Section 5

THEORY OF OPERATION

5.1 TAPE TRANSPORT

5.1.1 General

Tape motion is controlled by the tape transport mechanism for all operation modes. The transport consists basically of a tape supply system, a tape drive system, a tape takeup system, and a control system. These systems provide smooth and positive tape motion across the magnetic heads, and maintain correct tape tension.

A schematic diagram of the tape transport is provided in Fig. 6-20, and a simplified schematic in Fig. 6-21. The front and back of the transport are shown in Fig. 5-1. The power-distribution and fusing diagram is in Fig. 6-19.

5.1.2 Tape Supply and Takeup Systems

A separate motor drives each supply and takeup assembly. These two motors are connected so that if power is applied with no tape threaded, the turntables will rotate in opposite directions--the supply turntable clockwise and the takeup turntable counterclockwise.

In the play or record modes of operation, the capstan controls tape speed; it pulls tape from the supply reel (whose opposing torque helps to maintain tape tension) and delivers it to the takeup reel, which also helps maintain correct tape tension. The motor torque, and therefore tape tension, is adjustable at resistors R604 (supply) and R605 (takeup).

During fast-forward or rewind operation, the capstan is disengaged from the tape. The power of one of the motors is reduced by switching an adjustable resistor (R607) into series/circuit with it; the other motor continues to operate at full power. The turntable under full power pulls the tape against the torque of the other turntable, which provides required tape tension.

When reels with small hubs are used, additional resistors are operator-switched into the circuit to lower the tape tension to the correct level. The reel switches for large hub operation, short the adjustable resistors (R608, supply, and R606, takeup).

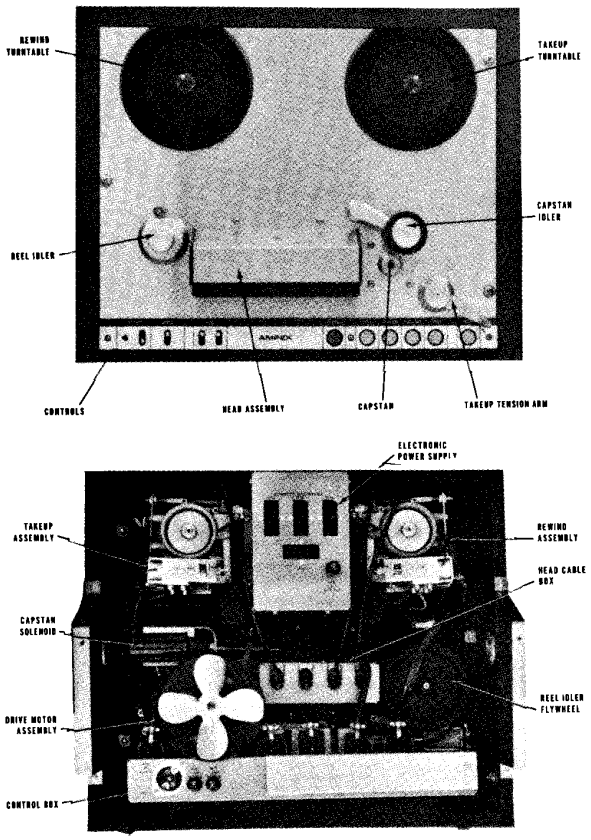

Fig. 5-1. Tape Transport

A pair of solenoid-controlled brakes is mounted on each of the two torque motors. The main-brake solenoid on each motor is energized (brakes released) whenever tape is placed in motion in any mode. The edit-brake solenoid on each motor is energized only in the stop-edit mode, to reduce braking force at each turntable. The edit brake always contacts the drum, but full braking force is applied only when it is energized.

To prevent the formation of tape loops when tape motion is stopped, the reverse-rotation main-brake force is adjusted to about triple the forward-direction force.

5.1.3 Tape Drive System

The capstan drive force is from hysteresis-synchronous motor. The capstan (tape drivewheel) is the motor shaft end that is precision-machined and hardened; the other end of the motor shaft mounts a flywheel and fan. A solenoid-controlled capstan idler clamps the tape to the capstan to provide the driving friction against the tape.

The drive motor has a separate field winding for each of the two tape speeds. A speed toggle switch selects the desired tape speed, and also automatically switches in the correct solid-state equalization circuit for each speed. The drive motor operates continuously when power is ON and a tape is correctly threaded.

When the recorder/reproducer is in the play (or record) mode, solenoid (K610) energizes and moves the capstan idler to clamp the tape against the rotating capstan. The main brake solenoids (K605 and K607) energize to release the brakes. The capstan then drives the tape across the head assembly at the selected speed.

5.1.4 Reel Idler

A reel idler assembly, on the transport left side, below the supply turntable, minimizes any tape motion transients caused by the supply assembly. The reel idler arm minimizes initial strain when tape motion starts (to avoid stretching or breaking the tape) and prevents formation of a tape loop between the supply reel and the heads. The idler pulley flywheel serves to dampen transients in tape speed that could result from torque motor cogging and uneven tape wrap on the supply reel.

To set the tape guide on the idler arm for either 1/4-inch or 1/2-inch wide tape, it is lifted and rotated to present the correct face to the tape.

5.1.5 Takeup Tension Arm

The tape takeup tension arm has two functions, it maintains a small tape loop (to prevent tape breaking or stretching during start and stop) and it actuates the safety switch (S603), to stop operation if a large tape loop forms, or if the tape breaks. The tension arm also stops the transport when either reel runs out of tape.

The guide for the tape is similar to that on the reel idler (refer to paragraph 5.1.4. A tape hook holds tape on the guide during threading and when the tape becomes slack.

5.1.6 Tape Lifter

A solenoid-operated tape lifter assembly raises the tape from contact with the heads during fast-forward or rewind operation. When either mode starts, the solenoid K609 energizes and moves the tape lifter mechanism. The tape lifter is defeated as long as the edit pushbutton is pressed. The tape lifter may be manually defeated by opening the head gate and pushing the right-hand tape lifter arm to the retracted position.

In the fast forward or rewind mode the tape-lifting arms do not retract instantly when the stop button is pressed. An electronic delay is provided so that the tape stops completely before contacting the head, which avoids the high-peak signal that results from the moving recorded tape contacting the heads.

The delay circuit for the record-stop function involves terminals E1 through E6 on the small circuit board in the control box.

The play relay circuit's negative side is connected through SCR Q603 to the power supply. During the play mode, pressing the STOP button causes Q603 to stop conducting and switch the play relay off. During the record mode, the record-relay holding current passes through Q602 (base to emitter) causing it to conduct the power supply voltage through E5 and CR620 to charge capacitor C619. When the STOP button is pressed, the capacitor discharges through CR621 into the play relay coil to hold the relay on for 1/4 second after Q603 de-energizes. Therefore, the time delay occurs only when the STOP button is pressed during the record mode.

The sole function of capacitor C620 is to maintain a charge to turn on Q603 when the play relay is actuated.

The sole function of diode CR619 is to block negative flowing current from interfering with delay of the relay.

In addition, when the tape is stopped in the record mode, the control logic assumes that the tape "coasts" about 250 milliseconds before stopping. This allows the tape-biasing rf current to completely decay before tape motion ends, which avoids the loud noise that results from the tape stopping while bias current is still present in the record head.

The delay circuit for the tape-return-to-head function involves terminals E7 through E13 and Q606 on the small circuit board in the control box.

When the transport isn't in the rewind mode, no voltage appears at E11 so the two-transistor flip-flop circuit has Q604 non-conducting and Q605 saturated. Power appears at E11 when the FAST FWD or REWIND button is pressed, which reverses the transistor states to turn on power transistor Q606 resulting in tape lifter actuation, to lift the tape from the heads.

When either fast wind mode is stopped, the tape lifter is held from the play position by the discharging of capacitor C621 through the adjustable potentiometer R619. The time delay for returning the tape to head-contact can therefore be set by adjusting R619.

5.1.7 Control Circuit

5.1.7.1 Play Mode

When tape is correctly threaded and power is applied, the capstan rotates at the speed selected at the speed switch. Pressing the PLAY pushbutton then results in the following circuit action:

Play relay K602, in the 24-volt dc circuit, is energized. Contact set 1-9-5 of that relay completes a holding circuit across the play pushbutton. Contact set 2-10-6 applies ac power (through the tension-adjust resistors) to the takeup and rewind supply motors. Contact set 3-11-7 completes the 115-volt dc energizing circuit to the capstan idler solenoid. Contact set 4-12-8 connects 115-volt dc to energize the supply and takeup main brake solenoids. Thus the brakes release, the turntable motors operate, and the tape (pressed against the rotating capstan) is driven at the selected speed.

5.1.7.2 Fast-Forward Mode

The negative return for fast-forward, rewind, and edit relays is through transistor Q601, which must conduct to allow those modes to actuate

(refer to record mode, paragraph 5.1.7.5).

With power on and tape threaded, pressing the FAST FWD pushbutton energizes fast-forward relay K604. Contact set 1-9-5 of that relay opens the 24-volt dc circuit to the play circuit, and closes a holding circuit across the fast-forward switch. Contact set 2-10-6 connects full ac power to the takeup motor (reel switch in large hub position) and reduced ac power (through resistor R607) to the rewind motor. Contact set 3-11-7 opens the 24-vdc circuit to the rewind relay, and closes the 24-vdc circuit to tape-lifter solenoid K609, through edit switch S611. Contact set 4-12-8 conducts the 115 vdc to energize main-brake solenoids K605 and K607. The takeup motor therefore operates at full torque, the rewind motor at reduced torque; tape is lifted from head contact, the brakes are released, and the tape winds from the rewind to the takeup reel.

5.1.7.3 Rewind Mode

The negative return for the rewind, fast-forward, and edit relays is through transistor Q601, which must conduct to allow those modes to actuate (refer to record mode, paragraph 5.1.7.5).

With power on and tape threaded, pushing the REWIND pushbutton energizes rewind relay K601. Contact set 1-9-5 completes a holding circuit across the rewind switch. Contact set 2-10-6 connects full ac power to the rewind motor (reel switch in large hub position), and connects reduced ac power (through resistor R607) to the takeup motor. Contact set 3-11-7 breaks the 24-vdc circuit to the play and fast-forward circuit and connects 24-vdc to tape-lifter solenoid K609. Contact set 4-12-8 connects 115 vdc to energize main-brake solenoids K605 and K607. Thus, the rewind motor operates at full torque, the takeup motor operates at reduced torque, the brakes are released, tape is lifted from contact with the heads, and tape rewinds from the takeup reel to the supply reel.

Tape lifter action in the rewind mode, as in the fast-forward mode, can be defeated by pressing the EDIT pushbutton.

5.1.7.4 Edit Modes

The negative return for the edit, rewind, and fast-forward relays is through transistor Q601, which must conduct to allow those modes to actuate (refer to record mode, paragraph 5.1.7.5).

When the edit relay is energized in either the stop/edit or the play/edit mode, contact set 1-9-5 completes a holding circuit across the edit switch. Contact set 2-10-6 opens the 115 vdc circuit to the takeup main brake solenoid and closes the 115 vdc circuit to the takeup and supply edit brake solenoids. Contact set 3-11-7 opens the 24 vdc circuit to the record switch, locking out the record mode. Contact set 4-12-8 opens the ac circuit to the takeup motor and closes a shorting circuit across the safety switch to bypass the switch.

In the stop/edit mode, therefore, the safety switch is shorted and the low braking force (supplied by the edit brake solenoids) makes it easy to manually turn the reels. In the play/edit mode, the safety switch is shorted, the record mode is locked out, ac power is removed from the takeup motor, the supply brake is fully released (by the supply main brake solenoid), and the takeup turntable is held by the takeup brake solenoid action; therefore the takeup turntable will not rotate, and tape will spill off the right side of the transport.

The edit relay is not energized in the fast-winding/edit mode. This mode simply defeats the tape lifting mechanism while the edit pushbutton is depressed during fast-forward or rewind operation. This opens the negative return lead to the tape lifter solenoid, which remains de-energized as long as the pushbutton is held down; therefore tape will contact the heads, and monitoring is possible.

5.1.7.5 Record Mode

To initiate the record mode, the tape is placed in motion in the play mode, and then the record pushbutton pressed to energize the record relays.

When any record relay is energized, as shown in Fig. 6-21, contact set 4-12-8 of that relay makes a return connection to the transport.

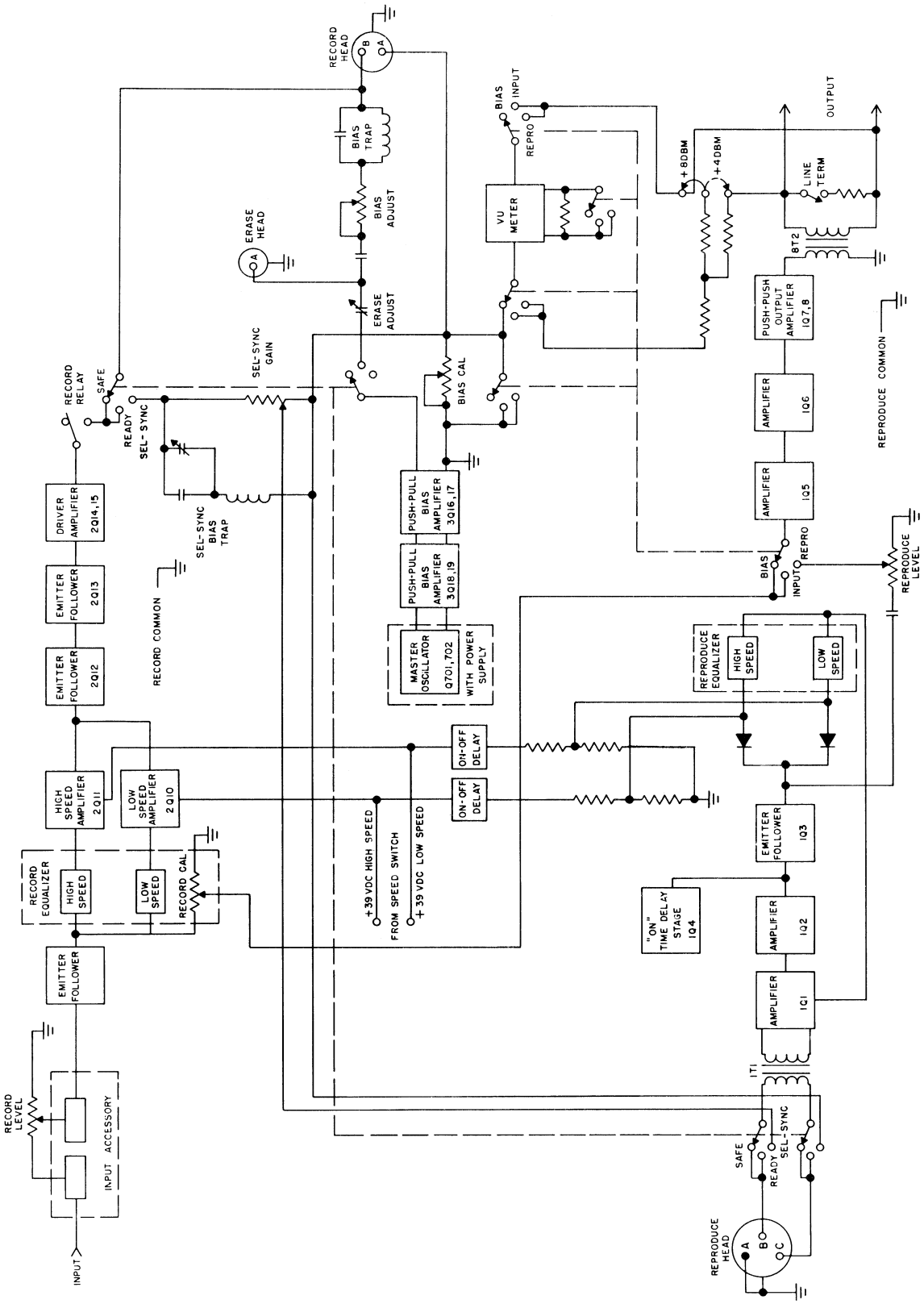

Fig. 5-2. Block Diagram

Since transistor Q601 must conduct to allow the fast-forward, rewind, or edit modes to be entered, it conducts during those modes. In the record mode, however, the record relay holding current places a bias on transistor Q602 causing it to conduct. When Q602 is conducting, Q601 is biased to cutoff, therefore the edit, rewind, and fast-forward modes are locked out when the unit is recording.

5.1.8 Tape Scrape-Flutter

Tape scrape-flutter can be likened to the drawing of a bow across a violin string. The string will vibrate at its resonant frequency, which is determined by the 'free' length of the string, its tension, and its size.

On a tape transport, the magnetic head acts as the bow, and the tape as the violin string, so instead of drawing a bow across a string, the tape is drawn across the head. As it moves across the head the tape will vibrate at its resonant frequency. For a given tape and tension, that frequency depends upon the 'free' length of tape between the reel idler and the capstan. This frequency is usually in the range to which the human ear is most sensitive, from 1,000 to 6,000 Hz. For example, the scrape-flutter frequency on this transport without a tape scrape-flutter idler would be about 3,500 Hz.

When a rotating idler (such as the supplied tape scrape-flutter idler) is installed in the tape path approximately midway between the reel idler and capstan, the length of 'free' (unsupported) tape is halved. This practically doubles the scrape-flutter frequency to about 7,000 Hz, which is out of the range of greatest ear sensitivity. This higher frequency also automatically drops the volume. The effect of tape scrape-flutter is therefore reduced to about 25% of its former value.

If the second tape scrape-flutter idler (optional accessory) is installed on the transport, the flutter frequency is again raised--to approximately 10,000 Hz. This, and the additional drop in volume practically nullifies tape scrape-flutter.

5.2 ELECTRONIC CIRCUITS (See Figure 5-2)

5.2.1 Power Supply

Components for the regulated power supply in a recorder/reproducer are mounted on the same printed circuit board as those for the bias oscillator (see Fig. 6-22). For the reproducer, the bias oscillator is omitted (see Fig. 6-23). In either case, the printed circuit board plugs into the electronics power supply box (at the back of the transport). A series-regulating transistor (Q705) is mounted on the power supply chassis.

A-C power is delivered to the power supply from the tape transport. It is fused by fuse F701, rectified by the bridge rectifier formed by diodes CR701 through CR704, and filtered by resistor R706 and capacitor C707. It then is connected to the voltage regulator.

In the regulator, a reference voltage is established by Zener diode VR702. A sampling voltage is taken across the output line at variable resistor R712 (in a voltage divider circuit with resistors R711 and R712). Voltage adjustment is made at R712. When the output voltage tends to vary with load, it affects the conductance of transistor Q706. This, in turn, changes the conductance of transistors Q704 and Q705 (connected in a Darlington circuit) to maintain the voltage at normal level.

Transistor Q703 acts as a constant-current source for Q704 and Q706. Overload protection is also provided with this transistor, in conjunction with diode CR707 and resistor R709. If a serious overload occurs, the increased voltage across R709 also appears across resistor R708, through diode CR707. This will bias transistor Q703 to cutoff. Deprived of their current source, Q704 and Q706 will cutoff, removing the bias on Q705. The power supply will thus automatically shut off until the overload is removed.

The regulator is adjusted to provide a +39 (-1/2+1) vdc to the electronic assemblies. It is also connected back to the tape transport speed selector which switches the +39 vdc (through the power supply box) to one of the transport's two equalization-switching circuits.

A power-distribution and fusing diagram is provided in Fig. 6-19.

5.2.2 Bias Oscillator and Amplifier Circuits

NOTE

These circuits are provided only with recorder/reproducer systems.

The master bias oscillator is mounted on the same card as the electronic power supply (see Fig. 6-22). This is simply a capacitively-coupled push-pull oscillator, operating at a nominal frequency of 150,000 Hz. Operating power of +39 vdc is direct from the power supply, so the oscillator operates continuously when power is on. Its transformer-coupled output is delivered to the bias amplifier in each record/reproduce unit.

Two push-pull bias amplifier stages are mounted on a plug-in circuit board for each record/reproduce unit. Operating power is applied to these stages through contact set 3-7-11 of the energized record relay K1. The circuits, therefore, operate only during the record mode.

The push-pull bias input from the oscillator, is connected at pins 1 (shield, 2, and 3 of receptacle 4J11 (see Fig. 6-24). It is connected to the amplifier circuit board, and routed to the bases of transistor 3Q18 and 3Q19. This circuit and the following circuit (3Q16 and 3Q17), together, provide normal push-pull amplification of the bias frequency. They operate at clipping level, to eliminate the need for a bias symmetry adjustment (an unsymmetrical bias waveform causes magnetization of the record heads, and high second-harmonic distortion). A fully acceptable sine wave output is obtained when transformer 3T3 is resonated with the record head, by adjusting the bias-adjust control (3C40) to peak the erase head current. The output is also taken through bias-adjust resistor 3R80, routed through the bias trap of capacitor 5C35 and inductor 5L2, and then mixed with the record signal before proceeding to the record head. A third output is through bias-calibrate resistor 3R44, through the output-selector switch, and then to the VU meter. A contact set on the output-selector switch shorts the bias-calibrate resistor 3R44, except when the switch is at BIAS; this removes the rf signal from the line, to reduce rf induction into other circuits during the record or reproduce modes.

5.2.3 Record Amplifier Circuit

A schematic diagram of the record amplifier circuit is given in Fig. 6-24. The record amplifier is provided only with recorder/reproducer systems.

The signal to be recorded is connected to input connector 4J7, and then is routed through the input accessory (or dummy plug) in receptacle 4J8. Receptacle 4J8 is wired so that during optional microphone preamplifier use, the record-level control is connected between the two stages in the preamplifier. This effectively makes the preamplifier a variable-gain amplifier for use with most types of professional-type microphones.

From the input accessory socket, the signal enters the plug-in board circuit and emitter-follower stage 2Q9. From there it proceeds to the plug-in record equalizer circuit. The record calibrate control, 11R108, is on the equalizer board but is connected before equalization is applied. From that control, the signal (through output-selector switch contacts) to stage 1Q5 in the reproduce amplifier circuit. It proceeds through the reproduce circuit to the output line and the VU meter, for record monitoring and record level measurement (refer to paragraph 5.2.4).

The high-speed and low-speed equalizers receive the signal from stage 2Q9. Each equalization circuit consists of a variable capacitor (11C53 for low speed, 11C54 for high speed) in parallel with a fixed resistor (2R51 for low speed, 2R52 for high speed). The capacitor is then adjusted to provide the correct high-frequency response.

From the equalizer, the signal goes through one of the two equalizer amplifiers, 2Q10 or 2Q11. If low speed is selected, +39 vdc is applied to pin 6 of receptacle 4J11. This voltage is applied, through resistor 2R64, to the emitter circuit of 2Q11, biasing that transistor to cutoff. In low speed, therefore, transistor 2Q10 conducts

and amplifies the signal. When high speed is selected, the +39 vdc is applied to pin 7 of 4J11. The voltage is connected to cutoff transistor 2Q10, and stage 2Q11 thus acts as the high-speed equalization amplifier. A low frequency boost is obtained from 2R54 and 2C25, for 2Q10; and from 2R59 and 2C27, for 2Q11.

From the equalizer amplifier the signal goes through two emitter-follower stages, 2Q12 and 2Q13, to the output-driver stage formed by 2Q14 and 2Q15. The output-driver stage is a high-impedance, constant-current, amplifier. Transistor 2Q15 acts as an active-load resistance for the collector of 2Q14, thus providing a relatively low d-c resistance and a relatively high a-c resistance. In the audio frequency range, therefore, transistor 2Q14 impedance is then high enough to provide the constant-current source for the record head, yet allows full utilization of the available d-c operating voltage.

The signal, through circuit board connectors 7 and 8, proceeds through the record-relay contact-set 1-5-9. It is mixed with the bias frequency, following the bias trap (5C35 and 5L2), and then proceeds through the record-selector switch (in the READY position) to the record head.

Record relay 4K1 is energized by pushing the transport RECORD pushbutton after initiating the play mode. It is held energized (refer to Fig. 6-21) by contacts of the play relay (in the tape transport circuit) through resistor R601. Energizing voltage is connected at pin 4, and the holding voltage at pin 10, of receptacle 4J11. Contact set 1-5-9, when energized, removes record amplifier output from ground, and routes that output to the record head.

Diode 4CR6, in the record relay circuit, restricts the record mode to units set to READY, when the RECORD pushbutton was pressed. Therefore, a record/reproduce unit previously set to SAFE (on Sel Sync) will not then record, when reset to READY.

5.2.4 Reproduce Amplifier Circuit

The reproduce circuit for record/reproduce units and reproduce modules is essentially the same except that no VU meter is supplied with the latter. Refer to schematic diagrams 6-24 (recorder/reproducer) and 6-25 (reproducer). A monitor jack for reproducers is mounted on the back panel of the module.

From the reproduce head, the reproduced signal goes through the record-selector switch to the reproduce circuit board and transformer 1T1.

From the input transformer, the signal goes to the base of amplifier stage 1Q1; base bias on this transistor is derived from the current through resistor 1R4, which is filtered by capacitor 1C1. Another amplifier stage, 1Q2, follows 1Q1. D-C feedback is applied through 1R3 (bypassed by 1C2) from the collector of Q2 to the collector of Q1. Collector voltage for both 1Q1 and 1Q2 comes through transistor 1Q4; so those stages cannot operate until 1Q4 conducts. A time-constant circuit (1C8 and 1R38) delays conduction of Q4, so that power application does not peak the VU meter indicator, or cause popping sounds at the output.

The signal from 1Q2 proceeds through the emitter-follower, 1Q3, emitter to the reproduce equalization circuits and back to the emitter of Q1. Equalization is selected by energizing diode 1CR2 (low speed) or 1CR1 (high speed) to allow them to pass the signal. At low speed, +39 vdc goes to pin 6 of receptacle 4J11. At high speed, the +39 vdc goes to pin 7 of that receptacle. A time-constant circuit is inserted in both +39 lines, again, to protect the VU meter and prevent popping sounds when the speed is switched.

When a speed is first selected, the "on" time-constant is determined by a 100 mfd and a 35 mfd capacitor contained in capacitor 9C9. When that speed is turned off (other speed selected) the 100 mfd capacitor is out of the circuit, and the delay is determined by the 35 mfd capacitor. Thus the "on" time-delay, when a speed is selected, is greater than the "off" time-delay for the same speed.

If low speed is selected, the positive voltage from the time delay circuit is connected through 1R15 to diode 1CR2, biasing that diode so that it will conduct the signal from the emitter of 1Q3 to the low-speed equalizer. If

high speed is selected, the positive voltage, connected through 1R14, causes diode 1CR1 to conduct the signal to the high-speed equalizer. Thus the low-speed or the high-speed equalizer is connected from the emitter circuit of 1Q3 back to the emitter of 1Q1.

From the emitter of 1Q3 the equalized signal is also routed through capacitor 1C7, the reproduce level control, and the output-selector switch, to the base of amplifier stage 1Q5 (where the record monitor is connected, refer to paragraph 5.2.3). Capacitor 1C10 in the base circuit of 1Q5, provides an rf bypass, while 1C12 decouples the dc bias to stage 1Q5. Capacitor 1C14, in the collector circuit, is inserted to permit attaining high levels without clipping.

After 1Q5, the signal is connected to stage 1Q6, which provides drive for the push-push output stage formed by the complementary pair of transistors 1Q7 and 1Q8. The output signal leaves the circuit board at the emitter junction of those two transistors.

The output signal is connected through the phones jack transformer 8T2 to the output connector. Line-termination switch 4S3 connects resistor 8R33 across the output line, to terminate the equipment during checks and adjustments.

The secondary of the output transformer is connected to the VU meter through a strapping circuit for a +8 dBm or a +4 dBm normal operating level (see Fig. 5-3). Equipment strapped for a +8 dBm output has resistors 8R34 and 8R35 connected as a voltage divider across the transformer, with 8R36 connected to their junction for the VU meter input.

Strapping for +4 dBm has resistors 8R34 and 8R35 connected in parallel on one side of the line, and series resistor 8R36 in the input circuit to the VU meter.

5.2.5 Sel-Sync Circuit

The Sel-Sync circuit is shown between the record and reproduce heads in Fig. 6-24. With the record-selector switch at SEL-SYNC, the reproduce and record heads are disconnected from their amplifiers, and the record head is connected to the reproduce amplifier. The record head reproduces the signal from the tape and delivers it to the reproduce amplifier for amplification for monitoring purposes.

A Sel-Sync gain control (4R43) sets the monitoring signal level. An adjustable bias-trap (4C18, 4C38, and 4L1) prevents bias leakage from a nearby channel that is recording. Other contact sets of the record-selector switch open the bias amplifier circuit to the record head, and the negative return circuit to the record relay.

In the Sel Sync mode, therefore, the record head acts as a reproduce head for monitoring purposes. Another record head in the same stack (on a different track) can then be used to record that track synchronously with the first.

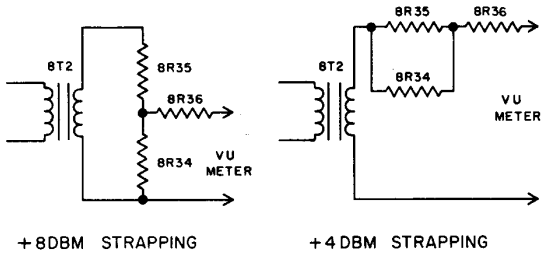

Fig. 5-3. Strapping Circuit, Simplified