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NRL Report 4510

SERVO SYSTEMS FOR RAPIDLY SCANNED
COUNTERMEASURES RECEIVERS

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ABSTRACT

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Improved methods have been developed for servo control of rapidly scanned countermeasures receivers. This progress is part of the program for obtaining high signal-intercept probability by use of a high-resolution high-sensitivity superheterodyne scanned through the tuning range at a rate of 1000 megacycles per second per second.

For receivers operated from a 400-cps source, such as the AN/APR-9, a 4.5-kc carrier system replaces the dc amplifiers previously used with hysteresis-type magnetic clutches. For receivers operated from a 60-cps source, such as the AN/BLR-1 and AN/SLR-2, recently developed two-phase motors have acceleration capabilities adequate to provide scanning control. Indications are that two-phase motors with the proper characteristics could be produced for 400-cps operation.

Sector sweep is now accomplished by direct change in reference voltage based on thyatron ignition points. Calibrated frequency of intercepted signals is obtained from a Veeder-Root counter which is also servo controlled.

PROBLEM STATUS

This is an interim report; work is continuing.

AUTHORIZATION

NRL Problems R06-02 and R06-04
Project Nos. NE 071-240-3 and NE 071-240-2 and
Bureau Nos. S-1255 and S-1256 5.7

Manuscript submitted February 23, 1955



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SERVO SYSTEMS FOR
RAPIDLY SCANNED COUNTERMEASURES RECEIVERS

INTRODUCTION [~~SECRET~~]

(UNCLASSIFIED TITLE)

A previously reported system* for servo control of rapidly scanned countermeasures receivers employed a dc amplifier to operate hysteresis-type magnetic clutches in a bidirectional actuator. Because of the inherent instability of dc amplifiers, a carrier system appeared to be more advantageous. Neither of the standard line frequencies (60 or 400 cps) is sufficiently high to provide response fast enough for the sampling type of carrier system needed with the bidirectional actuator. Therefore, a carrier system which operates at a frequency of 4.5 kc was developed. This system is independent of line frequency and hence adaptable to either shipboard or aircraft equipment.

Recent developments in compact, high-acceleration, two-phase motors also offered a possible solution to the servo problem which would greatly reduce the bulk and weight of the mechanical drive. Since no sampling process is involved in two-phase motor control, operating frequencies of 60 or 400 cps may be employed when motors designed for the particular frequency are used. Investigations at 60 cps revealed that one of the Diehl "Hi-Ac-Cel" motors has acceleration and power capabilities adequate for the purpose and is small enough to be used as a replacement for the scanning motor in the AN/BLR-1 and AN/SLR-2 receivers. However, since 400-cps motors operate at considerably higher speeds than 60-cps motors do, their torque is less for a given power output although their inertia is the same. Moreover, the higher operating speed increases the reversal time for a given torque-to-inertia ratio. Although it is considerably more difficult to obtain the high acceleration capability required in a motor designed for 400-cps operation, it appears that a satisfactory motor could be developed for driving the AN/APR-9 receiver.

In the previous system (NRL Report 4410), sector-sweep operation was obtained by a process of differentiating the sawtooth produced by the receiver potentiometer, and clipping and clamping the resultant square wave. The ability to set sweep limits and the stability of the settings made was not as good as was desired in this system. Therefore, to provide a definite sector limit, a system was developed which is similar to that employed in the AN/APR-9 except that the thyatron plate voltages themselves are used to control the sector sweep instead of relying on the action of relatively slow relays.

When the AN/APR-9 receiver was originally adapted to rapid scanning, the equipment for indicating frequency was removed because the Veeder-Root counter could not be safely operated at the high scanning rate. Since frequency indication is important only when the receiver is not scanning, a relatively slow-speed system was developed to servo the counter only to the particular manual tuning or "storage" potentiometer selected. This servo operates at the maximum recommended speed of the Veeder-Root counter and was designed for 60-cps operation. Because of the relatively slow speed of operation and the low power requirements, it is not expected that there would be any great difficulty in obtaining a motor satisfactory for 400-cps operation.

* Wald, Bruce, "Rapid Scanning Techniques for Countermeasures Receivers," NRL Report 4410 (Secret), Sept. 8, 1954

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CARRIER-CONTROLLED MAGNETIC-CLUTCH SYSTEM [UNCLASSIFIED]

The carrier-type control system for operating the magnetic-clutch bidirectional actuator (Fig. 1) consists essentially of an oscillator, modulator, carrier amplifier, reference amplifier, demodulator, antihunt circuit. The carrier frequency of 4.5 kc is provided by an oscillator which drives the cathodes of the balanced modulator in pushpull (Fig. 2). The two dc voltages to be compared are applied to the grids of the modulator, and the modulator plates are connected in parallel. The phase of the signal at the plates of the modulator depends on the relative dc voltages at the grids. After amplification and filtering, the modulated carrier is applied to a Sanders model 2 phase comparator for demodulation. The oscillator voltage is shifted in phase and applied through a reference amplifier to the phase comparator. The phase comparator, which consists essentially of a balanced double bridge of selenium rectifiers, produces a dc output. The polarity of this output depends on the relative phases of the modulated carrier and reference voltages, and its amplitude is directly proportional to the amplitude of the modulated carrier. This dc from the phase comparator controls the tubes which have the magnetic clutches in their plate circuits. The antihunt circuit at the input functions in the same manner as in the previous circuit which uses dc amplification (NRL Report 4410).

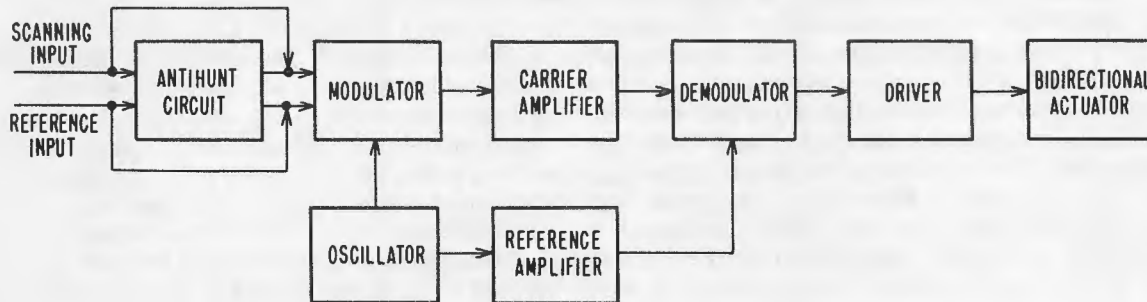


Fig. 1 - Carrier-controlled magnetic-clutch system [UNCLASSIFIED]

Since the phase comparator has a maximum rated frequency response of 5 kc for reasonable efficiency, the carrier frequency was made slightly lower. A 30-mh toroid is used as the inductance in the tuned circuit of the oscillator, and the fixed capacitors employed with it produce a carrier frequency of about 4.5 kc. The exact value is not important.

Considerable second-harmonic distortion of the carrier is produced by the type of modulator used, so a resonant circuit was employed as the modulator plate load to reduce the harmonics, power-supply ripple, and heater hum. The amplitude of the carrier was adjusted for a good ratio of conversion efficiency to second-harmonic distortion. Some quadrature signal was produced in this circuit, and it was cancelled by adjustment of the resistor-capacitor network across the common cathode resistor. A large cathode resistor was used to provide the 108-volt dynamic range necessary in the grid circuits of the modulator. Balance is obtained by adjustment of the cathode-return point on a potentiometer across the carrier transformer. Since this adjustment is critical, a 3-turn Helipot was employed. Type 12AU7 tubes were first used in this circuit, but they are not sufficiently stable mechanically to hold the null to a value equivalent to a 20-mv signal. The more rugged type 5814 tubes are satisfactory.

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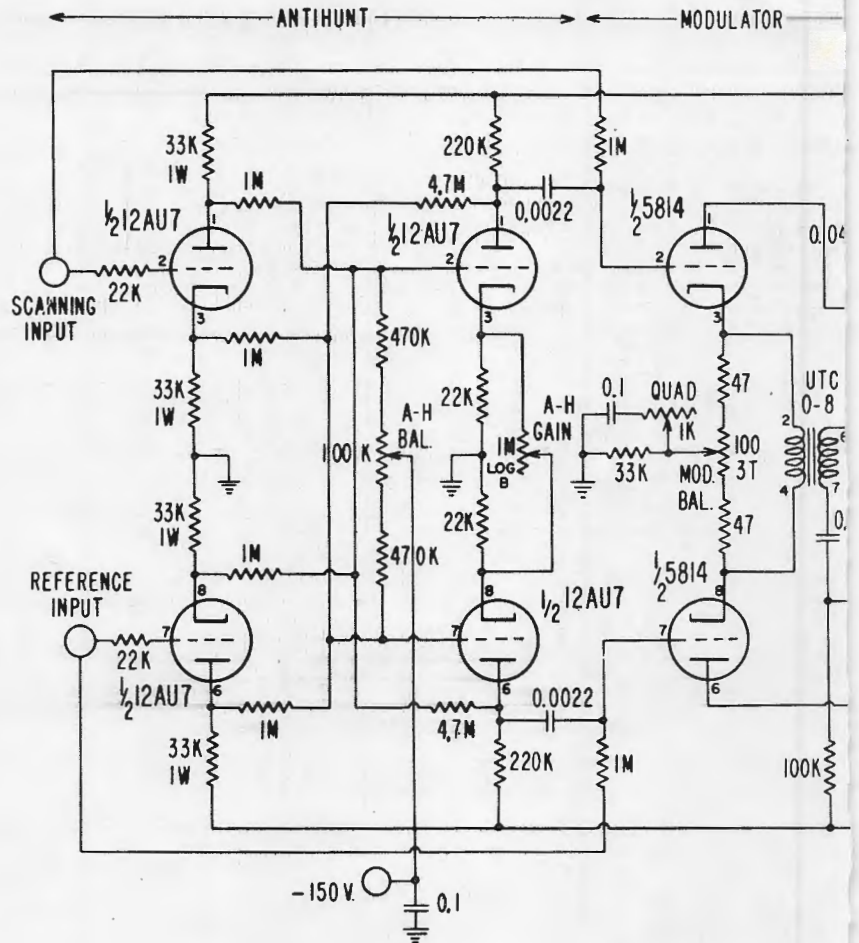
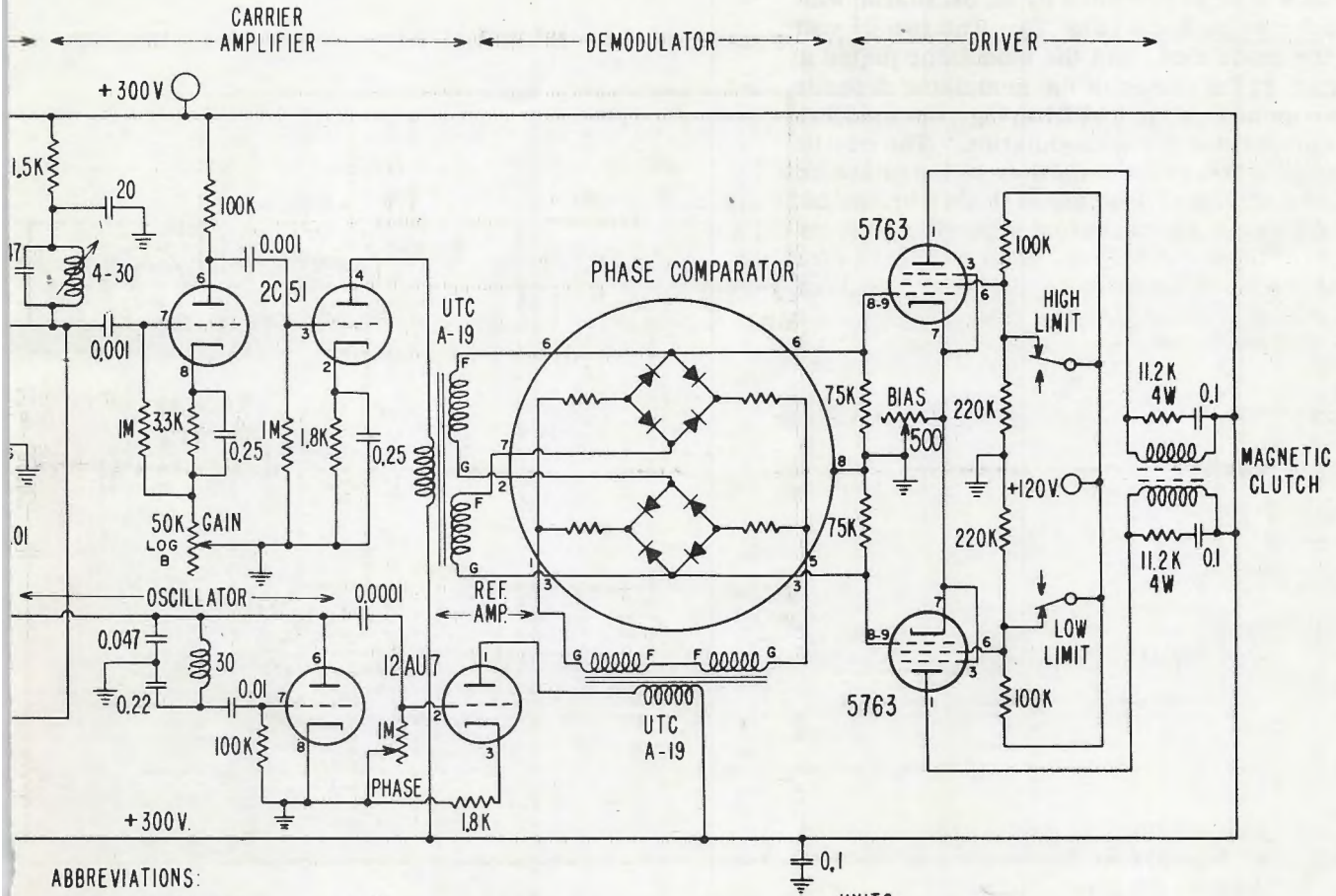


Fig. 2 - Circuit for e



ABBREVIATIONS:

- A-H - ANTIHUNT
- BAL - BALANCE
- MOD - MODULATOR
- QUAD - QUADRATURE
- T - TURNS
- REF - REFERENCE
- AMP - AMPLIFIER

UNITS:

- RESISTORS - OHMS. K = 10³, M = 10⁶
- CAPACITORS - MICROFARADS
- INDUCTORS - MILLIHENRYS

Carrier-controlled magnetic-clutch system [UNCLASSIFIED]

Before the electronic modulator was adopted, several types of mechanical modulators were investigated. Although many of the mechanical types are satisfactory at low frequencies, when operation is attempted near 5 kc, the contact noise and direct pickup of the carrier from coil to contacts produces an output which is too great compared to the signal level near servo null. The difficulties caused by drift in the balanced triode modulator are not as bad as those caused by the mechanical-modulator noise.

Except for the provision of greater dynamic range, the antihunt circuit is similar to that used previously (NRL Report 4410). The dc grid level of the antihunt amplifier was reduced from 150 volts to almost zero to double the plate-circuit dynamic range, and the tube type was changed to a 12AU7 for a slight increase in range. The gain sacrificed by the use of the lower- μ tube and by the dc dividing network in the grid circuit was offset by use of cross-coupled positive feedback.

SIXTY-CPS TWO-PHASE MOTOR SYSTEM [UNCLASSIFIED]

The servo system which uses the Diehl type S. S. FPE 25-80-1 motor is considerably simpler, smaller, and less expensive than that using the bidirectional actuator. The only disadvantage of two-phase motor operation is the relatively large amount of power required for the output stage. Basically the system consists of a modulator, amplifier, and antihunt circuit (Fig. 3).

The modulator is the same type employed in the carrier-clutch system, but is less critical for 60-cps operation. No difficulty was experienced with a quadrature component in the output, so this adjustment was eliminated. Since standard variable inductances do not have sufficiently high Q for sharply resonant circuits at 60 cps, a bridged-T filter was used for second-harmonic rejection. The 90-degree phase-shift network in the amplifier greatly reduces higher harmonics and noise, and the broadly resonant circuit formed by the 0.5- μ f capacitor across the motor terminals and the inductance of the motor also insures a reasonably good sine-wave voltage across the motor.

When the motor is running, a velocity component of voltage appears across the control winding because of counter emf. Although this voltage is relatively small compared to the driving voltage for the motor, it will provide a small amount of antihunt if inverse feedback is used from the motor winding to an appropriate point in the amplifier. To provide the remainder of the necessary antihunt voltage, a circuit similar to that used in the carrier-clutch system was employed. The principal difference is the elimination of the need for positive feedback by use of 12AT7 or 6201 tubes in place of the 12AU7 type. Since, in all the circuits tried, best operation was obtained with the antihunt control set for maximum gain, this control has been removed. Adjustment of amplifier gain alone is sufficient for control of hunting.

SECTOR-SWEEP TECHNIQUE [UNCLASSIFIED]

In the sector-sweep circuit (Fig. 4), the voltage from the scanning potentiometer in the receiver is fed through a cathode follower to the cathode of one thyatron and the grid of a second. The reference potentials for the sector-sweep limits are fed to the grid of the first thyatron and through a cathode follower to the cathode of the second. Thus, the voltages at both grid and cathode of the second thyatron are raised by the same amount and the upper limit of the scanning range can be reached.

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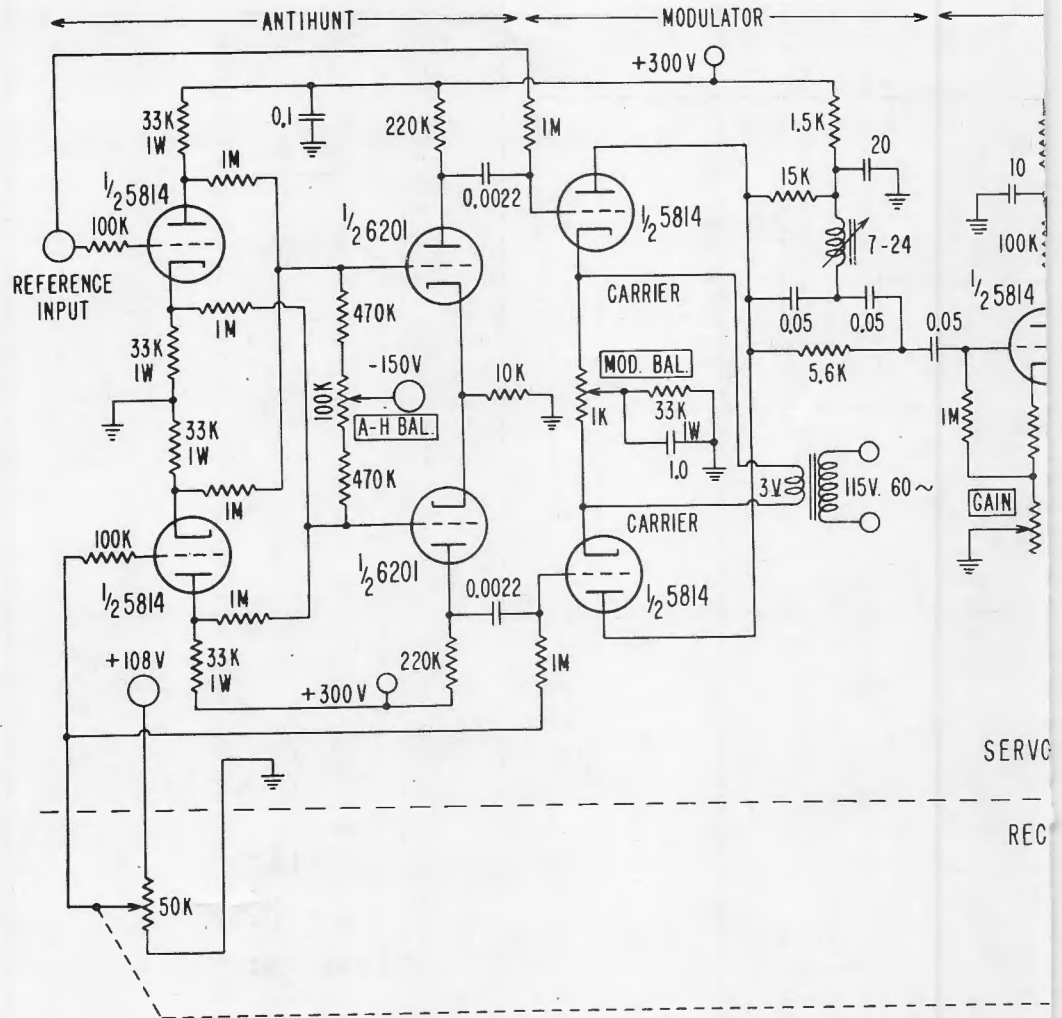
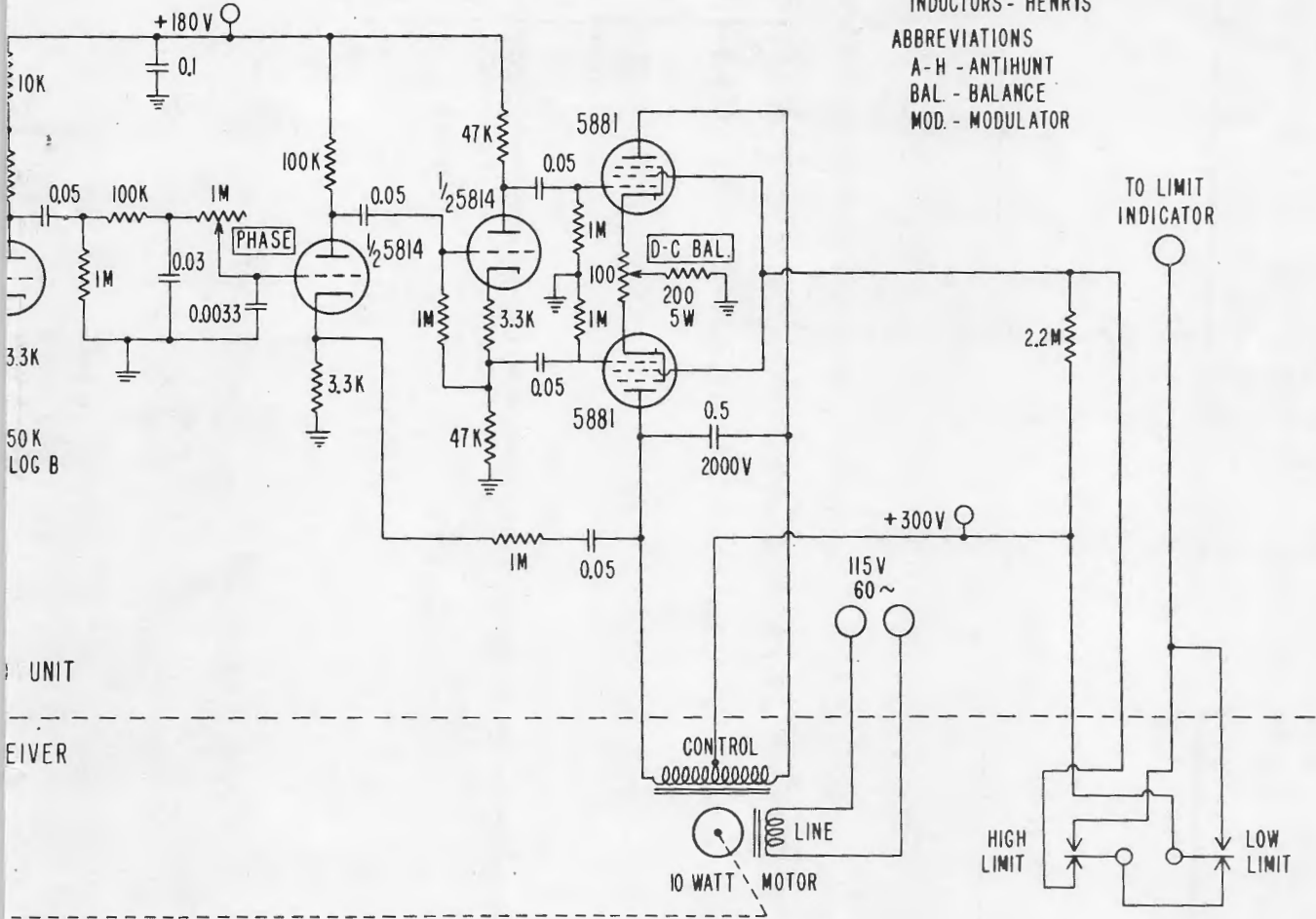


Fig. 3 - Sixty cps

AMPLIFIER

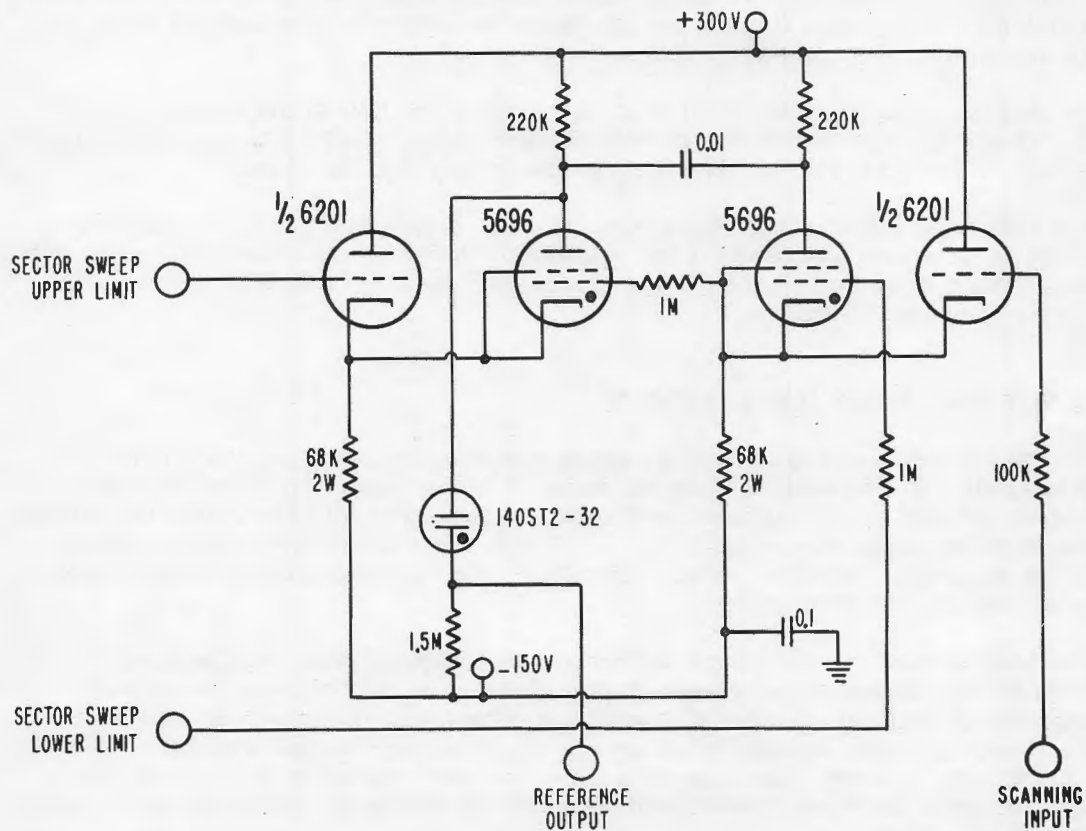
UNITS:
 RESISTORS - OHMS K=10³, M=10⁶
 CAPACITORS - MICROFARADS
 INDUCTORS - HENRYS

ABBREVIATIONS
 A-H - ANTIHUNT
 BAL - BALANCE
 MOD. - MODULATOR



UNIT
EIVER

two-phase motor system [UNCLASSIFIED]



UNITS:
RESISTORS - OHMS
K=10³, M=10⁶
CAPACITORS - MICROFARADS

Fig. 4 - Sector-sweep system [UNCLASSIFIED]

Depending on the scanning voltage compared with the limit-voltage settings, one or the other thyatron will be normally fired. When a thyatron fires, the drop in voltage at that plate is coupled through a 0.01- μ f capacitor to the plate of the previously conducting thyatron, which is thereby extinguished. The variation in dc level at one thyatron plate is changed in reference value by the drop through a subminiature voltage regulator which returns to -150 volts through a 1.5-megohm resistor. Circuit values were adjusted so that the limits on the voltage sent to the servo amplifier for reference were slightly above +108 volts and slightly below zero. Thus, the servo will sector towards one limit or the other until a thyatron fires to change the servo reference potential and start the receiver sweeping in the opposite direction.

One-megohm resistors are required in the grids of the thyatrons to prevent self-extinction caused by loss of grid charge with change in grid voltage. At least one megohm must be used in the grids for the size of resistors employed in the plates.

Type 5696 tubes were used as thyatrons because of their low power consumption. A 6201 tube (dual triode) was used for the cathode followers because its small cutoff voltage reduced the grid-cathode potential to a value which would not interfere with proper range limits on the sector sweep.

FREQUENCY INDICATION [UNCLASSIFIED]

The servo system used to control the Veeder-Root counter for frequency indication (Fig. 5) is similar to that used to drive the receiver motor except for its much lower power output and less complicated antihunt system. Sufficient velocity-controlled voltage is developed in the feedback winding of the 1-1/2 watt Ford motor used in this servo to produce the necessary antihunt control. Therefore, the separate antihunt circuit employing two dual triodes is not required.

A mechanical system employing a differential and latching relay was designed to permit manual adjustment of the Veeder-Root counter when the receiver was tuned to the lower limit of frequency for the rf head in use. The range of movement, and hence the upper frequency limit, was set by adjusting the voltage across the reference potentiometer in the servo system. In a complete receiver employing several rf heads, the reference voltage could be switched simultaneously with the heads so only the lower limit would require resetting.

CONCLUSIONS AND RECOMMENDATIONS [REDACTED]

A 60-cps two-phase motor system appears to be the most satisfactory method for rapidly scanning the AN/BLR-1 and AN/SLR-2 countermeasures receivers. For 400-cps equipment, such as the AN/APR-9 receiver, a carrier-controlled magnetic clutch can be used, but a more desirable system will be obtained when a suitable 400-cps servo motor is produced. The sector-sweep technique developed is satisfactory for either type of system. The Veeder-Root counter in the AN/APR-9 receiver can be used for frequency indication when operated by a properly referenced servo system. Adaption of this frequency-indication system to the AN/BLR-1 and AN/SLR-2 receivers is simpler mechanically because no resetting is required when tuning heads are changed.

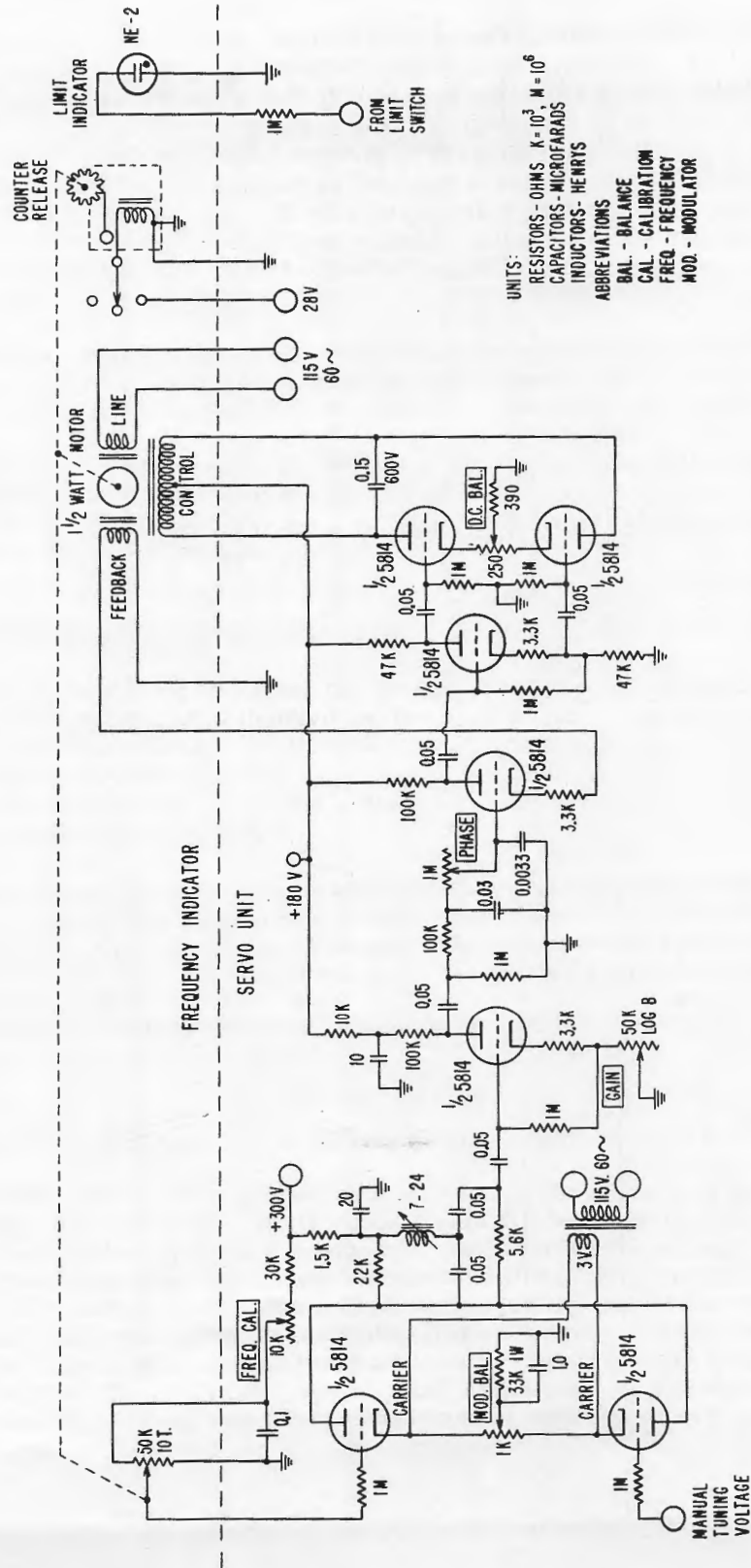


Fig. 5 - Frequency indication system [UNCLASSIFIED]

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ACKNOWLEDGMENTS [UNCLASSIFIED]

Appreciation is expressed to Mr. H. K. Weidemann of the Countermeasures Branch for suggesting many of the ideas incorporated into the systems developed. The work of Mr. W. F. Hoffmann, previously of the Countermeasures Branch, on antihunt techniques is gratefully acknowledged.

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