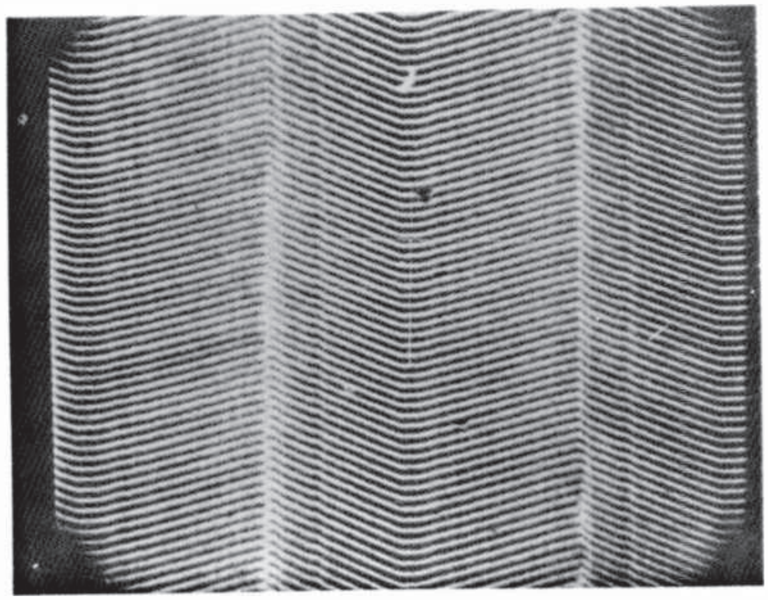

Fig. 5—Surface quality of a signal mechanically cut in copper.

piezoelectric element is in excess of 70 kilograms per square cm for 850 Å peak-to-peak motion at 2.5 MHz. Fig. 5 shows the resultant surface quality of a signal mechanically cut in copper.

Fig. 6 shows the mastering process flow including the cutterhead assembly and substrate preparation. One of the advantages of cutting in copper is that optical laser read-out can be made as soon as the copper is cut; no development time is required as in laser-photoresist mastering.

Recording tests have shown that copper can be cut more smoothly and with less loss of high frequencies than lacquer. Further, evaluation of electron beam-resist and laser-resist mastering generally have shown these systems to produce orders of magnitude higher defect levels than those found in copper mastering. For a groove spacing of about 5 μm, defect levels in a copper master were measured to be about 0.01/cm^2, while with baked and developed photo-resist they were 1/cm^2. This difference was confirmed by evaluating defect levels achieved in integrated circuit photolithography. Yields in IC photo-resist processing decrease exponentially with line spacing due to the increase in defects. This is similar to the results obtained in caddy dust studies (see Fig. 17), which show that the density of particles increases exponentially with

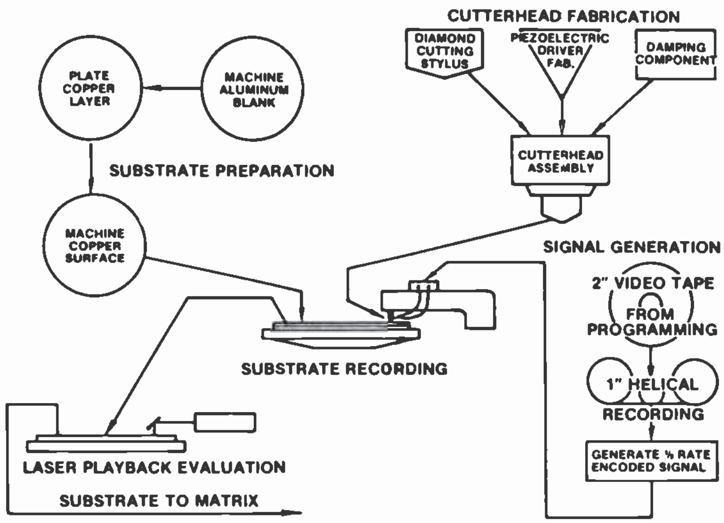

Fig. 6—Mastering process flow diagram.

decreasing particle size. Thus, the expected number of video disc recording defects follow a similar exponential increase with decreasing groove spacing. Actual copper recordings achieve yields well in excess of 50% for all failure causes.

Signal generation starts with input video tape that has been carefully prepared to match the recording standards of the CED system. Imperfections in editing, gamma correction, dynamic range, timing and many other parameters are not acceptable for mastering. Source signals are NTSC compatible, complying with EIA standard RS-170A, and chrominance is limited to peak levels represented by 75% of color bars. (CED system parameters and standards are given in Appendix 1.) If the recorded material is supplied in 2-inch quadruplex formats, it is fed into a 1-inch helical scan video tape machine to achieve a two-to-one slowdown. The head wheel of the 1-inch machine plays back at full speed while the capstan advances the tape at half speed. This means the output of the tape machine plays each TV field twice. One-inch tapes in C-format are acceptable to the system and are played directly on the one-inch helical scan recorder.

The composite video information is passed from the tape recorder through time-base correction, pre-emphasis, and encoding into buried subcarrier format. This analog signal is then converted to digital form (i.e., 14.3-MHz sampling rate, 8-bit amplitude quantitization), stored in two field storage units, and read out at half rate. The digital signal is converted to analog form and the field code added in the vertical blanking interval on lines 17 and 280. The slowed down video is then fed to a video FM modulator. The half-rate audio from the tape recorder is FM modulated and added to the video FM to produce the composite cutterhead drive signal.

The luminance signal is pre-emphasized (see Appendix 1) to improve the luminance signal-to-noise ratio. This means that high frequency luminance components are recorded at higher than normal amplitude. The pre-emphasis has two parts: (1) *RC* pre-emphasis, which boosts 6-dB per octave between 249 kHz and 995 kHz, and (2) linear phase pre-emphasis, which boosts high frequencies by a dB number equal to the square of the frequency in MHz to a maximum limit of 12 dB.

Replication of the copper substrate is done by conventional nickel electro-forming successive masters, mothers, and stampers as shown in Fig. 7. The original copper substrate has the surface relief pattern that will appear on the VideoDisc. Successive electro-forming steps can provide a fan-out of several hundred metal parts, sufficient to produce disc quantities in the hundred-thousand range from one recording operation.

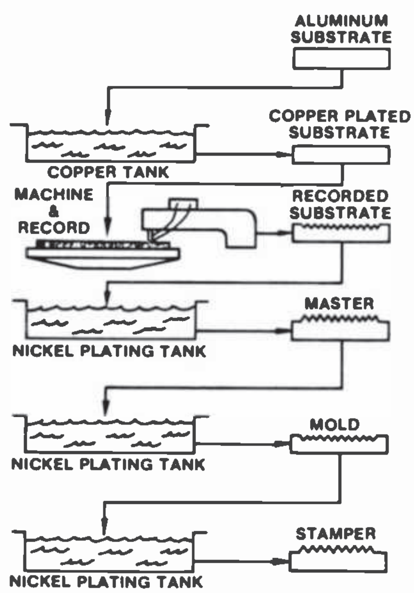

Fig. 7—Matrix process.

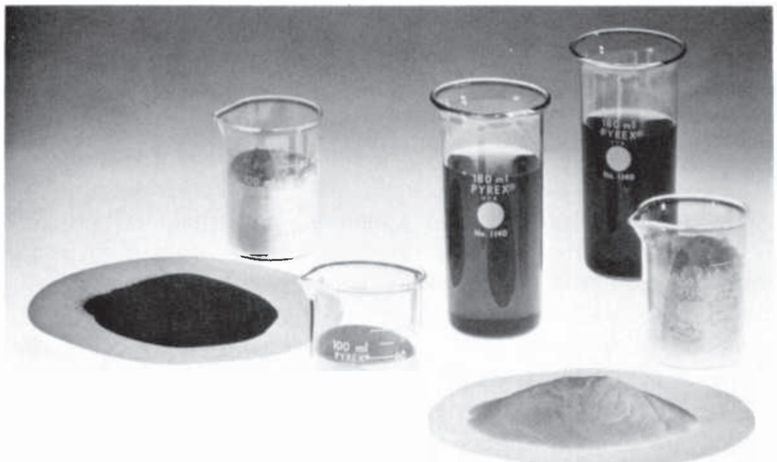

Fig. 8—Materials used in making compound.

2.2 Disc Material

Fig. 8 shows the various ingredients used in making the special compound material for the disc. The base material is a polyvinyl chloride (PVC) homopolymer resin. Conductivity is achieved by the addition of

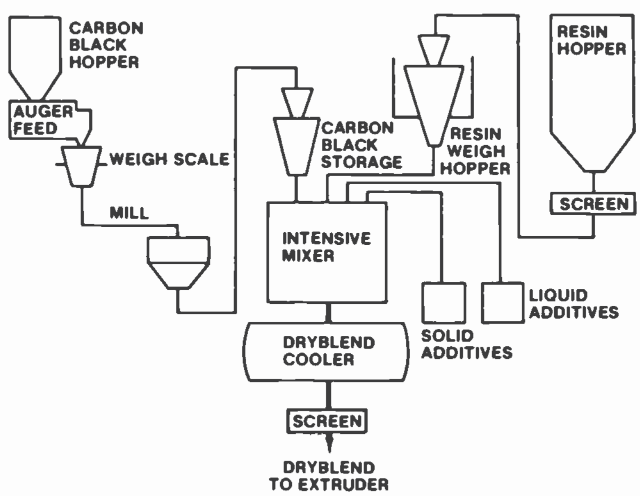

Fig. 9—Material flow sequence.

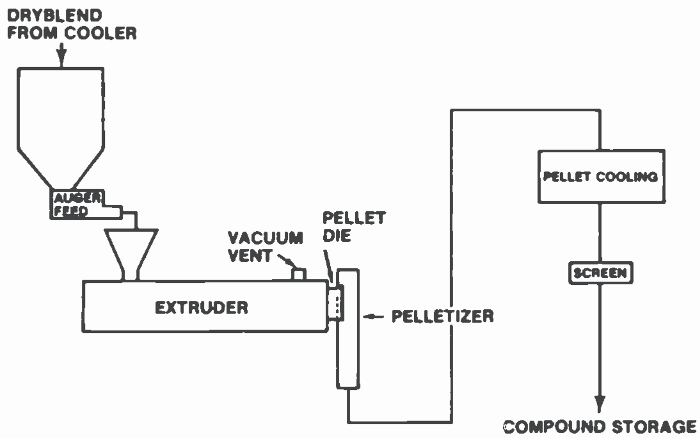

Fig. 10—Dryblend flow sequence.

carbon whose basic particle size is smaller than the 5000-Å minimum size information elements and with conductive properties sufficient to achieve a resistivity of less than 5 ohm centimeters with 15% loading of the base PVC material.

The basic compounding system is shown in Figs. 9 and 10. In Fig. 9, the carbon black is weighed, centrimilled to break up agglomerates and

Fig. 11—Pellets of dryblend.

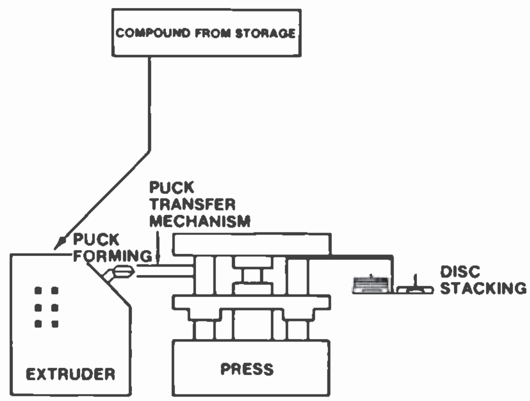

Fig. 12—VideoDisc molding.

mixed with the PVC and processing additives to produce the dryblend. In Fig. 10, the dryblend is fed to a twin screw extruder, pelletized and screened for size. These pellets are shown in Fig. 11.

The basic materials used in the compound have purities similar to those used in pharmaceuticals, i.e., impurities less than 50 parts per billion.

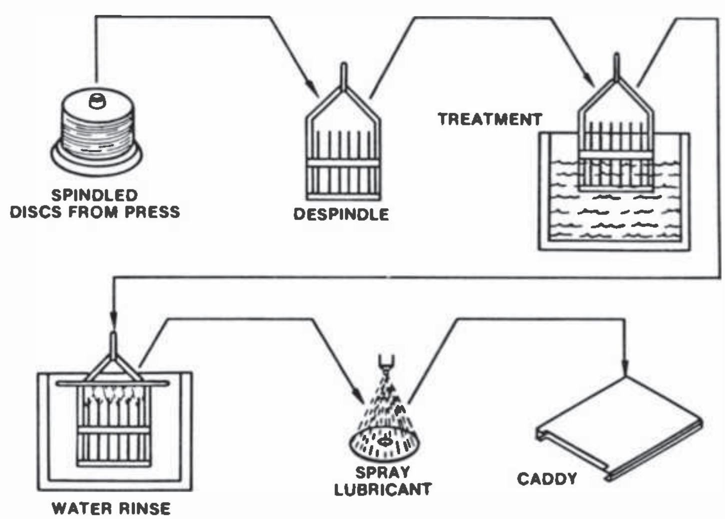

Fig. 13—Lubrication.

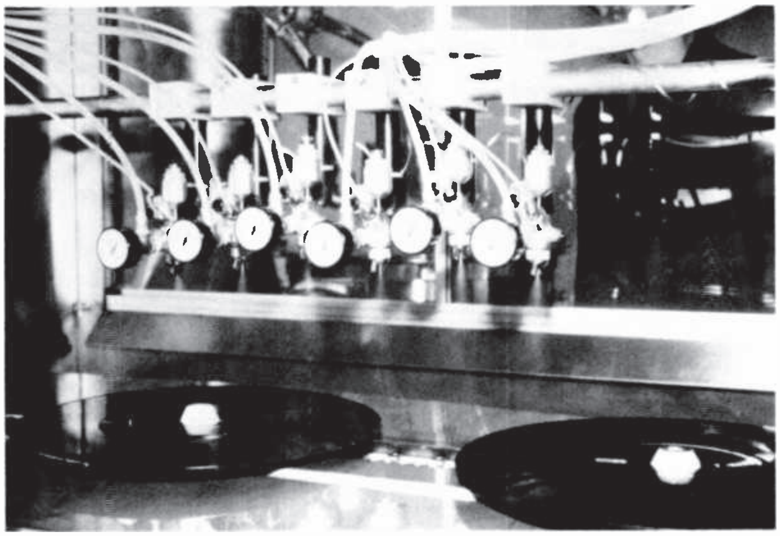

Fig. 14—Special spray configuration.

The pellets are fed to the press extruder (Fig. 12) and formed into a puck. The puck is automatically fed into a 100-ton hydraulic compression molding press, and the disc is formed in less than 40 seconds, trimmed of its flash, and spindled.

The spindled discs from the press are visually inspected for defects, sampled for performance and geometric integrity, and despindled into special carriers for post pressing treatment shown in Fig. 13. The discs are cleaned in special baths, water rinsed, dried, lubricated, and inserted into caddies. The lubricating oil is uniformly applied to the disc in a controlled 300 Å thick layer. Fig. 14 shows the special lubrication spray configuration.

2.3 Caddy Assembly and Packaging

The special caddy container assembly for the disc is shown in Fig. 15. The caddy halves first have the felt-like lip seals applied and are then sonically welded together. Spines, which act as the disc carrier for player insertion and extraction, are inserted into the caddy and the composite unit is provided to the packaging line.

Fig. 16 shows the disc packaging sequence. The assembled caddies have the label applied, discs are assembled into the caddy and the unit is shrinkwrapped. These final units are bulk packed for shipment. In

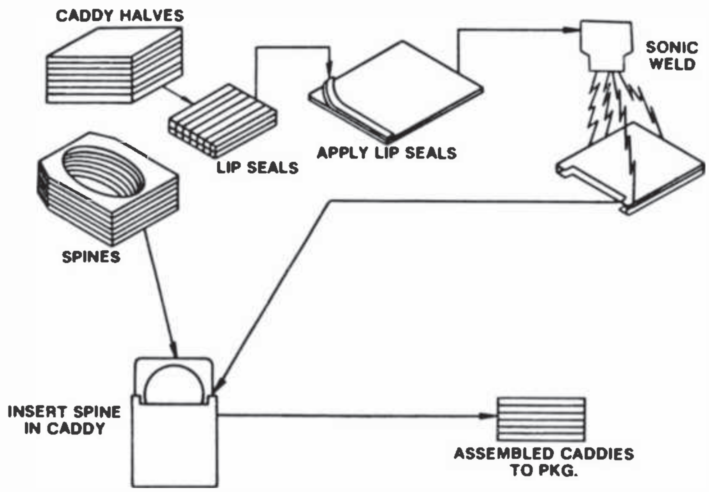

Fig. 15—Caddy assembly.

addition to protecting the disc from dust and from damage due to handling, the caddy package has the added advantages of providing space for a label, convenient storage and shipment. The disc never leaves its caddy, except during play when it is automatically extracted by the

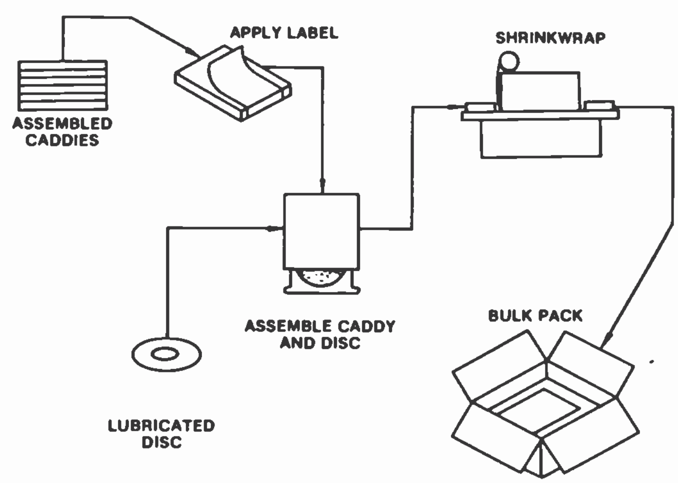

Fig. 16—Disc packing sequence.

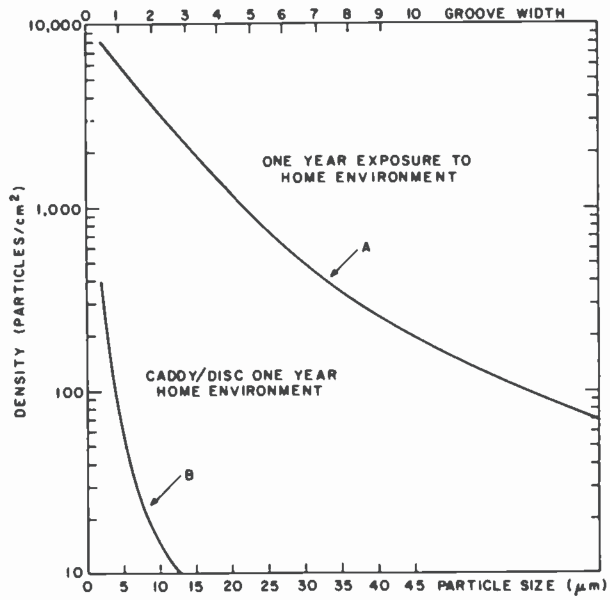

Fig. 17—Analysis of dust accumulated in 1-year simulated exposure to typical home environment. Curve A shows dust on outer cover; curve B shows dust on disc protected by caddy.

player mechanism. After play, the caddy is reinserted into the player and the disc is automatically inserted into the caddy through felt-like lips at the caddy mouth entrance. These lips act as a dust seal and remove gross debris from the disc. Fig. 17 shows results of studies of defects due to dust with and without the caddy.

2.4 Disc Testing

Extensive testing is provided for the product. Fig. 18 illustrates the play tests, physical tests, and environmental stress tests that are routinely performed on the product. In the early stages of production, large samples were taken to build the statistical data base. Today, sampling of one or two per cent per press run is more than adequate to monitor product quality.

The process outlined in the preceding discussion has produced more than 2 million discs in over 170 titles.

3. The Stylus

During playback, a metal electrode attached to a diamond stylus (Fig. 19), reads signals from the disc. The diamond foot is shaped to fit the

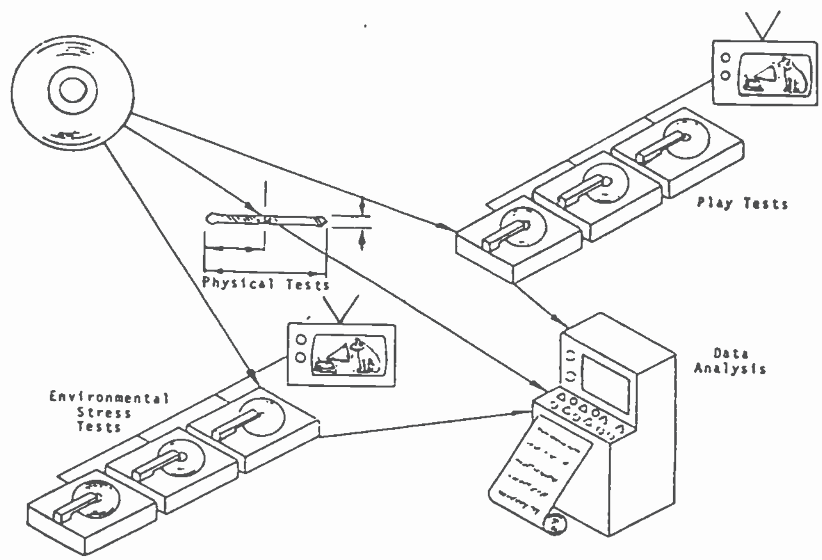

Fig. 18—Disc performance analysis.

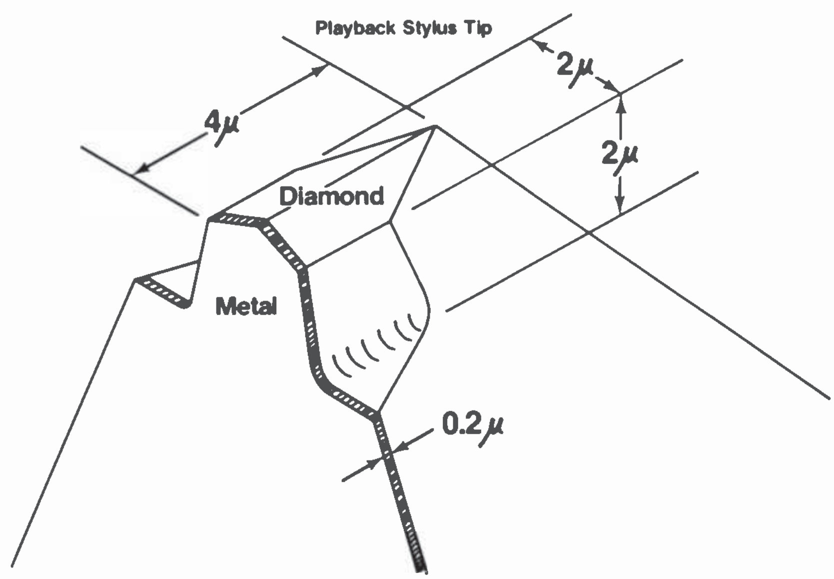

Fig. 19—Stylus tip. This inverted view of the stylus tip shows the relative sizes of the diamond tip and the readout electrode.

groove cross section and is sufficiently long to cover several of the longest recorded wavelengths (1.5 μm maximum). Thus, the diamond rides smoothly on the crests of the recorded waves much as a skier rides over small depressions in the snow. The undulations of the recorded signal rise and fall under the metalized end of the stylus, causing variations in the electrical capacitance between the electrode and the conductive disc surface.

The end of the stylus electrode is about 2 μm wide by 0.2 μm thick. The sides of the stylus tip are tapered as shown, providing a keel shape that maintains the electrode width as it is worn slowly during play. The 2 μm height permits extended useful play life of the stylus tip. In normal use, diamond wear is less than 1.0 μm per 1000 hours. The video FM waves pressed into the disc have a peak-to-peak amplitude of about 850 Å. For this height change, the variation in electrical capacitance experienced by the stylus electrode is proportional to the change in disc-electrode separation and is in the order of 1×10^{-16} farads.

The stylus-disc capacitance is part of a resonant circuit which has a resonance peak at about 910 MHz, shown in Fig. 20. Changes in the disc-stylus capacitance change the tuned circuit resonant frequency. By

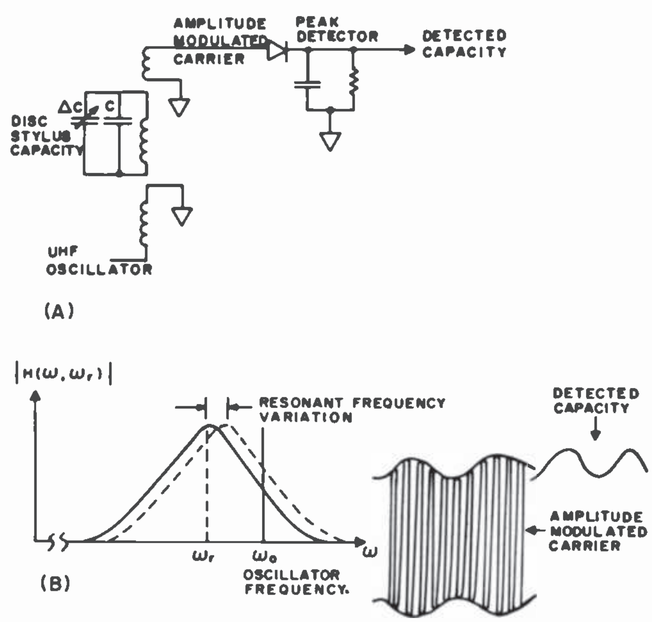

Fig. 20—Capacitance detection (signal pickup): (A) detection circuit and (B) circuit signal response.

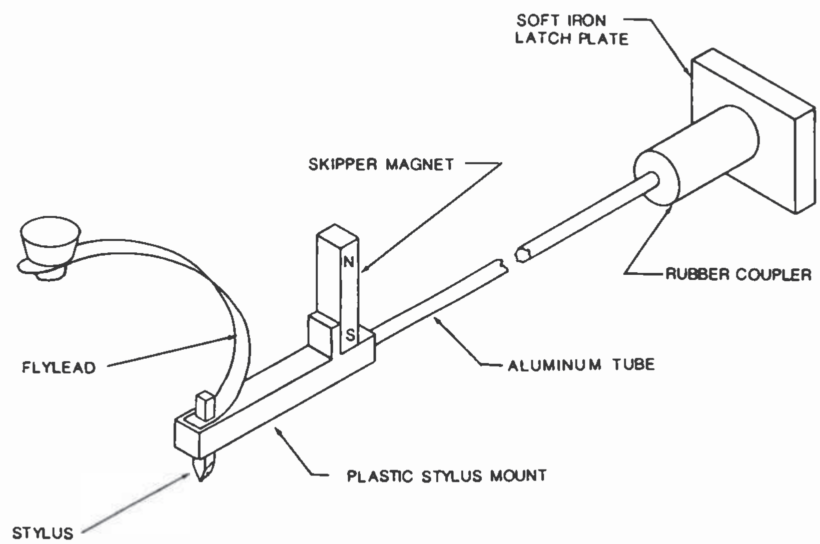

Fig. 21—Stylus arm.

coupling a 915-MHz oscillator signal to the tuned circuit, the 915-MHz oscillator signal is amplitude modulated by changes in the stylus-disc capacitance. The amplitude modulated 915-MHz signal is demodulated by a diode peak detector to extract the frequency modulated signal that corresponds to the signal recorded on the disc.

The diamond stylus is mounted (Fig. 21) on the end of a 8.4-cm long stylus arm made from thin-wall aluminum tubing. A flexible rubber mounting support provides the stylus arm with enough compliance so that the stylus follows irregularities in the disc both vertically and laterally. A small permanent skipper magnet mounted on the stylus arm near the stylus is used to provide limited lateral motions to the stylus when activated by a magnetic field from the stylus kicker coils (discussed later). The rear of the stylus arm is fitted with a soft iron plate that is held by a cup magnet on the arm stretcher transducer. The electrode on the diamond stylus is connected to the UHF circuitry by a flexible flylead, which also serves to hold the stylus against the disc with about 65 milligrams of force. The stylus arm, flylead, and compliant support are mounted in a replaceable cartridge (Fig. 22). The replacement of a stylus cartridge requires no tools or adjustments. The stylus is designed to provide years of service in normal use.

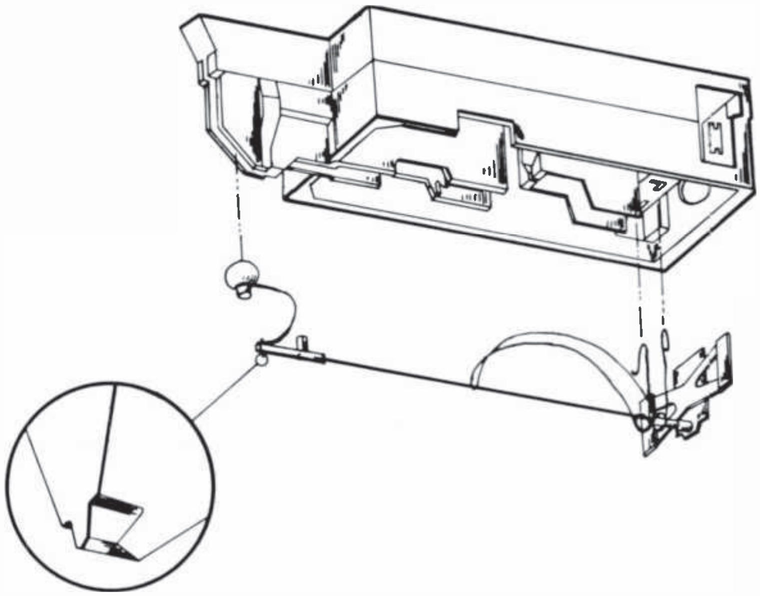

Fig. 22—Stylus cartridge.

4. The Player

4.1 Description

The VideoDisc player consists of a turntable driven at 450 revolutions per minute, synchronized with the 60 Hz power line, a mechanism for inserting and retrieving a disc, a stylus-cartridge pickup arm, signal processing circuitry and system control electronics. A simplified block diagram of the player is shown in Fig. 23.

The output of the 915-MHz oscillator is amplitude modulated by variations in stylus-disc capacitance. This AM modulation is diode peak detected so as to provide a reproduction of the FM signal that was originally impressed on the disc surface. This signal is fed to both audio and video demodulators. Whenever the audio or video FM carrier drops below a given threshold, defect detectors operate appropriate circuitry to prevent noticeable disturbances in the resultant audio or video output. When no audio disturbance is detected, the audio feeds through a track-and-hold circuit to the 4.5 MHz frequency modulator to generate the audio portion of NTSC signal. When a defect is detected, the audio is held at its last valid amplitude until the defect is corrected.

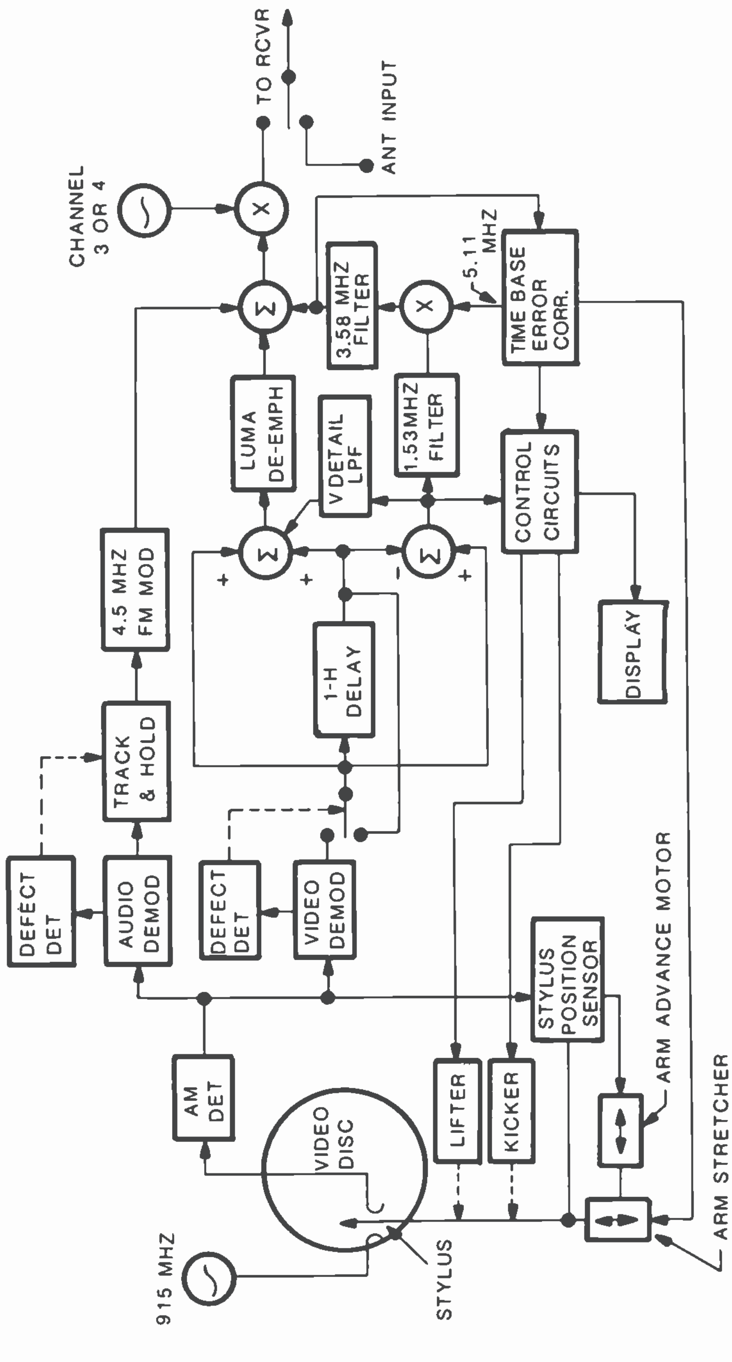

Fig. 23—Player block diagram.

When no defect is detected in the video signal, it is passed directly to a 1-H delay comb filter which separates the luminance and chrominance components as described in Appendix 2. (A detailed discussion of the comb-filter techniques employed in RCA VideoDisc system is given in an accompanying paper in this issue of RCA Review by Pritchard, Clemens, and Ross.) After deemphasis, the luminance signal is combined with other signals to make up the composite NTSC signal.

The output of the delay line is subtracted from its input to extract the color signal. The output of this filter containing the 1.53-MHz subcarrier and color sidebands is mixed with a 5.11-MHz oscillator to convert the color subcarrier to 3.58 MHz, the normal NTSC color subcarrier. The resultant 3.58-MHz color signal is added to the luminance and the 4.5-MHz audio FM to provide the composite NTSC signal which is then translated to either channel 3 or 4. This composite rf signal is available at an output jack at the rear of the player. The output jack of the player is connected directly to the antenna input of a consumer television receiver. When the player is turned off, the antenna input signal is fed directly to the output jack and passed unattenuated to the television receiver.

In traversing the comb filter, low-frequency vertical detail information is removed from the luminance signal. For example, the video signal necessary to produce alternate black and white lines is completely canceled when the input and output of the delay line are added together. To regenerate this low-frequency information, it is necessary for vertical detail to be added back into the picture. This information is extracted from the low-frequency portion of the combed chrominance signal by a low-pass filter and added to the combed luminance signal to provide an uncombed signal below 500 kHz.

When a defect is detected in the video FM carrier, the defect detector automatically switches the input of the delay line to the output of the delay line so that the signal is recirculated. When a defect is detected on any one horizontal line in the picture, the automatic throwing of the delay-line switch to permit recirculation results in a signal from the previous line being substituted during the disturbed video input signal. This type of substitution is similar to that used as "drop-out compensation" in VCR's. Since information on a line-to-line basis is highly correlated, such substitutions are nearly invisible. The result is that defects on the disc, which would otherwise be objectionable, are made inconspicuous.

Tolerance buildup as a result of commercial manufacture of the disc and player and the placement of the disc on the turntable is such that the information on the disc can be slightly off-center during playback. This non-centered condition would result in a speed variation along the groove that can be translated into horizontal picture jitter at the 7.5-Hz once-around rotation rate of the turntable. Such off-centering causes groove speed to be higher than average on one side of the rotation and lower on the other side.

The arm stretcher shown in the lower left-hand corner of Fig. 23 corrects for the effects of off-centering. This device is similar to a moving-coil loudspeaker mechanism which is fastened by a flexible coupling to the rear end of the stylus arm and moves the stylus arm tangentially along the groove. When the groove speed is low, the stylus arm is moved in a direction opposite to the groove velocity to increase its relative speed. When the groove speed is too high, the stylus arm is moved in the same direction as the groove velocity to reduce the relative speed. The signal for driving the arm stretcher is obtained by comparing the 3.58-MHz color burst from the disc with a fixed oscillator at the same frequency. The net result is that off-centered conditions as large as 254 micrometers do not produce detectable picture jitter in playback.

During the play of a disc, the stylus is maintained in the center of the groove. This is accomplished by sensing the lateral position of the stylus relative to the cartridge housing by capacitive coupling of the stylus flylead to varactor diodes driven out-of-phase by a 260-kHz oscillator. As the capacitance of one diode increases, the other decreases and vice-versa. These diodes are located on each side of the stylus flylead, so that a fraction of their capacitance is added to the stylus capacitance as a function of how close the flylead is to the diodes. When the stylus is centered, the resultant varactor-diode outputs are canceled. In the off-centered condition, the output of one diode is greater than the other causing a change in the stylus resonant circuit and giving rise to 260-kHz components in the output of the 915-MHz amplitude detector. The amplitude and phase of the 260-kHz signal indicate the amount and direction of stylus off-centering. A dc arm-advance motor is driven in response to this 260-kHz error signal to center the stylus arm and return the error signal to zero.

The stylus kicker shown in the lower left of Fig. 23 permits small, rapid lateral movements of the stylus during play. A tiny, permanent magnet mounted on the stylus arm near the stylus is "kicked" sideways by magnetic fields from small coils mounted in the stylus-cartridge arm housing. When movement of the stylus is desired, an appropriate pulse of current through the coils kicks the stylus sideways one or more grooves in either the forward or reverse direction. This operation is activated by pressing a visual search button on the player. A pulse is applied to the kicker coils just prior to each vertical blanking interval such that the stylus moves about two grooves. Since there are 8 fields per rotation, the picture shown on the TV screen advances (or reverses) at 16-times normal speed. Since the stylus movement takes place during the vertical blanking interval, no picture breakup occurs.

The stylus kicker is also used to correct for locked groove defects on the disc. Recorded on the disc is a unique field number in each vertical blanking interval. The numbers increase monotonically from the start of play to the end of play on the disc. Circuits are built into the player to decode and keep track of the field numbers. During normal play, these numbers progress regularly and after conversion to minutes are displayed on an LED 2-digit minute indicator. When a locked groove occurs, the numbers do not progress normally but instead decrease. The player recognizes this fact and causes the application of pulses to the kicker coils to move the stylus ahead by two grooves. These pulses continue until field numbers read from the disc equal or exceed the numbers predicted in the player microprocessor. In most cases, locked-groove defects are corrected so rapidly as not to be objectionable to a viewer. No corrective action is taken when forward groove skips occur. In general, forward skips cause little disturbance to the viewer.

The stylus lifter is activated to raise and lower the stylus as required for proper player operation. The stylus is lowered during normal play and visual search, and it is lowered momentarily onto a stylus cleaner each time a disc is removed from the player. In all other conditions, including power off, the stylus is lifted off the disc.

4.2 Player Operation

Fig. 24 is a photograph of the SFT100 player introduced in the United States on March 22, 1981. It measures 43.2-cm wide by 39.6-cm deep by 14.7-cm high, weighs 9.1 kg, and consumes 35 watts of power. Additional player parameters are given in Appendix 1. Jacks for antenna input and rf output, a channel selection switch, and power-line cord are on the back of the player. As shown in Fig. 24, a function lever switch on the right side of the front panel has positions for Load/Unload, Play and Off. In the Load/Unload position, a caddy-entry door is opened to permit the loading or retrieving of a disc by means of caddy insertion. In the Play position, the caddy-entry door is closed, the turntable is energized, the stylus is dropped onto the disc, and the disc is played.

Player operation is controlled by five push buttons. The Pause push button causes the stylus to lift from the disc and the arm advance to stop. A second push of this button causes the stylus to drop down onto the disc and the arm advance to engage. Thus, normal play is resumed. The Pause button allows one to interrupt the program for as long as desired without missing any of the program content and without harm to the disc. The two Visual Search buttons cause the stylus to be kicked nominally two

Fig. 24—Video Disc player—Model SFT100.

grooves either forward or reverse during the vertical-blanking interval so that the program action speeds up approximately 16 times normal rate without picture breakup. These Visual Search buttons conveniently permit locating a particular section of the program. The two Rapid Access push buttons cause the stylus to be lifted and move the stylus arm housing at about 150 times normal speed in either the forward or reverse direction. Both video and audio signals are muted during this operation.

The Play Time indicators give an indication of the stylus position measured in minutes of play starting at the beginning of the disc. These indicators also show an "L" for the Load/Unload position of the function lever, "P" for Pause, and an "E" to indicate the program has ended.

After a disc has been inserted into the player, the Side indicator shows which side of the disc is actually being played or is ready to be played.

The stylus cartridge access door on the top of the player permits simple and easy changing of the stylus cartridge when required. The stylus is designed to operate for years in normal home operation. Discs can be played many hundreds of times without deterioration. All of the parts of the system are designed for extended life.

4.3 Special Playing Modes

The design of the CED player-disc system has many options for unique playing modes. The stylus-disc interface permits radial disc scanning, repeat groove playing (millions of times) and random access by time or field index number, all without damage to the disc.

Typical of the features that have been demonstrated in the laboratory are:

- Fast Motion—Forward/Reverse
- Random Access—Forward/Reverse and Loop Back or Forward
- Slow Motion } With One-Frame Storage
- Stop Action }

The addition of these features to products requires appropriate software, development time, and market acceptability in terms of value versus cost.

5. Stereo/Bilingual

RCA plans to introduce a stereo version of its CED player in mid 1982 along with appropriate stereo discs. The form of the signal on the disc is similar to the monaural version with the addition of a second audio modulated FM carrier at 905 ± 50 kHz deviation, as shown in Fig. 25.

The left and right stereo channels are matrixed to produce L + R for modulation of the 716 kHz channel and L-R for modulation of the 905 kHz channel. This provides compatibility for the monaural players, which use 716 kHz as their normal audio decoding channel.

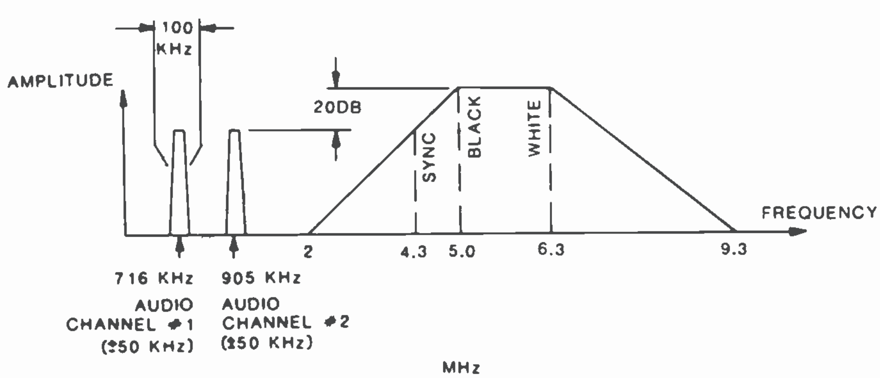

Fig. 25—Frequency spectrum. In stereo or two-channel recording, the audio carriers are 20 dB below the video carrier.

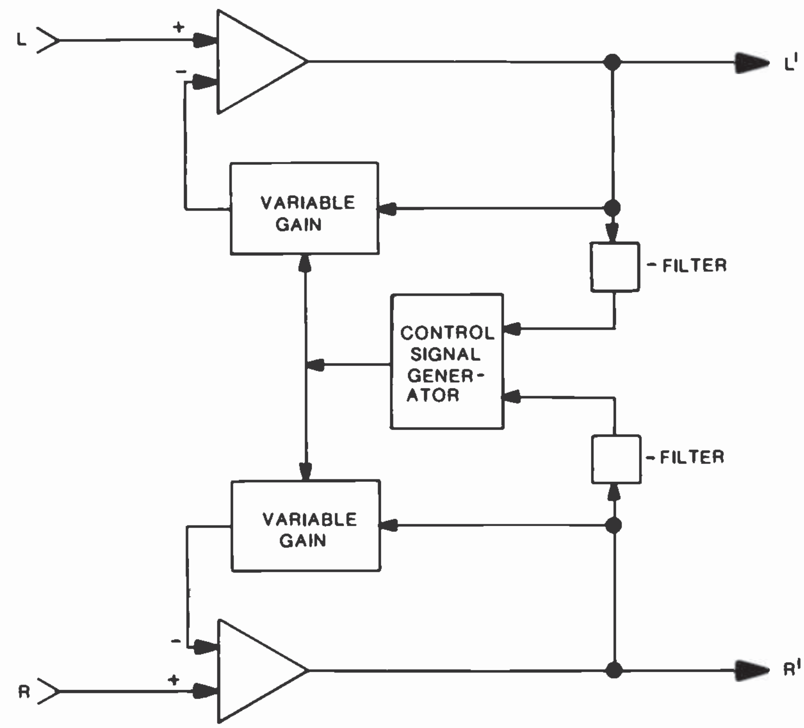

Fig. 26—CX Stereo signal compression block diagram (CX is a trademark of CBS Laboratories).

Each stereo channel prior to matrixing is encoded in the CX* system for noise reduction and extension of dynamic range. The CX compression system has the general form shown in Fig. 26. Voltage controlled amplifiers in the feedback loop of the left and right channels are adjusted by a control signal derived from the left and right channel outputs. Reference operating level is defined as that which produces half the maximum deviation of the FM modulated sum channel with 1 kHz applied to both the left and right channels (0 dB reference).

Steady state compression of a 1 kHz sine wave is 2:1 on a log-log plot at input signal levels greater than −40 dB and 1:1 for signals less than −40 dB. The filter, control-signal generator, and variable gain amplifiers produce a resultant steady state frequency characteristic for a constant input amplitude sine wave as shown in Fig. 27.

The control signal generator, shown in block diagram form in Fig. 28,

* CX is a trademark of CBS Laboratories.

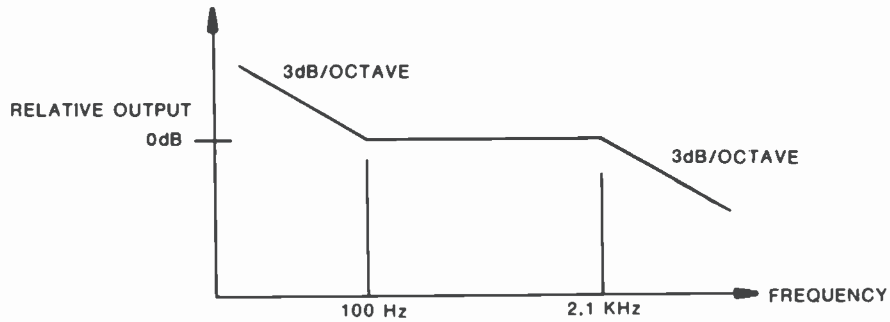

Fig. 27—CX signal compression amplitude versus frequency characteristic.

has a non-linear transient response. The details of the control signal generator are beyond the scope of this paper except to note that low amplitude transients do not modify the steady-state response whereas larger transients result in control signals that reduce the noise pumping associated with noise reduction systems. To take full advantage of the CX system the player must perform an inverse expansion of the audio signals that matches the original encoding. There is up to 20-dB additional noise suppression, resulting in 70-dB dynamic range with the full use of the CX system.

The use of the two independent audio channels for bilingual application requires a separate input to each of the available audio channels. CX encoding/decoding is not part of this type of system. Separation of the two channels exceeds 55 dB.

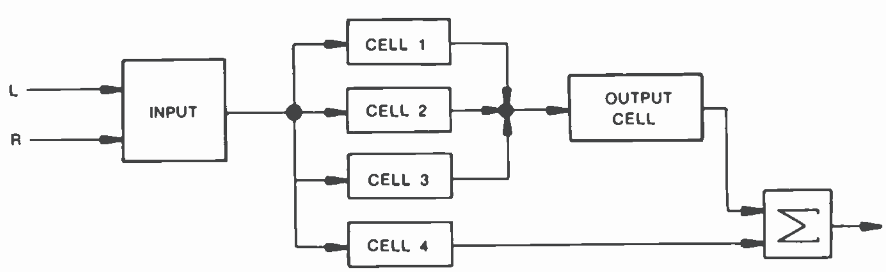

Fig. 28—CX system control signal generator.

6. 625 Line/50 Hz Field System

The developoment of a 625 line/50 Hz system has been based on maintaining similarity in disc manufacture while achieving improved signal performance. A summary of CED parameters for this system is given in Appendix 1 along with details of the signal encoding.

The following items are identical to those used in the 525 line/60 Hz field system:

- Disc Geometry
- Groove Dimensions
- 8 Fields/Revolution
- 1 Hour/Side
- Master Recording Disc
- Recording Cutterhead
- Matrix—Metal Parts
- Pressing
- Surface Treatment
- Caddy
- Stereo Audio Compansion
- Video FM Standards
- Cartridge Pickup System
- Player-Caddy Handling System

System parameters that are slightly different are as follows:

	525 Line/60 Hz	*625 Line/50 Hz*
Audio FM Carriers	715.9 kHz	710.9 kHz
Chrominance Subcarrier	1.534 MHz	1.523 MHz
Turntable Speed	450 RPM	375 RPM
Horizontal Scan Frequency	15.734 kHz	15.625 kHz

Major differences relate to (1) the input tape software standards, which for the 625 line/50 Hz system require PAL standards compatible with CCIR recommendation 472-1, (2) player video signal processing, which requires comb filter delay line decoding in accordance with 625 line/50 Hz standards, and (3) modulation of baseband signals to form PAL and/or SECAM compatible rf/video signals for television receiver input.

Another major difference is in the level of radio frequency emission the players may have in the 902–928 MHz band. Permissible radiation in Region 2* is up to 50,000 μv/meter at 30 meters whereas in Region 1

* ITU Regions as defined in Table of Frequency Allocation.

only 63.1 μv/meter is permitted (VDE 0871, ISM, Class B). This creates special problems for player design.

No other important difference exists in the CED standards for the two systems.

References:

H. N. Crooks, "The RCA SelectaVision VideoDisc System," *RCA Engineer*, **26**, No. 5, 1981, pp. 4–10.

J. K. Clemens, "Capacitive Pickup and the Buried Subcarrier Encoding System for the RCA VideoDisc," *RCA Review*, **39**, March 1978, pp. 45–50.

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D. H. Pritchard, J. K. Clemens and Ross, M. D., "The Principles and Quality of the Buried Subcarrier Encoding and Decoding System," *IEEE Trans. Consumer Electronics*, **CE-27**, No. 3 (ISSN0098-3063), Aug. 1981, pp. 352–360.

T. J. Christopher, F. R. Stave, and W. M. Workman, "The SelectaVision Player," *IEEE Trans. Consumer Electronics*, **CE-27**, No. 3 (ISSN0098-3063), Aug. 1981, pp. 340–351.

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Appendix 1—CED System Parameters

A1.1 525/60 Hz and 625/50 Hz Systems

Disc Physical Dimensions	
Diameter	30.2 cm
Thickness	1.9 mm
Center-Hole Diameter	3.3 cm
Rotation Rate (525/60 Hz)	450 RPM
(625/50 Hz)	375 RPM
Recorded Band	7.3 cm wide
Starting Diameter Preprogram Band	29.3 cm
Starting Diameter Program	29.1 cm
End Diameter Program (60 Minutes)	
(525/60 Hz)	14.38 cm
(625/50 Hz)	16.81 cm
End Diameter Post Program Band	
(525/60 Hz)	13.56 cm
(625/50 Hz)	16.00 cm
Groove Density	3793 grooves/cm
Groove Depth (p-p)	0.48 μm
Signal Amplitude (p-p)	0.085 μm
Disc Performance Parameters	
Play Time (4 Frames per Revolution)	60 minutes per side
Recorded FM Signal	4.3 to 6.3 MHz
Luminance Bandwidth	3.0 MHz

Chrominance Bandwidth	0.5 MHz
Video Signal-to-Noise Ratio	>46 dB (CCIR)
Chrominance Signal-to-Noise Ratio	>40 dB
Audio Carriers (525/60 Hz)	715.9 kHz
(625/50 Hz)	710.9 kHz
Audio Bandwidth	15 kHz
Audio FM Signal Deviation	±50 kHz
Audio Signal-to-Noise Ratio	>50 dBA(USASI)
Minimum Stereo Separation at 1 kHz	26 dB
Dynamic Range Mono (without compansion)	50 dB
Stereo (with compansion)	70 dB

A1.2 525 Line/60 Hz System

Source Signal

Source signals are NTSC compatible television signals, complying with EIA Standard RS-170A. Chrominance is limited to peak levels represented by 75% color bars.

Standard Predistortion

Composite signals to be encoded for the CED System are delay equalized before baseband video processing as follows:

$f < 3.0$ MHz: $t = 0$

$f > 3.0$ MHz: $t = (-170)\ (f - 3.00\ \text{MHz})/(0.58\ \text{MHz})$ nanoseconds.

Baseband Video Processing

The luminance signal is combed such that information contained at frequencies* $(2n + 1)\ f_H/2$ is attenuated by at least 40 dB with respect to frequencies nf_H (where n is any integer), in the band from 1.0 to 2.0 MHz. Vertical detail is added back such that at frequencies 0.9 MHz and below, vertical detail is not attenuated more than 3 dB. The vertical detail is attenuated at least 17 dB at 2.0 MHz.

Pre-emphasis

6 dB/Octave pre-emphasis is applied to the luminance signal between t_1 and t_2. The time constants are:

$t_1 = 640$ nanoseconds

$t_2 = 160$ nanoseconds

Maximum pre-emphasis 12 dB

* $f_H \doteq 15.734264$ kHz.

Additional linear phase pre-emphasis is added to luminance as follows:
$P = Kf^2$, ($f \leq 3.0$ MHz); P is pre-emphasis in dB; $K \approx 1$;
f is frequency in MHz.
Maximum $P = 12$ dB.

Chrominance

The chrominance signal is combed at all frequencies such that information contained at frequencies nf_H is attenuated by at least 40 dB.

Chrominance carrier frequency is 195 $f_H/2$, approximately 1.534 MHz

Frequency Modulation—Video

Carrier Frequency	IRE Units	Frequency, MHz
Sync tip	−40	4.3
Blanking	0	4.871
White Level	+100	6.3
Maximum Frequency	+144	6.929
Minimum Frequency	−66	3.929

Frequency Modulation—Audio

L + R; Monaural; Independent Channel 1
$91 f_H/2$, approximately 715.9 kHz
L − R; Independent Channel 2 115 $f_H/2$, approximately 904.7 kHz
Peak deviation: ±50 kHz
Pre-emphasis: 6 dB/Octave, time constant = 75 μsec.

A1.3 625 Line/50 Hz System

Source Signal

Source signals are 625 lines/frame, 50 fields/sec, PAL—compatible television signals complying with CCIR Recommendation 472-1 (Study Group II). Chrominance is limited to peak levels represented by 75% color bars.

Baseband Video Processing

The luminance signal is comb-filtered to remove information at frequencies* $\simeq (2n + 1) f_H/4$. Attenuation of information at (1135 $f_H/4$) + 25 Hz should be ≥30 dB. The information removed (which includes some vertical detail) is reinserted through a modified 2.5T sine^2 pulse filter (having its first zero at 4.0 MHz and a zero added at 4.43 MHz).

* $f_H \doteq 15.625$ kHz.

The resultant signal is comb-filtered to remove information at frequencies $\simeq (2n + 1) f_H/2$. The information so removed (which includes vertical detail) is reinserted through a band-rejection filter whose characteristics are such that, in the combined signal, information has been attenuated $\geq$20 dB at $(195f_H/2)$ and $\approx$3 dB at $(195f_H/2) \pm 48f_H$.

Pre-emphasis

6-dB/octave high frequency pre-emphasis is applied to the luminance signal between t_1 and t_2. The time constants t_1 = 640 nanoseconds; t_2 = 160 nanoseconds.

Maximum pre-emphasis 12 dB.

Additional linear phase pre-emphasis is added to luminance as follows:

$P = Kf^2$, ($f \leq 3.0$ MHz); P is pre-emphasis in dB; $K \simeq 1$; f is frequency in MHz.

Maximum P = 12 dB.

Chrominance

The chrominance signal is comb-filtered to remove information at frequencies $\simeq nf_H/2$. Attenuation of information at 568 $f_H/2$ should be $\geq$30 dB.

The resultant signal should be combed to separate PAL U and $\pm V$ components. The $\pm V$ component polarity is switched so that $+V$ is always recombined with U.

Chrominance carrier frequency is $(195\, f_H/2) - 25$ Hz, approximately 1.523 MHz.

Frequency Modulation—Video

Carrier Frequency	IRE Units	Frequency, MHz
Sync tip	−40	4.3
Blanking	0	4.871
White Level	+100	6.3
Maximum Frequency	+144	6.929
Minimum Frequency	−66	3.929

Frequency Modulation—Audio

L + R; Monaural; Independent Channel 1

91 $f_H/2$, approximately 710.9 kHz

L − R; Independent Channel 2

115 $f_H/2$, approximately 898.4 kHz

Peak deviation: ±50 kHz.

Pre-emphasis: 6 dB/octave, time constant = 75 μsec.

A1.4 CED System Parameters

Player (525/60 Hz) – SFT100

Electrical

Readout	Capacitance
RF Modulator Frequency	61.25 MHz (CH.3) 67.25 MHz (CH.4)
RF Output Level	2.0 mV/75OHMS
Luminance Bandwidth	3.0 MHz
Luminance Signal-to-Noise Ratio	>46 dB (CCIR)
Chrominance Bandwidth	0.5 MHz
Audio Bandwidth	15 kHz
Audio Signal-to-Noise Ratio	>50 dBA (USASI)
Power Consumption (115V AC, 60 Hz)	35 Watts

Mechanical

Cabinet: Width	43.2 cm
Height	14.7 cm
Depth	39.6 cm
Weight	9.1 kg
Stylus Set-Down Diameter	29.2 cm
Stylus End of Travel Diameter	14.0 cm
Cartridge Contact—Height from Disc	1.4 cm
Maximum TIR	102 μm

Playing Mode

Normal Forward
Visual Search, 16 ×, Forward/Reverse
Rapid Access, 150 ×, 30 Seconds/Side, Forward/Reverse
Pause

Appendix 2—Buried Subcarrier System—1-H Delay Comb Filter

An NTSC television signal is repetitively sampled at rates of f_H = 15.734264 kHz, 59.94 Hz and 29.97 Hz, which results from the horizontal and vertical scanning rates. A fourier analysis of the signal shows an energy spectrum concentrated at interval spacings of f_H, with subside-bands grouped around each f_H interval at multiples of 59.94 and 29.97 Hz spacing as shown in Fig. 29.

The addition of a color subcarrier at 1.53 MHz has its energy spectrum interleaved with the baseband video by synchronizing the subcarrier with horizontal sync at an odd multiple of one-half line rate (195 $f_H/2$ or 1.5340907 MHz).

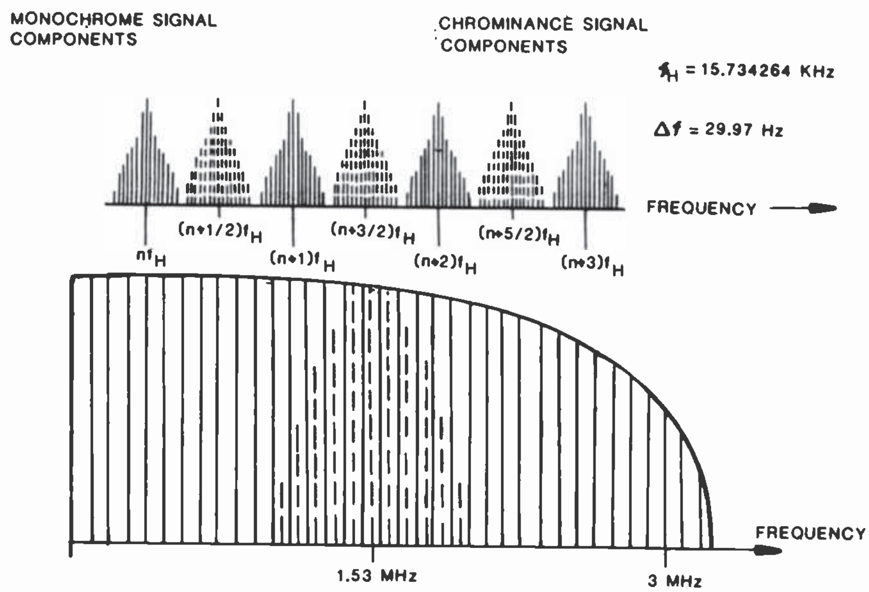

Fig. 29—Video signal spectrum.

The baseband luminance signal is limited in bandwidth to 3 MHz consistent with the resolution reproduced in home television receivers. The color carrier sidebands are similarly limited to 500 kHz, thus restricting all picture information within a 3-MHz band. This efficient coding system permits excellent picture reproduction with minimum spurious beats from the limited recording bandwidth of current video discs.

Separation of the color and luminance information is accomplished using a comb filter in the player. Fig. 30 shows the basic block diagram of a 1-H delay comb filter along with resultant amplitude versus frequency responses of the circuit operations. The video input is delayed by one horizontal scanning line in 585 stage CCD line with a 9.2 MHz clock frequency. The delayed and undelayed signals are added in the summation block such that all frequency components which are spaced in even multiples of $f_H/2$ are passed unattenuated to the output as shown. All frequency components spaced at odd multiples of $f_H/2$ are canceled. The frequency spectrum as shown follows a $|\cos(\pi f/f_H)|$ form. Thus, all luminance video components are passed through this comb filter while chroma components are rejected. Conversely, in the sub-

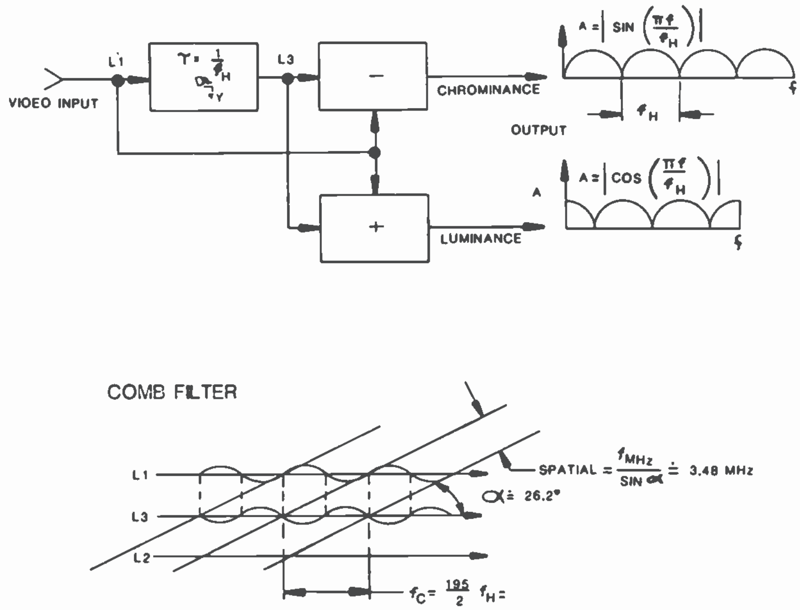

Fig. 30—Comb filter.

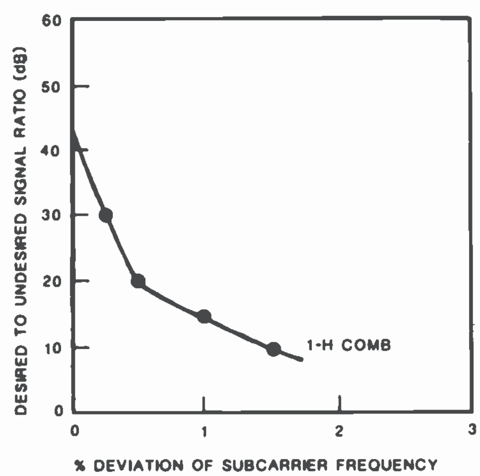

Fig. 31—Comb filter rejection ratio versus percent subcarrier frequency stability.

traction network, the luminance components are rejected and the chroma components are passed to the output.

In the player CCD 1-H delay line comb filter, the desired-to-undesired signal ratio is normally 28 dB at 1.53 MHz and more than 23 dB at the passband edges. The clock frequency of the delay line (6 × 1.53 MHz) is automatically adjusted to compensate for time base errors in all but extreme cases. Time base errors in excess of 8–10 nanoseconds causes 7.5 kHz horizontal striations to become visible due to comb filter imbalance. A plot of rejection ratio versus per cent frequency variation is shown in Fig. 31. As can be seen, the comb filter is reasonably insensitive to small changes in carrier frequency, i.e., less than 1%.