V. Aids to Computation

A. Shaft Position Indicator, Reversible Counters.

Staff: Dr. I. P. Stabler

## Introduction.

In connection with high speed computing devices it is sometimes necessary to have precise information about the position of a rotating shaft and to have this information continuously available in the form of a pulse wave-form number. The shaft may be required to turn in either direction at irregular intervals and speeds.

The position of a shaft having unidirectional motion frequently has been indicated by the use of a conventional scaling (or counting) circuit. A slotted disc is attached to the shaft and an optical system used to produce light pulses on a phototube when the shaft rotates. The resulting electrical pulses are then counted on the scaling circuit. The number of counts so recorded is a measure of the total angular motion of the shaft from an initial zero position.

The same type of approach can be made to the solution of the present problem. The requirements in block diagram form are as shown in Figure 1. Two phototubes are necessary in order to allow the system to recognize direction of shaft rotation. The pulse generator produces forward (or adding) pulses for forward rotation of the shaft and backward (or subtracting) pulses for backward rotation of the shaft. One pulse is to be produced per disc slot and the shape of the pulse is to be independent of the speed of rotation (up to a maximum of 60,000 pulses per second). The reversible counter differs from an ordinary scaling circuit in that it must take care of both adding and subtracting pulses. Its total indication is then a true measure of the shaft position with respect to an initial zero position. The counter must also control a reading circuit. The reader receives "clock" pulses from the synchronizing system of the computer (at perhaps micro-second intervals) and must produce a coded pulse wave-form number corresponding to the indication of the counter. The wave-form number is received by the storage system of the computer and is replaced whenever the counter indication changes.

Mechanical-optical system.

Information with respect to direction of rotation of the shaft is obtained by phasing the slit openings of the two phototubes with respect to each other as shown schematically in Figure 2. At the instant indicated in the figure, phototube A is in transition from non-illumination to illumination for clockwise rotation of the disc, and phototube B is dark. With this condition the pulse generator produces a forward pulse. With counterclockwise rotation A changes from light to dark, B dark, and a backward pulse is produced. The pulse generator gives no pulses for A tube transitions occuring at the upp-r edge of the slots because the illumination of B at these positions result in blanking the output.

For experimental test purposes for this research the Servo Laboratory has constructed a small disc with 150 slots mounted on a shaft which can be turned manually, together with housings for two 931 phototubes. Mr. C. H. Rider is investigating the possibility of of producing suitable "slots" and "teeth" photographically. The degree of angular subdivision possible depends on the closeness with which practical lines can be placed, the associated inertia of the disc system, and the acceleration to which it must respond. Possibly 500 to 1000 lines per inch can be obtained by the use of sound track techniques. No investigation has been made as to whether the sensitivity of the 931 will be sufficient for such arrangements.

Pulse Generator.

The essential features of a satisfactory pulse generator are shown in Figure 3. A complete schematic (differing slightly from Figure 3) is given by R.L. DWG. NO. D-14-A. V1, V2 constitute a direct coupled multivibrator that is stable only when one tube is completely cut off. The circuit constants have bedn chosen so that the high transition (V1 changing suddenly from non-conducting to conducting) occurs as the potential of G1 increases above 60 volts, while the low transition (V1 changing suddenly from conducting to non-conducting) occurs as the potential of G1 decreases below 50 volts. The sudden rise of plate potential of V1 at the low transition (phototube A dark to light) causes a positive pulse on the grid of V5, which (if B is dark) produces a positive pulse in the "forward" 70 ohm line output. A similier rise of the plate potential of V2 at the high transition causes a positive pulse on the grid of V6 and (for B dark) a positive pulse in the "backward" 70 ohm lime output. Phototube B controls a multivibrator V3-V4 identical to V1-V2 . V5 and V6 can transmit pulses only if V4 is non-conducting.

The differential of 10 volts between the high and low transition points insures that the multivibrators remain stable even if the disc jitters across a transition point. DC coupling is required between the phototubes and G1, G3, in order to take care of very slow speed disc motion. 55 volts is a convenient DC level for the 931 plates. Their "dark" voltage must be above 65 volts and their "light" voltage below 45 volts.

When the disc turns at constant speed the voltages applied to grids G1 and G3 will vary approximately sinusoidally about 55 volts. For forward rotation the G1 voltage leads the G3 voltage by about 90 degrees, while for backward rotation the G1 voltage lags G3 by about 90 degrees. The pulse generator has been tested by applying sinusoidal voltages form an oscillator to G1 and G3 with appropriate phase difference. Satisfactory operation was observed at 60 cycles and at 250 kilocycles, as well as for DC transitions. The upper frequency limit can be extended if necessary. The generator has not yet been tested with phototubes and a rotating disc. Approximately 15 volt pulses of 0.7 mácro-seconds duration are obtained in the 70 ohm line outputs.

## Reversible Counter.

Figure 4 shows the design of a reversible binary counter. Two stages only have been drawn. In each stage, a and b tubes are direct coupled multivibrator components similar to those of a conventional scaling circuit. Each stage is designed to respond to negative pulses and the same pulse is applied to both a and b grids. Conduction by an a tube, non-conduction by a b tube represents a zero for the corresponding binary digit. During addition a carry-over pulse to the next stage occurs on the transition b conducting to non-conducting (1 to 0). This produces a positive pulse on the grid of the c tube and a negative pulse on the a and b grids of the next stage. During addition all d tubes are inactivated by reason of the positive square -wave applied to the grid of BA. On the other hand, for subtraction a carry-over pulse occurs on the transition a conducting to non-conducting (0 to 1) by means of the d tube. During subtraction a positive square-wave is applied to the grid of BS and all c tubes inactivated.

The two micro-second delay multivibrators (of a self-restoring type) are necessary to allow time for the add or subtract gates to be adjusted properly before the counting pulse is received. Since necessary carry-over for all stages must take place in the time interval between pulses it is desirable that successive triggering occur rapidly. The 5 micro-second duration indicated for the add and subtract gates probably will be sufficient for a 14 stage counter.

Circuit constants for the counter have been determined and two stages constructed and operated (with only a, b, c tubes active). It responds satisfactorily to pulses at 2.5 micro-second intervals and the speed of response can be increased if necessary. Carry-over time for two stages is of the order of 0.1 micro-second. A few more bread board stages are being assembled and tested before specifications are drawn up for a 14 stage system. The latter must also await final design of the reader.

## Reader.

A tentative design of the reader has been drawn up but no circuit constants have been decided and no tests yet made.

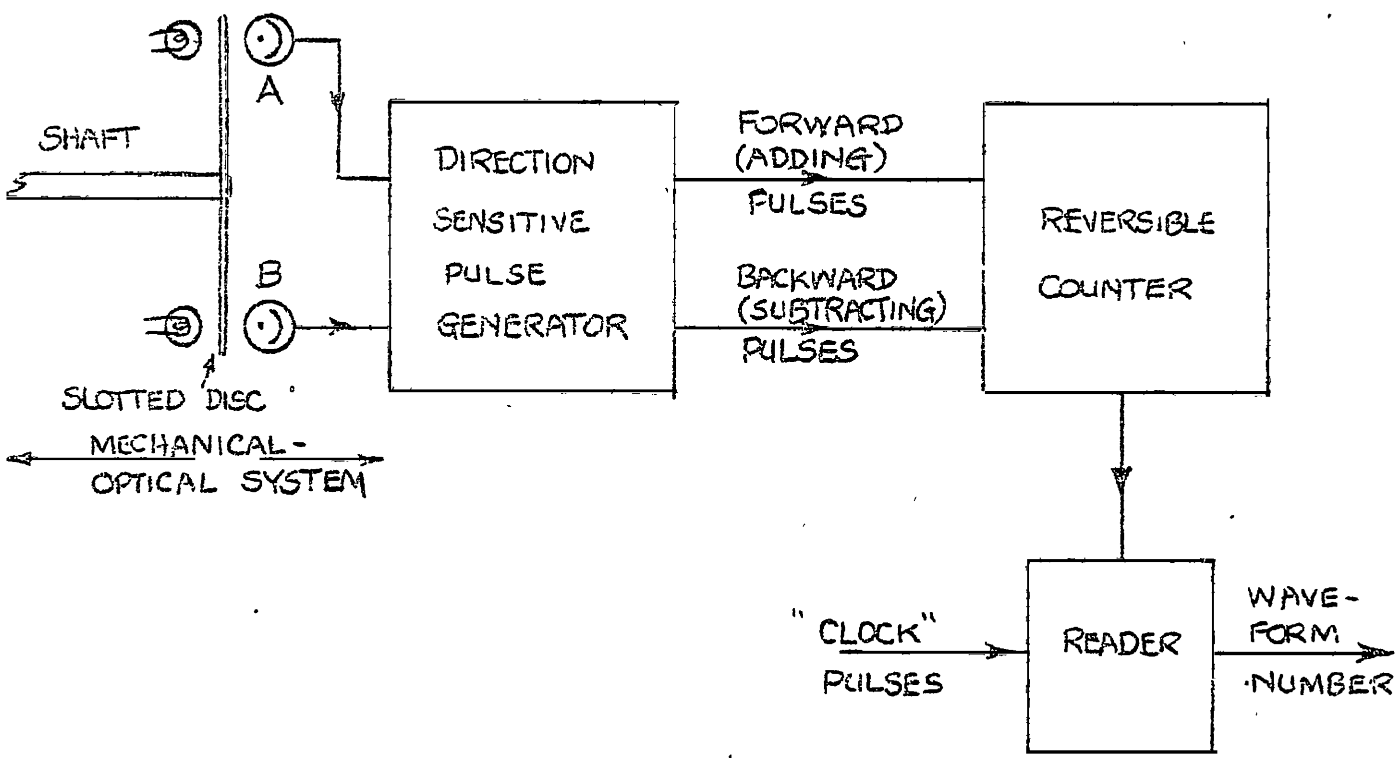
A
SHAFT
B
SLOTTED DISC
MECHANICAL-
OPTICAL SYSTEM
DIRECTION
SENSITIVE
PULSE
GENERATOR
FORWARD
(ADDING)
PULSES
BACKWARD
(SUBTRACTING)
PULSES
REVERSIBLE
COUNTER
"CLOCK"
PULSES
READER
WAVE-
FORM
NUMBER

FIGURE 1

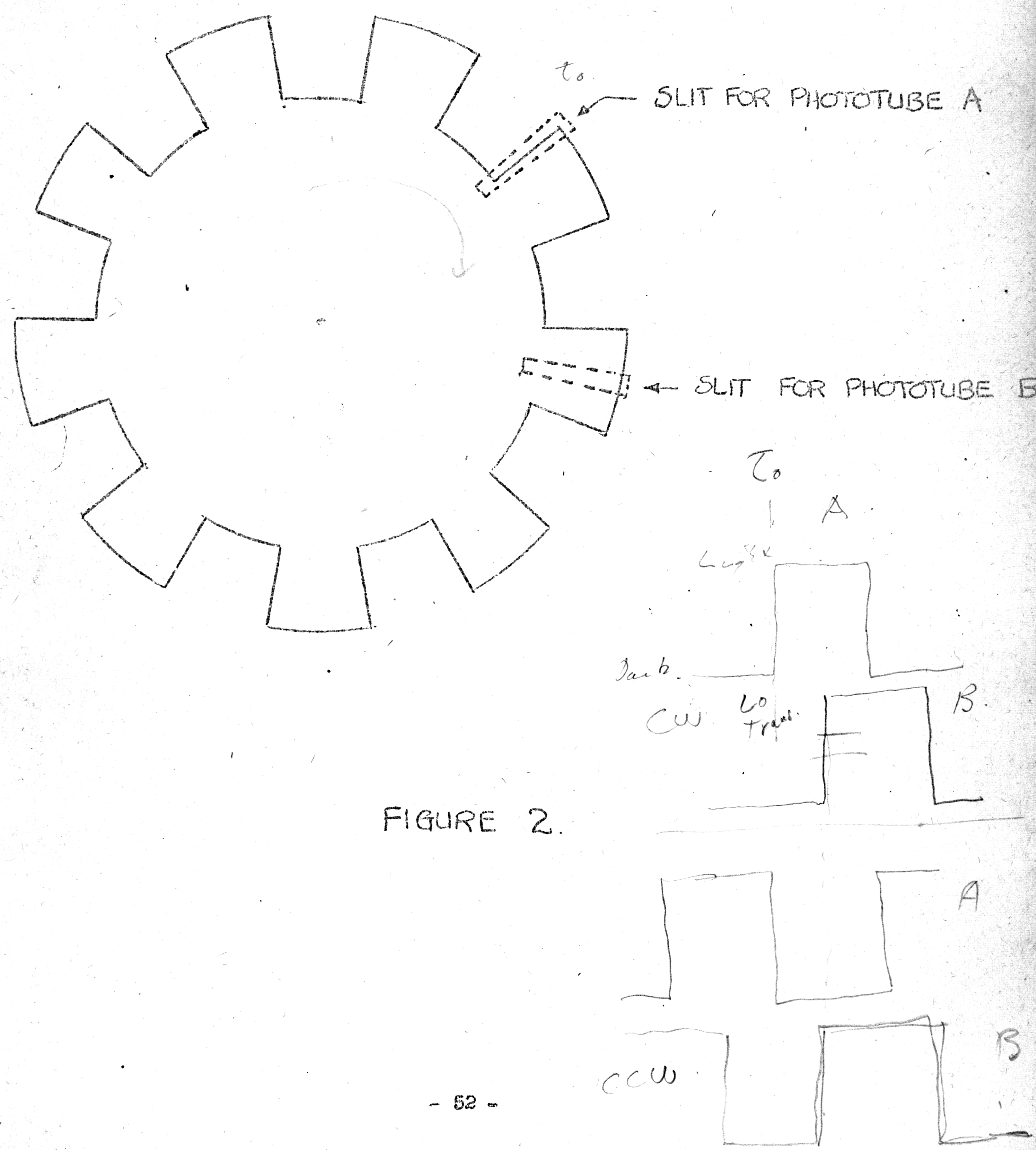


FIGURE 2.

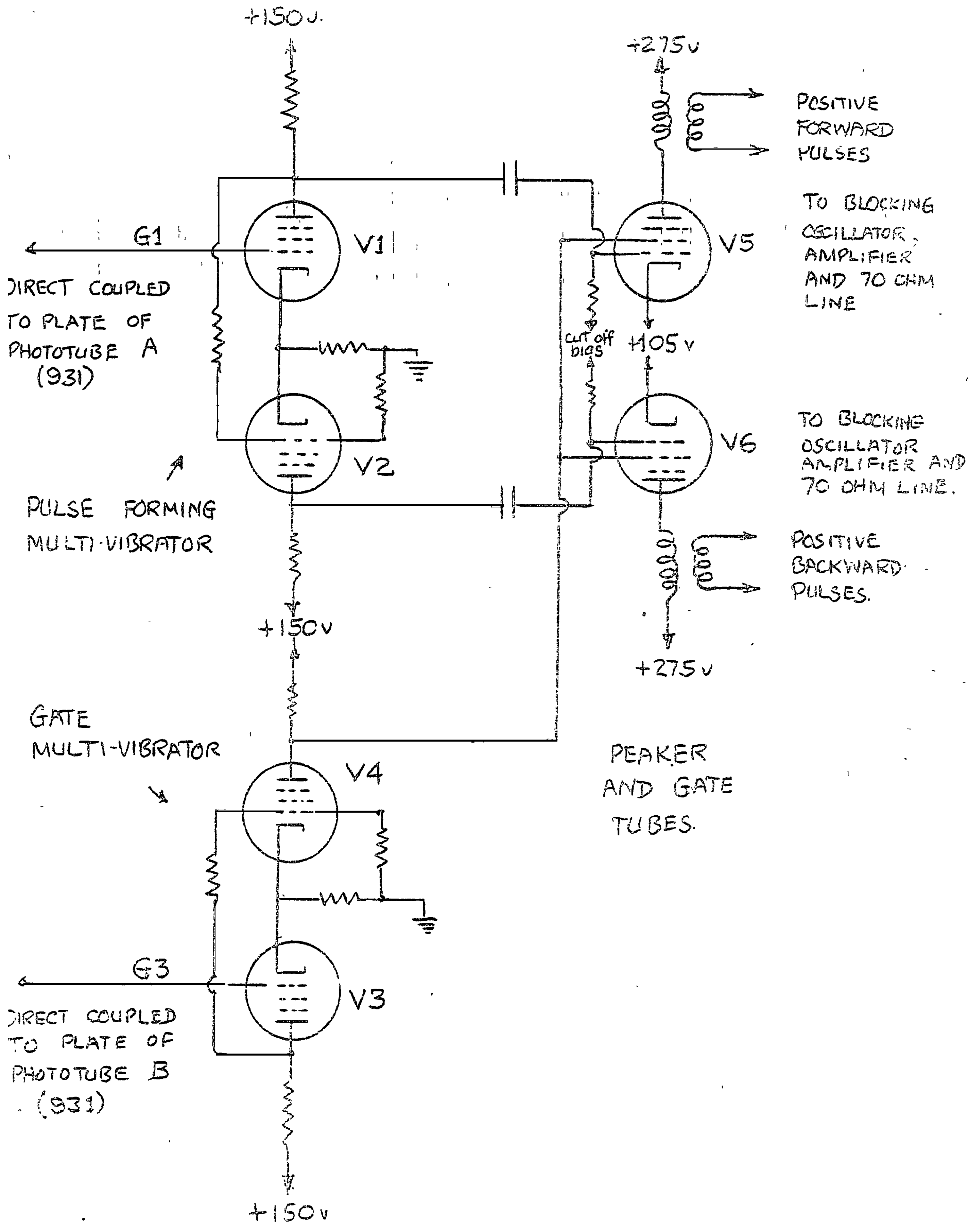
+150v.
+275v
POSITIVE FORWARD PULSES
TO BLOCKING OSCILLATOR, AMPLIFIER AND 70 OHM LINE
G1
V1
V5
DIRECT COUPLED TO PLATE OF PHOTOTUBE A (931)
cut off bias
+105 v
V6
V2
TO BLOCKING OSCILLATOR AMPLIFIER AND 70 OHM LINE.
PULSE FORMING MULTI-VIBRATOR
POSITIVE BACKWARD PULSES.
+150v
+275v
GATE MULTI-VIBRATOR
PEAKER AND GATE TUBES.
V4
G3
V3
DIRECT COUPLED TO PLATE OF PHOTOTUBE B (931)
+150v



FIGURE 3

FOR ZERO INDICATION ALL d TUBES CONDUCT

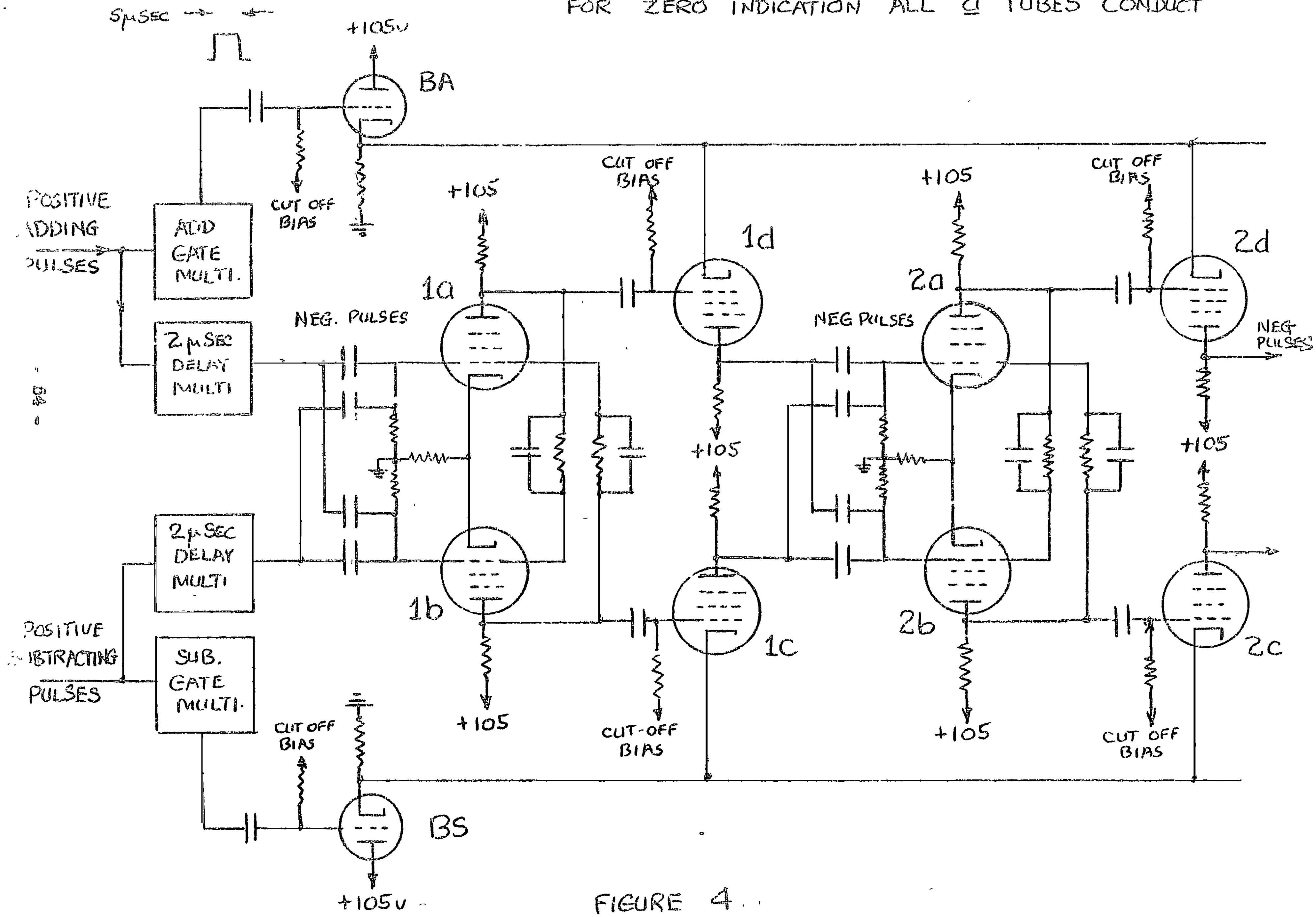


FIGURE 4

REVERSIBLE BINARY COUNTER

V. B. Electro-Mechanical Computers

Staff: Mr. R. M. Redheffer

Design of an electro-mechanical computer for solving certain types of integral equations appearing in antenna radiation pattern problems has been completed. This work was started in Group 54 of the Radiation Laboratory. Mr. Kylin, now with the Naval Research Laboratory Field Station, is responsible for the mechanical design, and a computer probably will be constructed by the Naval Research Laboratory.

A tentative design of a device for following an unprepared curve, with a method of removing discontinuities in the error voltage, has been made.