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A REMOTE POSITIONING SERVO SYSTEM

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1.0 Introduction

A frequent requirement in the receiver group is the remote adjustment of some mechanical component in the front-end box from the telescope control room. Requirements have recently arisen to remotely control stub tuners, the tuning screw on a klystron, mechanical attenuators and filters. Obviously, it would be very convenient to have a design that is standard from the circuitry point of view and needs only simple mechanical changes to be used for a wide variety of mechanical loads. This report describes such a system. Six of these systems have been built to date and have given good performance.

2.0 System Description

2.1 Choice of System

To the designer of servo systems of this nature, a wide variety of components are available. The system finally decided on is rather unconventional but the reasons for making it so are easily justified. It was felt that the main features of the system should be:

1) Completely self-contained.
2) Highly reliable.
3) Easily adaptable to different mechanical configurations.
4) The servo system should be easily stabilized (by a simple pot adjustment) for all reasonable mechanical requirements.

The first decision to make was whether the system should use an AC or a DC motor. AC servo motors are generally far more reliable than DC motors; a wide range of standard gearheads are available and they are obtainable with AC generators connected to the same shaft. This last point is quite an important one: the output of the AC generator gives a rate signal that can be used very easily to stabilize the system. Another important point is than an AC system is far less prone to drift than one using DC amplifiers.

A synchro is the obvious position sensor to use in an AC system. However, there are two main objections. The first is that 60 c/s synchros are rather difficult to obtain in small sizes. The second is that most of our applications require a multi-turn positioning system and the use of a synchro would nearly always mean additional gearing. With some misgivings, two 10-turn potentiometers were finally decided on as the "master" and "slave" position sensors.

2.2 General Description of System

A block diagram of the system is shown in Figure 1 and may be seen to be a simple type "1" servo system. The position sensing potentiometers are supplied with AC signals that are equal in amplitude but differ in phase by 180°. These two voltages are summed in an operational amplifier: when they are equal, indicating zero positional error, the amplifier output is zero. The sign and magnitude of a positional error determines the phase and magnitude of the amplifier output which in turn controls the direction and speed of the servo motor shaft. The mechanical arrangement is such that the motor rotates the slave pot in the direction needed to reduce the positional error to zero. For a high speed, high accuracy system without some form of stabilization, the large loop gain required would result in poor transient performance or complete instability. In an AC system there are many ways in which the system may be stabilized. A rate generator, although rather old fashioned, is one of the simplest ways of introducing the correct amount of damping into a system that is to be used with different mechanical loads. The rate signal produced by the generator is an AC signal whose phase and amplitude vary with the direction and speed of the generator. This signal is fed into the system at the summing junction of the amplifier.

2.3 Detailed Description of System

2.31 Form of Construction

The system is built in three parts. In the front-end box are the control unit, containing the circuitry, and the slave unit driving the mechanical load. In the control room are the master pot and an on-off switch. A printed circuit has been produced; this is shown in Figure 3.

2.32 Circuitry

A circuit diagram of the system is given in Figure 2 and is fairly self-explanatory. The amplifier is directly coupled and uses positive and negative supply rails, thereby eliminating coupling capacitors and generally giving a neater design. The only adjustment needed is to adjust the output to zero DC level (with no signal input) by means of VRI. The gain is determined by the value of R15 and the amount of rate feedback is set by R20 in conjunction with VR2.

In many applications the slave pot will be required to turn less than ten times for ten turns on the master pot. The values of resistors R16 and R17 determine this relationship between the two pots.

Two transformers are necessary to avoid interaction between the power supplies to the amplifier and the AC voltage supplied to the position sensing pots.

2.33 Servo Motor Generator

The servo motor generator used is manufactured by the Vernitron Corporation and may be supplied with any of 41 gearheads having ratios from 12 to 12,015. The specifications of the motor generator are given below.

Type ------------------------------	15G6L ACZ-COGH-(gear head ratio)
Volts (Fixed and Gen. Ref.) -----------	115 V
Volts (Control Phase) -----------------	36/18 V
Stalled Torque ------------------------	2.0 oz. ins.
Free Speed --------------------------	3100 RPM
Power in Fixed Phase ----------------	6.0 watts
Power in Control Phase ---------------	6.0 watts
Power in Gen. Ref. Phase ------------	1.5 watts
Stall Impedance, Fixed Phase ---------	1380 + j 1000 ohms
Stall Impedance, Control Phase --------	136 + j 99 ohms
Impedance Gen. Ref. Phase -----------	3600 + j 4200 ohms
Generator Output Volts ---------------	3.0 volts/1000 RPM
Null Voltage ------------------------	50 mV

3.0 System Performance

The performance of the servo system is, of course, determined almost solely by the mechanical arrangement of the load. For any particular load the important factors are:

a) The positional accuracy required.

b) The total rotary movement required.

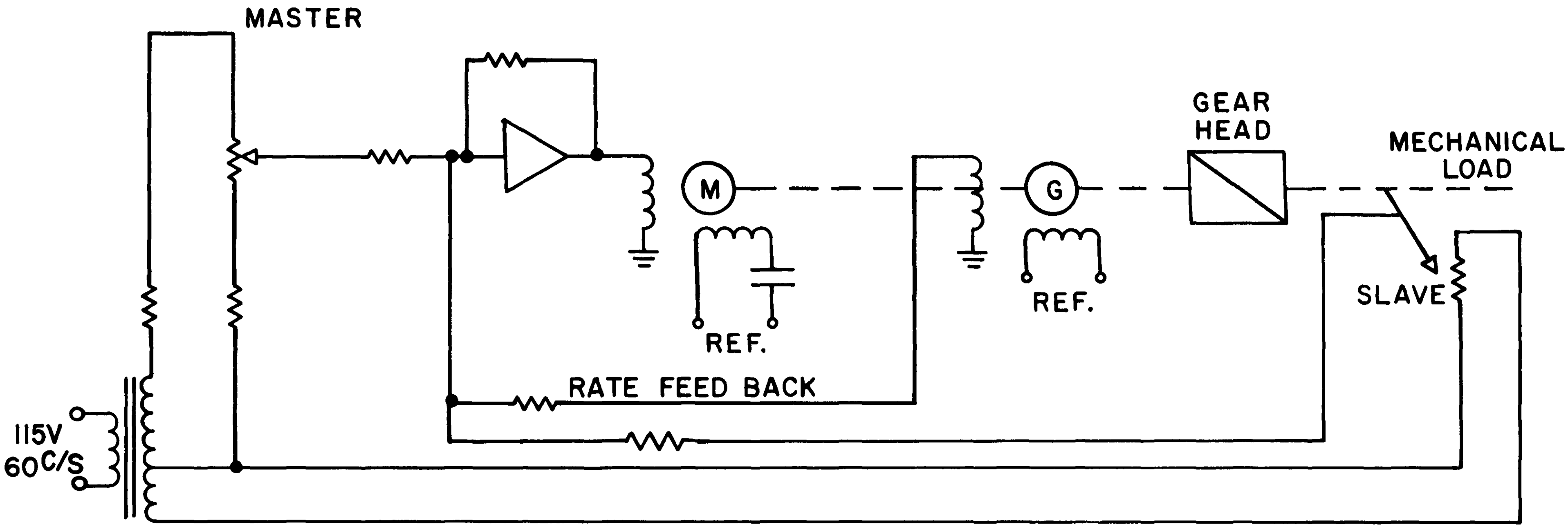
c) The tracking rate.

d) The load torque.

e) The load inertia.

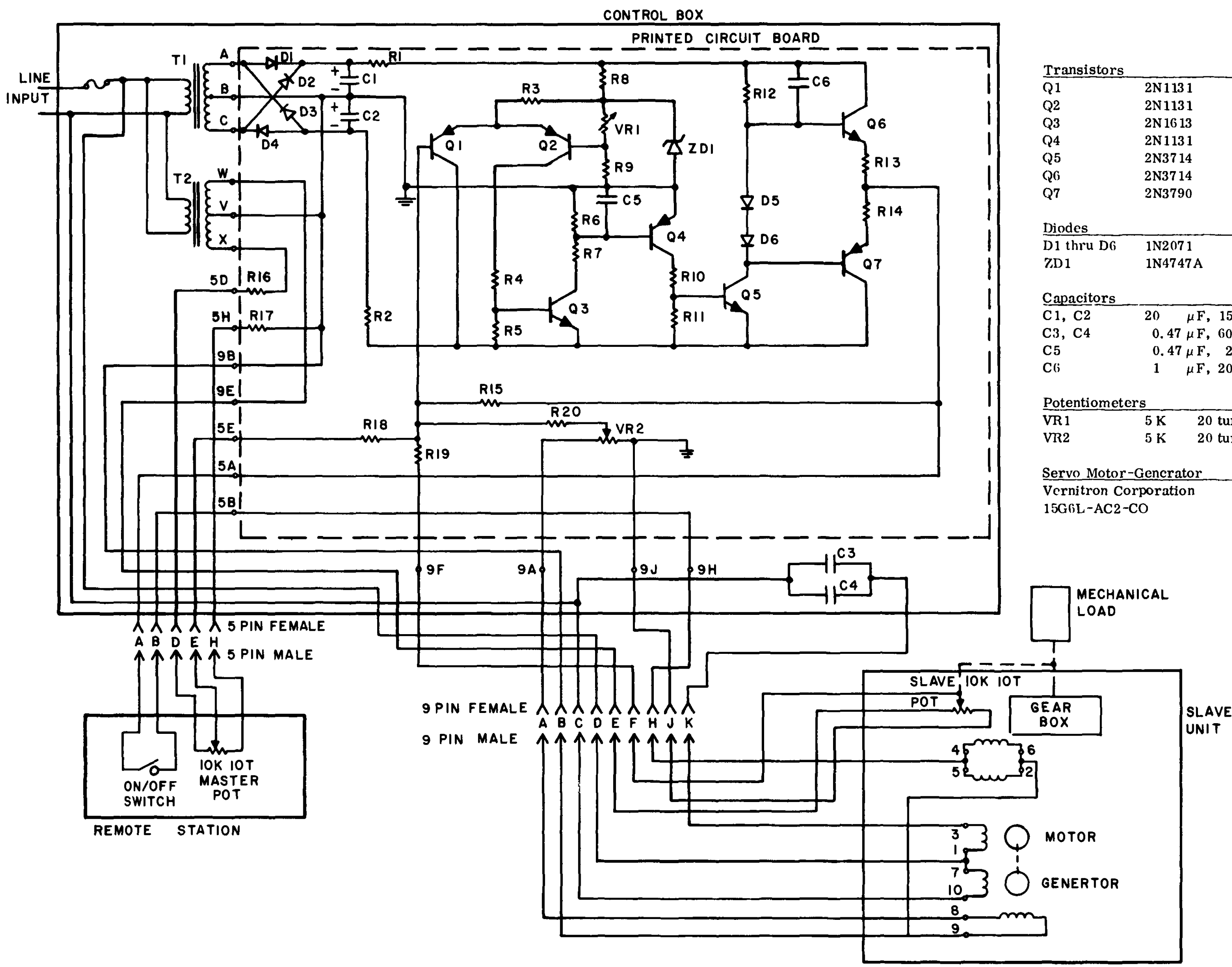
The factors can all be taken into account and the performance of the system may be worked out in advance. This is rather time consuming and we have found that, provided the gear box ratio required to satisfy the tracking rate requirement does not impose torque limitations on the motor, the best method is to build the system and optimize the transient response by applying rate feedback.

As the system is a "type 1" servo, the positional error should be zero, any departure from this being due to friction in the gear train. This may be minimized by increasing the loop gain (increasing R15).



BLOCK DIAGRAM OF SYSTEM

FIGURE I



Transistors	
Q1	2N1131
Q2	2N1131
Q3	2N1613
Q4	2N1131
Q5	2N3714
Q6	2N3714
Q7	2N3790

Diodes	
D1 thru D6	1N2071
ZD1	1N4747A

Capacitors		
C1, C2	20 μF,	150 V
C3, C4	0.47 μF,	600 V
C5	0.47 μF,	25 V
C6	1 μF,	200 V

Potentiometers		
VR1	5 K	20 turn
VR2	5 K	20 turn

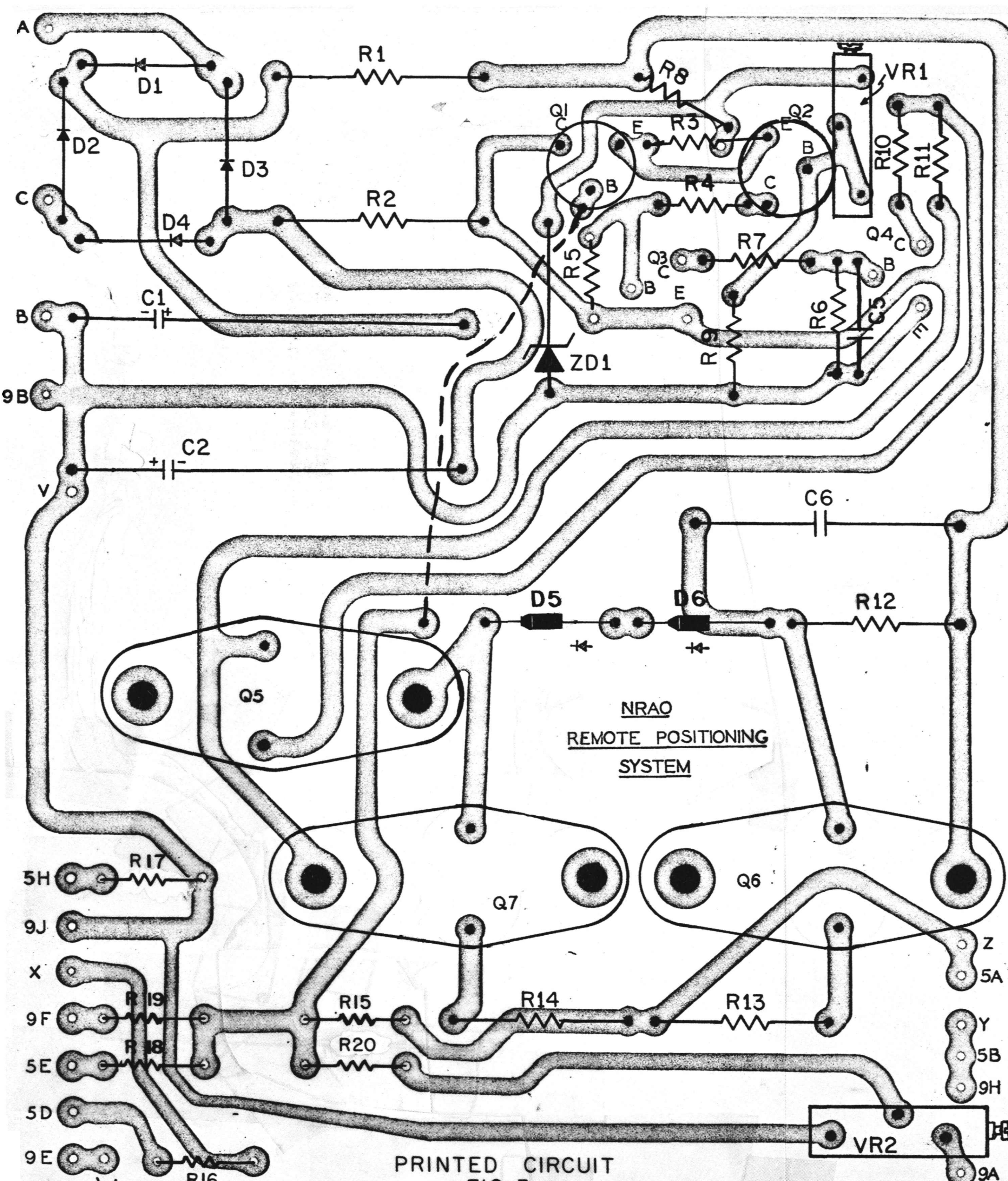
Servo Motor-Generator
Vernitron Corporation
15G6L-AC2-CO

Resistors		
R1, R2	25 Ω	5 W
R3, R18, R19	10 K	1/4 W
R4, R5, R8	1.5 K	1/4 W
R6	1 K	1/4 W
R7	3.3 K	1/4 W
R9	47 Ω	1/4 W
R10	330 Ω	1/4 W
R11	100 Ω	1/4 W
R12	2.2 K	1 W
R13, R14	10 Ω	1 W
R15	220 K	1/4 W *
R16, R17	Depends on mechanical system	
R20	100 K	1/4 W *

* Denotes components that may be varied according to mechanical arrangement.

Transformers			
T1	30-0-30 V	at	150 mA
T2	30-0-30 V	at	150 mA

FIG. 2 REMOTE POSITIONING SYSTEM CIRCUIT DIAGRAM



PRINTED CIRCUIT
FIG. 3