Operating and maintenance instructions, recording equipment of AN/GRD-501 direction finder: provisional

Cox, L. G.

https://doi.org/10.4224/21273930

Report (National Research Council of Canada. Radio and Electrical Engineering Division : ERB); no. ERB-567, 1960-08

ERB-567

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RADIO AND ELECTRICAL ENGINEERING DIVISION

OPERATING AND MAINTENANCE INSTRUCTIONS - RECORDING EQUIPMENT OF AN/GRD - 501 DIRECTION FINDER

(PROVISIONAL)

L. G. COX

OTTAWA

AUGUST 1960

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OPERATING AND MAINTENANCE INSTRUCTIONS - RECORDING EQUIPMENT OF AN/GRD-501 DIRECTION FINDER

(Provisional)

- L.G. Cox -

1. DESCRIPTION

1.1 GENERAL

1.1 (a) Over-all Description The recording equipment of the AN/GRD-501 Direction Finder consists of a dual-drum magnetic recorder with associated electronic equipment and power supply. The block diagram of the recording system is shown in Fig. 1, and views of the recorder unit in Plates I and II.

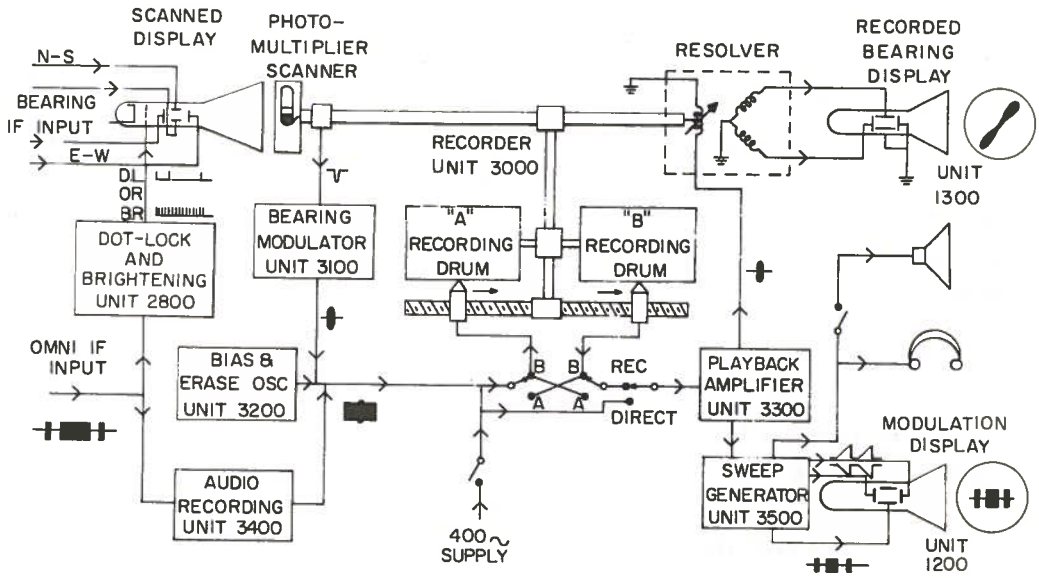

FIG. 1 BLOCK DIAGRAM OF RECORDING SYSTEM

A rotating photomultiplier scanner produces a pulse whenever a tapered radial slot passes over the major axis of the trace on a bearing-display cathode-ray tube connected in parallel with the operator's bearing-display cathode-ray tube. The drums and scanner are gear-driven with an integral gear ratio between them, so that the angular position of the drum with respect to the record/playback head corresponds to a definite angular position of the slot on "record" or "playback". Since the recurrence frequency of the photomultiplier output pulses is too low to allow direct recording with the amplitude-modulated system in use, the pulses are used to drive a 5 kc/s balanced modulator which produces a recordable bearing signal. The audio signal is also recorded.

On "playback", the combined audio and bearing signal is amplified and separated into its two components by simple filters. The 5 kc/s bearing signal is converted

from polar to rectangular coordinates by a resolver on the scanner shaft; this produces a filled-in "propeller pattern" on the recorded bearing-display cathode-ray tube, as shown in Fig. 1. The audio signal triggers a linear sweep generator, and is presented on a modulation-display cathode-ray tube, as well as on headphones or speaker.

A leadscrew, geared 1:1 with the recording drums, moves the heads slowly along the drums as it revolves. When the heads reach the end of the drum the carriage is automatically lifted and returned. One drum is being continuously erased and re-recorded with a two-minute storage length, while the other drum is playing back. The time at which the functions of the two drums are exchanged by the operator is printed on a card, from which the exact time at which a signal has been recorded may be determined.

The scanned cathode-ray tube uses a magnesium fluoride P19 phosphor which has almost no initial "flash" but very long persistence. Short cathode-ray tube brightening pulses are generated either continuously in "normal" operation or singly whenever the intermediate-frequency level rises through an adjustable threshold level. The long afterglow of the scanned cathode-ray tube ensures that rapid modulation of the trace does not affect the recorded bearing. If a transient signal occurs while the recording head is being returned to its starting position the bearing (but not the modulation) will be retained by the long persistence of the scanned cathode-ray tube.

1.1(b) Purpose The recording equipment may be used to:
1) record the bearings of signals received by the direction finder,
2) record the modulation (voice or keyed CW) of the signals received,
3) record the time of transmission of a signal,
4) reduce the bearing fluctuation of multimode signals.

1.1(c) Power Requirements (supplied from receiver).

TABLE I

POWER REQUIREMENTS

Volts	Cycles	Amperes
117 regulated 28 unregulated	60 a-c d-c	1.5 2.0 (peak)

1.2 DESCRIPTION OF MAJOR ASSEMBLIES

1.2(a) Location The recording equipment is principally contained in the right-hand cabinet of the AN/GRD-501, although the power supply, display units, time unit, and controls are located in the center section.

1.2(b) Recorder Unit (No. 3000) This recording unit consists of a dual-drum magnetic recorder, a bearing cathode-ray tube with a rotating photomultiplier scanner, and a resolver.

1.2(c) Bearing Modulator Unit (No. 3100) This consists of a 5 kc/s oscillator-amplifier, a logarithmic pulse amplifier, and a suppressed carrier modulator.

1.2(d) Bias Erase Oscillator Unit (No. 3200) The unit contains a 39 kc/s bias and erase oscillator-amplifier and recorder switching relays.

1.2(e) Playback Amplifier Unit (No. 3300) This unit contains a playback pre-amplifier, filters, and a 5 kc/s amplifier.

1.2(f) Audio Recording Amplifier Unit (No. 3400) This contains an intermediate-frequency amplifier, BFO, diode mixer, output cathode follower, and a switching relay.

1.2(g) Sweep Generator Unit (No. 3500) The sweep generator unit contains an audio amplifier, triggered sweep generator, vertical and horizontal amplifiers, and a cathode-ray tube blanking unit.

1.2(h) Modulation Display Unit (No. 1200) This unit contains a 5-inch cathode-ray tube and controls.

1.2(i) Recorded Bearing Display Unit (No. 1300) This contains a 5-inch cathode-ray tube, with controls for both the recorded bearing display cathode-ray tube and the scanned cathode-ray tube.

1.2(j) Audio and Switching Unit (No. 2800) The audio and switching unit contains the dot-lock and brightening unit used by both the direction-finder bearing display and the scanned bearing display. Operator's controls are mounted on the front panel.

1.2(k) Time Unit (No. 1000) This contains the main power switches, a Calculagraph elapsed time recorder, switches to exchange the functions of the two drums, and a precision 60 cycle supply.

1.2(l) Power Supply Unit (No. 2600) This unit provides regulated + 300 volts and + 150 volts, and unregulated heater voltage.

1.3 OPERATOR'S CONTROLS

1.3 (a) Audio and Switching Unit Controls The right-hand row of controls on this unit is exclusively for the recorder. The center and left-hand rows are principally for the direction finder. The recorder controls in vertical order are (top to bottom):

1) Playback Gain — This controls the gain of the playback preamplifier, thus controlling both the 5 kc/s output and the audio output.

2) Display — In the "recorder" position the recording system works normally, the recorded and played-back bearing and modulation being displayed. In the "direct" position, the actual recording process is bypassed, and the bearing and modulation of the signal being recorded are displayed. The displays are direct also when the "bearing reference" switch on the frequency control panel is at "inject", regardless of the position of the "display" switch.

3) BFO — This switch controls a BFO in the audio recording amplifier unit (3400). The BFO is used when receiving keyed CW or FSK.

4) Sweep Rate — When the audio output exceeds a preset level the sweep generator is triggered. The three-position switch allows selection of sweep times of "slow" (1 second), "medium" (250 milliseconds) or "fast" (70 milliseconds) for the modulation display.

5) Retrace — A leadscrew moves the heads slowly along the drums as it revolves. Portions of the signal may be examined by operating the "retrace" switch, which moves the carriage back one thread of the leadscrew (4.2 seconds) for each operation.

6) Volume — This potentiometer controls the gain of the audio amplifier, and sets both the audio level (speaker or headphones) and the height of the trace on the modulation display.

There are two other controls on this panel used jointly for the recorder and direction finder. They are:

7) Speaker — This three-position switch connects the speaker on Unit 1000 to either the direction finder or the recorder audio output. The center position of the switch disconnects the speaker entirely.

8) Threshold — This potentiometer determines the intermediate-frequency level necessary to produce brightening pulses for the bearing displays when the "operation" switch is at "dot-lock" (D.L.).

1.3 (b) Display Units

1) Modulation Display — This unit has only three cathode-ray tube controls, "brightness", "vertical centering" and "focus". The horizontal centering is a preset control on the sweep generator chassis.

2) Recorded Bearing Display — This unit has a dual set of cathode-ray tube controls, "brightness", "horizontal centering", "vertical centering" and "focus". The upper row controls the scanned cathode-ray tube in the recorder, and the lower row controls the recorded bearing display cathode-ray tube.

1.3 (c) Time Unit The main recorder "on-off" power switch buttons are mounted on the time unit to the left of the receiver power switch buttons. They control a magnetically operated thermal cutout switch (S2601) mounted on the recorder power supply unit.

Another pair of switches are mounted internally in the calculagraph, and operated when the right-hand calculagraph lever is pushed upwards. One switch causes a 400 cycle warning signal to be recorded, and the other exchanges the functions of the two drums, after a short delay to allow time for the warning to be recorded.

2. THEORY OF OPERATION

2.1 GENERAL DESCRIPTION

2.1(a) Purpose of Equipment The recording equipment is designed to:

1) record the bearing of signals received by the direction finder,
2) record the modulation of the signals received,
3) record the time of transmission of a signal,
4) reduce the bearing fluctuations of multimode signals.

2.1 (b) Circuit Description A block diagram of the recording equipment is shown in Fig. 1. The scanned cathode-ray tube is connected in parallel with the operator's bearing cathode-ray tube, and displays the same bearing pattern. The display is brightened by brightening pulses generated by the Dot-Lock and Brighten Unit (No. 2800). The brightening pulses are generated either continuously when the "operation" switch is at "normal", or singly whenever the "omni i-f" level rises through an adjustable threshold while the "operation" switch is at "dot-lock".

The rotating scanner contains a photomultiplier tube behind a tapered slot, the photomultiplier producing a pulse whenever the slot crosses the major axis of the

trace. The pulse from the photomultiplier is amplified and attenuated by a two-stage logarithmic attenuator in the Bearing Modulator Unit (No. 3100). Logarithmic attenuation produces a pulse with limited range of amplitude, but without squaring. The output pulse from the logarithmic attenuator drives a suppressed-carrier balanced modulator which produces a burst of 5 kc/s signal for each pulse from the scanner.

The Bias and Erase Unit (No. 3200) generates a 39 kc/s output used for bias on the recording head and for erasing on the erase head. A group of four relays permits one record/reproduce head to be connected to the playback amplifier, and the other to the bias and recording signals, at the same time preserving the necessary isolation between the recording and playback signals. In the Audio Recording Unit (No. 3400) the "Omni i-f" signal is amplified by a tuned amplifier stage, and mixed with a crystal-controlled BFO output to produce a nominal 1 kc/s audio signal. A low pass filter removes frequencies which might interfere with the 5 kc/s bearing signal, and a cathode follower output stage drives the recording head. A relay operated by the Display switch (Recorder or Direct) can feed a portion of the bearing modulator output directly to the playback amplifier bypassing the actual recording process in Direct Display.

The Playback Amplifier Unit (No. 3300) consists of two parts, the preamplifier common to both the bearing and audio signals, and the 5 kc/s output stage which drives the rotor of the bearing resolver. The "playback gain" control is located between the first and second preamplifier stages. Simple filters separate the two components of the combined signal. The audio signal is fed to the sweep generator, through a frequency compensation network and the "volume" control.

The Sweep Generator Unit (No. 3500) has several functions. It contains an audio amplifier and an audio output stage, a vertical deflection amplifier (both audio and 175 kc/s), and a triggered linear sweep generator with three sweep speeds. It also contains a phase inverter to provide push-pull deflection voltages for the horizontal sweep output, and a blanking oscillator to cut off the modulation-display cathode-ray tube between sweeps.

The Recorder Unit (No. 3000) contains the mechanical components of the recorder, with the associated electrical circuitry necessary for automatic return, step retrace, and carriage position indicators. Also included in the unit are the scanned cathode-ray tube, scanner, and resolver. Although the carriage position indicators are shown on the recorder unit schematic they are mounted on the sloping panel of the center bay to the right of the audio and switching unit.

2.2 DETAILED DESCRIPTION OF UNITS

The detailed description should be studied in conjunction with AN/GRD-501 schematics

No. 1000, 1200, 1300, 2600, 2800, and 3000 to 3500. In these schematics, where a type-12AT7WA tube is shown, the elements connected to pins 1, 2, and 3 are considered to be the "A" section of the tube, and elements connected to pins 6, 7, and 8, the "B" section.

2.2(a) Dot-Lock and Brightening (No. 2800) This is part of the Audio and Switching Unit described in the AN/GRD-501 Receiver Handbook, and it will not be described in detail here. The only part of the circuitry not common to the receiver is the pulse-clipping circuit. This consists of a clipping diode V2807, clipping level potentiometer R2855, and series resistance R2853. When the "operation" switch is at "normal" the cathode (pin 5) of V2807 is held at a potential set by R2855. If the pulse amplitude exceeds the clipping level the diode conducts, and the excess voltage is dissipated across R2853. By this means the brightness of the scanned cathode-ray tube is adjusted to be approximately the same on either "dot-lock" or "normal" with a moderate speed keyed-CW signal.

2.2(b) Scanner (part of No. 3000) and Bearing Modulator Unit (No. 3100) The slot in front of the type-931 VA photomultiplier scanner tube (V3002) is $\frac{1}{16}$" wide for $\frac{3}{4}$" from the center and 10° wide for an additional $1\frac{1}{2}$". The tapered portion gives some resolution for very wide (e.g., 2:1) ellipses, while the straight slot will give an output on very short traces. The anode of V3002 is connected through a slip ring and coaxial cable to the modulator unit where the anode load is situated.

The anode load of V3002 is a "Thyrite" varistor RV3101 whose resistance varies greatly with current, being 300K at 10 μa and 15K at 1 ma. R3101 and R3102 provide a 10 μa bias current for RV3101 to reduce photomultiplier noise by reducing the sensitivity with extremely small signals.

Triode V3101A is used in a voltage amplifier circuit with a gain of 10. The small gain is due to the large unbypassed cathode resistor. The output from V3101A is fed to a 1 megohm resistor in series with a second varistor RV3102, to provide a second stage of logarithmic attenuation. The voltage pulse across RV3102 drives the grid of V3101B, used as a cathode follower with a preset "pulse amplitude" potentiometer in the cathode circuit.

V3102A is used in a 5 kc/s parallel-T oscillator circuit. At a single frequency there is 180° phase shift across the parallel-T feedback loop from plate to grid, and oscillations build up. The preset "frequency" control, R3111, can alter the frequency by several hundred cycles. An output control (5 kc/s level) is located in the plate circuit of V3102A. V3102B is used in a 5 kc/s amplifier circuit with negative feedback from plate to grid to reduce distortion to less than 1%. The plate load is the primary of the balanced-modulator driver transformer T3101.

V3103 and V3104 are twin triodes used in a full-wave balanced modulator. All the grids are at +150 volts, and the positive pulse is applied to the grids of V3103A and V3104A. When the pulse is applied the plate currents of these two sections in-

crease, and the plate currents of V3103B and V3104B decrease by approximately the same amount, so that the average voltage at the center of the voltage divider joining the plates of V3103A and V3104B remains constant.

About 60 volts rms of 5 kc/s carrier voltage is developed across the center-tapped secondary of T3101, in series with the +300 volts. One side of the winding is connected to the V3103 plates, and the other side to the V3104 plates, through 39K series resistors. When the positive pulse is applied to the grid of V3103A, the plate resistance, and consequently the amount of 5 kc/s voltage at the plate, decreases. Similarly, the amount of 5 kc/s voltage of opposite phase at the plate of V3104B increases. A burst of 5 kc/s, therefore, appears at the center of the voltage divider between the plates, with no change in the average voltage.

If only two triode sections were used, 5 kc/s voltage would appear across the cathode resistor, decreasing the effectiveness of the modulator. The additional sections give balanced action, and allow the addition of a capacitive "phase null" adjustment. The null controls balance out most of the fundamental, second, and third harmonics from the carrier leak, so that the carrier leak does not exceed 75 mv. The harmonics are not recorded owing to the limited frequency response of the recorder, but are visible on direct display.

The two diodes, CR3101 and CR3102, are d-c restorers which prevent overshoot at the end of the pulse. The output stage (V3105) is a cathode follower with a low impedance output to drive the recording head and direct display potentiometer.

2.2(c) Audio Recording Amplifier Unit (No. 3400) The "omni i-f" input from J3401 is applied to the "audio level" potentiometer (R3402). The lower end of R3402 is grounded when the "display" switch is at "recorded". V3401 is a pentode intermediate-frequency amplifier tube with a tuned plate load.

The BFO (V3403) is a modified Pierce crystal oscillator operating at 176 kc/s to provide a nominal 1 kc/s beat note. Plate and screen voltages are switched by the BFO switch on the recorder switching panel.

The audio output from the V3402 diode detector feeds a low pass filter (L3401, C3411, and C3414) whose variable capacitor C3411 is adjusted to produce maximum attenuation at 5 kc/s. A cathode follower output stage to drive the recording head follows the low-pass filter. A 175 kc/s filter removes any intermediate-frequency voltage from the audio output signal.

Relay K3401 is operated by either the "display" switch or the "bearing reference inject" switch, and switches circuitry to produce a direct display of bearing and modulation. R3403 is connected in series with potentiometer R3402, and the small intermediate-frequency voltage developed across R3403 drives the modulation-display vertical amplifier. Also, the portion of the bearing modulator output con-

trolled by R3405 is switched to drive the grid of the 5 kc/s output stage of the playback amplifier.

2.2(d) Bias and Erase Oscillator Unit (No. 3200) One section of V3201 is used in a 39 kc/s Colpitts oscillator circuit. Both sections of V3202 are used in tuned amplifying stages, V3202A to supply bias for the recording head and V3202B to drive the erase head.

The impedance of the recording head varies with frequency; hence, series resistors R3202 and R3203 are made large enough so that the recording head current is almost independent of frequency in the audio range. The bearing modulator signal is fed to J3204 and the audio signal to J3203, and the recording currents add in the recording head. The tuned circuit L3202/C3205 permits the recording head to be tuned to the bias frequency, and reduces the amount of bias voltage fed back to the bearing modulator unit.

Four relays are required to provide sufficient isolation between the recording signal and the playback signal. Relay K3201 switches the recording signal to either K3202 or K3203 and grounds the unused line. It also connects the erase voltage to the proper erase head, and grounds the unused erase head.

Relay K3204 connects the playback amplifier coaxial cable and shield to either K3202 or K3203, and grounds the unused line. Relays K3202 and K3203 connect the respective record/playback coaxial cable and shield to either K3201 or K3204. The shield of the playback head is grounded only at the playback amplifier input to minimize hum pickup. The large electrolytic capacitors across the relay-operating coils prevent signal leakage between pairs of non-energized relays through the coil connections.

2.2(e) Playback Amplifier Unit (No. 3300) The playback head is tuned to 5 kc/s by capacitor C3303. V3301 is a pentode amplifier tube with double decoupling in the plate and screen supply. A gain control potentiometer is connected between the plate of V3301 and the grid of V3302. V3302 is a pentode amplifier tube with negative feedback from the plate of V3302 to the cathode of V3301. The output from the plate of V3302 is coupled to V3303, a cathode follower tube.

The first three tubes are common to both audio and bearing signals, but filters separate the two components after the cathode follower.

The full cathode follower output is fed to the audio output jack (J3308) through a 60 cps rejection filter C3310-L3301, a 5 kc/s rejection filter L3302-C3311, and a frequency compensation network R3318, R3319, and C3313.

About one-third of the cathode follower output voltage is used to drive the 5 kc/s output stage. J3306 is connected to J3305 through the relay in the audio recording

amplifier unit if the "display" switch is at "recorded". C3314, L3303, C3315, C3316, and L3304 comprise a 5 kc/s band pass filter to eliminate the 0-3 kc/s audio signal. L3305 and C3318 are a 39 kc/s filter to remove the bias voltage from the direct display.

A pentode (V3304) output stage is used to drive the resolver. C3321 tunes the resolver rotor to reduce second harmonic distortion in the output stage.

When the "display" switch is set to "direct" a portion of the bearing modulator output is fed through the audio recording amplifier to J3305 and the output stage, and J3306 is disconnected.

2.2(f) Sweep Generator Unit (No. 3500) The audio signal from the playback amplifier and "volume" control enters at J3501. V3501 is a pentode audio amplifier, and V3502 an audio output tube.

V3503B is a vertical amplifier tube for the modulation display. The plate load is 100K for audio signals. On "direct display" 175 kc/s signals entering at J3505 are amplified by V3501. The plate load of V3503B is a tuned circuit consisting of L3502 and stray capacitance. The 100K plate load is bypassed by a series resonant 175 kc/s LC circuit so that it will not damp the tuned plate load.

Two diodes, CR3501 and CR3502, are connected in series across +0.8 volts, with the grid of V3503A held at +0.4 volts. V3503A is used in a limiting amplifier stage, and any signals below ±0.4 volts amplitude are amplified without distortion, but signals exceeding 0.4 volts cause the diodes to conduct, and the grid voltage is limited to 0.8 volts peak-to-peak.

V3505 is the sweep timing tube, a twin triode used in a cathode-coupled multivibrator. V3505A is normally cut off, with the plate at No. 300 volts. The plate and cathode of the trigger diode (V3504A) are at the same potential. A negative-going waveform at the plate of V3503A is coupled to the plate of V3505A by the trigger diode, and initiates the multivibrator action. The sweep period is controlled by grid resistor R3527 and the appropriate coupling capacitor, C3516, C3518, or C3520.

A boostrap linear sweep generator is used which gives a sawtooth sweep waveform of approximately 175 volts peak-to-peak. Both the charging capacitors C3517, C3519, and C3521 and variable charging resistors R3530, R3531, and R3532 are switched. The variable resistors are used to adjust the sweep lengths on the three ranges. The discharge tube, V3506A, is connected in parallel with the sweep capacitor, and between sweeps conducts heavily with the grid returned to +300 volts.

When the V3505 multivibrator is triggered a portion of the negative pulse at the

plate of V3505A is coupled to the grid of V3506A, cutting off the tube. The sweep capacitor begins charging towards +300 volts, but the grid of the bootstrap cathode follower V3506B is connected to the sweep capacitor so that, as the capacitor voltage rises, so does the cathode voltage of V3506B. This voltage rise is coupled by a large capacitor to the supply end of the charging resistor, and provides a fairly constant voltage across the charging resistor, and consequently a relatively linear sweep.

The charging resistor is connected to the +300 volt line through the diode V3504B. When the sweep starts, the output from the cathode follower raises the diode cathode voltage above +300 volts, so that the diode stops conducting. The sweep charging current is supplied by the coupling capacitor, which recharges through the diode and R3533 after the end of the sweep. The diode cathode voltage reaches +470 volts at the end of the sweep.

One horizontal deflection plate of the modulation display cathode-ray tube is connected to the sweep capacitor. Since a deflection voltage of 350 volts plate-to-plate is required, a phase inverter (V3507) is used to supply the other deflection plate. V3507 is a pentode amplifier tube with 100% negative feedback from plate to grid. The time constants of the input circuit and feedback circuit are the same (0.3 second), so the one-second sawtooth waveform can be inverted without distortion. The variable cathode bias resistor R3543 is used to adjust the average plate voltage, and is used as the horizontal centering control of the modulation display. After the control is changed, a minute or more is required for the trace to reach its final position.

The neon tube DS3501 has a constant voltage drop of about 55 volts, and is used to prevent the plate of V3507 from bottoming when the inverted sweep output voltage drops to 20 volts.

V3508 is a gated oscillator tube which supplies a 100 kc/s blanking voltage to the modulation cathode-ray tube. A cathode follower (V3508B) is cut off between sweeps, and in this condition does not affect V3508A, the oscillator tube. When the timing multivibrator is triggered, the positive pulse from the plate of V3505B causes the cathode follower V3508B to conduct heavily, damping the oscillator tuned circuit and stopping oscillations.

2.2(g) Display Units (No. 1200 and No. 1300) The Recorded Bearing Display Unit (No. 1300) has a dual set of cathode-ray tube centering, focus, and brightness controls. The second set is used to control the scanned cathode-ray tube. The 250K "recorder brilliance" control has a 470K resistance in series with it to maintain the scanned cathode-ray tube at cutoff unless brightening pulses are applied. This is necessary because the P19 phosphor of the scanned cathode-ray tube burns very easily.

The Modulation Display Unit (No. 1200) has a single set of controls similar to the dual set in Unit No. 1300, but the horizontal centering control is a preset potentiometer on the sweep generator unit. A voltage doubler (V1202) rectifies the 100 kc/s output from the sweep generator blanking oscillator and this is used to cut off the cathode-ray tube between sweeps.

2.2(h) Recorder Unit (No. 3000) The 9-stage photomultiplier tube, V3002, is operated with the cathode at -1200 volts, dynode No. 9 at ground, and anode at +150 volts. These voltages are supplied through slip rings, the voltages for the other dynodes being developed by a voltage divider network inside the scanner.

Receptacle J3011 supplies 117 volts a-c for the recorder drive motor and oil pump motor, and regulated +150 volts for the carriage position indicators. The "recorder drive" switch, S3004, allows the motors to be turned off independently of the main recorder power.

There is 50 volts d-c across the carriage position potentiometers, R3005 and R3024, which are connected to the carriage drive chains. The voltages between sliders and ground operate 0-500 μamp carriage position indicators, M3001 and M3002, through 100K series resistors. Variable resistors R3015 and R3018 are used to adjust the full-scale deflection of the indicators, which are calibrated in 0-125 seconds.

The carriage return schematic for "A" channel is shown in Fig. 2. The components shown are:

K1001	Channel switching relay
S2814	Retrace switch
S3001	Fast clutch lockout switch
S3002	Carriage limit switch
S3003	Carriage lift switch
L3001	Carriage stepping solenoid
L3002	Carriage stepping clutch
L3003	Fast clutch
L3004	Carriage lift solenoid

The numbers 1 to 42 on Fig. 2 refer to terminals on terminal boards TB3001 and TB3002. There is -28 volts on terminal 1, and terminal 9 is grounded when the "retrace" switch is "off".

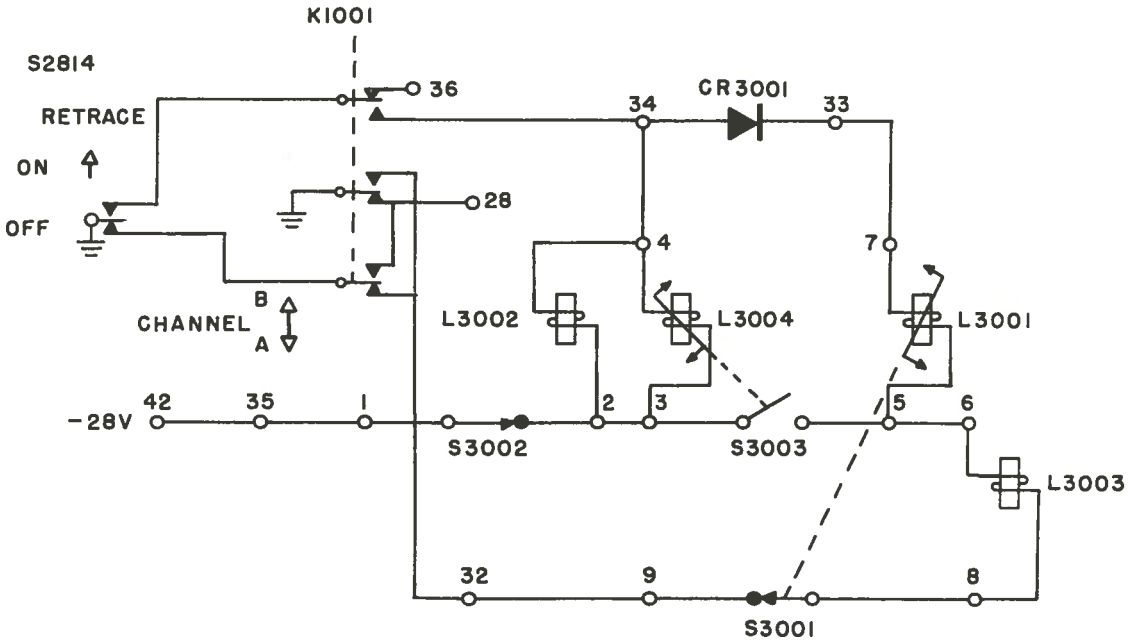

FIG. 2 DIAGRAM OF "A" CHANNEL CARRIAGE RETURN CIRCUIT

The recording head carriage is at all times connected to an endless-loop ladder chain which circles gears connected to the two clutches. When the carriage reaches the end of its travel a cam on the leadscrew lifts the carriage free of the leadscrew. Switch S3003 closes, energizing the fast clutch L3003 which drives the carriage back to the starting position. When the carriage reaches the starting position the carriage limit switch S3002 opens, de-energizing the clutch. The cam holds the carriage elevated long enough for the carriage to return, and then lowers the carriage allowing it to engage the leadscrew. The carriage return time is about one second. If the blocking diode CR3001 were not in the circuit there would be sufficient current through the series circuit L3003, L3001, and L3002/L3004 to energize L3003 slightly and cause a drag on the chain.

When the "retrace" switch S2814 is operated, terminal 32 is lifted off ground and terminal 34 grounded. This energizes clutch L3002, which mechanically connects the stepping solenoid L3001 to the carriage drive chain, and solenoid L3004, which lifts the carriage off the leadscrew. The lifting of the carriage closes switch S3003 which energizes the stepping solenoid L3001. The solenoid moves the carriage back $\frac{1}{8}$", allowing it to engage the previous thread of the leadscrew when the "retrace" switch is released. The initial motion of solenoid L3001 opens switch S3001, which does not close again until after S3003 has reopened. This prevents the fast clutch L3003 from giving a short jerk on the chain when the "retrace"

switch is released, and before the carriage lowers.

Relay K1001 connects the "retrace" switch to the channel being played back, so that in the recording channel only the automatic carriage return is operative. The operation of "B" channel is identical to that of "A" channel.

2.2(i) Time Unit (No. 1000) The time unit contains three distinct sections — an intercom, a precision 60-cycle clock supply, and a recorder channel switching unit. The first two sections have been described fully in the receiver handbook, and will not be discussed here.

The recorder switching unit comprises a Schmitt trigger circuit operating relay K1001. This relay switches the carriage return circuits and the channel indicator lamps in Unit 3000, and the channel switching relays in Unit 3200.

S1003 is a single-pole push-push switch actuated by pushing the right hand Calculagraph lever. When S1003 is closed the grid of V1003A is at ground potential, and V1003A is cut off. V1003B conducts heavily and relay K1001 is closed.

When S1003 is opened the junction of R1007-R1008 rises to +45 volts, and V1003A conducts heavily. The plate voltage of V1003A drops, causing the grid voltage of V1003B to drop also and V1003B is cut off. Relay K1001 opens, switching channels.

The resistor-capacitor combination R1009-C1006 causes a delay of about $\frac{1}{5}$ second in the operation of the relay, permitting a warning signal to be recorded. A 26-volt 400-cycle signal supplied from Unit 1400 through series resistor R2859 is normally shorted to ground by switch S1002, except while the Calculagraph lever is pushed. Then, it is applied to the recording head to override the audio signal, and give warning of the end of the recording.

2.2(j) Recorder Power Supply Unit (No. 2600) This unit comprises five parts: a magnetically operated thermal cutout switch, unregulated power supply, voltage reference, voltage comparator and amplifier, and series regulator.

The cutout switch is controlled by "on" and "off" push buttons on the Time Unit panel, and switches both heater and plate transformer primaries. The unregulated d-c power is obtained from a capacitor-input full-wave rectifier followed by a single-section L-C filter, and is about +450 volts on load.

The reference voltage is developed across a 150-volt type-OA2WA voltage regulator tube. The difference voltage between fixed portions of reference voltage and the output voltage is used as the grid-cathode voltage for amplifier tube V2603B. V2603A is also an amplifier tube, whose cathode is held at +150 volts to allow direct coupling from the plate of V2603B to the grid of V2603A. The plate voltage of V2603A drives the series regulator tube grids through 1K parasitic oscillation

suppressors. The three series tubes, which act as variable resistors, have current-equalizing resistors in their cathode circuits. A large capacitor, C2604, in parallel with the output, prevents high-frequency oscillation, and also reduces the output impedance at high frequencies.

3. OPERATION

3.1 STARTING AND STOPPING EQUIPMENT

Since the recorder power is supplied through the receiver power relay, the receiver must be switched on before the recorder. The recorder "on" and "off" push button switches are located on the Time Unit panel.

If the recorder is out of use for some time the tension spring on the recorder drive puck plate should be released to prevent a flat spot from developing on the drive puck. The end of the spring must be hooked over the spring anchor pin before use.

3.2 OPERATING THE RECORDER

The recording system has been designed to record automatically, but there are several controls which must be adjusted according to the signal being received (or expected) to obtain the best results.

3.2(a) Dot-Lock and Threshold If the signal is continuous (FSK, FM, or voice modulation) the "operation" switch must be set to "normal", and the scanned cathode-ray tube will be brightened continuously. If, however, the signal is not continuous (keyed CW or transients) better results may be obtained with the "operation" switch set to "d.l.", and the "threshold" control set just below the point where noise brightens the bearing display. The display will be brightened for 100 microseconds each time the intermediate-frequency signal exceeds the threshold level. This may be especially effective in increasing the relative brightness of transient signals when there is keyed CW interference. The part of the transient signal which occurs during off periods of the interfering signal will produce brightening pulses with a high repetition rate, but the keyed CW interference will produce only one brightening pulse each time the carrier begins.

Dot-lock can be used with keyed CW signals to reduce bearing wander caused by wave interference due to multimode propagation, if signals due to one mode arrive more than 100 microseconds before signals due to other modes. Only the signal which arrives first, by the shortest path and presumably the closest to the correct bearing, will trigger the dot-lock unit. A striking example of this was seen at

Ottawa while observing CFH, Halifax on 8542 kc/s. The true bearing is 90°, but the observed bearing wandered between 30° and 90° with "normal" operation. With "dot-lock" operation the bearing varied between 87° and 90°.

It is sometimes possible to use the dot-lock method of reducing bearing wander with FSK signals, if the crystal filter is used to suppress either the mark or space. The settings of receiver gain and threshold level are quite critical with a very narrow bandwidth.

3.2(b) Scanned CRT Controls If the display on the scanned cathode-ray tube is not exactly centered the areas of maximum brightness will not be 180° apart, and a double (split) propeller pattern will result. The centering controls must be adjusted in the following manner.

The "bearing reference" dial is set to 0°, the "bearing reference" switch set to "inject", and the "recorder brightness" adjusted to give a 4-inch propeller pattern on the recorded bearing display. The "horizontal centering" control is adjusted to produce a single propeller, which may vary in length at the scanner rate.

The injected reference bearing is changed to 90°, and the "vertical centering" control adjusted to produce a single propeller pattern. The steps are repeated, if necessary, so that a single steady propeller pattern is produced at any goniometer angle.

The scanned cathode-ray tube display must be viewed directly through the hole in the top of the scanner while adjusting the "recorder focus". A switch mounted on the oil pump unit at the rear of the recorder allows the recorder drive motor and oil pump motor to be shut off while the recorder power is on.

3.2(c) BFO (Recorder) If the intelligence contained in the signal is to be preserved, the BFO switch must be "off" when recording voice modulation, or "on" when recording keyed CW or FSK. A transient or short signal may be recorded better with the BFO switched off if the keying rate is high, although the reproduced modulation is useful only for recognition, and the intelligence may be lost.

3.3 CHANGE-OVER AND CARRIAGE POSITION

One of the two recorder drums is always recording, and the other playing back, until the functions are exchanged by the operator pushing the right lever of the Calculagraph upwards. Actuating the lever also causes a 400 cycle warning note to be recorded on the drum for a fraction of a second before the recording ends.

The two vertical edgewise-style panel meters shown at the lower left of Plate II

indicate the positions of the recording/playback head carriages, the upper meter for the front carriage. Only the meter showing the position of the playback carriage is illuminated. The meters are calibrated in 0 - 125 seconds.

3.4 PLAYBACK

During playback the recorded audio signals may be listened to using headphones or speaker. Throwing the "speaker" switch to "playback" connects the speaker in the Time Unit to the recorder audio output. The "playback gain" control is normally adjusted to produce a 4-inch propeller pattern on the recorded bearing display, and the "volume" control adjusted to produce a pattern $\frac{1}{2}$ inch to 1 inch high on the modulation display.

Center the alidade on the recorded bearing display over the propeller pattern and set the "bearing reference" switch to "inject". With the "operation" switch at "normal", rotate the goniometer to bring the goniometer propeller pattern under the alidade. Switch off the bearing reference, and read the recorded bearing on the goniometer bearing dial. Sense is not recorded, so there is a 180° ambiguity.

3.5 LOG CARD AND TIME PRINTER

The front and back of a blank log card, and a sample card with the change-over time and interval time printed are shown in Fig. 3. The Calculagraph time printer prints the time of change-over on a 24-hour clock face dial with an auxiliary seconds dial. The outside triangle on the clock dial is the hour indicator and the inside pointer is the minute indicator. The change-over time is printed with the card inserted in the Calculagraph slot so that the figure "1" is visible.

The time interval is printed with the figure "2" visible. Both the 30-minute and 60-second dials and pointers rotate continuously. When the right handle is pulled down the dials print on the card. When the left handle is pulled down the pointers print, indicating the interval between pulling the right and left handles.

3.6 TRANSIENT SIGNALS

If transient or short signals are to be recorded, make sure the "operation and threshold" controls are properly adjusted (Sec. 3.2 (a)) during recording, and that a log card has been inserted in the time printer with the figure "1" visible. After the transient has occurred, the right handle is pushed up and the left handle is pulled down. The card is then removed and replaced with the figure "2" visible.

The modulation display should be carefully watched while listening to the recorded audio signal, and the transient may be easily identified. Operation of the

"retrace" switch allows a 4-second portion of the recording to be replayed as many times as necessary to ensure identification. When the transient has been definitely identified, the retrace switch is operated again and the right printer handle pulled down at the moment the transient occurs. The recorder is allowed to play back for the remainder of the recording, and the left lever is pulled when the 400 cycle warning note is heard. This prints the time interval between the recording of the transient and the end of the recording. The interval time is subtracted from the change-over time to give the transmission time.

3.7 RAPID BEARING FLUCTUATIONS

The very long persistence of the scanned cathode-ray tube can sometimes be used to reduce rapid bearing fluctuations. The cathode-ray tube will integrate the picture over short periods, and the scanner sees an averaged bearing. The scanner is more sensitive to larger signals, so a weighting effect is added to stronger signals in addition, which also helps to reduce fluctuations due to wave interference between modes. The averaged bearing propeller pattern is viewed on the recorded bearing cathode-ray tube, with the "display" switch at "direct".

3.8 TIME UNIT

The time unit contains an accurate 60-cycle fork-controlled frequency standard to drive the Calculagraph and one or two external clocks. The frequency of the time unit is usually set (by an internal screwdriver adjustment) to make the Calculagraph run about $\frac{1}{2}$ second per day fast because it is much easier to make adjustments by stopping the Calculagraph than by setting it forward.

The Calculagraph is adjusted to the correct time once per day, if necessary. A small flush pushbutton ("clock set") on the time unit panel removes the voltage from the Calculagraph motor, and allows the clock to slow down. Caution must be used, because the clock movement will coast for as long as five seconds after the voltage is removed, with a similar delay in starting.

If the clock has been stopped too long, the "clock set" button must be pressed for approximately a minute to allow the second hand to be in the proper position, and then the minute hand must be reset using the short end of the clock key.

If the Calculagraph does not print the same time that the hands indicate, the instrument must be removed from its case, and reset as described in the Calculagraph manual.

4. MAINTENANCE

4.1 GENERAL

The maintenance instructions in this section include tables of d-c voltages for the various recorder units, the recorder electrical specifications, response curves, and miscellaneous data.

The equipment should be allowed to warm up at least 15 minutes before specification tests are performed.

4.2 VOLTAGE CHECK

The following tables of typical d-c voltages are given as a guide to servicing. Measurements were made with a vacuum-tube voltmeter with 11 megohms input resistance. Voltages may vary as much as 20% owing to variations in resistance values and tube currents.

TABLE II

TIME UNIT (No. 1000) VOLTAGE CHECK

Tube No.	Tube Type	D-C Voltages from Chassis to Pin No.								
		1	2	3	4	5	6	7	8	9
V1003[1]	12AT7WA	290	0	30	90	90	180	30	30	90
V1003[2]	12AT7WA	160	24.5	25	90	90	300	15	25	90
V1004	6AU6WA	-0.1	0.5	0	0	200	90	0.5	-	-
V1005	6AU6WA	0	1.0	0	0	130	130	1.0	-	-
V1006	6AU6WA	0	115	0	0	115	115	3.9	-	-
V1007	5R4WGA	0	325	0	0	0	0	0	325	-
V1008[3]	12AT7WA	100	40	0	0	0	100	40	0	0
V1009	6CL6	6.5	0	0	0	0	325	0	250	0
V1010	6CL6	6.5	0	0	0	0	325	0	250	0

Notes: 1. top meter illuminated
2. bottom meter illuminated
3. voltages vary with settings of R1036

TABLE III

RECORDER POWER SUPPLY (No. 2600) VOLTAGE CHECK

Tube No.	Tube Type	D-C Voltages from Chassis to Pin No.								
		1	2	3	4	5	6	7	8	9
V2601	5R4GY	0	475	0	0	0	0	0	475	-
V2602	6L6WGB	0	300	450	450	285	0	300	300	-
V2603	12AT7WA	300	150	150	90	90	175	72	74	90
V2604	OA2WA	150	0	0	0	150	-	0	-	-
V2605	6L6WGB	0	300	450	450	285	0	300	300	-
V2606	6L6WGB	0	300	450	450	285	0	300	300	-

TABLE IV

DOT-LOCK AND BRIGHTENING UNIT (No. 2800) VOLTAGE CHECK

Tube No.	Tube Type	D-C Voltages from Chassis to Pin No.								
		1	2	3	4	5	6	7	8	9
V2801	6BA6W	0	2.5	0	0	300	125	2.5	-	-
V2802	6AL5W	92	0	0	0	0	0	1	-	-
V2803	12AT7WA	150	0	1.4	0	0	180	1.0	2.4	0
V2804	12AT7WA	240	0	3.5	0	0	300	0	17	0
V2805	6AL5W	300	0	0	0	0	0	300	-	-
V2806	12AT7WA	300	10	31.5	0	0	180	31.5	31.5	0
V2807	6AL5W	35	35	0	0	145	0	0	-	-

Note: unit switched to "dot-lock", threshold control fully counter-clockwise, no input signal

TABLE V

BEARING MODULATOR UNIT (No. 3100) VOLTAGE CHECK

Tube No.	Tube Type	D-C Voltages from Chassis to Pin No.								
		1	2	3	4	5	6	7	8	9
V3101	12AT7WA	125	17	20	90	90	300	150	152	90
V3102	12AT7WA	150	-0.8	1.2	90	90	300	0	3.2	90
V3103	12AT7WA	255	150	151	90	90	255	150	151	90
V3104	12AT7WA	255	150	151	90	90	255	150	151	90
V3105[1]	12AT7WA	300	158	160	90	90	-	-	-	90

Note: 1. Pin 2 voltage of V3105 measured at junction of R3134, R3135

TABLE VI

BIAS AND ERASE OSCILLATOR UNIT (No. 3200) VOLTAGE CHECK

Tube No.	Tube Type	D-C Voltages from Chassis to Pin No.								
		1	2	3	4	5	6	7	8	9
V3201	12AT7WA	255	-2.5	0	90	90	-	-	-	90
V3202	12AT7WA	300	-30	1.0	90	90	300	-30	1.0	90

TABLE VII

PLAYBACK AMPLIFIER UNIT (No. 3300) VOLTAGE CHECK

Tube No.	Tube Type	D-C Voltages from Chassis to Pin No.								
		1	2	3	4	5	6	7	8	9
V3301	6AU6WA	0	0.9	90	90	30	40	0.9	-	-
V3302	6AU6WA	0	2	90	90	92	82	2	-	-
V3303[1]	6AU6WA	178	300	90	90	300	300	180	-	-
V3304	6CL6	5.7	0	190	90	90	300	5.7	190	0

Note: 1. Pin 1 voltage of V3303 measured at junction of R3313, R3314

TABLE VIII

AUDIO RECORDING AMPLIFIER UNIT (No. 3400) VOLTAGE CHECK

Tube No.	Tube Type	D-C Voltages from Chassis to Pin No.								
		1	2	3	4	5	6	7	8	9
V3401	6BA6W	0	5	90	90	170	143	5	-	-
V3402[1]	6AL5W	-	0	90	90	0	0	-	-	-
V3402[2]	6AL5W	-	-3.5	90	90	20	0	-	-	-
V3403[1]	6AU6WA	0	0	90	90	0	0	0	-	-
V3403[2]	6AU6WA	-10	5.5	90	90	45	56	5.5	-	-
V3404[3]	6BA6W	30	170	90	90	170	170	32	-	-

Notes: 1. Recorder BFO switch "off"
2. Recorder BFO switch "on"
3. Pin 1 voltage measured at junction of R3415, R3416

TABLE IX

SWEEP GENERATOR UNIT (No. 3500) VOLTAGE CHECK

Tube No.	Tube Type	D-C Voltages from Chassis to Pin No.								
		1	2	3	4	5	6	7	8	9
V3501	6AU6WA	0	.6	90	90	190	25	.6	-	-
V3502	6AU6WA	0	2.3	90	90	280	160	2.3	-	-
V3503	12AT7WA	165	0.4	2	90	90	125	0	1.6	90
V3504	6AL5W	300	300	300	300	300	0	300	-	-
V3505	12AT7WA	300	25	38	90	90	150	35	35	90
V3506	12AT7WA	0	0	0	90	90	300	0	6	90
V3507	6AU6WA	0	4.2	90	90	200	150	4.2	-	-
V3508	12AT7WA	190	-15	0	90	90	300	50	75	90

Note: sweep not triggered

4.3 RECORDER SPECIFICATIONS

The following specifications are a part of the specifications for the AN/GRD-501 HF DF receiver. Sections 4.3 (a) to (f) cover the individual units, and Sections 4.3 (g) to (i) the over-all performance. Units should be able to exceed the specifications, which are, in general, set conservatively.

4.3 (a) Recorder Power Supply

1) Conditions — All measurements shall be made with a 7500-ohm load across the 150-volt (d-c) supply.

2) Output — The supply shall provide an output of 300 volts (d-c) with a 2000-ohm load, and not more than 305 volts (d-c) with no load.

3) Hum Level — Hum level of the 300-volt section shall not exceed 0.05 volts (rms) at full load of 2000 ohms. Hum level of the 150-volt section shall not exceed 0.01 volts (rms) at full load of 7500 ohms.

4.3 (b) Bearing Modulator

1) Conditions — This unit shall be tested with plate supplies of 300 volts (d-c) and 150 volts (d-c), and filament supply of 6.3 volts (a-c). Tube V3102 shall be plugged into a 9-pin test adapter (CBS-Hytron type SH29 or equivalent). Oscillator output shall be measured at pin 6 of V3102.

2) Oscillator — The oscillator frequency control shall vary the frequency over a minimum range of 4900 - 5100 cps. The frequency shall be set to 5000 ± 50 cps for subsequent tests. With the 5 kc/s level control fully clockwise, oscillator output shall be at least 25 volts (rms). Set the level control to 15 volts (rms) for subsequent tests.

3) Carrier Suppression — With no signal input, and amplitude and phase null controls alternately adjusted for minimum output, the output at J3103 with optimum null settings shall not exceed 75 mv (rms).

4) Efficiency — A low-voltage 60-cps source shall be connected to J3102 through a series 0.1 mfd capacitor, and pulse amplitude control set fully clockwise. With an input of 0.2 volts (rms) the output from J3103 shall not be less than 2 volts peak-to-peak. With inputs of 2 and 20 volts (rms), the outputs shall not be greater than 8 volts and 16 volts peak-to-peak, respectively.

4.3 (c) Playback Amplifier

1) Conditions — The unit shall be tested with supply voltages of 300 volts (d-c)

and 6.3 volts (a-c). A 1-megohm and 100K attenuator shall be used to connect terminals J3303 and J3304, to provide 91% attenuation between terminals. Input to the amplifier shall be from an audio signal generator through a step-down transformer. The transformer secondary shall be grounded only at the input terminal, J3302. All voltages are to be measured with an a-c vacuum-tube voltmeter.

2) Audio Output — The output shall be measured between J3308 and chassis, with the shell of J3308 not grounded. With 0.5 mv (rms) input, the output shall be at least 0.3 volts rms at 1 kc/s, and within 2 db of the 1 kc/s output at any frequency between 50 cps and 6 kc/s.

With the shell of J3308 grounded and the same input level, the 60-cps output shall decrease by at least 12 db.

3) Bearing Output — J3305 and J3306 are to be interconnected, and a 100 pf and 100K load connected to J3307. With the padder capacitor, C3321, at maximum capacity, the output at 5 kc/s shall be at least 75 volts (rms) with 0.5 mv (rms) input. The output at 4 kc/s shall be at least 10 db less.

4) 40 Kc/s Rejection — Conditions are to be the same as 4.3 (c) 3. With an input of 5.0 mv (rms) at 40 kc/s, capacitor C3318 is to be adjusted for minimum output. The output at 40 kc/s shall not be greater than 10 volts (rms) and the outputs at 36 or 44 kc/s shall not be more than 12 db above the 40 kc/s output.

4.3 (d) Audio Recording Amplifier

1) Conditions — Power requirements are 300 volts (d-c) and 6.3 volts (a-c). Input to J3401 shall be from 175 kc/s signal generator with 2 volts input. Outputs shall be measured with a vacuum-tube voltmeter at J3408.

2) BFO Output — A plug with an SPST switch shall be connected to pins C and F of J3402 to control the BFO. With the BFO in operation, audio level control at maximum, and T3401 tuned for maximum output, output shall be at least 3 volts rms. The audio level control shall be set to give 2 volts rms output, and the BFO shall be switched off for subsequent tests.

3) Detector — With conditions as in preceding paragraphs and signal generator modulated 30% at 400 cps, output shall be at least 0.5 volts rms.

4) Rejection Filter — With conditions as in preceding paragraphs and signal generator modulated 30% at 5 kc/s, adjust L3401 for minimum output. Output should be not greater than .05 volts rms.

4.3 (e) Sweep Generator

1) Conditions — Power requirements are 300 volts (d-c), 28 volts (d-c), and

6.3 volts (a-c). Inputs shall be from RF or AF signal generator to J3505. Output measurements shall be made with a vacuum-tube voltmeter and/or d-c oscilloscope.

2) Sweep Output — The unit shall trigger with an input of not over 3 mv rms at 200, 1000, and 3000 cps, and 45 mv rms at 175 kc/s, modulated 30%. The sawtooth waveform from J3507 or J3508 shall have an amplitude of 150 ± 15 volts peak-to-peak for all combinations of input and sweep speed.

3) Vertical Output — Output shall be measured across a load consisting of 165 pf capacitance (including vacuum-tube voltmeter). An input level of not over 15 mv rms at 200, 1000, and 3000 cps, and 100 mv at 175 kc/s unmodulated, shall produce an output of 30 volts, rms.

4) Blanking Output — Output shall be measured at J3509 across a load consisting of 165 pf (including vacuum-tube voltmeter) in parallel with a 10K resistor. Output shall be zero during sweeps and at least 20 volts (rms) at 100 kc/s ± 20 kc/s between sweeps.

5) Audio Output — Output shall be measured between pins E and G of J3503 across a 3.3 ohm load. Output shall be 0.25 volts (rms) with an input of not over 20 millivolts (rms) at 500 cycles or 2 kc/s.

4.3 (f) Bias/Erase Oscillator

1) Conditions — The unit shall be tested with supply voltages of 300 volts (d-c), 28 volts (d-c), and 6.3 volts (a-c). All output voltages shall be measured with a vacuum-tube voltmeter.

2) Output — Bias voltage shall be measured at J3207 or J3208 across a Brush type-BK1090 record/reproduce head in parallel with 190 pf capacitance (including vacuum-tube voltmeter). The bias voltage shall be 90 ± 10 volts (rms) at a frequency of 40 ± 4 kc/s with C3205 tuned for maximum output.

Erase voltage shall be measured at J3205 or J3206 across a Brush type-BK1110 erase head in parallel with 165 pf capacitance (including vacuum-tube voltmeter). The erase voltage shall be 95 ± 25 volts, rms.

4.3 (g) Sweep Generator

1) Conditions — Input shall be to J3505 from audio oscillator with sufficient level to trigger sweeps regularly. Sweep length shall be adjusted to 3" at any sweep speed.

2) Centering — The horizontal centering control shall be capable of centering the 3" trace on the modulation display tube.

3) Linearity — Using audio frequencies of 20 cps with slow sweep rate, 50 cps with medium, and 100 cps with fast, the lengths occupied by one cycle at the start and finish of each sweep shall be equal within 10%.

4.3 (h) Steady State Recording

1) Conditions — Input shall be to J3203 from audio oscillator — 2 volts rms at 1 or 5 kc/s with J3204 open-circuited.

2) Playback Output — With 1 kc/s recorded, the output from each playback head (J3106 and J3108) shall be at least one millivolt rms.

3) Amplitude Variation — With a 1 kc/s signal recorded on either belt, playback gain shall be set at about midpoint and volume adjusted to give a 1" deflection on the modulation display. During at least one one-second period, amplitude shall not vary by more than ±0.5 db. Repeat on other belt.

4) Erasure — With a 5 kc/s signal recorded on the entire drum, set the playback gain to give 130 volt rms output from J3307. Record on the same drum again with no audio input. The output shall not be greater than 1.0 volt rms. Repeat on other belt.

5) Wow — This can be measured easily with an oscilloscope, camera (preferably Polaroid-Land), and NRC wow meter*. Record a 1 kc/s signal. Play back with "playback gain" set as in 4.3 (h) 4, and volume adjusted to give $\frac{1}{2}$" deflection on the modulation display. The output from J3506 shall be used to trigger the wow meter. There will normally be a good track and a poor track. The wow during the best part of the good track shall not exceed 2%, with the maximum trace variation during a $\frac{1}{10}$ second oscilloscope sweep not to exceed ±4% of the trace height.

On the poor track the wow indication shall be regular, with no high-frequency components present.

6) Distortion — A 1 kc/s tone shall be recorded. With playback gain set midway, and volume control set to give a $\frac{3}{16}$" trace on the modulation display, the output from J3506 shall be used to operate a distortion meter. The distortion on a good part of the good track shall not exceed 4%.

4.3 (i) Bearing Recording

1) Conditions — With "gonio" switched on, and "operation" switch at "normal", the recorder brilliance control shall be set to produce a 4" propeller pattern on the playback display, and the recorder vertical and horizontal centering controls adjusted.

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* Cox, L.G., "A Simplified Wow and Flutter Indicator". NRC Report ERB-414, June 1957

2) Recorded Bearing Accuracy — With conditions as in 4.3 (i) 1, the gonio signal shall be recorded at 45°, and the gonio dial then moved and gonio injection switched off. The recorded signal shall be played back, and the cursor of the playback scope centered over the playback propeller. Gonio injection shall then be switched on, the direct propeller pattern centered under the cursor, and gonio injection switched off again. The bearing on the gonio dial shall be 45° ±1°. The test shall be repeated on the other belt.

3) Bearing Retention — With centering controls adjusted as in 4.3 (i) 1, and "operation" switch at "D.L.", a pulsed signal from a low impedance signal generator shall be injected into gonio input J4509. The pulsed signal shall be a chopped c-w signal $\frac{1}{10}$ second long with a chopping rate of approximately 250 pps. The recorder brilliance control shall be set to give a 4" propeller pattern on direct display during the recording. During playback the usable propeller pattern shall last at least 15 seconds.

4.4 RESPONSE CURVES

4.4(a) Recording Head Response curves are shown in Fig. 4(a) for the record/playback head with constant current recording (0.06 ma rms). Curves are given for the head, both untuned, and tuned to 5 kc/s.

4.4(b) Playback Amplifier (Bearing) Response curves are given in Fig. 4(b) for the bearing playback amplifier with constant input voltage, and a 21-db attenuator (1M and 100 K) in place of the gain control. A full curve is shown for 0.5 mv rms input, and a partial curve for 5.0 mv rms input. The high input level is used to check the 40 kc/s rejection filter. The output noise level is about one volt. A 100K resistive load is used, as in the recorder specifications. Selectivity is greater with the resolver load.

4.4(c) Playback Amplifier (Audio) The curves are given in Fig. 4(c) for the playback amplifier response with the output taken at J3308, with 0.5 mv rms input and a 21 db attenuator in place of the gain control. Grounding the shell of J3308 completes the circuit for the 60 cps and 5 kc/s rejection filters and frequency compensation circuit.

4.4(d) Audio Recording Amplifier Fig. 4(d) shows the response curve of the audio recording amplifier, with an input of 2 volts rms at 175 kc/s, modulated 30% with frequencies from 50 cps to 10 kc/s. The audio level control was set to give 2 volts audio output with 2 volts of unmodulated 175 kc/s input and the BFO switched on. C4311 is adjusted for maximum 5 kc/s rejection, T3402 for maximum 175 kc/s rejection.

4.4(e) Over-all Recording System The over-all response curves for the audio and bearing recording systems are shown in Fig. 4(e). The bearing

curve was taken with 2 volts rms input to J3204, and a 100K load across J3307. The audio curve was taken with 2 volts rms 175 kc/s input to J3401, and the output taken at J3308, with the shell of J3308 grounded.

4.5 INTERNAL CONTROLS

Various chassis-mounted controls, principally potentiometers with shaft locks, are not accessible from the front panels. Chassis having preset controls peculiar to the recorder are listed below, with procedure for adjusting the controls.

4.5(a) Unit 2600 The output voltage of the regulated power supply is adjusted to + 300 volts by "voltage set".

4.5(b) Unit 2800 Settings of all controls except " clipping level" are covered in the receiver handbook. This control adjusts the brightening pulse amplitude during "normal" operation to produce similar average brightness of the scanned tube with either "normal" or "D.L." operation when receiving a moderate-speed keyed c-w signal. With an appropriate signal, the direct display propeller is observed on "D.L.", the "operation" switch changed to "normal", and "clipping level" control adjusted to produce the same propeller pattern length.

4.5(c) Unit 3000 This unit contains the carriage position indicator potentiometers, and carriage position indicator set controls. The potentiometers (R3005 and R3024) have servo-type mountings, and after loosening the three clamps the potentiometer bodies may be rotated to give zero meter indication with the carriages at the start of their tracks. The "carriage position indicator set" variable resistors are then adjusted to give 120-second indicator readings with the carriages lifting at the end of the track.

The direct bearing propeller pattern should be almost vertical when the "gonio inject" dial is at 0°. If it is not, the knurled resolver clamping ring should be loosened and the resolver body rotated the necessary amount.

4.5(d) Unit 3100 There are four preset potentiometers and one variable capacitor in the bearing modulator unit which require adjustment.

The 5 kc/s oscillator output is checked at pin 6 of V3102. The "frequency" control is adjusted for 5000 ± 50 cps, and the "level" control for 15 volts rms output.

The balanced modulator null controls are adjusted with the pulse amplitude control fully counterclockwise. An oscilloscope is connected to J3104 or J3105, and "amplitude null" and "phase null" alternately adjusted for minimum output. With optimum adjustment the output should not exceed .075 volts rms.

The proper "pulse amp" control setting is dependent on the scanned scope brightness and photomultiplier sensitivity. With "gonio injection" producing a long clean trace, and "operation" switch at "normal", the "pulse amp" control is adjusted to produce a 4 volt peak-to-peak output pulse at J3102.

4.5 (e) Unit 3200 The only preset control on this chassis is variable capacitor C3205, part of the 40 kc/s bias filter which isolates the recording head from audio and bearing sources. The filter minimizes loading of the bias amplifier and also feedback of the bias voltage to the direct display amplifier. The capacitor is adjusted to produce maximum bias voltage across the recording head.

4.5 (f) Unit 3300 The playback amplifier has three variable capacitors. C3318 is adjusted for minimum 40 kc/s output to J3307 on direct display, and C3311 is adjusted for minimum 5 kc/s output in the audio signal to J3308, with the shell of J3308 grounded.

C3321 is used to tune the resolver to 5 kc/s in the following manner: the "display" switch is set to "direct", and the "amplitude null" control (R3126) completely offset to give a considerable carrier leak. C3321 is then adjusted so that the direct display consists of a single solid circle instead of two concentric circles.

4.5 (g) Unit 3400 There are three tuned circuits and two preset potentiometers on the audio recording unit chassis. For most of the adjustments a signal generator with a 2 volt 175 kc/s output is connected to J3401, and a sensitive audio vacuum-tube voltmeter connected to J3408 in parallel with a 27K load.

With the 175 kc/s input unmodulated, and the Recorder BFO switch on, T3401 is adjusted for maximum audio output, and then the "audio level" control is set for 2 volts rms out. The BFO is then switched off, and T3402 is adjusted for minimum 175 kc/s voltage at J3408. The 175 kc/s input is then modulated 30% at 5 kc/s, and C3411 adjusted for minimum 5 kc/s output.

P3401 is reconnected to J3401, and a long clean trace obtained with "gonio injection" and "normal" operation. The "direct gain" control is set to produce a 4" propeller pattern on the "direct display".

4.5 (h) Unit 3500 There are five preset potentiometers on the sweep generator chassis: the trigger level control, three sweep length controls, and the modulation display horizontal centering control.

The trigger level control "sweep freq" is turned counterclockwise until the sweep does not trigger with no input. The sweep should trigger with a $\frac{1}{4}$" pattern on the modulation display. The three "sweep length" controls are adjusted to give 3" long traces with the "sweep rate" switch in the appropriate position.

The "horizontal centering" control is adjusted with the "sweep rate" switch at the "fast" position. Because of the large amount of negative feedback in the output stage, the display requires several minutes to reach a stable position.

4.6 MECHANICAL DETAILS

4.6(a) Recording Head Alignment The erase head cores are 0.110" wide, and the record/playback head cores .090" wide. For optimum performance the playback head must be centered on the erase track, with the head flat on the belt and the head gap located on an imaginary line joining the axes of the recording drum and the recording head mounting bolt. If these three conditions are not met there may be incomplete erasure, low output from the playback head, and a response with much greater attenuation of the high frequencies.

Adjustments are not required normally unless the heads are replaced or moved. Track alignment may be checked quite easily by observing the track on the oiled surface of the drum just behind the playback head, as the playback head is alternately lifted clear and then allowed to contact the drum again. The tracks made by the heads are quite visible on the oiled surface of the drum, and it is apparent when the playback head is not centered on the erase track.

The record/playback head pivot shaft is held by a ball and thrust pin at each end. To move the head a small amount the setscrew on the thrust pin in the direction of the required motion is loosened, and the thrust pin is moved the necessary amount by pressure on the pivot arm. The setscrew is then tightened, and the other thrust pin moved in to give the proper pivot pressure.

Proper pivot pressure is such that there is no play at the balls to allow lateral head movement, but the friction is small enough to permit the head to follow belt irregularities. Pivot pressure may be checked by the use of a spring scale to raise and lower the heads. The reading while raising the head slowly must not be more than 5 grams more than the reading while lowering the head slowly, or the head may not follow irregularities closely.

The record/playback heads are adjusted so that the surface of the laminations at the gap is parallel to the surface of the belt. The angle of the head is controlled by rotating a tapered washer placed between the head and the pivot arm. One method of checking parallelism is as follows: the recording drum is wiped clear of oil and a curved piece of shim stock 2" to 3" square is placed on the drum. A light source is inserted between the head and leadscrew. It may be a miniature pilot lamp with soldered leads, such as a type 327 or 328 lamp, or a small piece of mirror at 45° illuminated by a flashlight. The light source is observed while the head is raised and lowered slowly, and the side of the head which clears the shim stock first may be easily distinguished. The washer is then ro-

tated to make the head parallel to the shim stock.

There is almost a line contact between the head and the drum, so the playback head gap must be located on the line of contact. If the gap is not placed exactly, the playback loss is proportional to frequency, and is about 50 db per .001" of separation at the bearing recording frequency. A steady audio signal is recorded on the drum, and on playback the playback head is rotated in small steps until the largest output is obtained.

4.6(b) Lubrication The belts are lubricated by oil-soaked wicks which press against the bottom of the drums, and the wick reservoirs must be kept partially filled with Dow Corning type DC200 30 centistoke silicon fluid ONLY. If mineral oil is used, the belts eventually stretch and become loose on the drums. The belts are made of synthetic rubber impregnated with iron oxide, and are very abrasive when dry; hence, the recorder must never be operated without lubrication of the belts. When the recorder has been out of service for some time the belts dry off, and the carriages must be raised manually for several seconds when initially starting the recorder again.

The recorder gearbox uses No. 10 mineral oil, and the oil level should be maintained between $\frac{1}{3}$ and $\frac{2}{3}$ up the sight glass. The same oil may be used on the leadscrews, which require about two drops every month.

4.6(c) Gearbox The only part of the gearbox which should have to be removed is the scanner shaft, in case repairs are necessary to the slip-ring assembly. The resolver is first lifted off the recorder, then the resolver coupling, which is fastened by a single nut and key, is removed from the top of the scanner shaft. The top scanner bearing housing may be taken off after removing six cap screws, exposing the two right-angle helical gears. Make sure mating marks are visible on the two gears before removing the scanner shaft. The gear train has been lapped in, and wrong mating of the gears can increase low frequency rumble and wow by as much as 10 db. If mating marks are not visible, mark the gears before disassembly.

4.6(d) Drive Puck The drive puck must be free from oil and dirt to drive without slippage. The surfaces of the puck, scanner drive band, and motor drive wheel should be cleaned regularly with alcohol and wiped dry. Other solvents such as varsol, trichlorethylene or carbon tetrachloride are not satisfactory and must not be used. If the surface of the puck should remain soaked with oil for very long the puck may be ruined, and a new puck should be installed if the surface cannot be restored to proper condition. The puck used is a $2\frac{1}{2}$" Walsco type-1430 idler wheel with the hub removed, mounted on a special hub.

4.7 MISCELLANEOUS

4.7(a) Burned CRT Screen The magnesium fluoride P19 phosphor used in the

scanned cathode-ray tube has very long persistence, but it is extremely susceptible to being burned. A clean stationary trace, such as produced by the gonio injection signal, should not be left on the screen for long periods unless the brightness is turned down.

If a line has been burned on the screen, the direct propeller pattern will decrease greatly in size and symmetry when the trace approaches the same azimuth as the burned line. If the burned line is at 0° or 90° it will be necessary to center the scanned trace (Section 3.2 (b)) at an azimuth close to the burned area, and the number of steps necessary to achieve a steady propeller pattern will probably be increased.

4.7 (b) Recording Belt Installation The life of the belt and heads is extremely long under lubricated conditions, but both can be ruined rapidly by unlubricated use. The belts are quite stiff at room temperature, but become fairly soft when heated. The belts can be pressed on the drum by hand (wearing leather gloves), if the belts are first immersed in boiling water for a few minutes. After installation the belts must be erased.

4.7 (c) Deep Erasure of Belts Recording belts, when received from the manufacturer, contain small areas of magnetization which are not affected by the surface high-frequency erasure. These areas induce strong low-frequency signals into the playback head. A belt demagnetizer may be constructed from a $\frac{3}{16}" \times 1" \times 8"$ cold-rolled steel bar and a Hammond type-158J filter choke. The ends of the bar are rounded, and it is bent into a horseshoe shape. The coil of the choke is slipped on one leg of the bar and the ends of the bar closed to a $\frac{1}{16}"$ gap. The belt demagnetizer is shown in Plate III.

With the recorder running and 100 ma d-c coil current, the demagnetizer is slowly moved along the full length of the belt while keeping the ends of the bar in close contact with the belt.

It is possible that the recording head may become magnetized during the above process, and it should be demagnetized with a commercial tape-recorder-head demagnetizer.

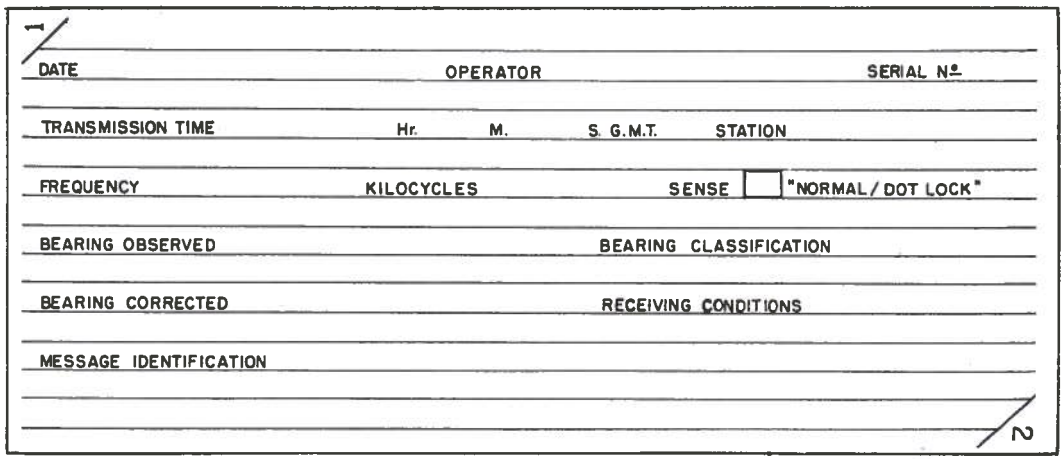
4.7 (d) Excessive Hum The outside shielding of the playback head coaxial cable is connected through insulated BNC chassis connectors at all but one point, to avoid causing a ground loop which could induce 60 cps voltages into the playback amplifier.

If there is excessive hum, disconnect the coaxial cable to J3302, and check that there is no continuity between the cable shield and ground at any other point.

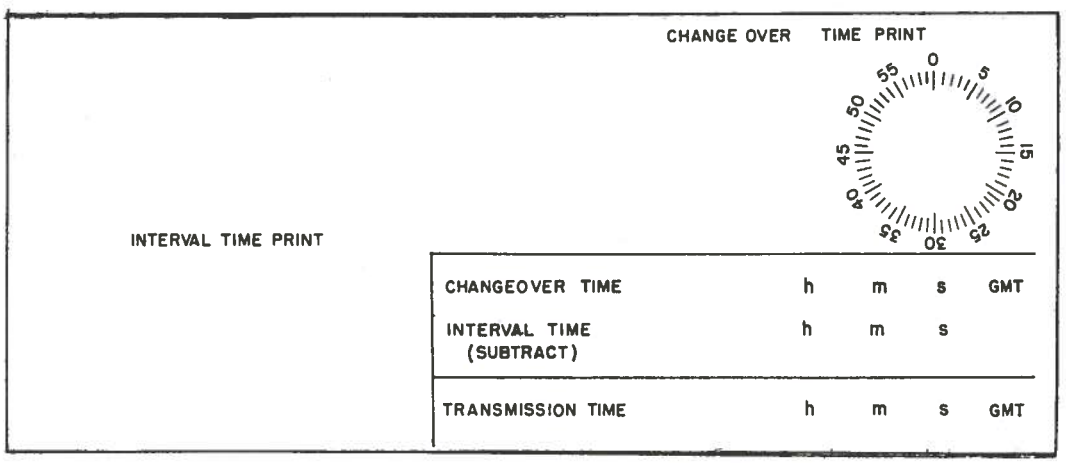
4.7 (e) Low Head Output There are various possible causes for low playback

amplitude from one channel only. Among them are: partially or totally short-circuited playback head windings, improperly aligned head (Section 4.6(a)), a worn head due to operation without proper belt lubrication (Section 4.6(b)), a magnetized playback head (Section 4.7(c)), dirty relay contacts on record or playback, and faulty coaxial cables or connections.

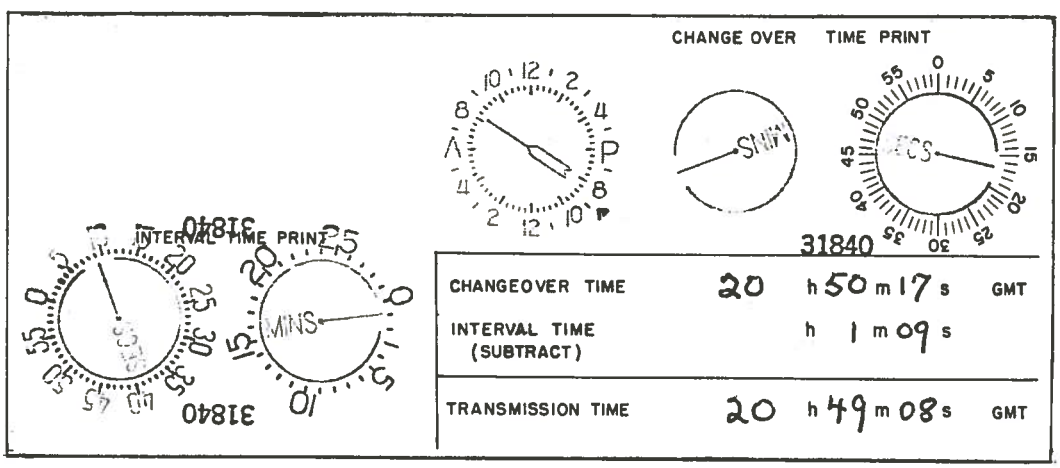
A rough check on the condition of cables, head windings, and playback relay contacts may be made by measuring the d-c resistance of the circuit at P3302, which should be approximately 110 ohms. Head alignment or head wear may be checked by applying several ounces of finger pressure to the top of the playback head. This will deform the rubber belt and allow better contact with a worn or misaligned head.



(a) FRONT SIDE



(b) REVERSE SIDE



(c) SAMPLE CARD

FIG. 3 LOG CARD

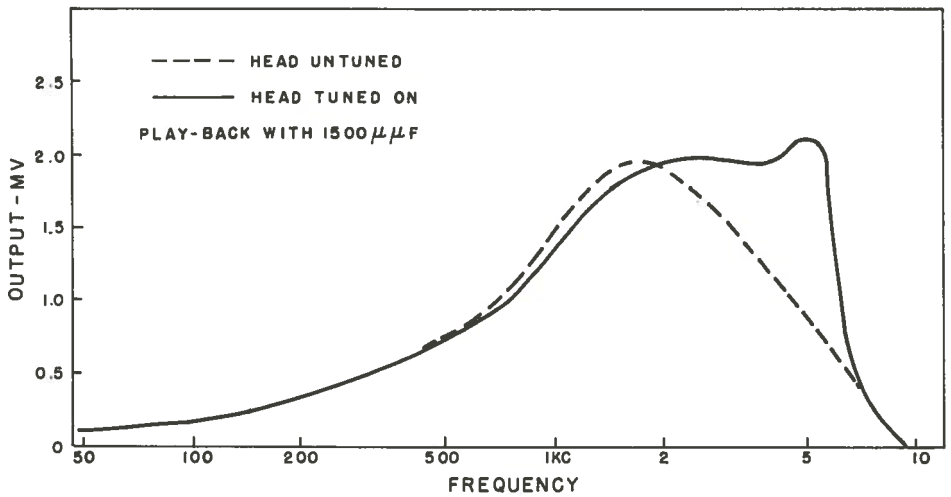


FIG. 4(a) RESPONSE CURVE OF RECORD/PLAYBACK HEAD

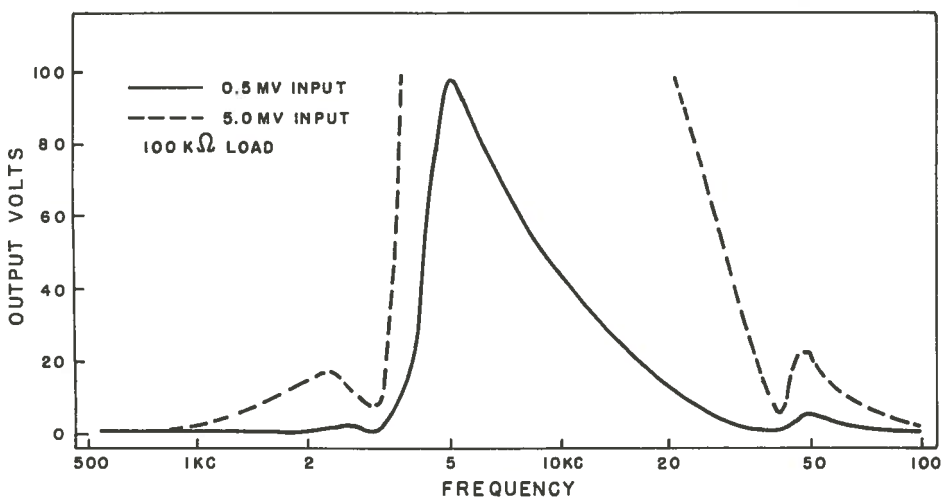


FIG. 4(b) RESPONSE CURVE OF BEARING PLAYBACK AMPLIFIER

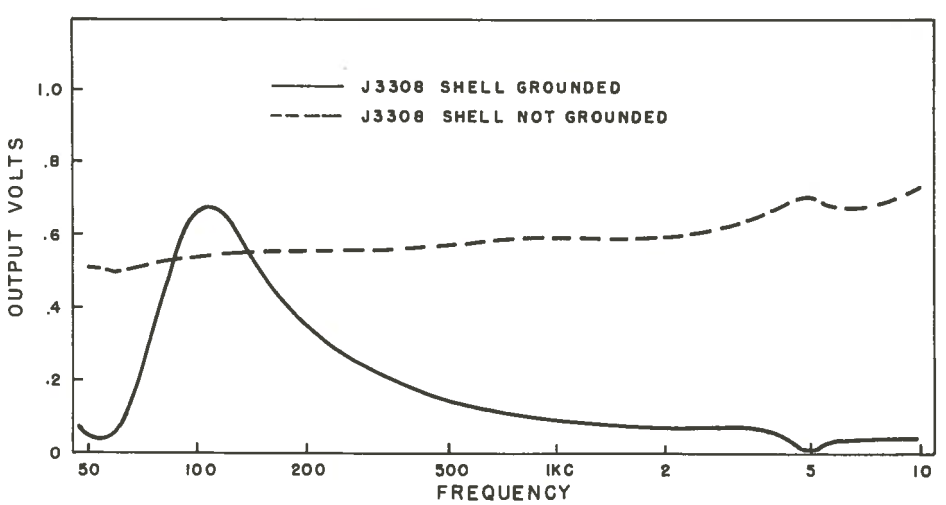


FIG. 4(c) RESPONSE CURVE OF AUDIO PLAYBACK AMPLIFIER

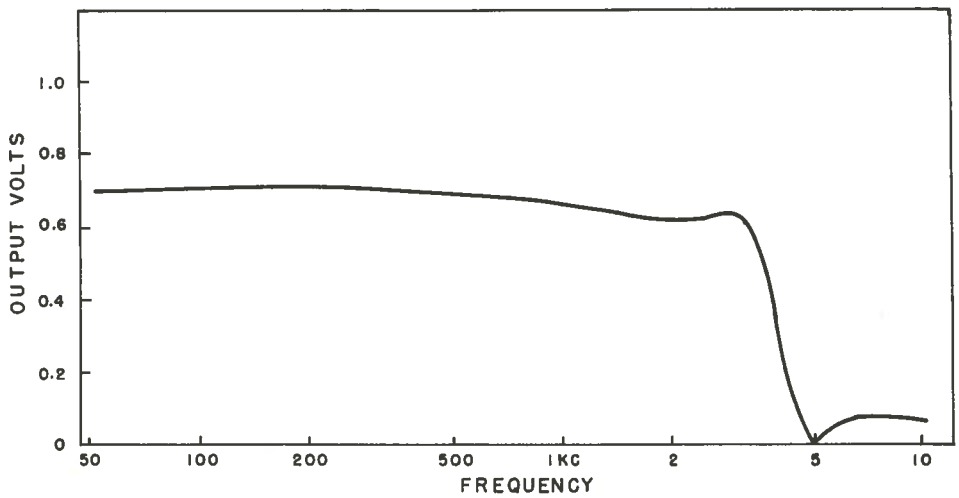


FIG. 4(d) RESPONSE CURVE OF AUDIO RECORDING AMPLIFIER

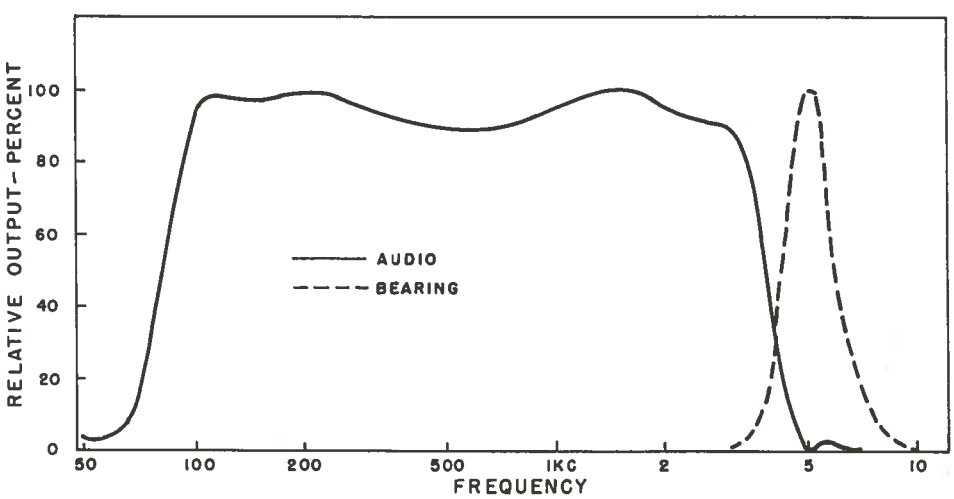
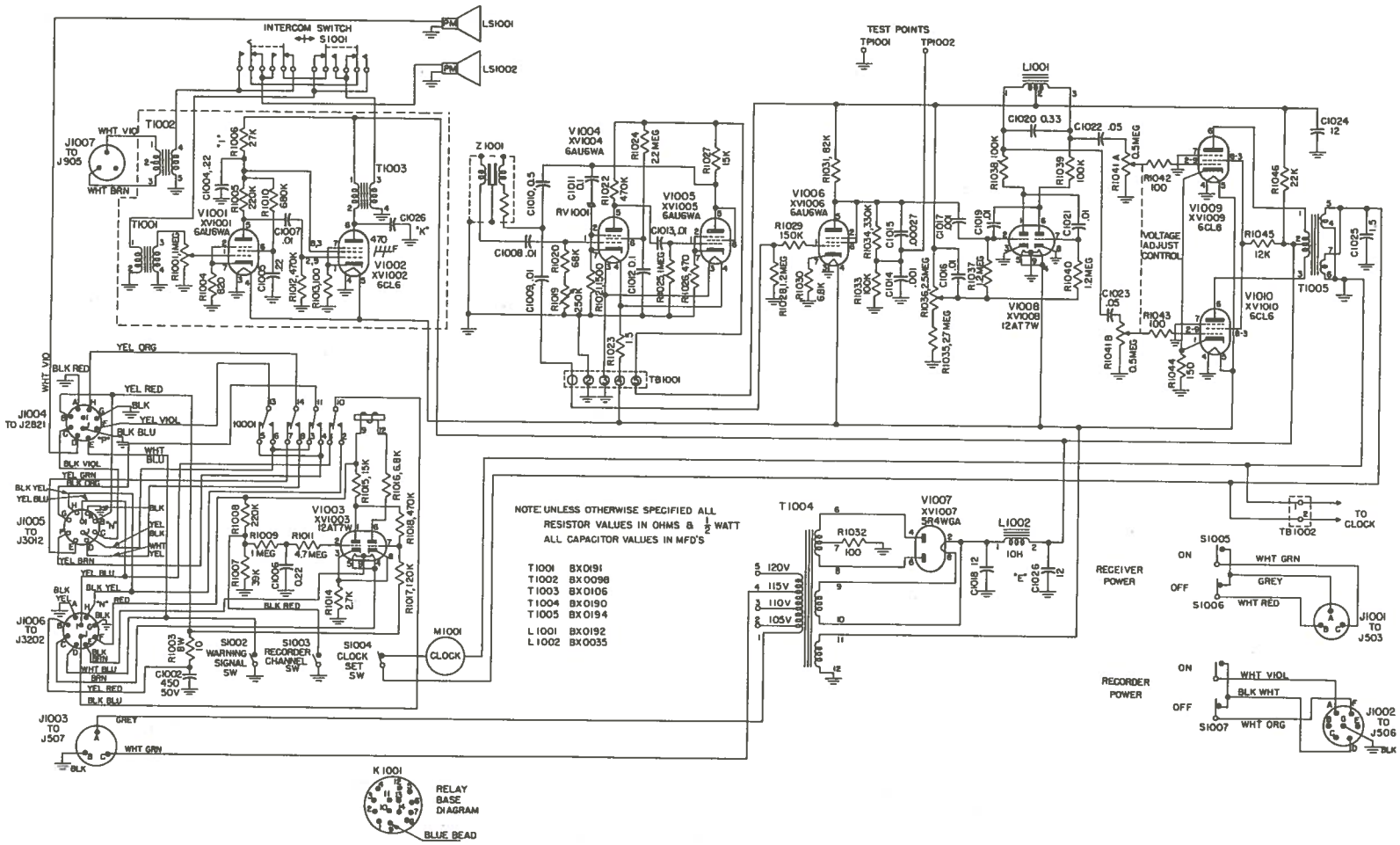
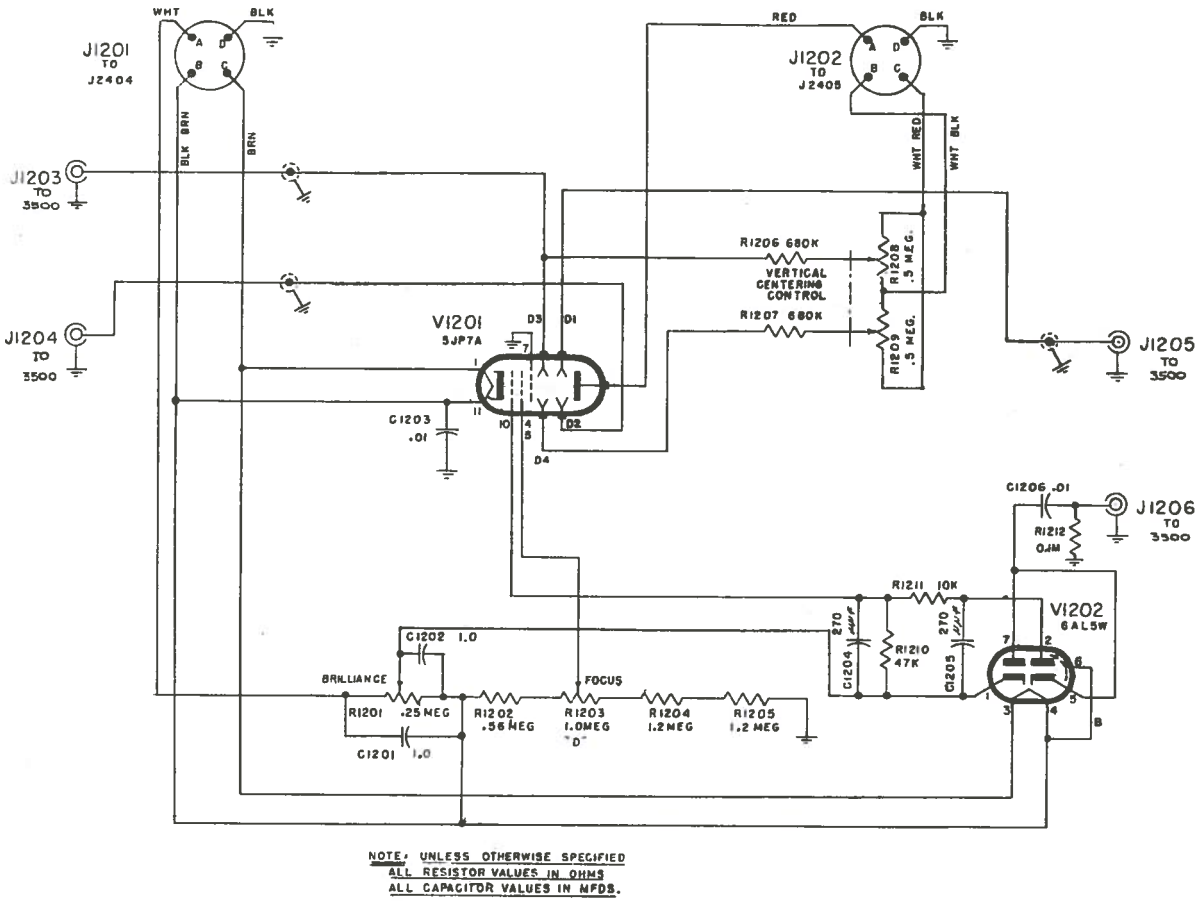


FIG. 4(e) OVER-ALL RESPONSE CURVE

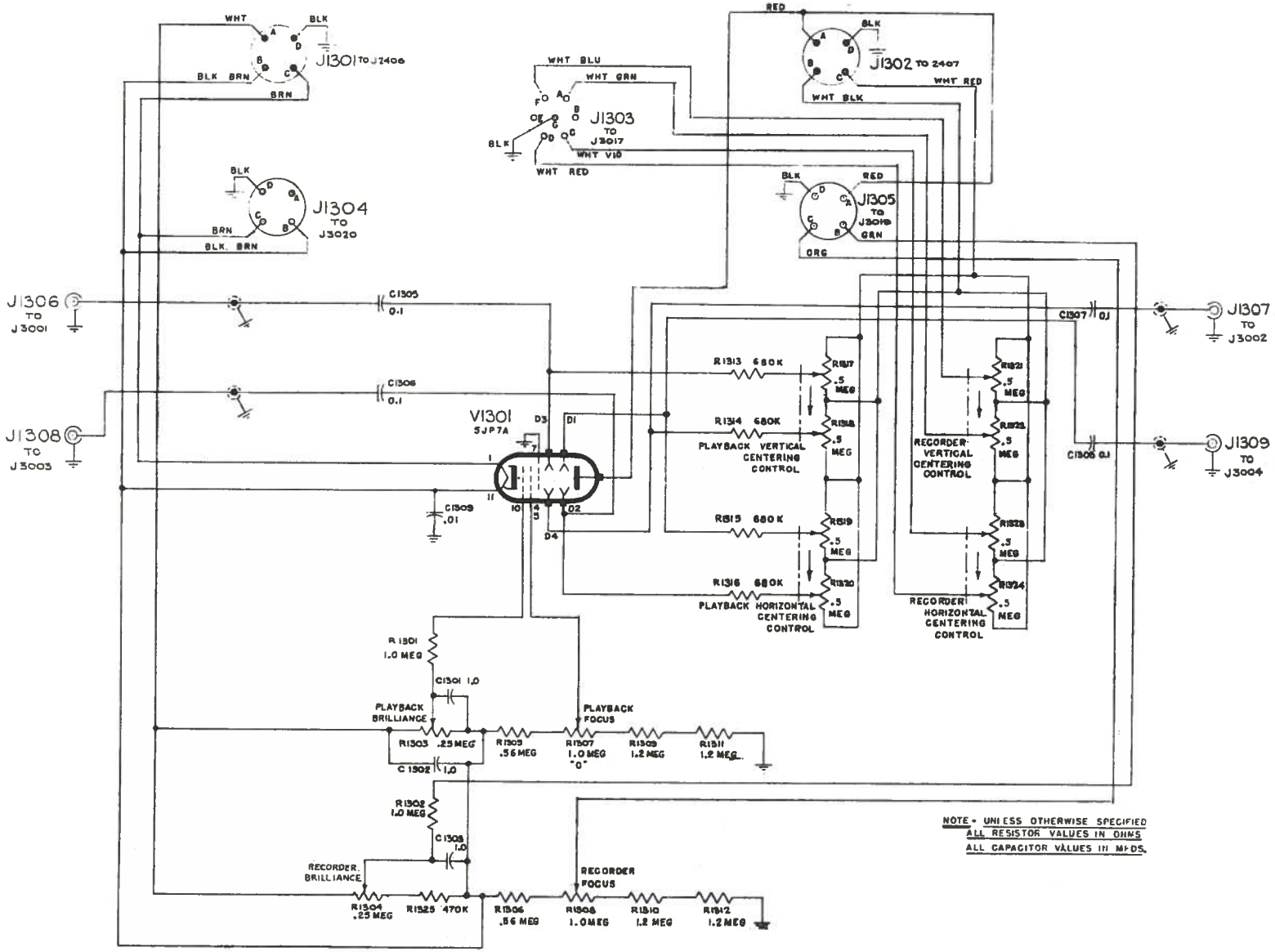


CIRCUIT DIAGRAM OF TIME UNIT (No. 1000)

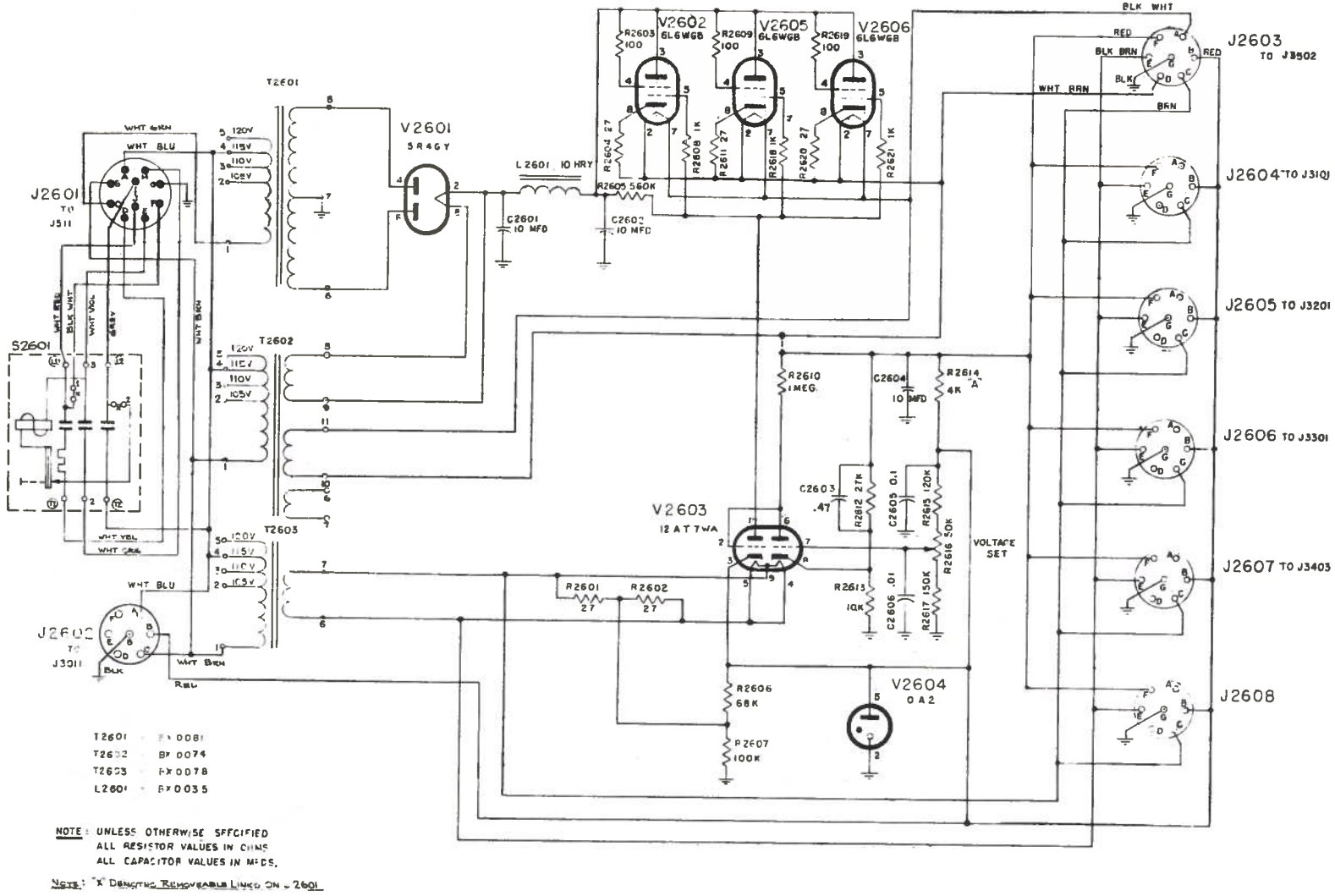


NOTE: UNLESS OTHERWISE SPECIFIED
ALL RESISTOR VALUES IN OHMS
ALL CAPACITOR VALUES IN MFDS.

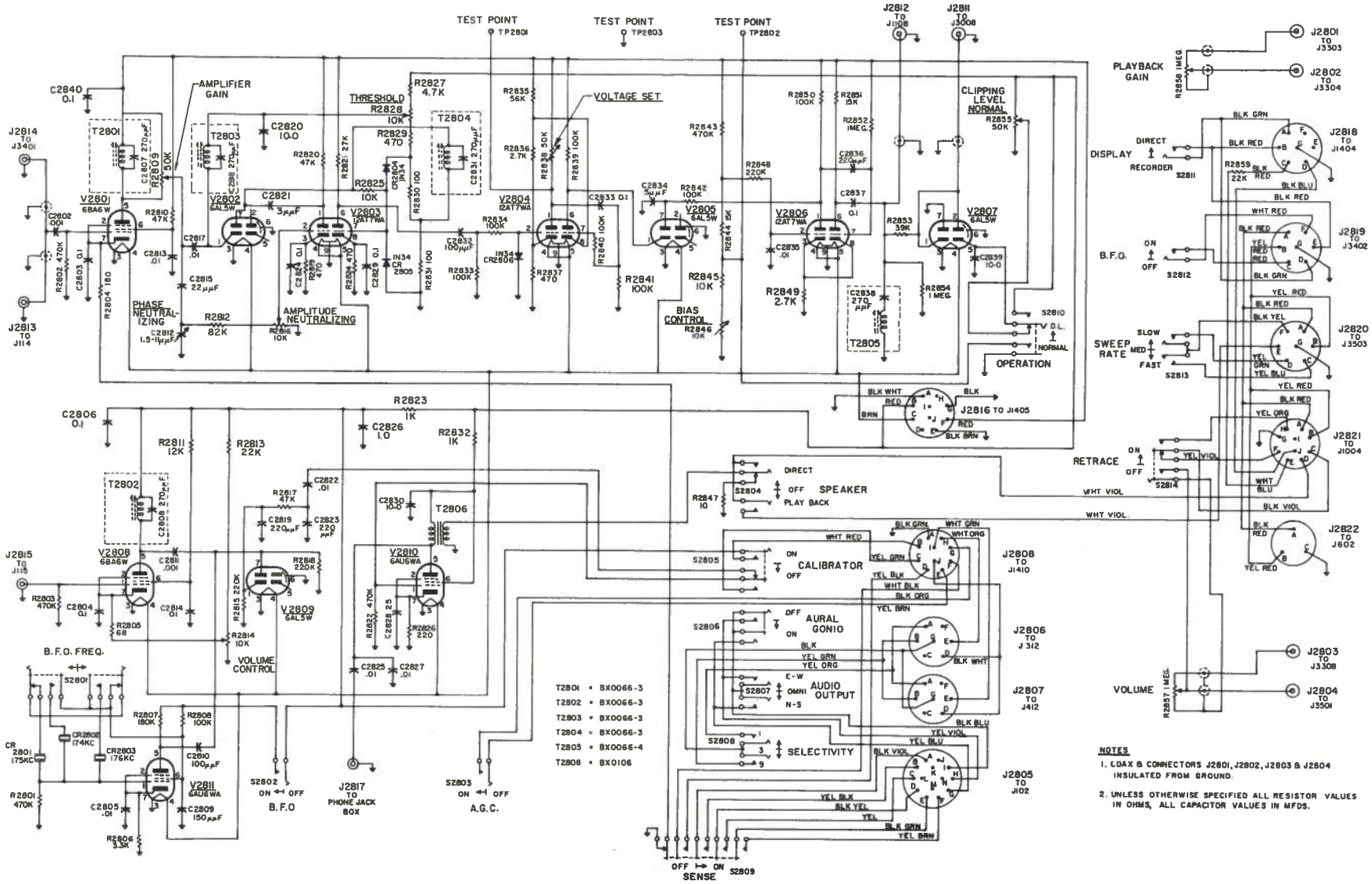
CIRCUIT DIAGRAM OF MODULATION DISPLAY UNIT (No. 1200)



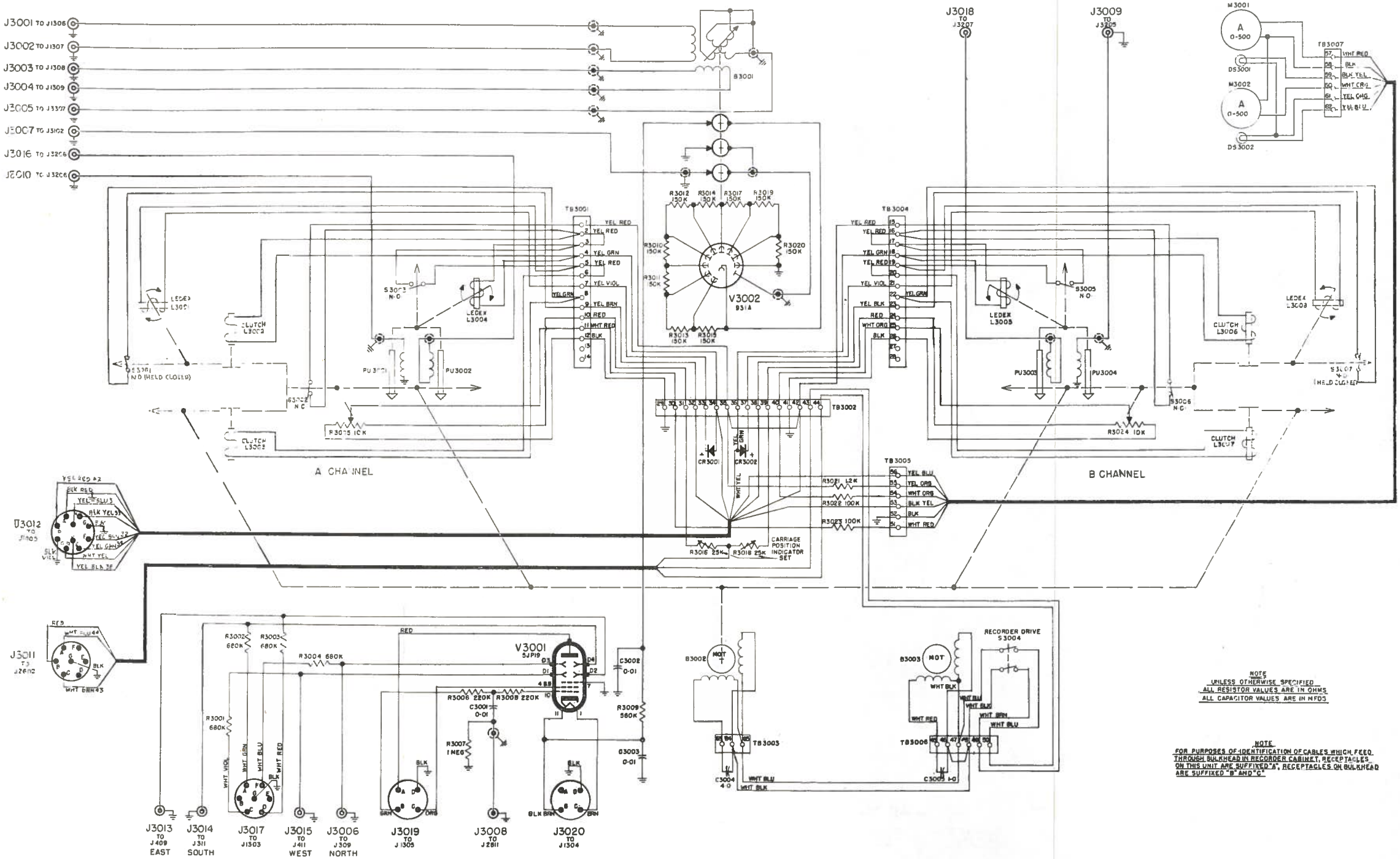
CIRCUIT DIAGRAM OF RECORDED BEARING DISPLAY UNIT (No. 1300)



CIRCUIT DIAGRAM OF POWER SUPPLY UNIT (No. 2600)



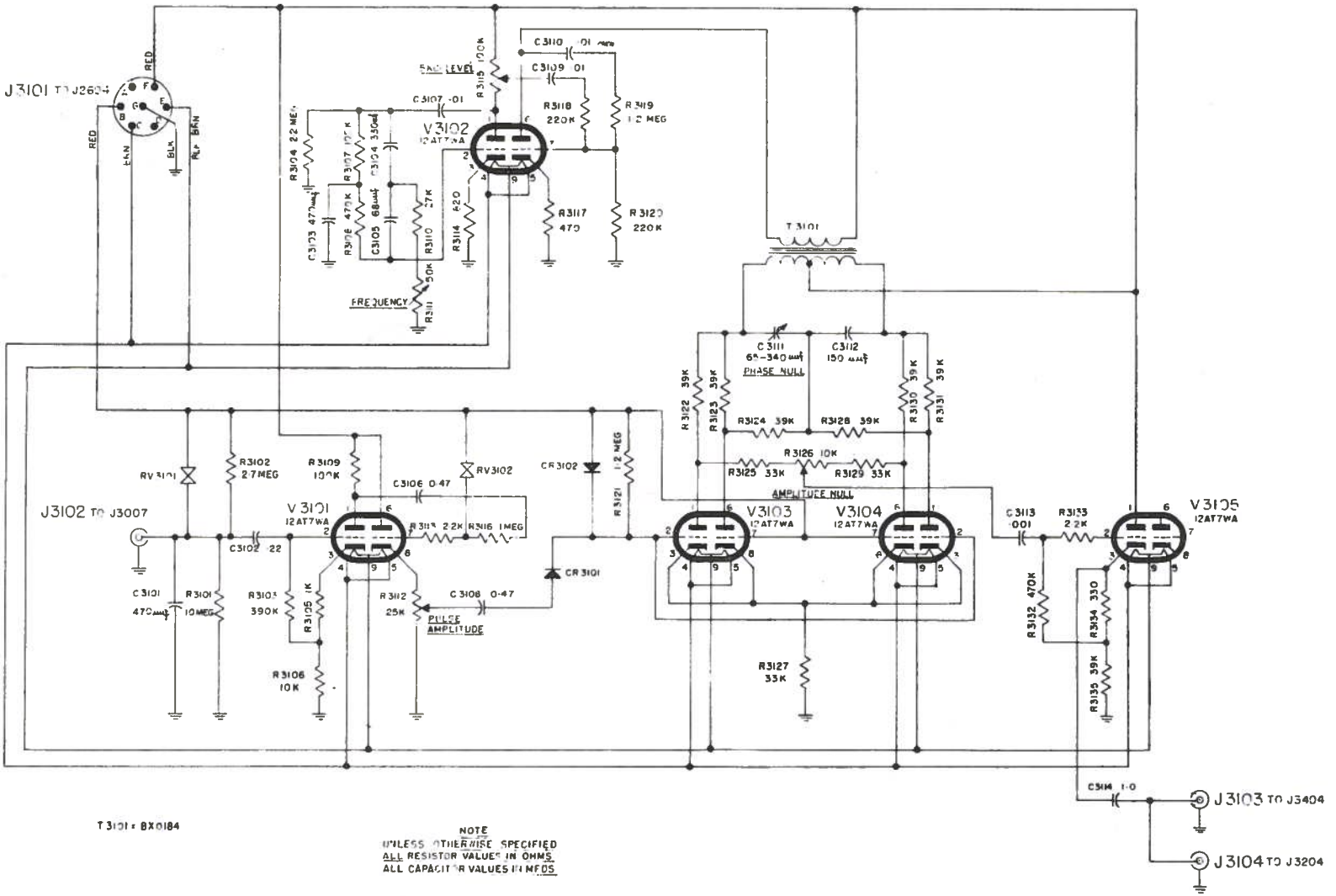
CIRCUIT DIAGRAM OF AUDIO AND SWITCHING UNIT (No. 2800)



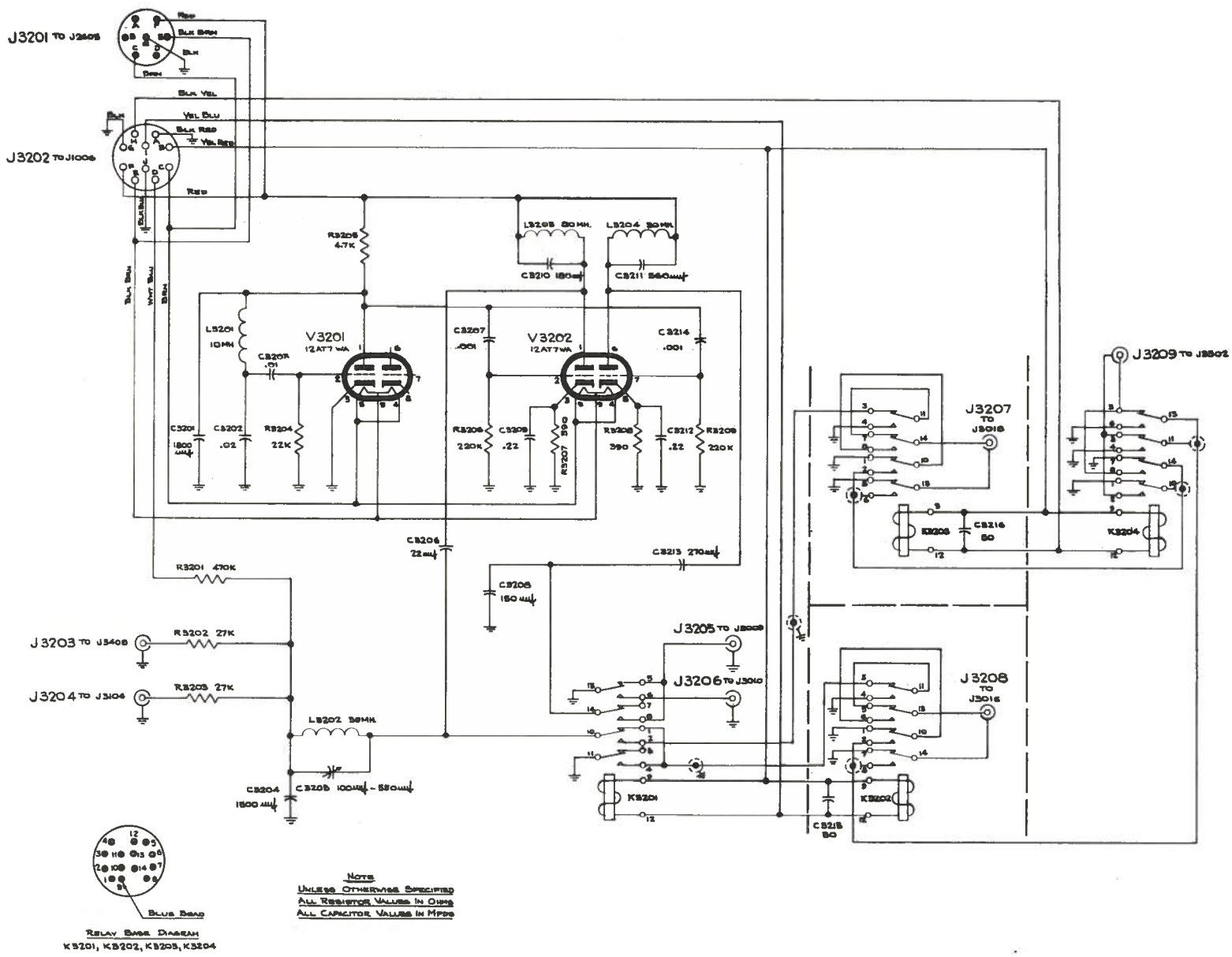
NOTE
UNLESS OTHERWISE SPECIFIED
ALL RESISTOR VALUES ARE IN OHMS
ALL CAPACITOR VALUES ARE IN MFDS

NOTE
FOR PURPOSES OF IDENTIFICATION OF CABLES WHICH FEED THROUGH BULKHEAD IN RECORDER CABINET, RECEPTACLES ON THIS UNIT ARE SUFFIXED "A", RECEPTACLES ON BULKHEAD ARE SUFFIXED "B" AND "C"

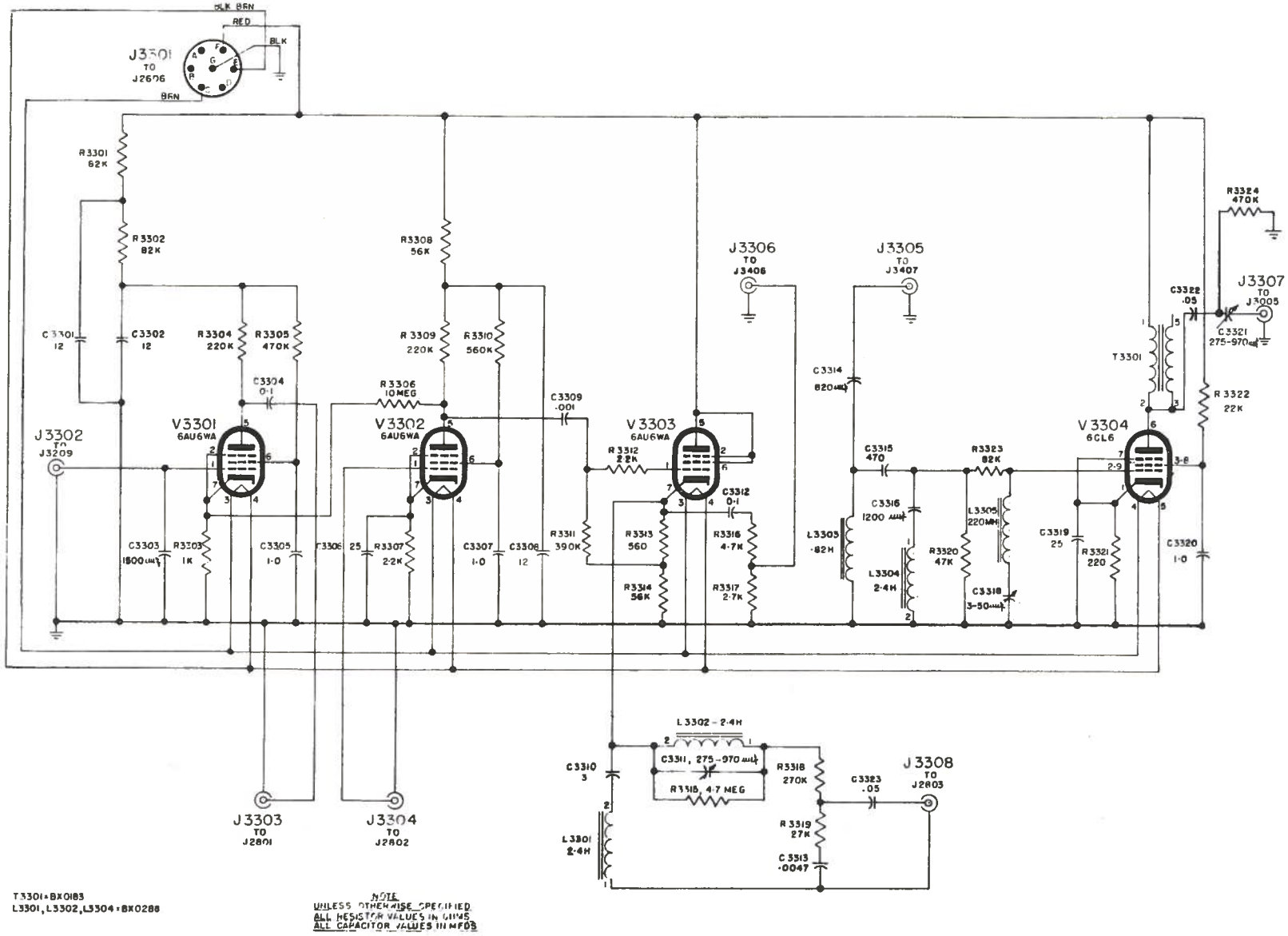
CIRCUIT DIAGRAM OF RECORDER UNIT (No. 3000)



CIRCUIT DIAGRAM OF BEARING MODULATOR UNIT (No. 3100)



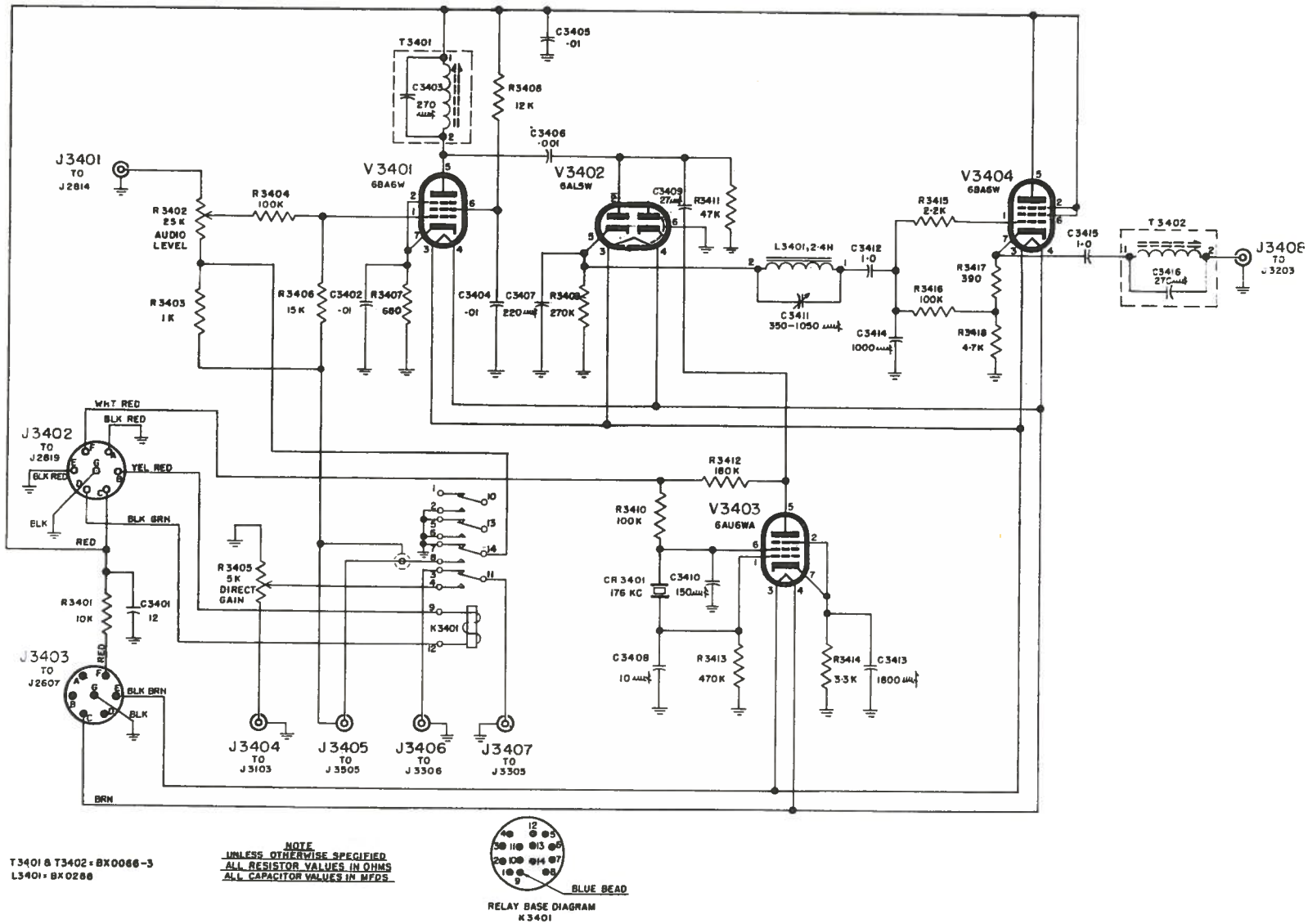
CIRCUIT DIAGRAM OF BIAS-ERASE OSCILLATOR UNIT (No. 3200)



T3301=BX0183
L3301, L3302, L3304=BX0288

NOTE
UNLESS OTHERWISE SPECIFIED
ALL RESISTOR VALUES IN OHMS
ALL CAPACITOR VALUES IN MFDS

CIRCUIT DIAGRAM OF PLAYBACK AMPLIFIER UNIT (No. 3300)

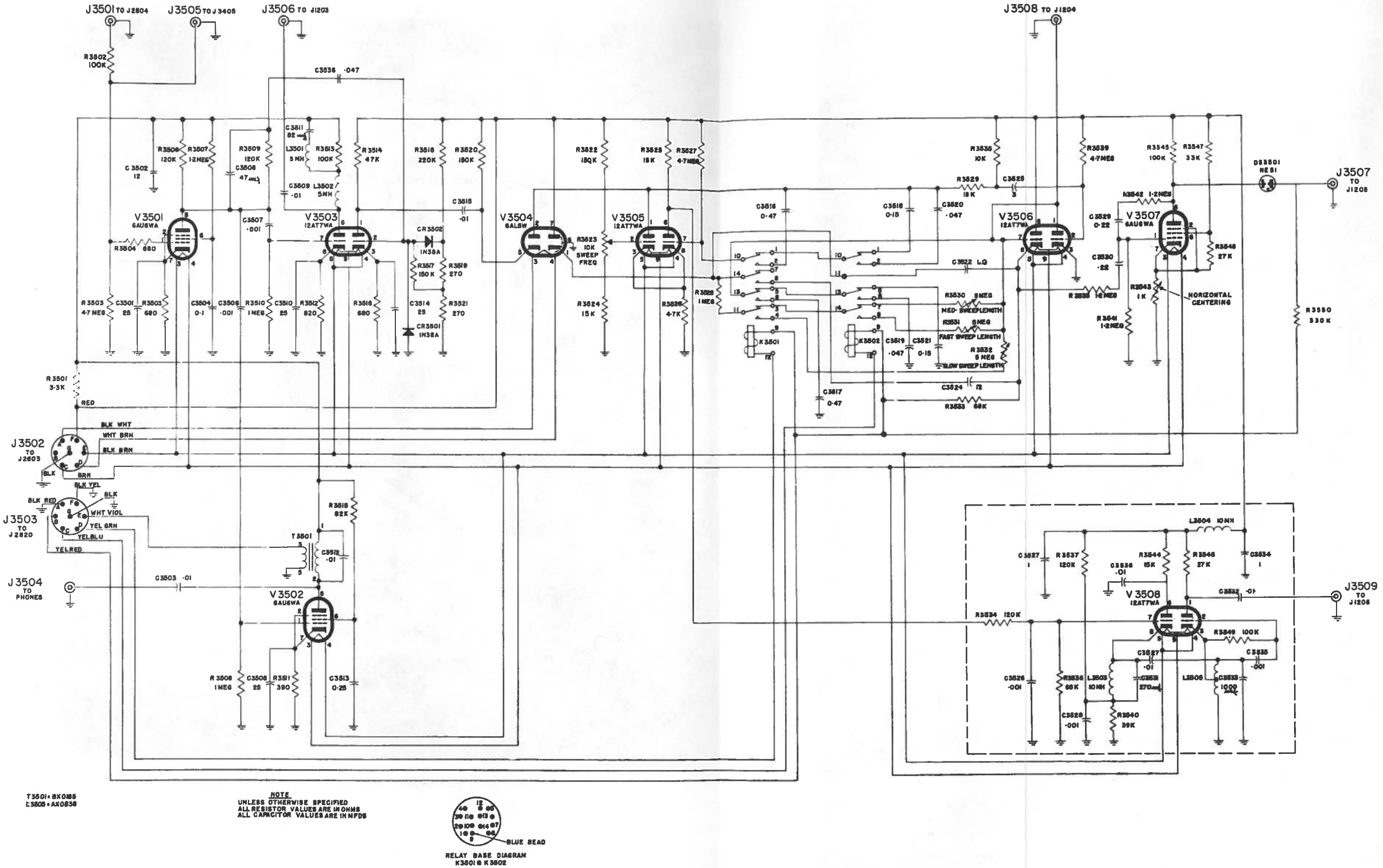


T3401 & T3402 = BX0066-3
L3401 = BX0286

NOTE
UNLESS OTHERWISE SPECIFIED
ALL RESISTOR VALUES IN OHMS
ALL CAPACITOR VALUES IN MFDS

RELAY BASE DIAGRAM
K3401

CIRCUIT DIAGRAM OF AUDIO RECORDING AMPLIFIER UNIT (No. 3400)



T3501 = 8X0185
L3505 = AX0838

NOTE
UNLESS OTHERWISE SPECIFIED
ALL RESISTOR VALUES ARE IN OHMS
ALL CAPACITOR VALUES ARE IN MFDS

RELAY BASE DIAGRAM
K3501 & K3502

CIRCUIT DIAGRAM OF SWEEP GENERATOR UNIT (No. 3500)

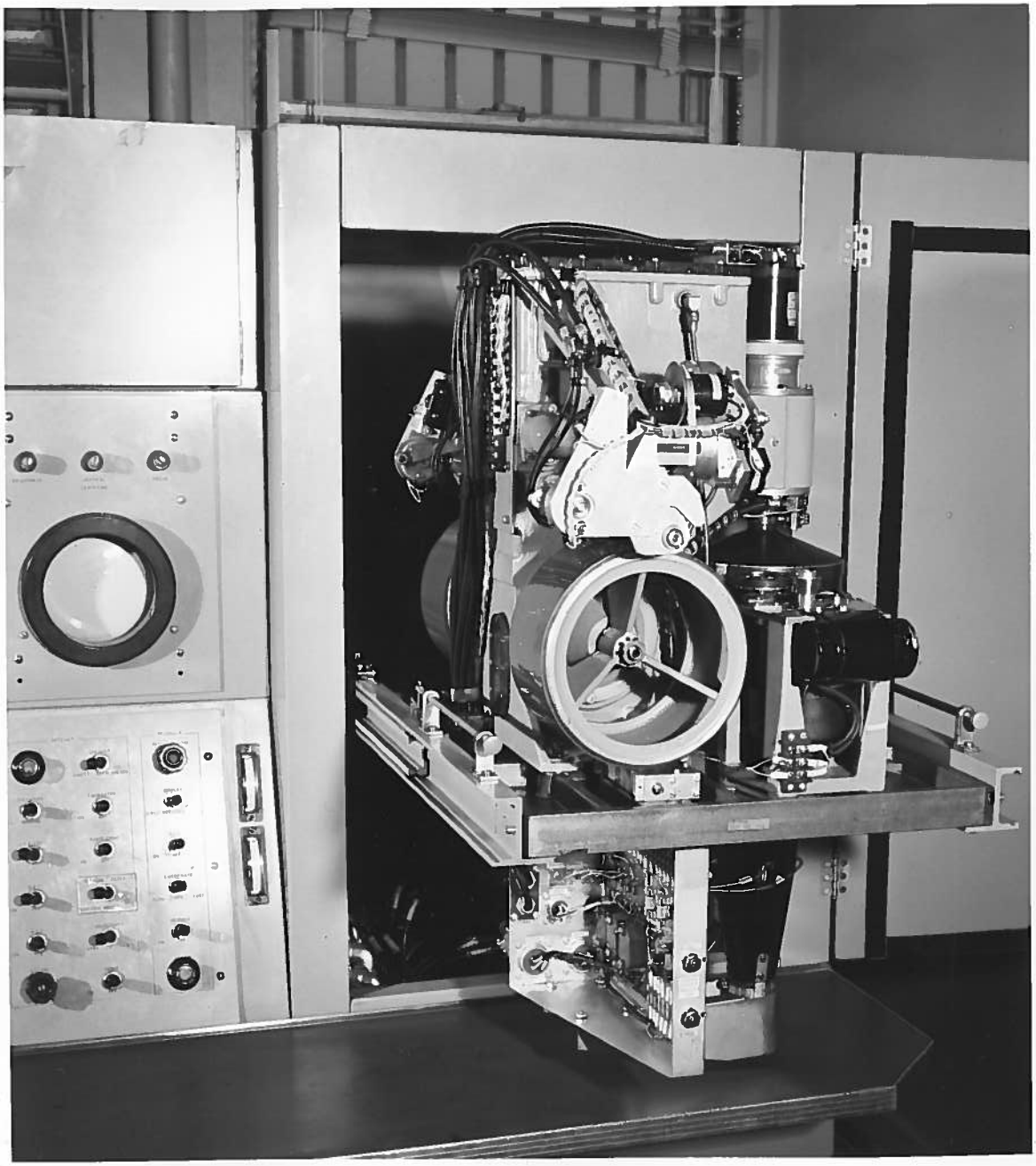


PLATE I — FRONT VIEW OF RECORDER

PLATE II — LEFT-SIDE VIEW OF RECORDER

PLATE III — BELT DEMAGNETIZER