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A PRECISION ENDLESS-LOOP MAGNETIC TAPE RECORDER FOR SPACE APPLICATIONS

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SUMMARY

The tape recorder developed for the Tiros satellites is a miniaturized, low power, two-speed recorder whose endless-loop tape cartridge stores 200 feet of 1/4-inch lubricated magnetic tape. A two-phase 137.5-cps 14-vac hysteresis synchronous motor, requiring less than 0.300 watts drives the tape at 0.4 inch/second for recording. During playback, a 5000 rpm motor requiring less than 1 watt drives the tape at 12 inches/second. A transistorized dc speed control unit maintains better than 1 percent regulation of this motor. Speed reduction from the motors to the capstan drive is obtained with reduction pulleys utilizing polyester film belts. Frictional drag from components not used during certain operating cycles is minimized by using spring clutches which prevent power drain on the motor. The record motor operates continuously, and spring clutches allow this motor to be overridden during the playback mode. Flutter and wow is maintained below 2.5 percent peak to peak from 0 to 1000 cps.

This exceptional performance is made possible by an extremely accurate gyro-type capstan assembly. The capstan has maximum runouts of 5×10^{-5} inch and the assembly uses the duplex bearing and integral race technique. The bearings in this assembly are preloaded by means of a fixed center distance. This recorder has survived sinusoidal vibration at 10 g from 0 to 2000 cps for 1/2 hour, and random vibration test at 20 g rms from 0 to 2000 cps for 4 minutes.

A time-sharing switch, operated from the record mode reduction system, time-divides the information to be recorded. A playback timing switch, operated through a 16,650 to 1 gear reduction from the playback motor, activates a microswitch that cuts off power to the motor and resets the record mode electronics after a playback cycle of 3.33 minutes.

This paper describes in detail the design of the particular components which combine to make this recorder a reliable, high performing, precision unit.

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ITRODUCTION

Satellites are not always in an orbital position where their data can be immediately relayed to a ceiving station on the earth. Therefore, some method of data storing must be used until the satel- te is in a position to transmit information to a ground receiving station. When the Tiros program as conceived, magnetic tape recorders were the most practical answer to this problem. Existing pe recording methods required more power, weight, and space than could be afforded, and their rformance capabilities were limited.

Project Vanguard was the beginning of a new concept in magnetic endless-loop tape storage sys- ms.* The principal reasons for selecting the endless-loop cartridge are the following: The single el provides compact storage; reversal mechanisms are not required for record and playback func- ons; the tape can drive beyond one pass without requiring safety cutoff devices for the motors; and pe storage makes momentum compensation simple when required.

During the Vanguard program many of the presently employed instrumentation techniques were iginated. The next program employing a recorder of this type was Project Score, the first com- unications satellite; the Vanguard recorder was so functionally reliable that no significant improve- ents were required for Project Score.

When the Tiros program was initiated, a rigid set of specifications was introduced to assure that e satellite would have the desired longevity and reliability. These specifications called for the de- lopment of a high-speed endless-loop tape recorder with a large data storage capacity. Initial tempts were made to use the techniques successfully employed in Projects Vanguard and Score. it these techniques were inadequate to achieve the required performance, reliability, and low flutter thin the necessary weight and power limitations. Therefore, mechanical accuracy, low-tolerance achining, and assembly techniques had to be developed beyond the levels existing at that time.

The objective of this paper is to describe in detail the problems that arose and the solutions that re applied in the design and development of the Tiros satellite tape recorder. This recorder has en successfully flown in five Tiros satellites and its basic design will be used in future satellites.

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nel, R., Licht, J., Nordberg, W., Stampfl, R., and Stroud, W. G., "The Satellite Vanguard II: Cloud Cover Experiment," *IRE Trans. on l. Electronics,* MIL-4(2 and 3):245-247, April-July 1960.

OPERATIONAL DESCRIPTION

The Tiros IR tape recorder (Figure 1) is a miniaturized, low power, two-speed recorder using an endless-loop tape cartridge. Its external overall dimensions without a time-sharing switch are: diameter, 6.25 inches; and height, 2.3 inches. The recorder weighs 4 pounds.

The operation of the recorder is divided into a record and a playback mode. For the record moc a two-phase hysteresis synchronous motor operates continuously and drives a capstan through two belt passes; a complete tape cycle requires 100 minutes. A servo controlled dc motor operates the playback mode through one belt-reduction; a complete playback cycle requires 3.33 minutes. A spri clutch connecting the record motor pulley to the capstan shaft allows the playback motor to override the record motor during a 3.33 minute interrogation.

Linear velocity is imparted to the tape from the rotating capstan by means of a pivoted spring-loaded rubber roller. Positive head-gap-to-tape contact and accurate tape guidance across the head are obtained by the use of pressure pads and tape guides.

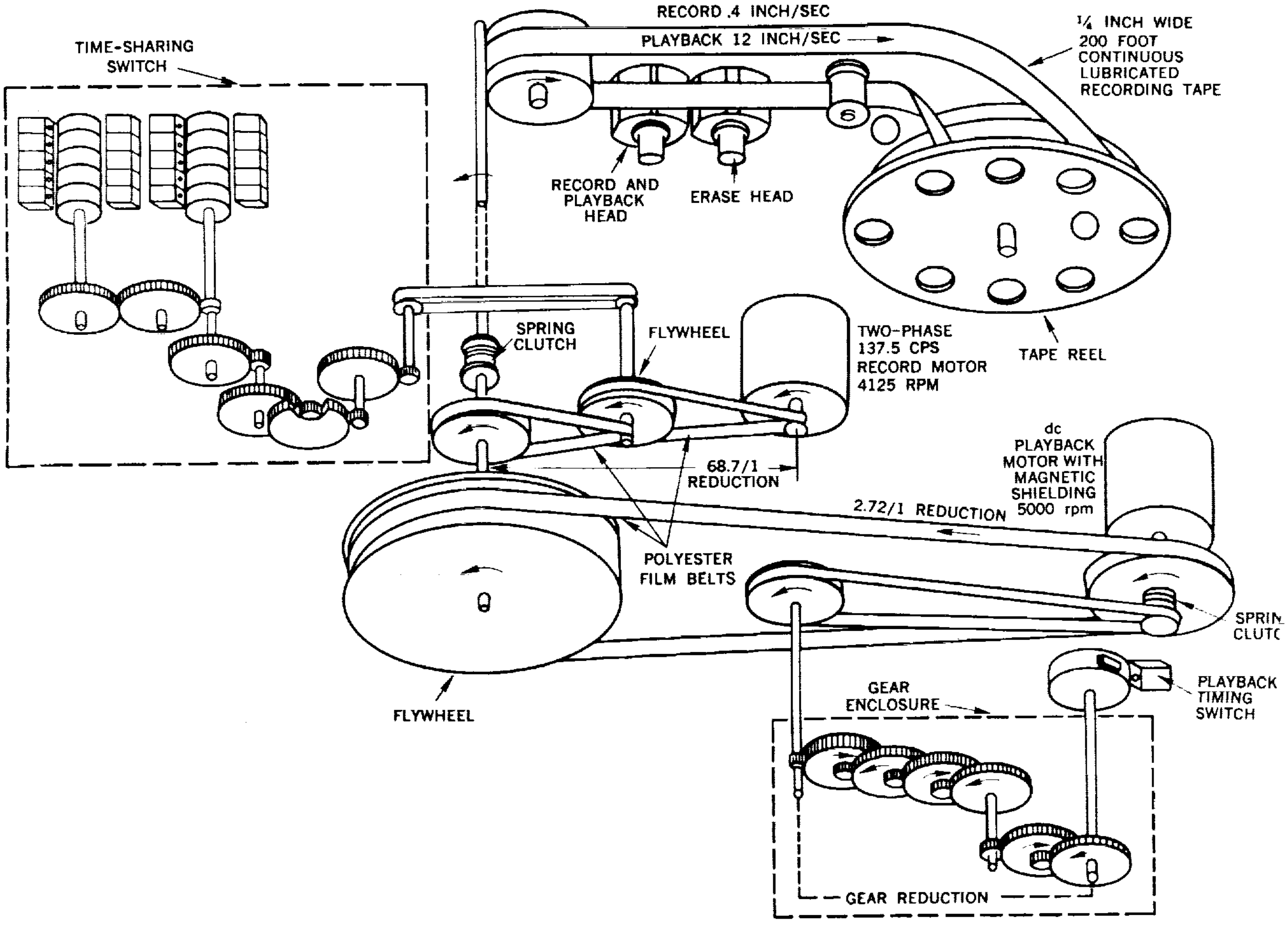

Figure 1—Tiros tape recorder schematic

A time-sharing switch driven from the intermediate jack shaft of the record system permits data be recorded in a preselected sequence. A gear box driven through a belt pass from the dc motor erates a microswitch which, by means of a relay, shuts off the playback mode and switches on the cord mode electronics after one complete playback cycle.

ECHANICAL DESIGN

The mechanical design of the tape recorder had to meet the following requirements: (1) a 30 to speed ratio, i.e., tape speeds of 0.4 inch per second on record and 12 inch per second on playback,) an increase of tape length from Vanguard's 75 feet to 200 feet, (3) the incorporation of a time-aring switch, (4) an orbital life of 6 months, (5) an overall flutter of less than 2.5 percent peak to ak, (6) 0.750 watt power for the playback mode, and (7) 0.300 watt power for the record mode. ese requirements led to many significant design advancements in miniature precision recorders.

Motors

Sufficient drive power was needed to drive the recorder under loads due to the 200-foot tape and sociated tape cartridge, pressure pads, tape guides, guide roller brush, flywheels, etc. Therefore, achieve the required low system power and low flutter, motors with high starting and running tor-es, high efficiencies, and better than 1 percent speed regulation were needed. The requirement for orbital life of 6 months demanded motor development efforts. Properly preloaded bearings and oper sealing to eliminate dirt, yet not increase torque, were primary concerns.

A special two-phase hysteresis synchronous motor was developed for the record system. It ighs 4.28 ounces and requires a 0.300 watt input at 137.5 cps and 14 volts ac. Its efficiency is about percent, with a running torque of 0.026 inch-ounce at a synchronous speed of 4125 rpm. It is 31 inches in diameter and 2 inches long. Because of the low starting torques, the system design ows the ac motor to run continuously. A transistorized power supply was built for this motor and discussed later in this report.

The high-speed playback mode required a motor with a high starting torque for rapid acceleration the tape from record speed to playback speed. The acceleration time is approximately 2 seconds. is requirement was satisfied by a 5000 rpm dc motor with a 0.750 watt input power rating at 15 lts dc, delivering about 0.1 inch-ounce of torque and weighing 1.94 ounces. This motor is 0.88 inch diameter and 2.44 inches long. To compensate for the inherently poor speed regulation of the dc tor, an alternator (Figure 2) is mounted on the rear shaft of the motor for the speed control. This speed control (described later) provided better than 1 percent regulation.

The ac motor is operated continuously to eliminate the possibility of its failure to start due to aring damage; thus, the dc motor has to override the ac motor at certain times with minimum fric-nal torque loss. This was accomplished by the use of a spring clutch in the capstan assembly which rmits the dc motor to rotate the capstan in the same direction as in the record mode without affect-g the ac motor drive system. The frictional drag of this spring clutch reflected back to the dc motor is about 0.011 inch-ounce. Since both motors are interconnected through belts and pulleys to the common capstan shaft, an additional spring clutch (Figure 2) is incorporated on the dc motor to prevent the ac motor from dragging the dc motor during the record mode. This results in a frictional drag torque reflected to the ac motor of about 0.0012 inch-ounce.

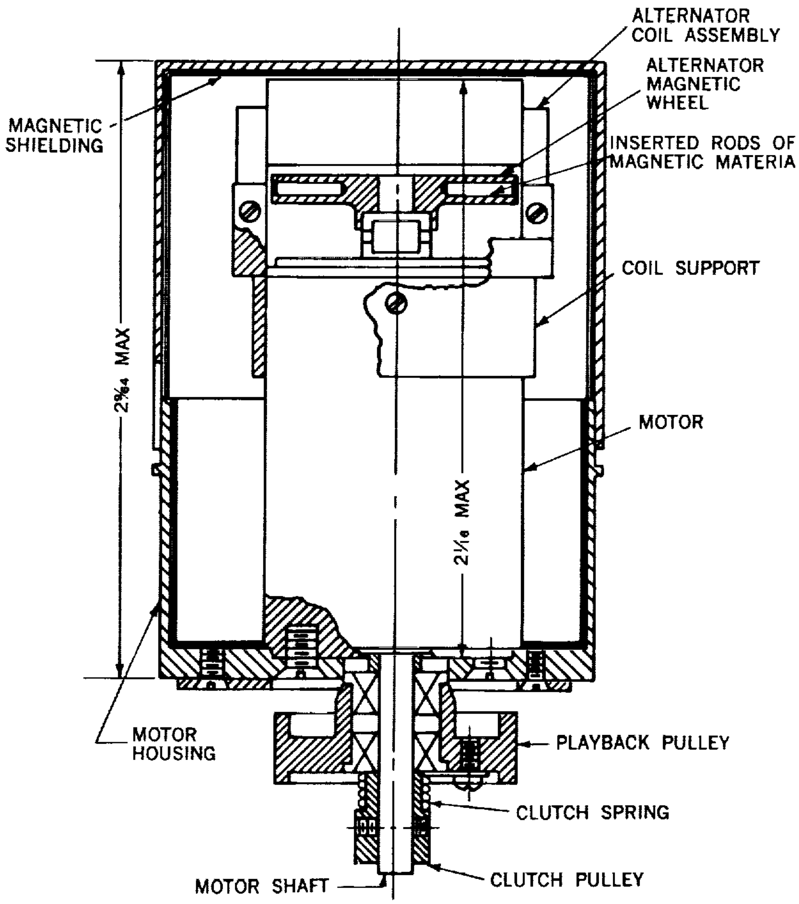

Figure 2—Playback motor assembly

Belt Drives

An efficient and accurate system of speed reduction and power transmission is provided by using endless-loop polyester film belts. Speed variations are minimized between the drive motors and the capstan because these belts are extremely uniform in thickness, are relatively stretch-free, and can handle transition from large to extremely small pulleys without showing bending fatigue or slippage. These belts were made by cutting a "donut" from a Mylar sheet 0.001 inch thick, stretching it into an endless-loop belt on two cone-shaped mandrels, and heat treating them for stress relief.

Although the thickness and uniformity of the belt in belt drive systems* is frequently neglected, for extreme precision they must be taken into account. The use of 0.001 inch thick Mylar belts whic exhibit an average variation in thickness of only .0001 inch results in extremely small pitch line variations in the drive system. In addition, the minimum thickness results in very low alternating stress profiles over the pulley. The latter permits the use of extremely small pulley sizes where possible without affecting belt life radically; permits the use of small bearings for low power drain; and makes possible an extremely compact design. An example of the reliability of these belts is the Tiros II tape recorder, which has been operating in the record mode continuously since November 2 1960.†

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*Licht, J., and White, A., "Polyester Film Belts," NASA Technical Note D-668, May 1961; also published in *Machine Design* 32(22):137-143, October 27, 1960.

†Interrogation of recorder was possible up to 18 months; however, a power failure in the satellite made it impossible to determine further operation.

For additional control of speed variations, each pulley is machined to dimensional tolerances ch that the speed variations due to the total accumulation of runouts will not exceed the required tter values. There are three pulleys in the low-speed system and two in the high-speed system igure 1). To achieve the desired tolerance on the ac motor pulley, a pulley blank is cemented onto e motor shaft and then turned in place as the motor shaft is rotated by an externally applied torque.

Capstan Assembly

An ideal approach to the design of the capstan assembly would have been to use a large diameter pstan; this would provide easy fabrication and facilitate a sufficient tape wrap around the capstan. owever, a large capstan would cause more frictional drag and consequently require more power; is would subject the motors to torques beyond their design limits because of the increased tape ten-ons, larger bearings, and large pulley reduction ratios which could possibly present problems in lt slippage. Therefore, a 0.125-inch capstan diameter was selected.

During the initial phases of the program the design of the capstan unit was similar to the design those used in the Vanguard and Score projects. However, it was realized that greater total indi-ted runout accuracies were required because of the flutter requirement. (Total indicated runouts 5×10^{-5} inch were necessary on the capstan shaft.) Attempts to obtain centerless ground shafts the specified tolerances and either press-fit or shrink-fit them into the capstan flywheel were un-ccessful: the final runouts were much too large. The problem was finally solved by grinding the afts on centers and cementing them into the flywheels. In addition, to eliminate runouts due to the lerance of the inner race of the bearing, it was decided to make the inner race part of the capstan aft and to grind the raceway on the same centers of the shaft. Also, the use of duplexed bearings ade it possible to assemble the capstan record-mode pulley on the shaft so that it would rotate in a ane perpendicular to the capstan axis with minimum runout.

An additional problem was the proper preloading of the bearings to insure their survival in a vere vibration environment. In previous designs, fixed preloads of capstan bearings had been used. owever – because of inadequate measurement techniques – excessive preloads which could cause inelling of balls and raceways, or insufficient preloads resulting in bearing damage during vibration, isted. Spring preloading met with little success. Bellville type springs were displaced sufficiently ring vibration to unload the bearings and cause damage. Therefore, in this design, the only adequate y of preloading was the bearing cap method. That method necessitated measuring the distance re-ired between the two outer bearings for a specific preload. This dimension varied by a few thou-ndths of an inch for any given unit because of the accumulation of tolerances.

The entire capstan assembly is mounted in a basket which fastens to the upper plate of the re-rder (Figure 3). This feature eliminated the necessity of removing the capstan unit every time the ttom plate had to be removed, and thus minimized the chance of damaging a bearing or scratching e capstan shaft. The basket was machined to fixed dimensions; therefore, the preload cap was the ly part which had to be machined in order to determine the preload accurately. The amount of pre-ad is determined from the load-deflection curves of the specific bearing used, and is based upon a

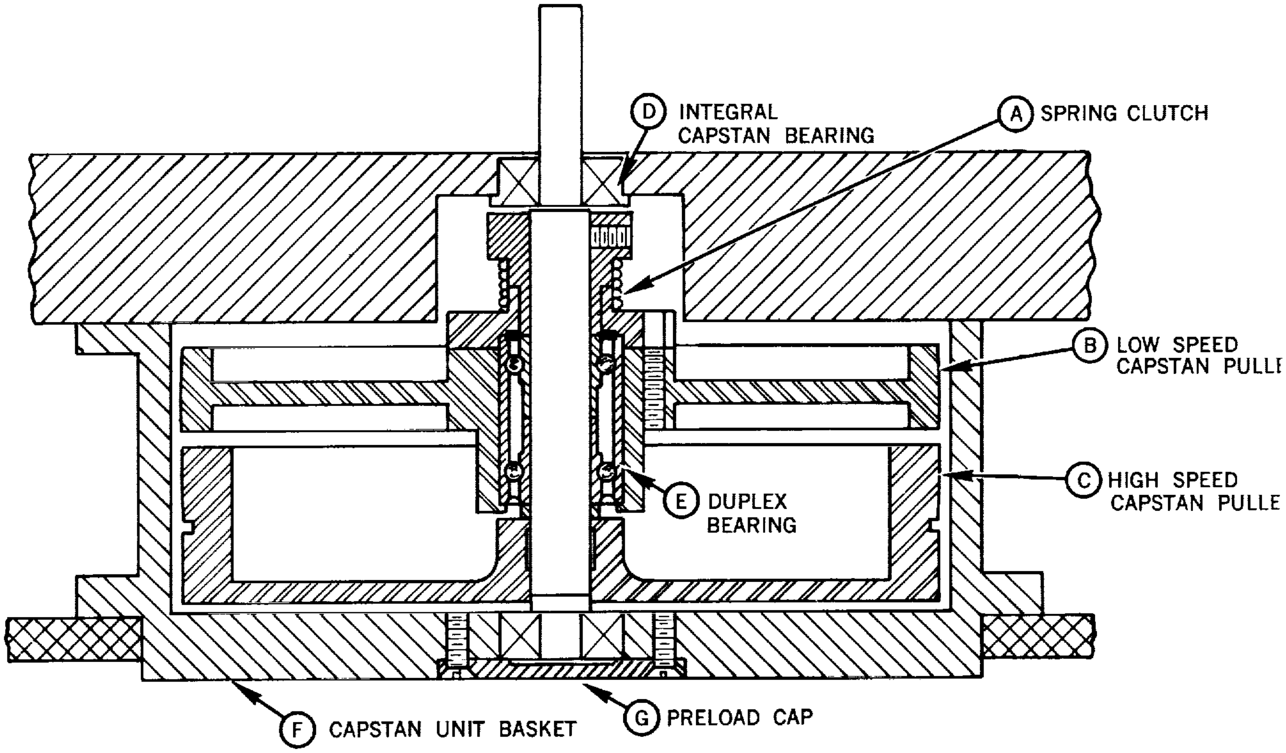

Figure 3—Capstan assembly

load equal to 20 times the capstan weight; this takes into account all vibrations to which the unit is subjected. The final bearing was preloaded by machining the bearing cap so that interference amoun ing to 0.0004 inch introduced the required pressure on the outer race. Since the inception of this method of preload determination no bearing failure has occurred in the unit. The resulting configuration of the capstan unit appears in Figure 3. The capstan consists of the following components: (A) spring clutch; (B) low-speed capstan pulley; (C) high-speed capstan flywheel pulley; (D) outer capstan bearings – the top one having its inner race integral with the capstan shaft; (E) duplexed bearing pair; (F) capstan unit basket; and (G) preload cap.

Pressure Roller Assembly

Another recorder design problem involved the location of the pressure roller (Figure 4) with respect to the capstan. In previous designs, the pressure rollers had been located a fixed distance from the capstan shaft with the major wrap of the tape around the roller. This resulted in a number of undesirable features: For

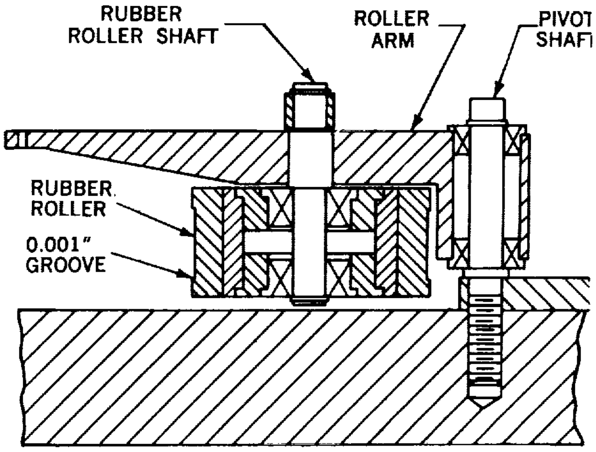

Figure 4—Rubber roller assembly

xample, the capstan caused an indentation in the roller whenever the recorder was idle; also, the oller acted more as a capstan than the capstan itself; i.e., its runouts actually influenced the flutter alues. In the Tiros design, the tape wrap had to remain the same. If the major wrap were around he capstan, the amount of tape contact with the capstan would be small. In addition, the lubricated ide of the tape would be in contact with the capstan; this tape path would have required excessive oller pressures to maintain tape speed without slippage, and thus would have caused higher transnitted torques and a possibility of bending the capstan. To alleviate these effects the rubber roller as ground to a diameter of 0.900 inch and mounted on a pivotal arm. The arm is spring loaded to 4 ounces to maintain constant tape speed. The spring is removable and when the recorder is not n use it is removed to minimize the amount of indentation. Another preventive measure against oller indentation was the selection of a rubber with a durometer rating between 50 and 60, which is ard enough to prevent indentation.

During vibration, with the tape driven in the record mode, the tape tends to ride up between the apstan and the rubber roller. This riding up was caused by fluctuations induced in the load spring at ts resonant frequency which caused the roller periodically to leave contact with the capstan. The atural frequency of the roller system was etermined, and a viscous damper was emloyed to critically damp the roller at this requency. An additional precaution consisted f grinding a slot 0.25 inch wide by 0.001 inch eep into the roller to help guide the tape and revent vertical motion.

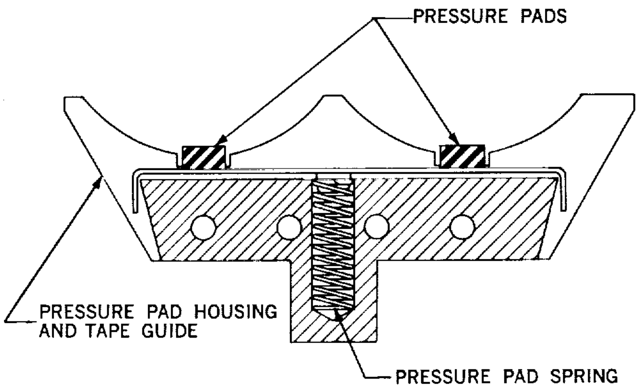

Figure 5–Tape guide assembly

Tape contact with the record-playback nd erase heads is maintained by indenting ne heads 0.0313 inch into the tape path from ne guide roller to the capstan. In addition, ressure pads (Figure 5) are used for posive contact. A tape guide provides a mount r the pressure pads and also guides the tape cross the heads. The record-playback head s adjustable for signal peaking purposes. A ressure arm, located on the guide roller Figure 6) where the tape emerges from the eel, maintains tape tension across the heads nd damps any erratic motion of the tape manating from the cartridge.

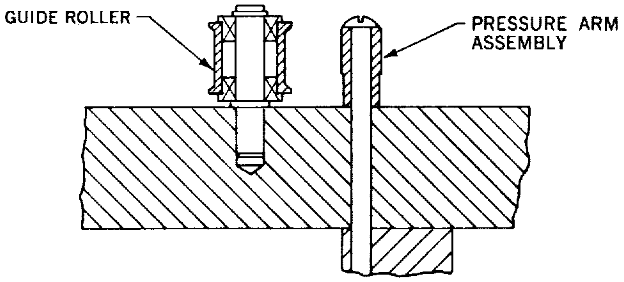

Figure 6–Pressure roller assembly

Tape Path

Figure 7 shows the upper plate of the reorder. The tape path starts at the inner

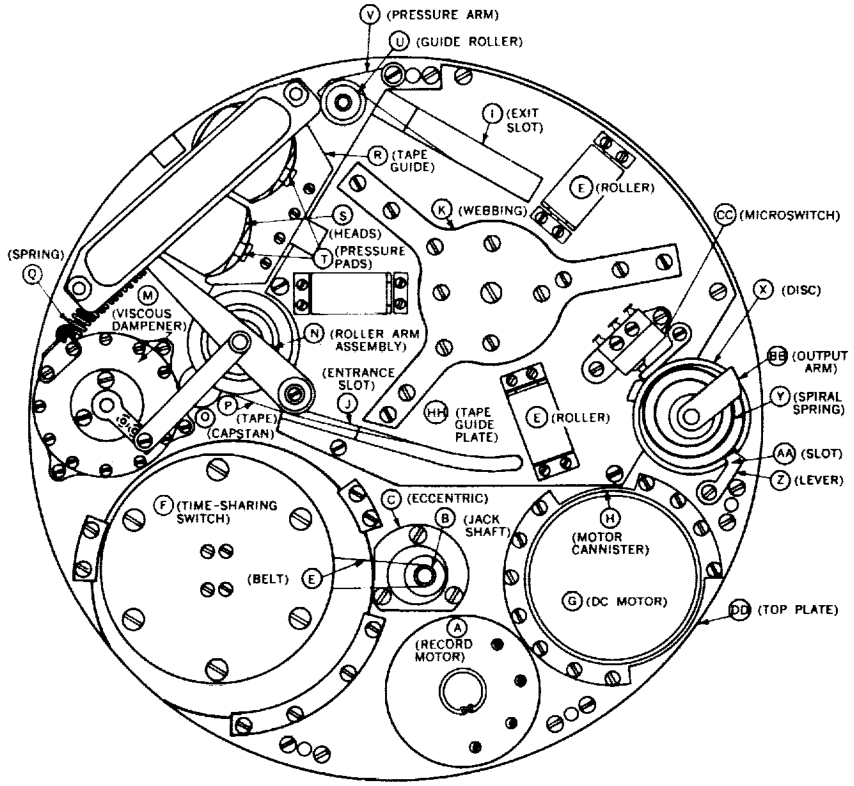

Figure 7—Upper plate top view

diameter of the tape reel where the tape emerges through the upper plate, and passes along the guid roller and pressure arm through the tape guide and pressure pads in front of the record-playback a erase heads. It then passes between the capstan and rubber roller down through the top plate to rewind onto the outside wrap of tape on the tape reel.

The tape cartridge contains 200 feet of 0.0014-inch magnetic tape coated with a special lubrican on the side opposite the oxide. This cartridge operates by allowing the inner wrap of tape to be pull by the capstan, the resultant force causing the cartridge to rotate. Because the tape moves at a spe cific velocity, the outer layer of tape moves at a speed lower than that of the reel. The resulting frictional drag rewinds the outer layer of tape on the periphery of the spool. Lubrication reduces th interlayer friction, thus reducing the flutter imparted to the tape and the amount of drive power required.

Playback Cutoff Switch

After one complete playback cycle, a mechanical switch shuts off the playback motor and reset the electronics to the record mode. Basically, a gear box is operated by a belt pass from the dc motor. Six gear passes (Figure 8) using 200-pitch gears are incorporated to provide the necessary

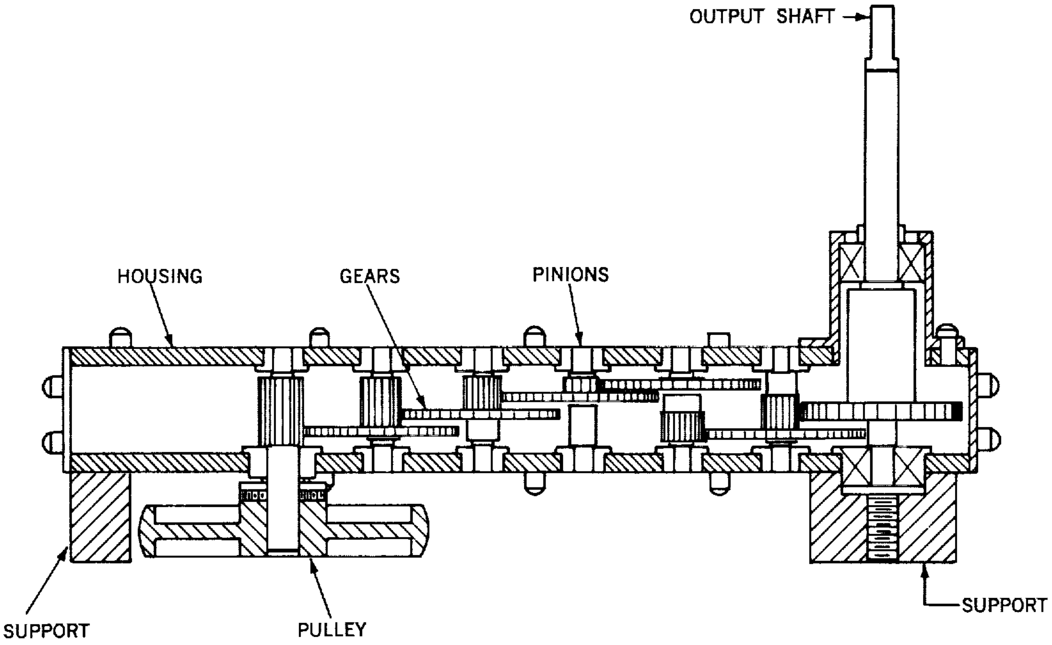

Figure 8—Speed reduction for playback cutoff switch

ır reduction. The entire gear reduction is en-
ısed in a magnesium case 3.4 inches long, 0.9 inch
le, and 0.45 inch thick. The pitch diameters of the
ırs vary from about 0.15 to about 0.6 inch and a
al of twelve gears comprise the gear reduction.
e total reduction is 16,650 to 1. The output shaft
the gear box is connected to a spring-operated
c. When this disc (Figure 9) moves approximately
revolution, the stop lever engages and stops the
c, causing the spring to be wound. When the entire
olution is completed, an arm on the output shaft
eases the stop lever, permitting the disc lobe to
uate a microswitch. This results in a 15 to 25
llisecond pulse which initiates the aforementioned
uence of events.

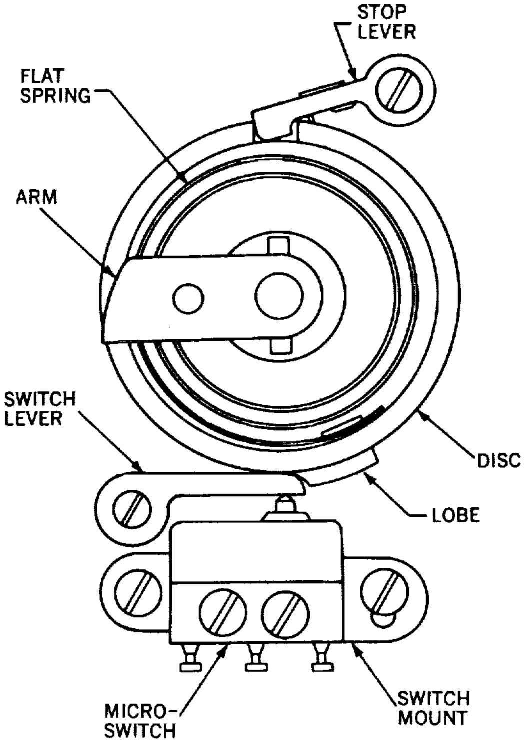

Figure 9—Reset switch assembly

Structure

The recorder supporting structure consists pri-
rily of two plates, top and bottom, separated by

standoffs. The structure is designed so that all parts are connected to the top plate, thus allowing t bottom plate to be removed without disturbing the alignment of any part. Initially, because of the weight consideration, both plates were made of 0.125-inch-thick magnesium. However, in testing t recorder for wow and flutter it was found that vibrations from the motors were being transmitted across the top plate to the record-playback head and affecting performance. It was then decided t use a material that would adequately damp any extraneous vibrations before they reached the heads. Investigation led to a special highly damped magnesium alloy called K-1A. A top plate 0.5 inch thic of this material eliminated the vibrational effects due to the motors.

Time-Sharing Switch

In the design of spacecraft telemetry systems it frequently is convenient to time-share items o data onto a single channel of a suitable storage or transmission medium. Electronic commutators are used for this purpose where features such as low signal levels, high data rates, and long life ar required. Ordinary mechanical commutators are used where low data rates are required, but they are usually limited to applications involving medium signal levels. Furthermore, the lifetimes of ordinary mechanical commutators are usually limited. However, the time-sharing switch (TSS)* di cussed in this paper operates reliably with low signal levels (about 20 microamperes, 0.05 microvolt, 450 cps) for long periods of time. In addition, this TSS rivals the ordinary mechanical commutator in low driving torque (0.0005 inch-ounce at 256 rpm), accurate timing, small size, and low weight.

The time-sharing sequence is obtained basically by stacking microswitches to face one or mor cams. The cams are driven through a gear box located beneath the banks of switches, and levers a used to transform the rotary motion of the cams into a linear motion necessary to depress the mic switch plungers.

Successful operation of the TSS has been demonstrated in the Tiros II satellite's infrared instr mentation, where it was used to cycle data from twelve separate sensors onto a channel of the infr tape recorder.

The TSS is composed of two assemblies: the lever-switch assembly and the transmission assembly. The lever-switch assembly includes the levers, microswitches, and supporting structure; transmission assembly includes the input pulley, gear reduction and housing, and the cams. Figur 10 is a cutaway view of the entire assembly, showing the relative positions of the switches, levers, and cams.

The levers transform the rotational motion of the cams into a linear motion necessary to depr the switches. Figure 11 shows the switch stacking arrangement.

The input pulley, driven by a 1-mil Mylar belt 0.062 inch wide, is aluminum and operates at 256 rpm.

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*Leavy, W. A., "A Time Sharing Switch for Spacecraft Telemetry Systems," NASA Technical Note D-1172, March 1962.

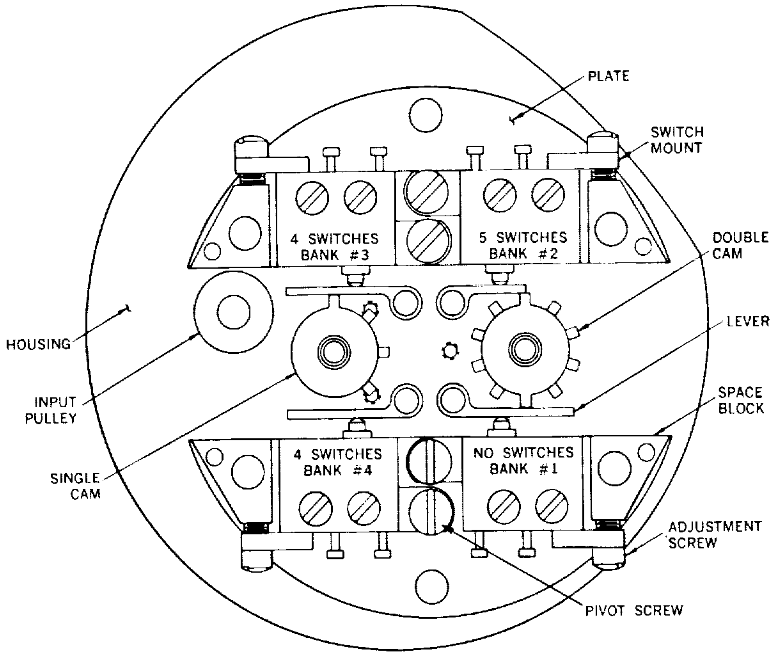

Figure 10—Time-sharing switch assembly

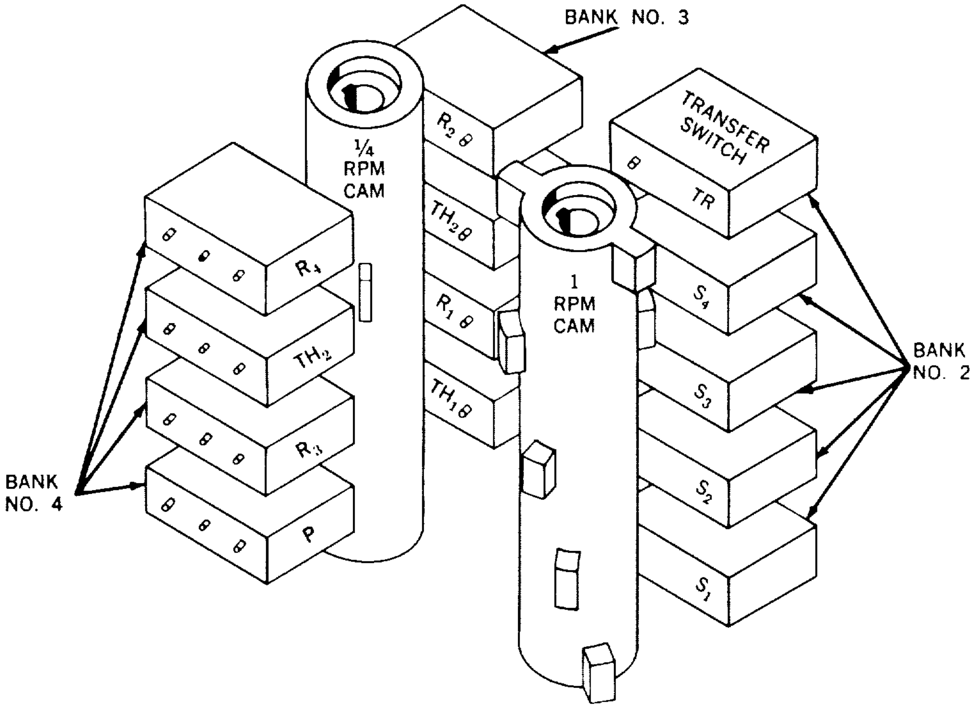

Figure 11—Time-sharing switch stacking arrangement

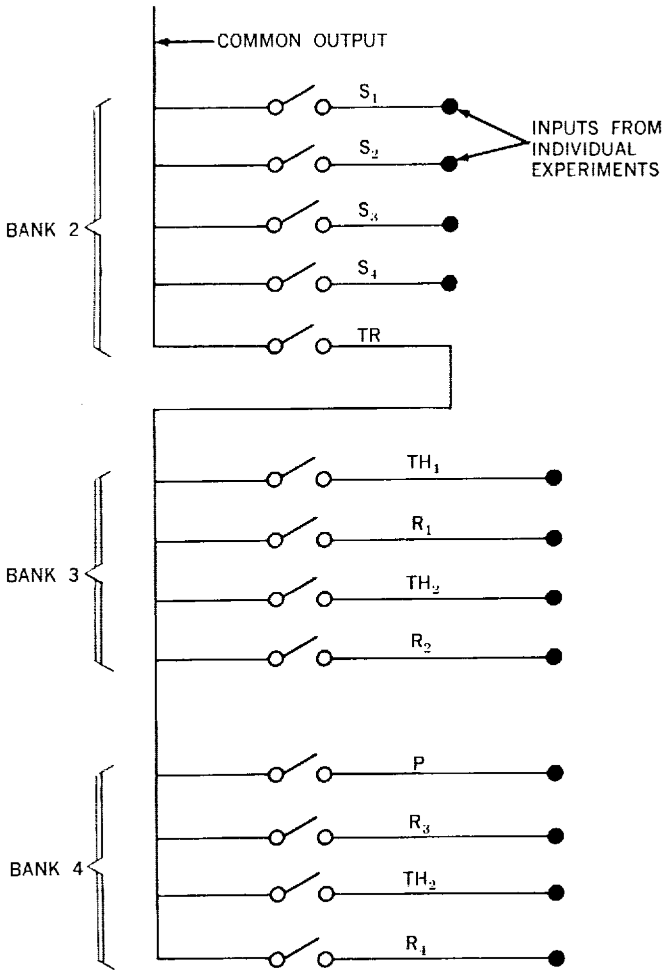

Figure 12—Time-sharing switch circuit

The gear reduction consists of six gears, five pinions, and the shafts, all ma of type 303 stainless steel.

The magnesium housing of the gear train resembles a hat, being cylindrical i shape with a large flange on top. A round magnesium plate is screwed into the bott of the housing to close it off. This plate the top of the housing encompass the enti gear train.

The switch actuating cams are made Kel-F plastic, and are fastened to the sh by a key and snap ring. The cams are cylindrical as Figure 11 shows.

As is shown in Figure 12, switches S_1, S_2, S_3, and S_4 in bank 2 are wired ind vidually, and the transfer switch is wired in series with all the switches in banks 3 and 4. This gives the following cycle of operation:

S_1, S_2, S_3, S_4, TH_1, S_1, S_2, S_3, S_4, R_1, S S_2, S_3, S_4, TH_2, S_1, S_2, S_3, S_4, R_2, S_1, S_2, S_3, S_4, P, S_1, S_2, S_3, S_4, R_3, S_1, S_2, S_3, S_4, TH_2, S_1, S_2, S_3, S_4, R_4.

Each reading lasts approximately 6 seconds with an overlap of about 1/2 second between switching operations.

Environmental Testing

The prototype recorder has survived sinusoidal vibration test levels of 10 g from 0 to 2000 cp for 30 minutes total sweep time, and white noise random vibration of 20 g rms in a frequency bandwidth from 5 to 2000 cps for 4 minutes. It was subjected to temperature cycling from 0° to 60°C over extended periods with no degradation in performance. During the Tiros II and Tiros III testin programs, the flight acceptance units were subjected to flight environmental testing levels, repeat demonstrating the high reliability achieved.

ECTRICAL DESIGN

Record Motor Electronics

Because of the slow speed (0.4 inch/second) of the tape in the record mode, it was advantageous use a synchronous motor. The motor is driven two-phase in preference to using a capacitor for e phase shift needed for the second motor winding; this gives a more constant torque pattern and us less tape flutter. The supply voltage frequency is obtained by counting down a 550 cps tuning rk clock to 137.5 cps for the synchronous motor by the use of two bistable multivibrators. The 7.5 cps square wave is then fed to an amplifier tuned to 137.5 cps to obtain the fundamental sine ve. From this point the sine wave feeds two circuits: It feeds directly a class-B push-pull ampli- er to drive one winding of the motor; it also feeds a 90 degree phase shift network which drives the her winding of the motor through a second class-B amplifier.

Playback Motor Electronics

A synchronous motor was considered for use as the playback motor, but was found impractical r the following reasons:

1. Synchronous motors with the power rating required for playback were too large.
2. Synchronous motors are much less efficient than are dc motors. The playback motor requires appreciable power as compared to other components in the system; therefore, the maximum efficiency obtainable in the design area is important.
3. Since the playback duty cycle is quite short, the long-life advantage of a brushless motor was considered unnecessary.

dc motor controlled by a servo loop was chosen. The use of mechanical governors was ruled out cause of the inherent vibration problem and the interference caused by the constant making and eaking of contacts. Thus, an elec- nic means (Figure 13) was de- sed to control the speed of the dc tor.

The ac generator mounted on the tor shaft produces an output volt- e whose frequency is proportional the motor speed. The frequency, 3.3 cps, was selected for mechani- l design reasons. The ac generator nsists of 14 magnetic poles (7 north d 7 south) alternately spaced

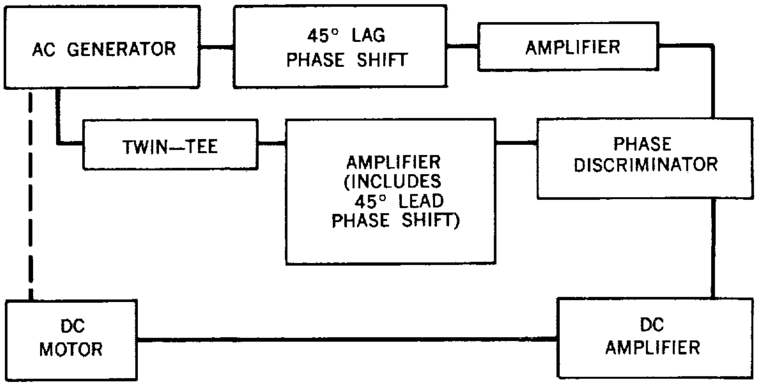

Figure 13–Speed control block diagram

around the circumference of a magnesium disc. The stator winding produces 583.3 cps output at the de sign motor speed of 5000 rpm. This signal is fed to a twin-tee network which is used as a frequency r erence, and thence to a two-stage transformer-coupled amplifier including a 45-degree-lead phase sh at 583.3 cps and a phase detector. At the same time, the stator output is fed through a 45-degree-la phase shift network (at 583.3 cps), through an am fier, and back to the phase detector to be compare with the output of the amplified twin-tee signal. The phase characteristic of the twin-tee plus that of the 90 degree RC phase shift (45 degrees lead plus 45 degrees lag) add up as shown in Figure 14

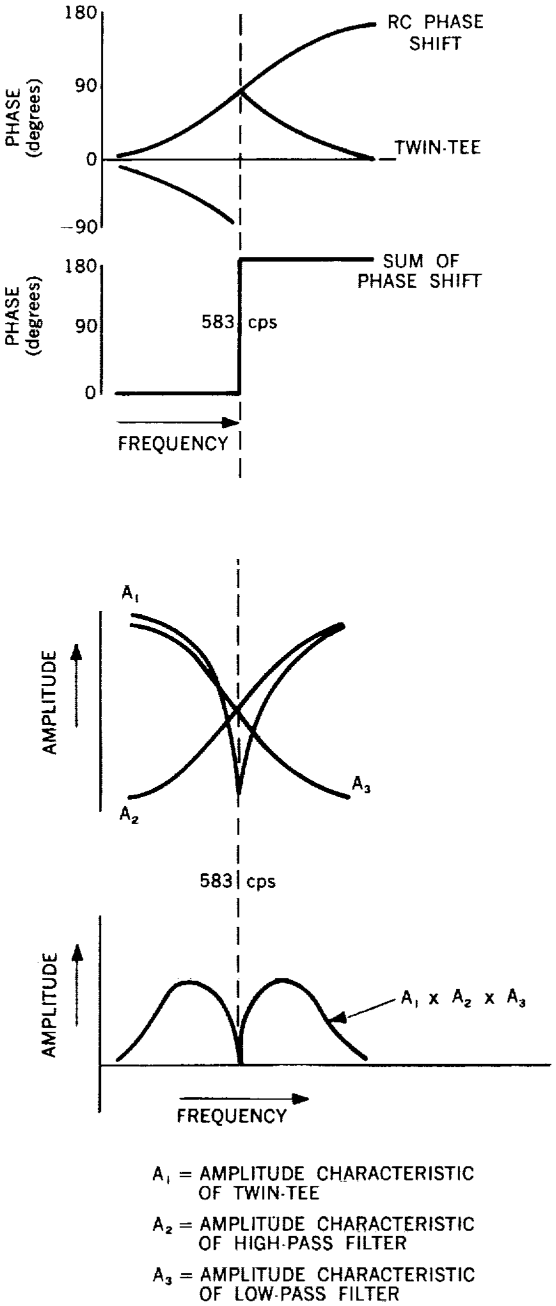

Figure 14—Phase and amplitude characteristics of the twin-tee and 90 degree RC phase shift

The phase detector circuit adds this amplitud characteristic to the 180 degree phase reversal, and the final output is as shown in Figure 15. Th slope is about 1.5 volts/cps and the peaks are at ±5 volts. The transformers are tuned to about 583 cps to improve the waveforms and maximize the loop gain at this point. The slope of the discriminator output is made as large as stability considerations will allow. Note also that the discriminator curve has a positive slope from zero motor speed up to the operating region; this insur positive, rapid starting.

The correction voltage is coupled to the mot by means of a dc amplifier which is designed to provide the nominal dc motor voltage for correct motor speed and to provide sufficient input impedance to prevent loading of the phase detector. Th motor is series-controlled by means of a power transistor. A trim pot is included to afford easy compensation for mechanical torque variations in different tape recorders and electrical variations in the dc motors. Voltage feedback in the dc amp fier is essentially 100 percent; therefore, the err voltage is added directly to the motor voltage.

The degree of speed correction available depends on the loop gain; or, since the dc amplifier has unity gain, on the slope of the phase detector characteristic. By superimposing the motor spee versus voltage curve (for a given load) on the spe control motor voltage curve, the final speed regulation may easily be found as shown in Figure 16.

le speed change produced by the increased ad without the control system is ΔS. With the eed control operating, the speed change is duced to ΔS_c. Measurements show that this stem provides better than 1 percent speed gulation over a temperature range from 0° to °C.

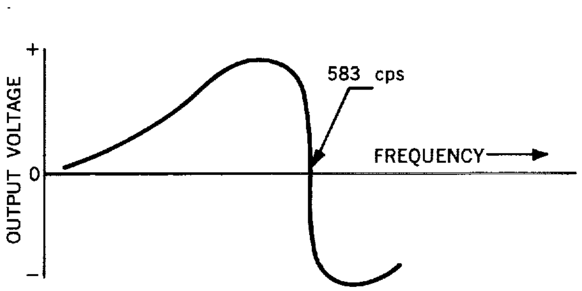

Figure 15—Output voltage of dc motor speed control

MPONENT LAYOUT DESCRIPTION

Figures 7 and 17 show the assembled tape corder. The record motor (A) is fastened to top plate on an eccentric which allows the justing of belt tensions between the record tor and the intermediate jack shaft (B). This kshaft is also mounted on an eccentric for purpose of adjusting belt tension between elf and the low-speed capstan pulley (C). In dition to being a step pulley, the jackshaft is flywheel which is necessary because the ge capstan flywheel (D) does not provide ough filtering at the low speed; 0.0015-inch lyester film belts are used for this reduction. om the jackshaft a belt (E) is connected to time-sharing switch (F).

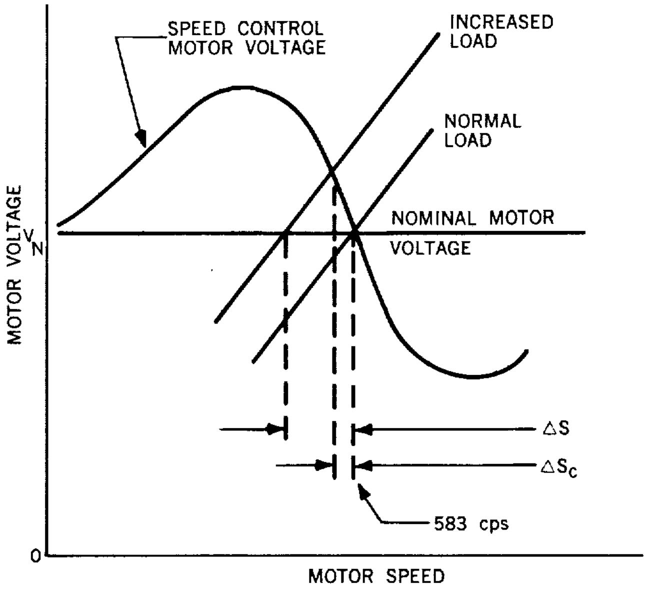

Figure 16—Speed regulation of dc motor

The playback system consists of the dc tor (G) potted in the lower half of a cannister) to reduce vibration. The upper half of the cannister is lined with magnetic shielding to isolate reproduce head from motor electrical noise. The canister itself is an eccentric to permit the adsting of belt tension between the motor and the capstan flywheel pulley (D). The tape guide plate H) covers the tape cartridge, and slots cut into it at (I) and (J) allow the tape to leave and enter the rtridge. The webbing (K) stiffens the cover plate. The rollers (E) prevent the tape from rubbing the inside of the cover plate. The viscous dampener (M) critically damps the roller arm assembly) to maintain rubber roller pressure on the capstan (O) and tape (P) under vibration. The spring) provides the roller force required to prevent tape slippage.

The tape guide (R) guides the tape as it passes the heads (S), minimizing errors due to skew. The essure pads (T) provide positive contact between the tape and the head gaps.

The guide roller (U) and pressure arm (V) provide tape tension and tend to damp any pulsations anating from the cartridge.

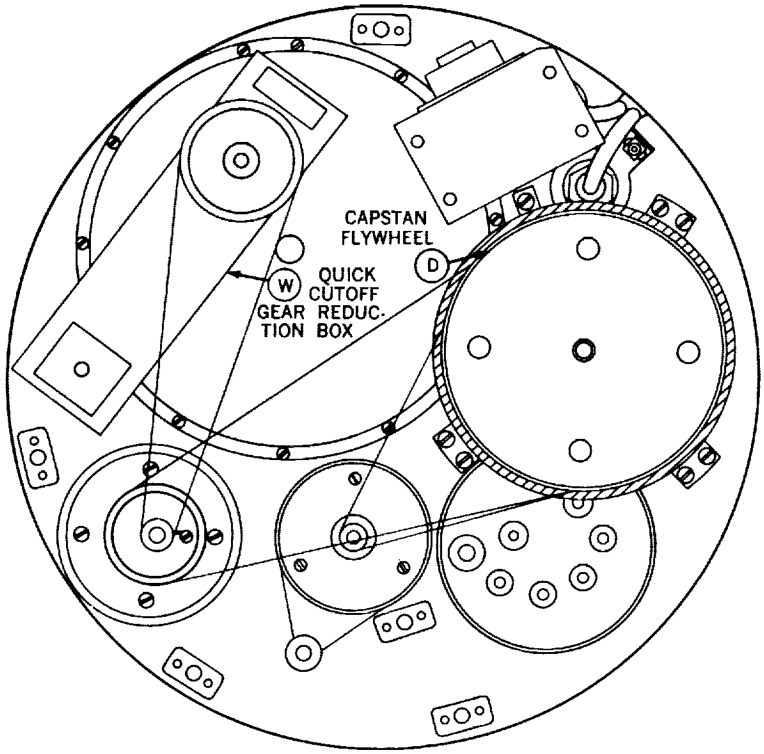

Figure 17—Upper plate bottom view

A belt pass from the dc motor operates the quick cutoff gear reduction box (W). The output sha of this box is connected to the disc (X) through a spiral ring (Y). The lever (Z) engages the slot in the disc (AA) when the cam has completed about 3/4 revolution. When a revolution is completed, th output arm (BB) releases the lever, causing the disc to snap around actuating the microswitch (CC) shutting off the playback mode and setting the electronics into the record mode.

The top plate (DD) is made of K-1A magnesium to damp vibrations from the motors, which mig otherwise affect the heads. All of the bulkier structural components are constructed of magnesium for weight economy.

CONCLUDING REMARKS

The Tiros recorder configuration has been adapted for use in the Nimbus meteorological satellite as a medium resolution infrared tape recorder. This modified Nimbus configuration is also bei used in the later Tiros satellites. The basic tape cartridge and transport design have remained unchanged; however, some modifications were incorporated to satisfy the different interface problem and the modular design of the satellite components.

At present, work is proceeding toward the development of larger capacity endless-loop cartrid and the related problems involved in the dynamics of these cartridges are under study. Special studies are being undertaken to develop tapes that will withstand high speeds and temperature without adverse effects on their magnetic performance.

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