A SYSTEM FOR COUNTING AND RECORDING ELECTRICAL IMPULSES IN PRINTED DECIMAL FORM

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INTRODUCTION

This paper describes a system for adding and subtracting electrical impulses and recording the algebraic sum of the impulses in printed decimal form.

The paper is divided into four main sections. The first section describes in general the overall system. The second section describes the solenoid controlled adding machine. The third section describes the electronic counters and sub-assemblies. The fourth section is an appendix which contains more detailed data on the counters and the scanning system. The appendix also contains data on additional gating and counting arrangements which may be used for special applications. Only the first three sections will be presented but copies of the entire paper will be available in approximately two months from this date. Copies may be obtained by writing to Clary Multiplier Corporation, Engineering Department, 408 Junipero Street, San Gabriel, California.

I. GENERAL SYSTEM DESIGN AND OPERATION

FIG. 1 is a photo showing a front view of the overall system. The solenoid controlled adding machine is on the right and the electronic counting unit is on the left. The adding machine has solenoids located under the amount entry keys on the two decimal columns farthest to the right as well as solenoids which control the add, subtract, and sub-total keys. A solenoid also operates the unit key in the third decimal order from the right. The machine has a basic cycling or printing rate of approximately 180 cycles per minute.

The electronic counting unit on the left contains four binary coded decimal counting decades, two for adding, two for subtracting. It also contains gate circuitry for switching incoming pulses into either add or subtract counters, a memory device which stores data coming from the counters until it is entered into the adding machine and printer, conversion equipment to convert the binary coded information to decimal information for operating the adding machine and printer solenoids, scanning equipment to sequentially connect the binary to decimal decoder from decade to decade and enter the data into the solenoid controlled adding machine, and a power supply unit which supplies power to all counters and sub-assemblies.

FIG. 2 is a functional block diagram of the entire system.

The following is a brief description of the operation of the system.

Pulses to be added and subtracted are entered on the "input pulse" line to the gate circuits. Energizing either the "add" or the "subtract" gate control lines or both permits the pulses to enter the 2 decade add or 2 decade subtract counters or both. The 100th pulse from either or both of these counters is stored in the 100's add-subtract memory unit. From this unit the data is entered into the solenoid controlled adding machine. This memory unit simply stores the information coming from the add or subtract counter during the period that the adding machine may be busy making an entry and therefore permits the adding machine to receive information from both add and subtract counters without loss of pulse count.

At the end of the period of pulse counting and when it is desired to know the algebraic total of the pulses which have entered the unit, a trigger pulse initiates scanning circuits. The scanning circuits sequentially enter the remaining count from each counter decade into the solenoid controlled adding machine. Since the counters use binary coded decades, the data remaining in each decade is in binary form. This binary coded information is converted to decimal information by means of buffer tubes which operate a relay decoder. The relays close circuits so as to energize the appropriate solenoid in the adding machine unit. Reduction of equipment is effected by using only one binary to decimal converter. This relay converter is switched in sequence from one decade to the next during the read out interval.

The scanning equipment which switches the binary to decimal decoder from one decade to the next is a linear type counter composed of a chain of relays. The read out scan is initiated by either a positive or negative pulse on the scan initiate lead.

After the last data entry to the adding machine is made, the machine makes a totaling cycle and prints the algebraic sum of the pulses received. The machine also causes all

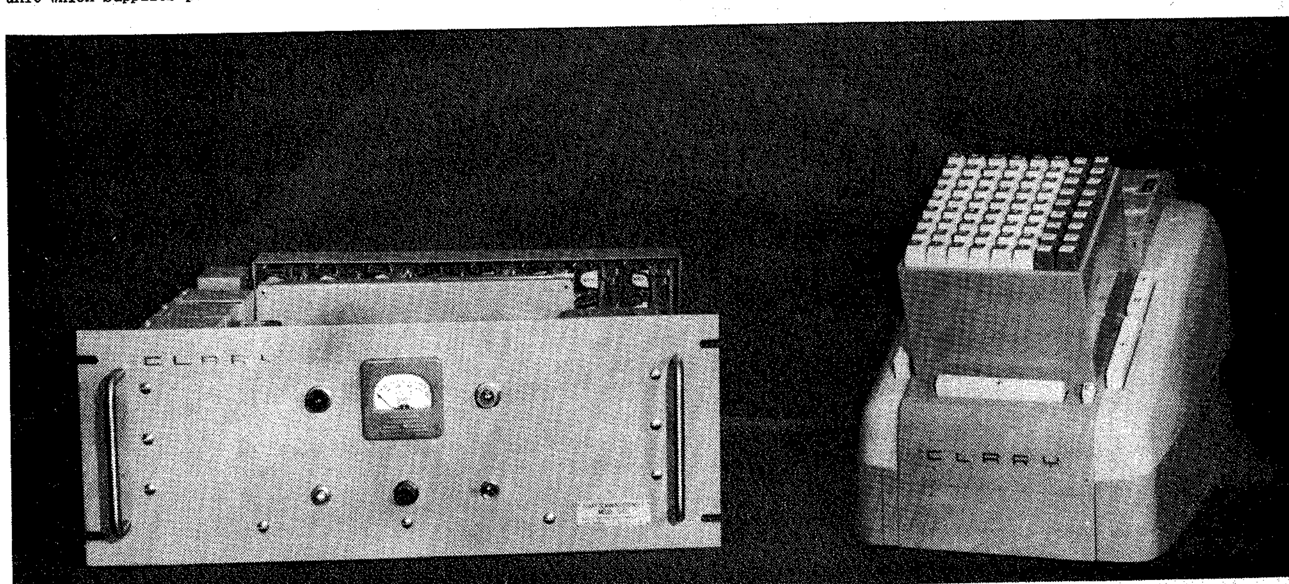


FIGURE 1

FIG. 2

BLOCK DIAGRAM OF PULSE COUNTING SYSTEM

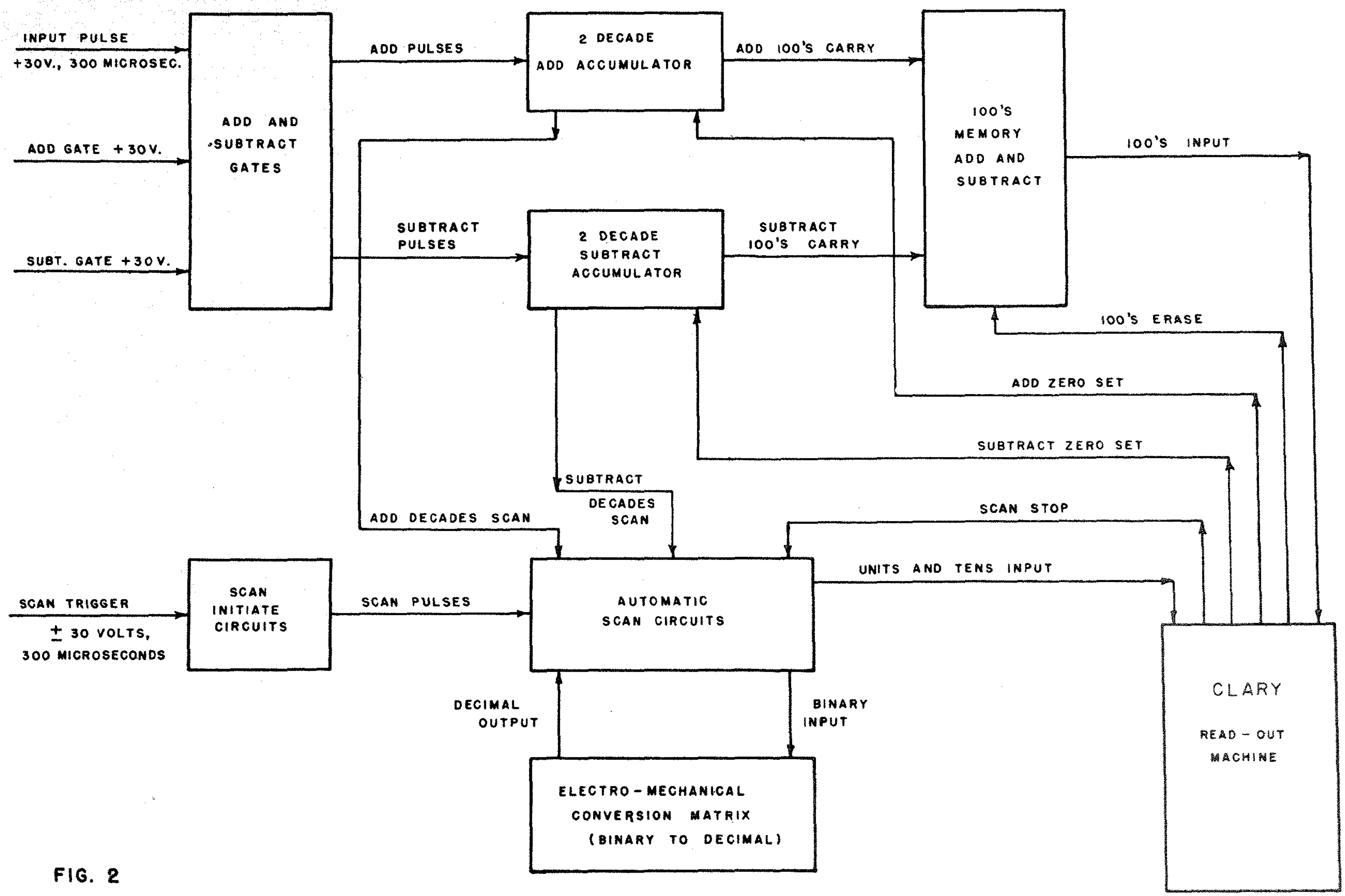


FIG. 2

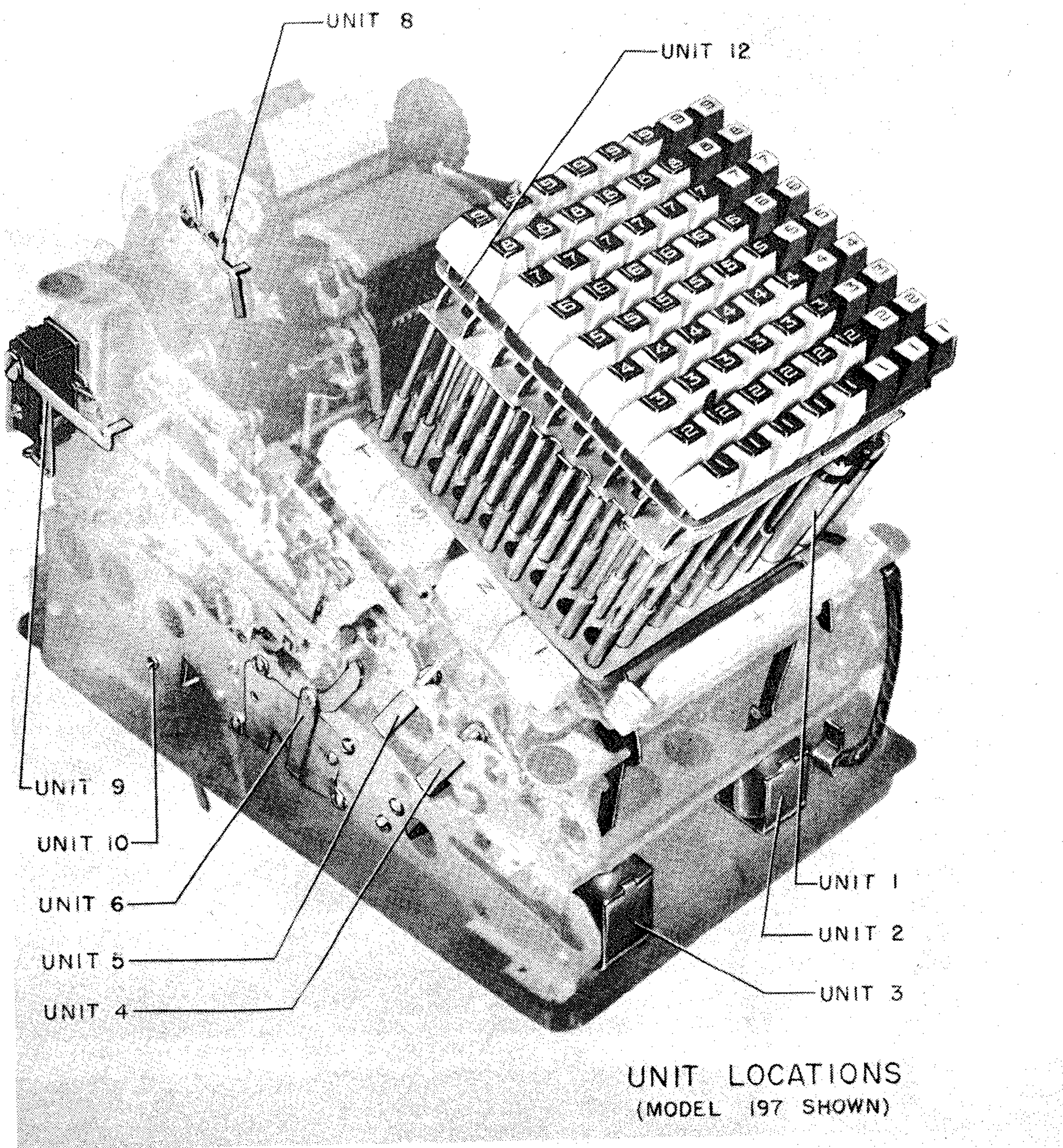


FIGURE 3

electronic counters to be reset to zero. The complete scan and totaling operation takes approximately one and one half seconds.

II. THE SOLENOID CONTROLLED ADDING MACHINE.

FIG. 3 is a view of the solenoid controlled adding machine with the cover removed. Call outs show the location of the electrical control units that have been added. Unit 1 is the amount key solenoids. The solenoids are designed to be operated on 115 volts A.C. 60 cycles. The solenoid has a resistance of approximately 200 ohms. A 40 millisecond pulse gives reliable latching of the amount key. Circuits to these solenoids are set up by the relays in the binary to decimal converter. Power is applied and broken by the pulse generator relay only. This limits sparking to one set of contacts and simplifies the problem of spark suppression.

Units 2, 3, and 4 are the carry solenoid, add solenoid, and subtract solenoid, respectively. These units are of standard construction and operate on 115 volt 60 cycle A.C. A longer pulse of approximately 60 milliseconds is used to energize these solenoids.

Units 5, 6, and 7 are non-add, sub-total, and total solenoids. These solenoids are similar to the add solenoid and are operated with a longer pulse than the amount key solenoids.

Unit 8 is the printer control solenoid. It is similar to the add solenoid. Operation of this solenoid during the machine cycle keeps the printer from operating. In the system to be described this solenoid is used to prevent printing operations on the add and subtract machine cycles but allows printing on a sub-total cycle.

Unit 9 is a microswitch which operates when the machine cycles. It is used to feed signals back to the electronic unit so as to permit smooth synchronized operation of the machine from the electronic counter unit.

The appendix to this report describes a machine which has a full complement of amount key solenoids (72) and a relay selector system in the base of the machine for selecting any digit in any decimal column with a total of 18 input leads.

III. ELECTRONIC COUNTERS AND SUB-ASSEMBLIES

FIG. 4 shows a rear view of the electronic counting unit. The entire unit is constructed on a 7 x 19 inch standard rack panel. The chassis proper is 1¼" high and 14" deep. The electronic plug in sub-assemblies are shown in the upper center of the photo. One of the plug in sub-assemblies has been removed and is shown in the foreground of the picture. The regulated power supplies occupy the right side of the chassis. The power transformer is next to the panel. The ripple smoothing choke is mounted next to the transformer and

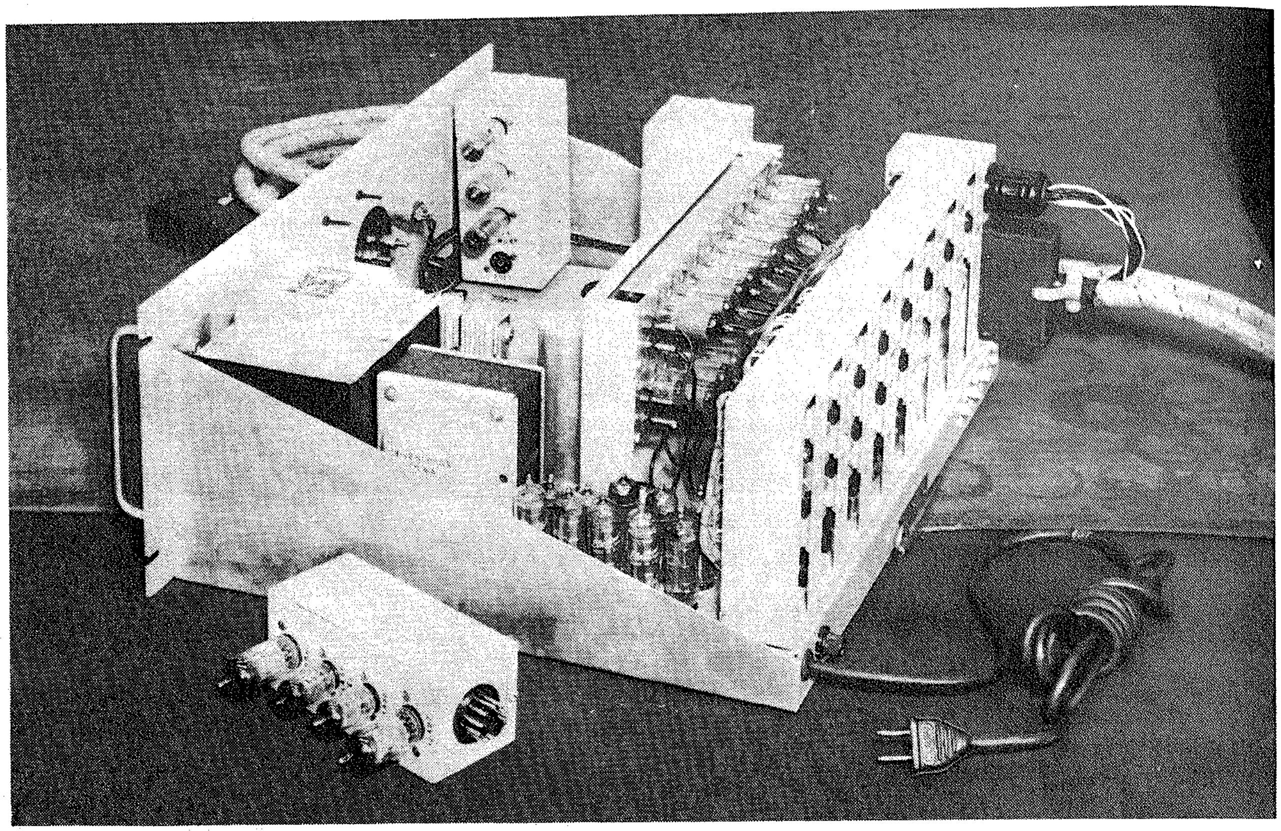


FIGURE 4

the regulator tubes are to the rear of the choke. The dry disc type of rectifiers are visible just above the choke in the photograph. The counter decades are located in the center part of the chassis just forward from the relay frame. For easy access and simplicity in servicing all relays are mounted on a plug in frame at the rear of the chassis.

FIG. 5 shows a unit with the relay frame removed from the chassis.

Resistors, capacitors, and small components are mounted on terminal strips below the chassis.

FIG. 6 is an under chassis view of the unit. Resistors and capacitors have their leads sunk into strips of Tenite #2. This material makes a firm mounting for the components but permits easy changing if replacement should be necessary.

There are at least three basic types of counters. These are the straight binary type, the straight decimal type, and the coded decimal type. The elements in any one of these types of counters may be relay, gas tube, vacuum type, magnetic core or transistor type. For the same count capacity, the straight decimal type takes roughly three times the equipment that the straight binary type does and the coded decimal

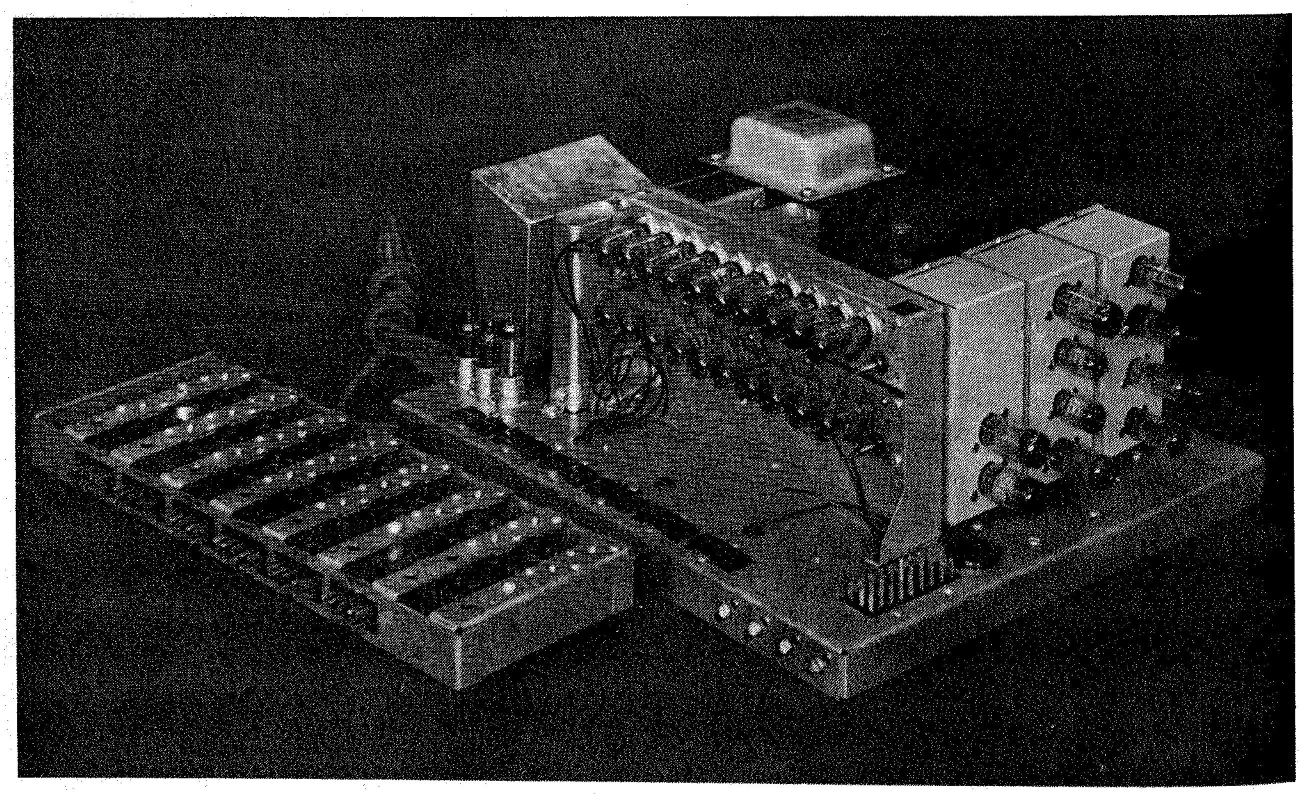


FIGURE 5

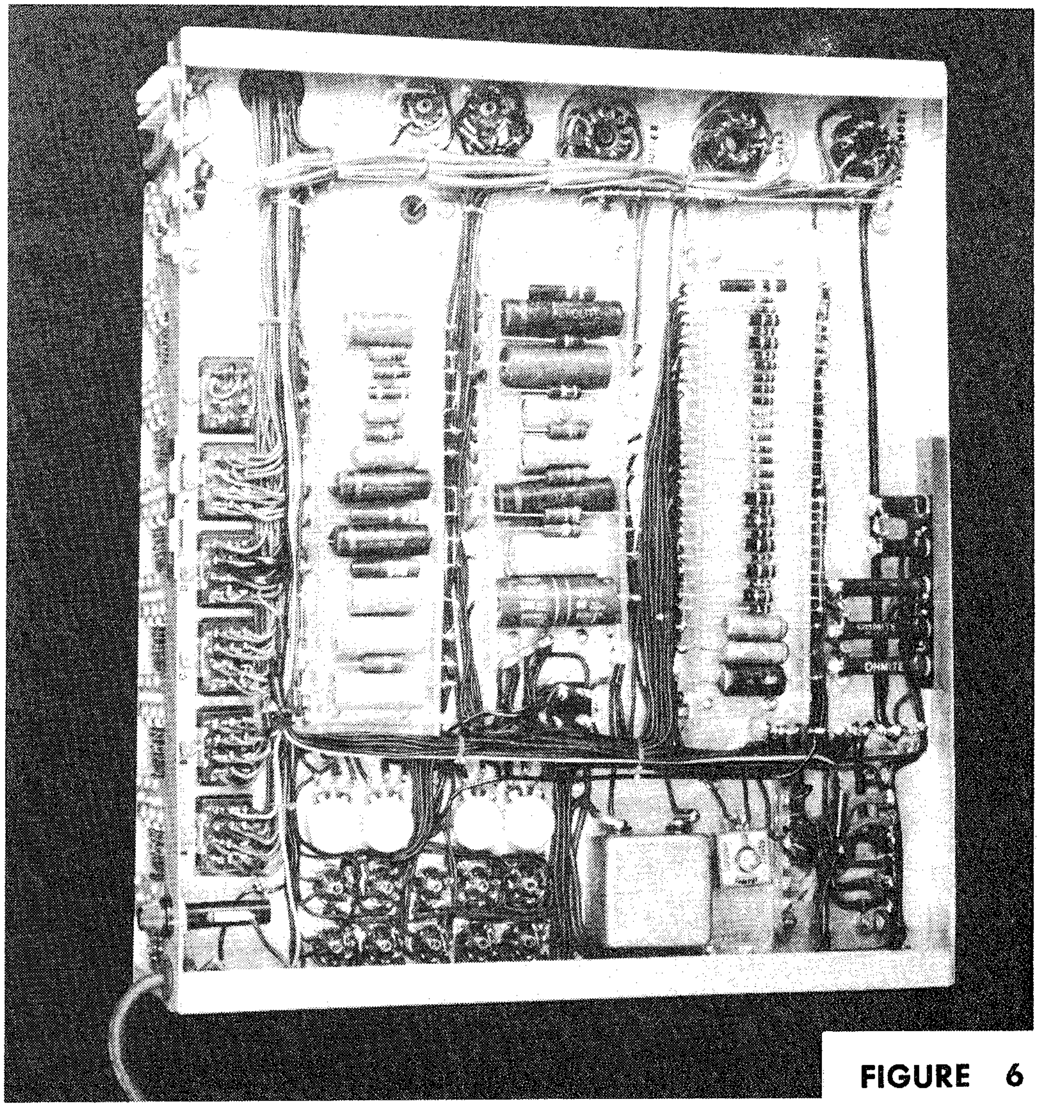


FIGURE 6

type takes approximately one and one half times the equipment that the straight binary types does.

Of the various coded types of decimal counters, the binary coded type lends itself readily to decimal read out. The counters used in the system are of this type and utilize cold cathode gas tubes (type 5823) as the counting element. A simple relay decoder reduces the binary information to decimal output.

FIG. 7 shows one of the counter strips. The counters are designed and manufactured by the Condor Radio Manufacturing Company, Prescott, Arizona. Each strip contains two decades of binary coded counters. The strip has a total of ten tubes. Five tubes are used in each decade. Four of these are in the decade proper while the fifth tube is used in a feed back stage to cause decimal reset of the decade on the tenth input pulse.

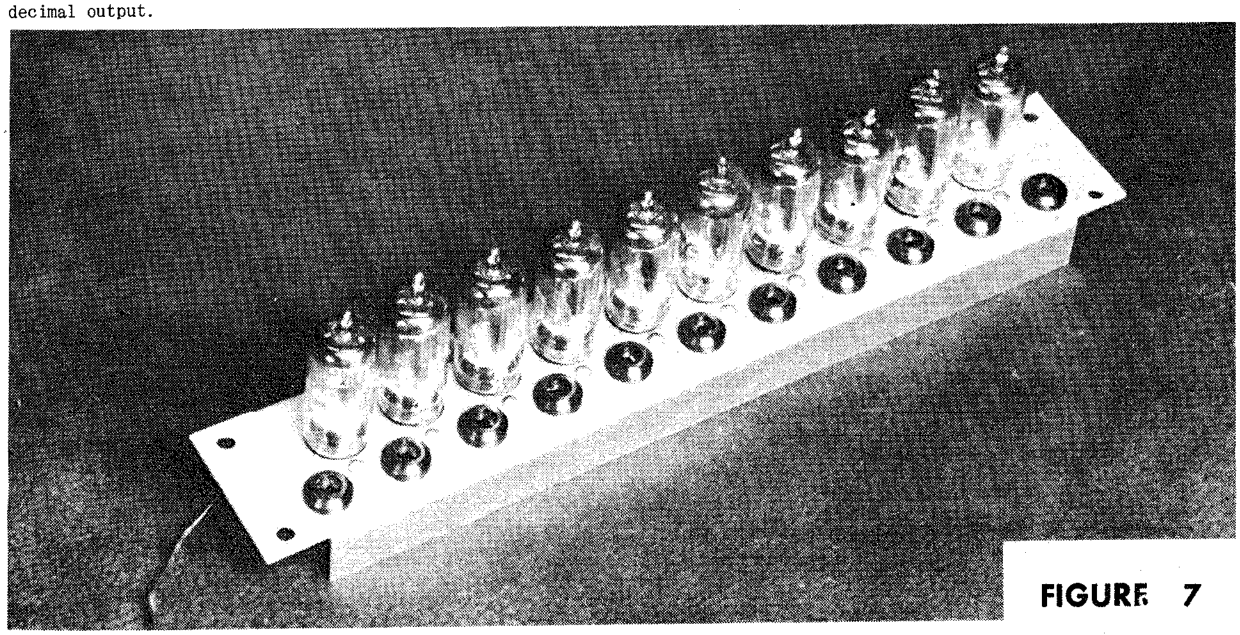


FIGURE 7

TYPICAL BINARY USING 5823 IGNITRON

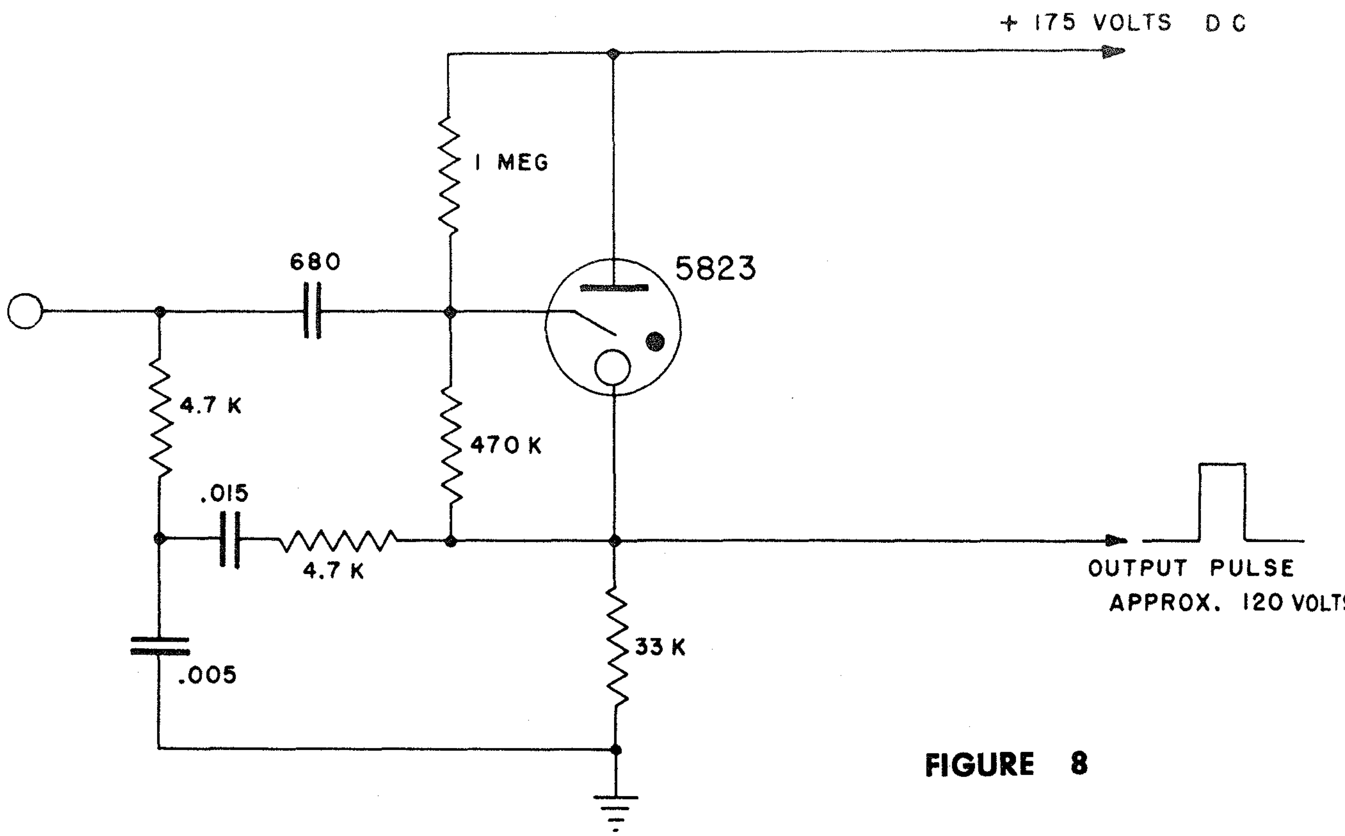


FIGURE 8

All decimal digits are represented as combinations of the four binaries 1, 2, 4, and 8. For example, decimal 7 is the sum of binaries 1, 2, and 4. The maximum counting speed of such a decade is limited by the deionization time of the gas in the tube. The maximum counting speed of this counter is approximately 600 impulses per second. The maximum usable counting speed for two decades in cascade with the carry or overflow from the second decade entering the solenoid controlled adding machine is 250 pulses per second. This pulse rate at the input of the first decade cycles the adding machine continuously. For two decade operation into the machine the counter has a counting speed well in excess of what can be utilized.

FIG. 8 is a schematic of the basic gas tube binary used in the unit.

The counter tube is an RCA type 5823 cold cathode gas tube. The 33K ohm load resistance is placed in the cathode circuit. The plate supply potential is 175 volts. This is low enough so that the gas will not ionize unless a positive pulse is applied to the ignitor terminal. The ignitor is biased upward from the cathode by means of the 470K and 1 meg. resistors to a point slightly below ignition potential. The binary is driven from a low impedance source with a pulse having an amplitude of approximately plus 100 to 120 volts and a rise time which is steep enough to give reliable ionization of the gas and a duration which will give reliable deionization. A suitable pulse has a rise time of 10 microseconds and a duration of 400 microseconds. In operation the positive rise of the input pulse is differentiated by the 680 mmfd condenser and the 470K resistor and causes the ignitor potential to go positive sufficiently to ionize the gas. Anode to cathode ionization takes place and the potential at the cathode rises to approximately 120 volts. The second pulse has no effect on the ignitor terminal since the stage is now in a conducting condition. The .015 capacitor however has charged up sufficiently so that the second pulse forces the cathode terminal sufficiently positive and for a duration long enough to extinguish the tube. If such a binary has its output or cathode terminal connected to the input terminal of another like unit etc., a binary counting chain can be built up. By using four such stages in cascade the counter can count up to sixteen input pulses before recycling. In order to have the four stages recycle on the tenth input pulse a fifth stage is added which feeds back impulses to appropriate circuit points to cause reset on the tenth input pulse.

FIG. 9 is a schematic diagram of a typical binary coded decade using the gas tube binary. In this particular type of decade the digit "0" is represented by a stage being in the conducting condition and the digit "1" is represented by the stage being in the non-conducting condition. The four stages are set to their "0" condition by momemtarily raising the supply bus voltage to approximately 260 volts. A more detailed description of the decade counter operation is given in the appendix to the report.

FIG. 10 shows a schematic of one of the various types of gate circuits which has been used with the unit. This is one of the plug in sub-assemblies and is shown in the foreground in FIG. 4. This particular gate circuit has two 6AS6 tubes used as "and" gates, one for add, one for subtract. They are driven by positive pulses on the #3 grids which are normally biased so that the tube is at plate current cutoff. Either the add or the subtract gate or both may be turned on by a steady positive 30 volt signal on their respective #1 grid input leads. The negative pulse output from the plate of each of the 6AS6 gate tubes is then inverted by one half of a 12AU7 tube and the resulting positive pulse output fed into the other half of the 12AU7 which operates as a cathode follower so as to provide the low impedance pulse source required to drive the gas tube counters. This gate arrangement also has a small capacitor from the cathode of each cathode follower to ground which serves to stretch the pulse duration. The pulse input in this case was approximately 250 microseconds. The addition of the capacitor doubled the pulse width at the 100 volt amplitude point. A more elaborate gate arrangement for a special purpose is described in the appendix to the report.

FIG. 11 is a schematic of the 100's add-subtract memory unit. This is a portion of one of the plug in sub-assemblies. It permits the overflow or carry pulse from each of the two decade add and subtract counters to be entered into the adding machine with the appropriate sign and without loss of data

FIG. 9

TYPICAL BINARY CODED DECADE

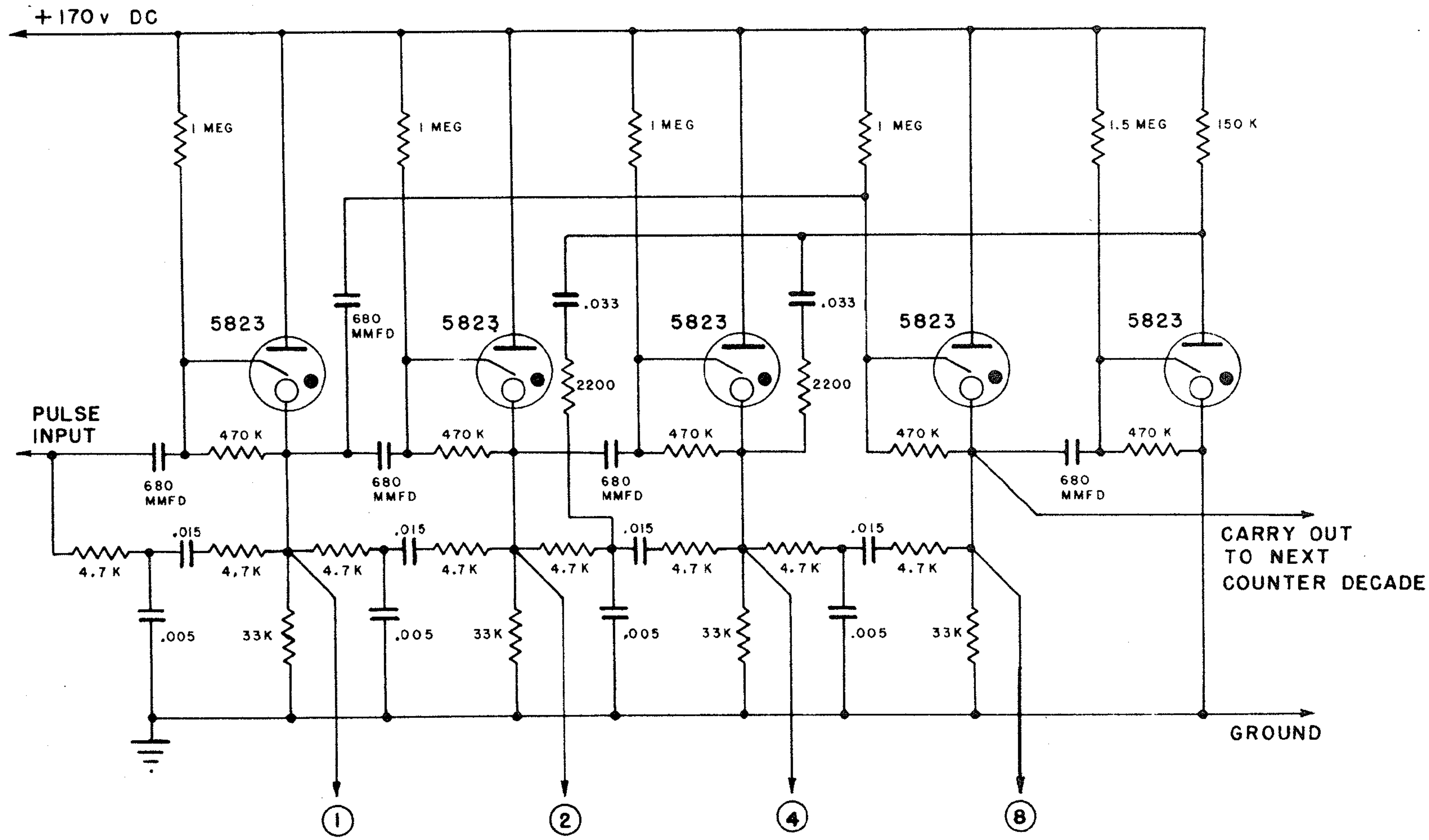


FIG. 10

ADD – SUBTRACT GATE CIRCUIT

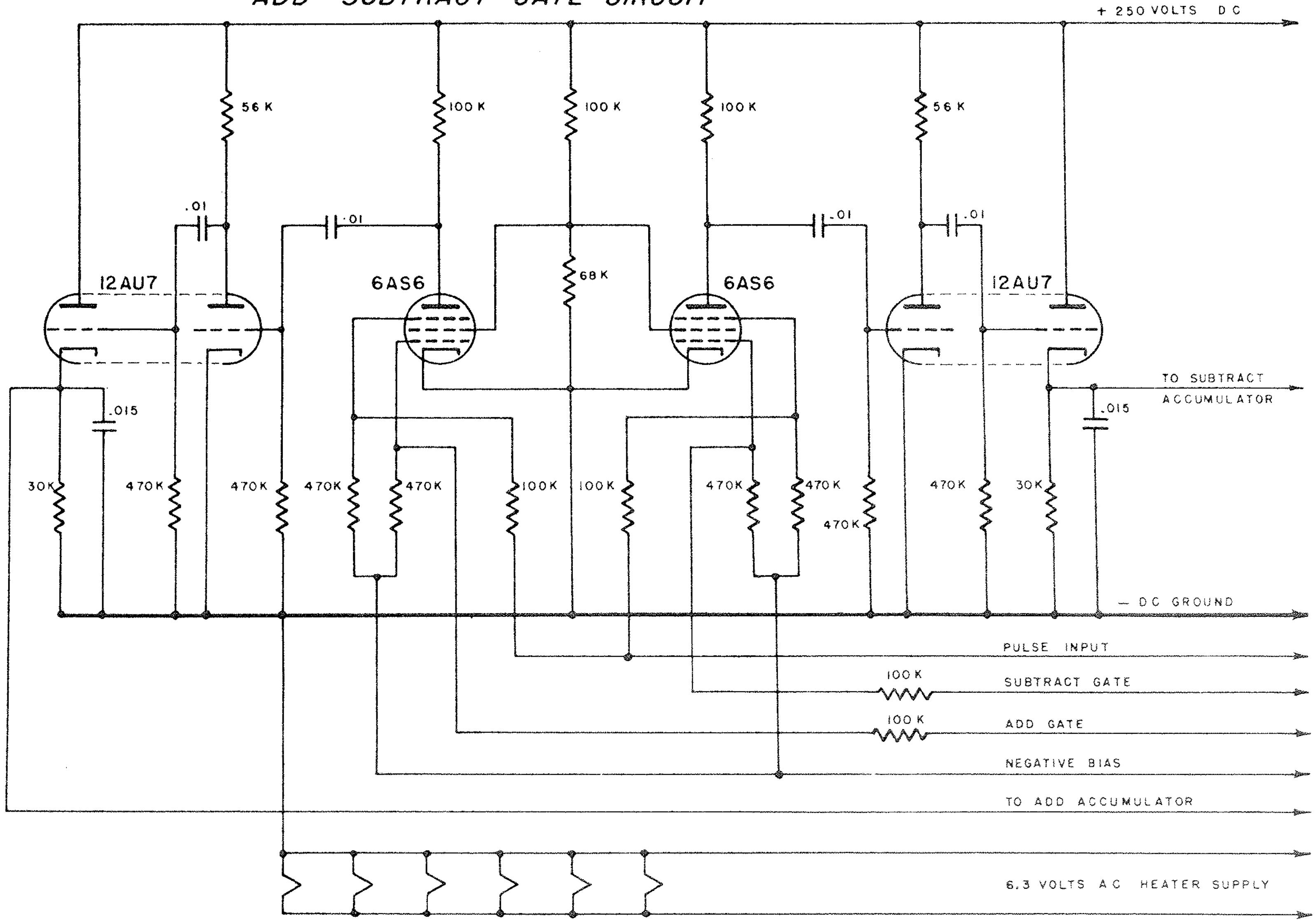


FIG. 11

100's ADD–SUBTRACT MEMORY AND INTERLOCK

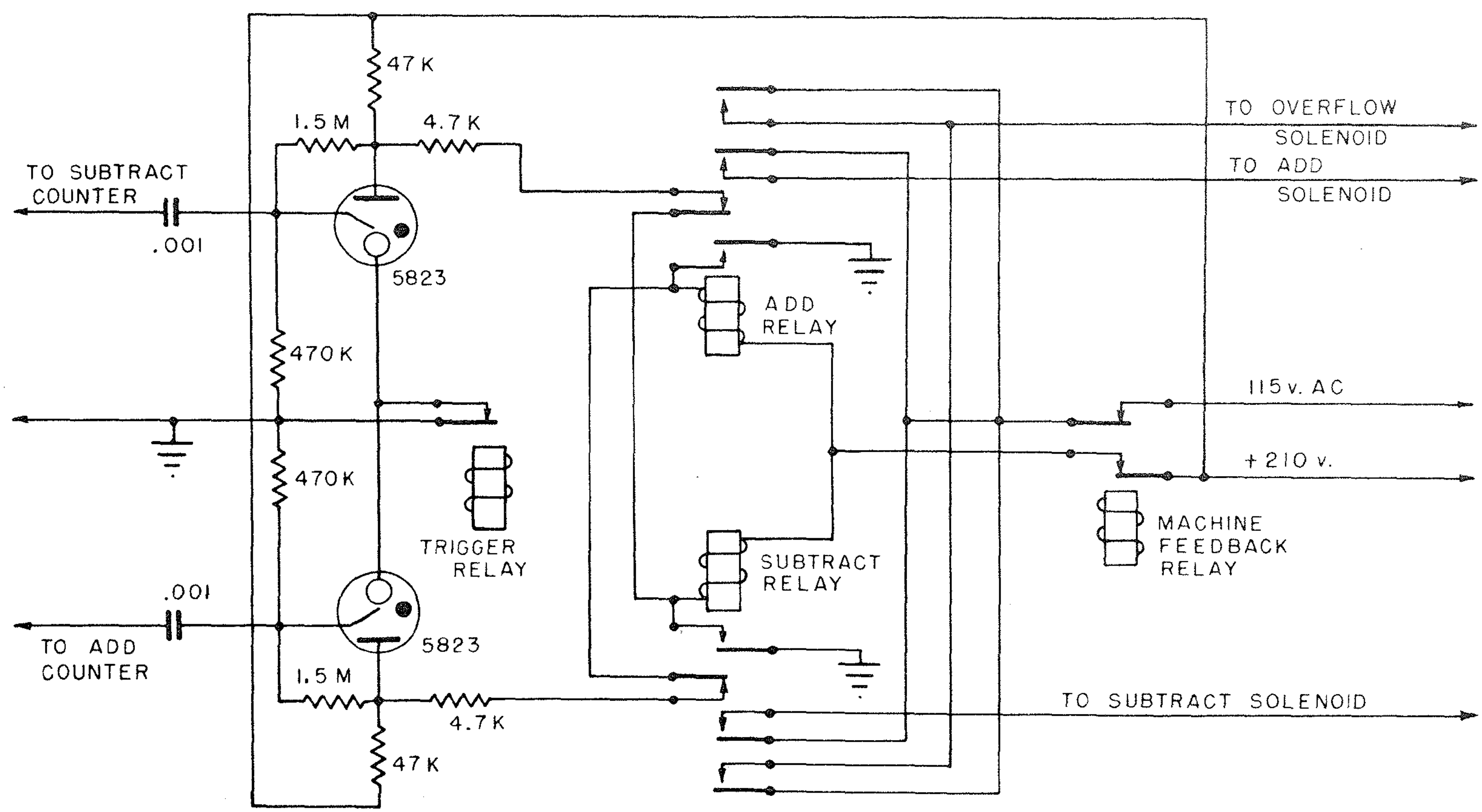
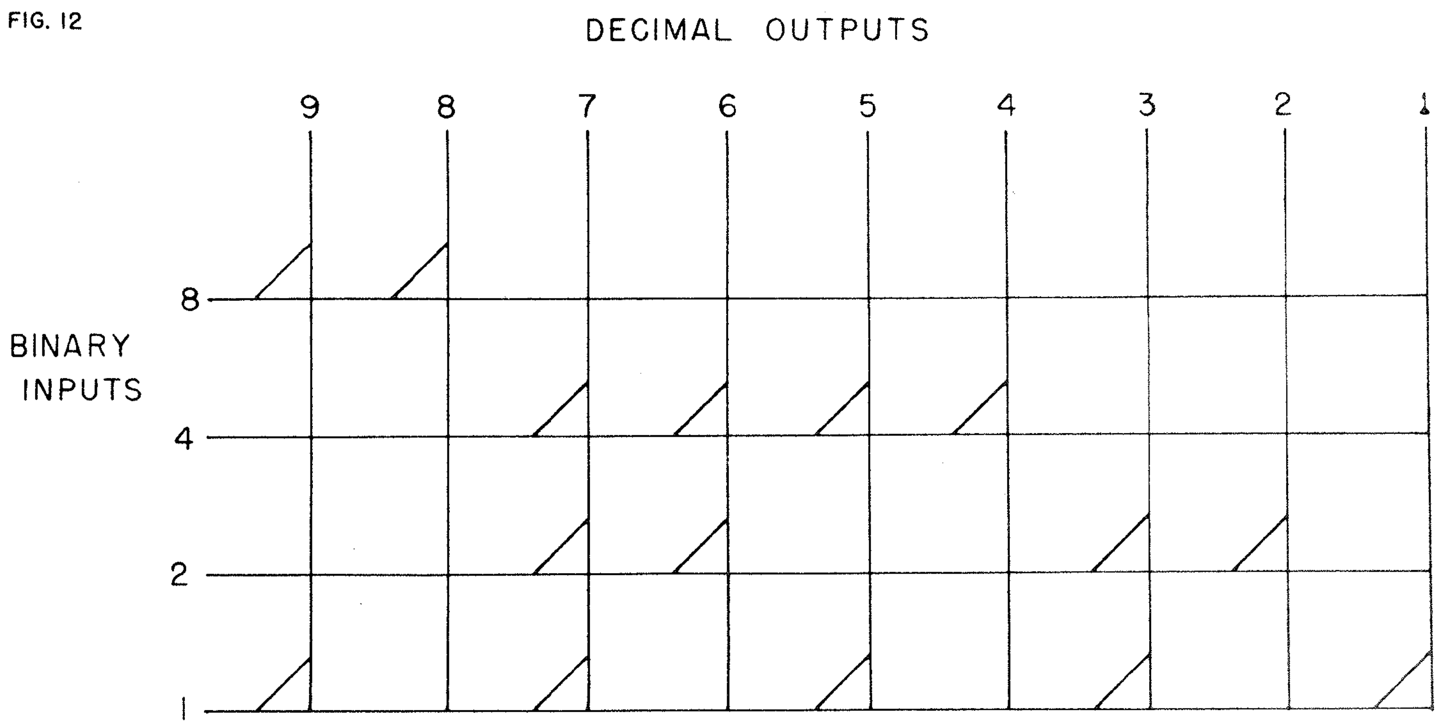


FIG. 12



THE DIAGONAL CONNECTING HORIZONTAL AND VERTICAL LINES INDICATES THAT AN "AND GATE" MUST BE OPERATED BY THE HORIZONTAL LINE AND ENERGIZE THE CONNECTING VERTICAL LINE.

FIG. 13

BINARY TO DECIMAL CONVERTER

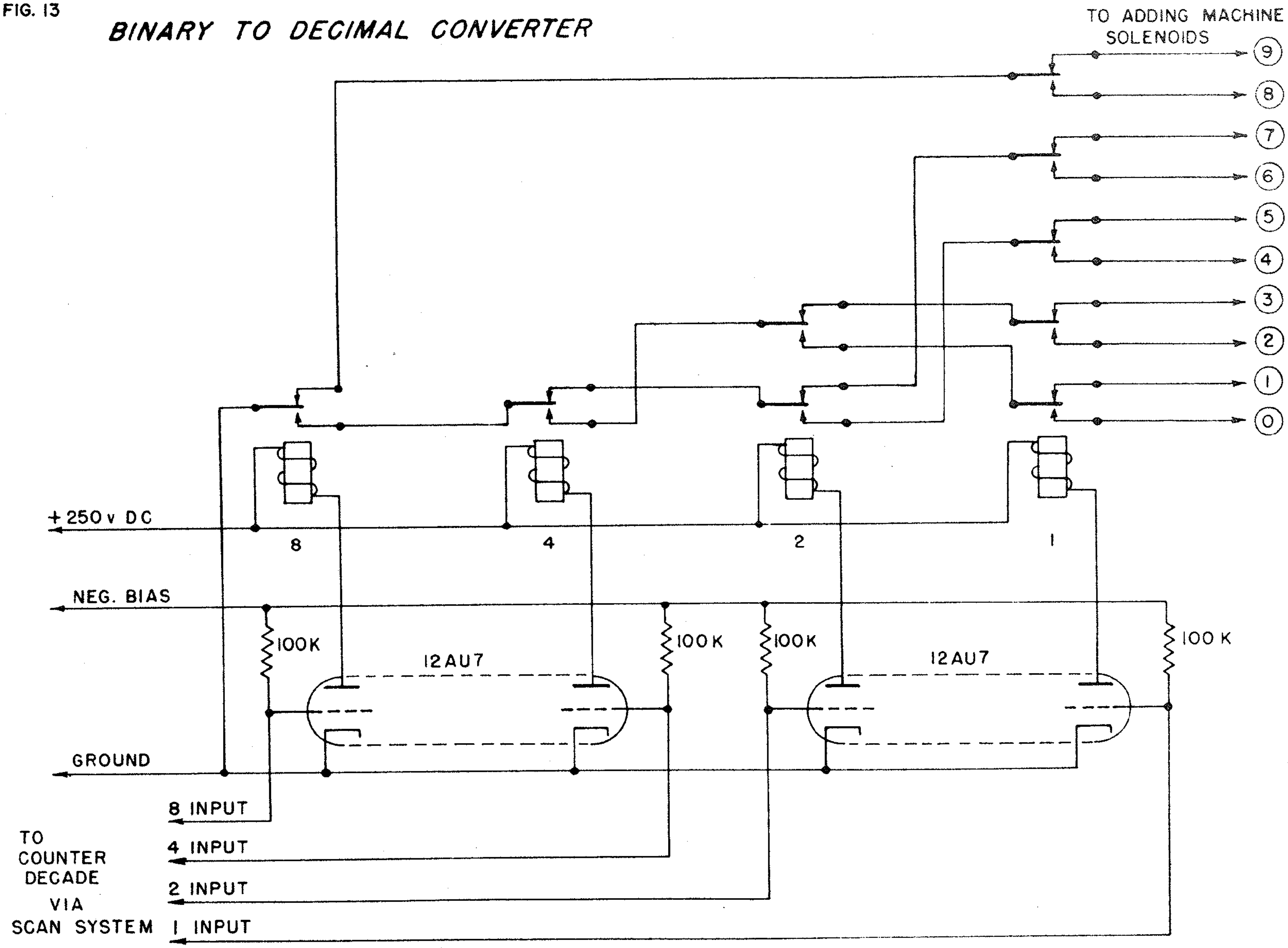


FIG. 14

BASIC SCANNING SYSTEM

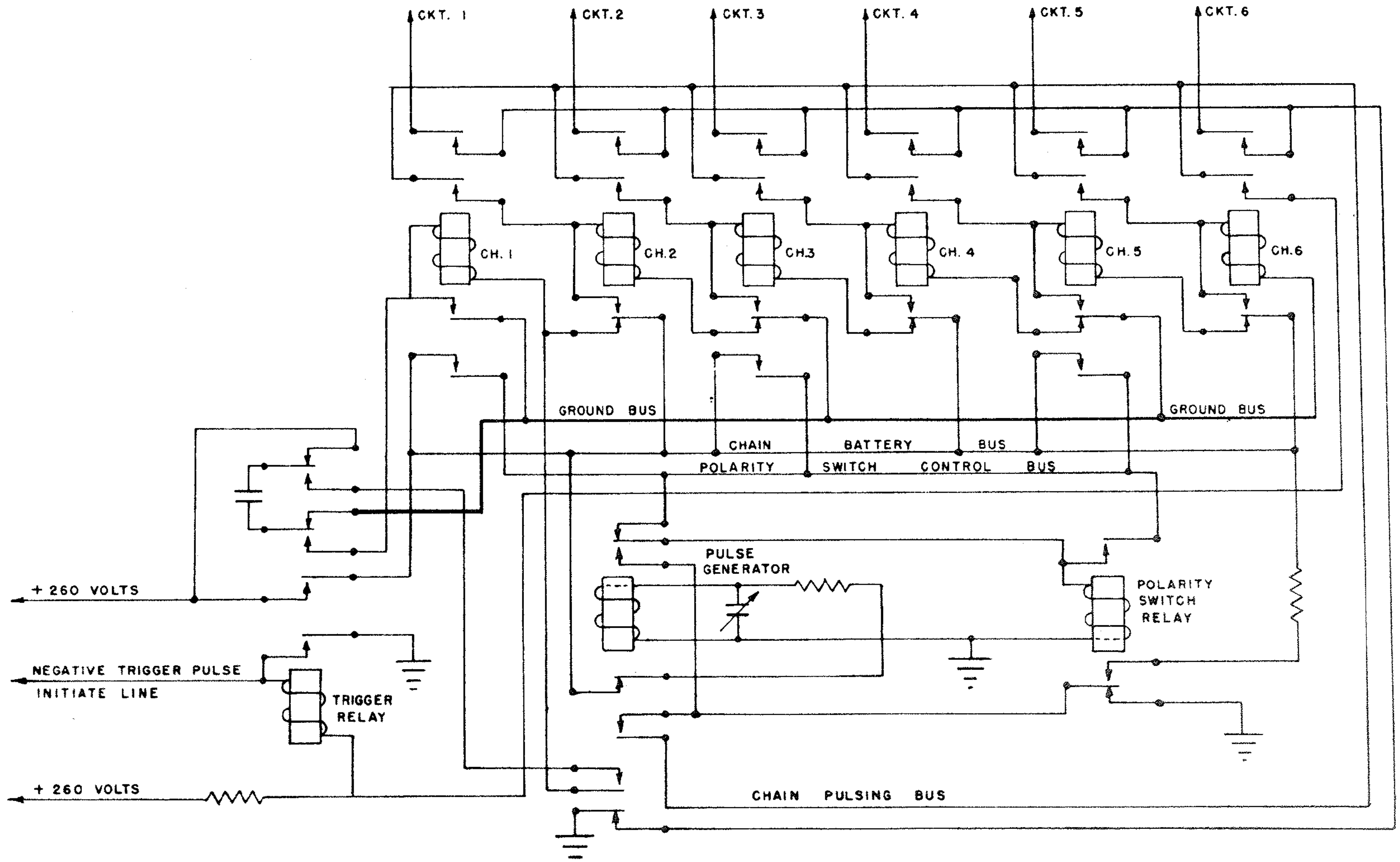
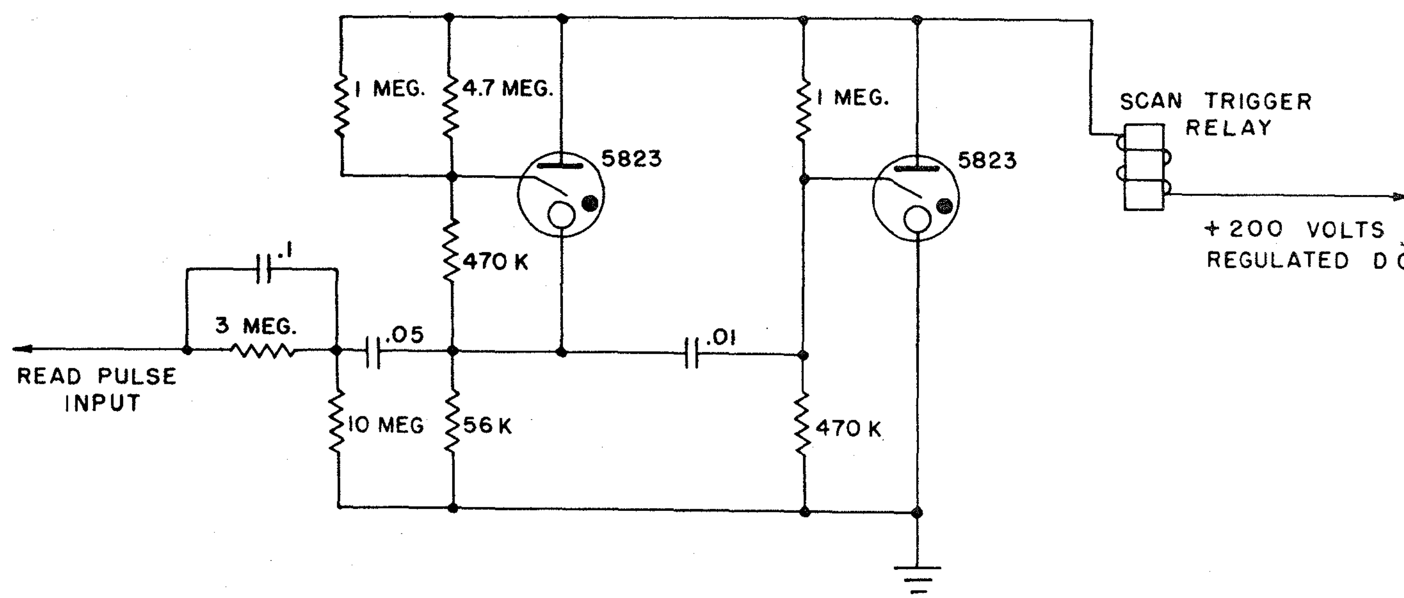


FIG. 15

SCAN INITIATE CIRCUIT



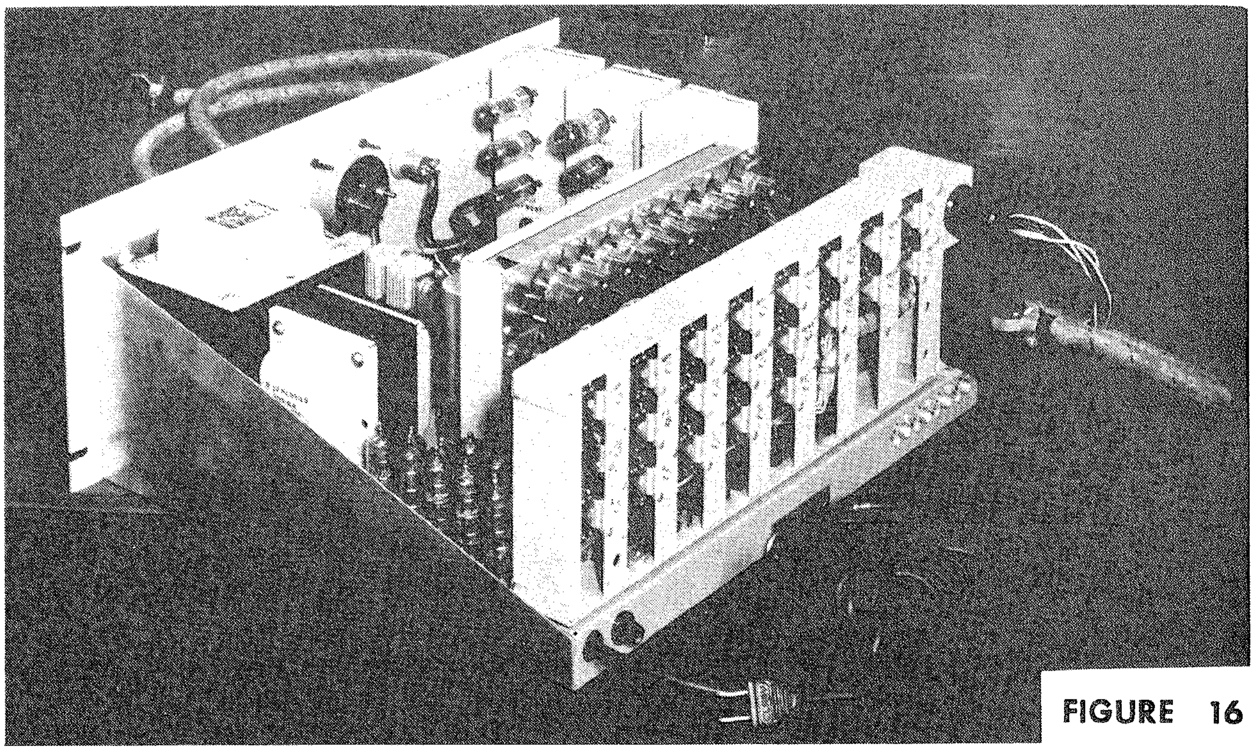
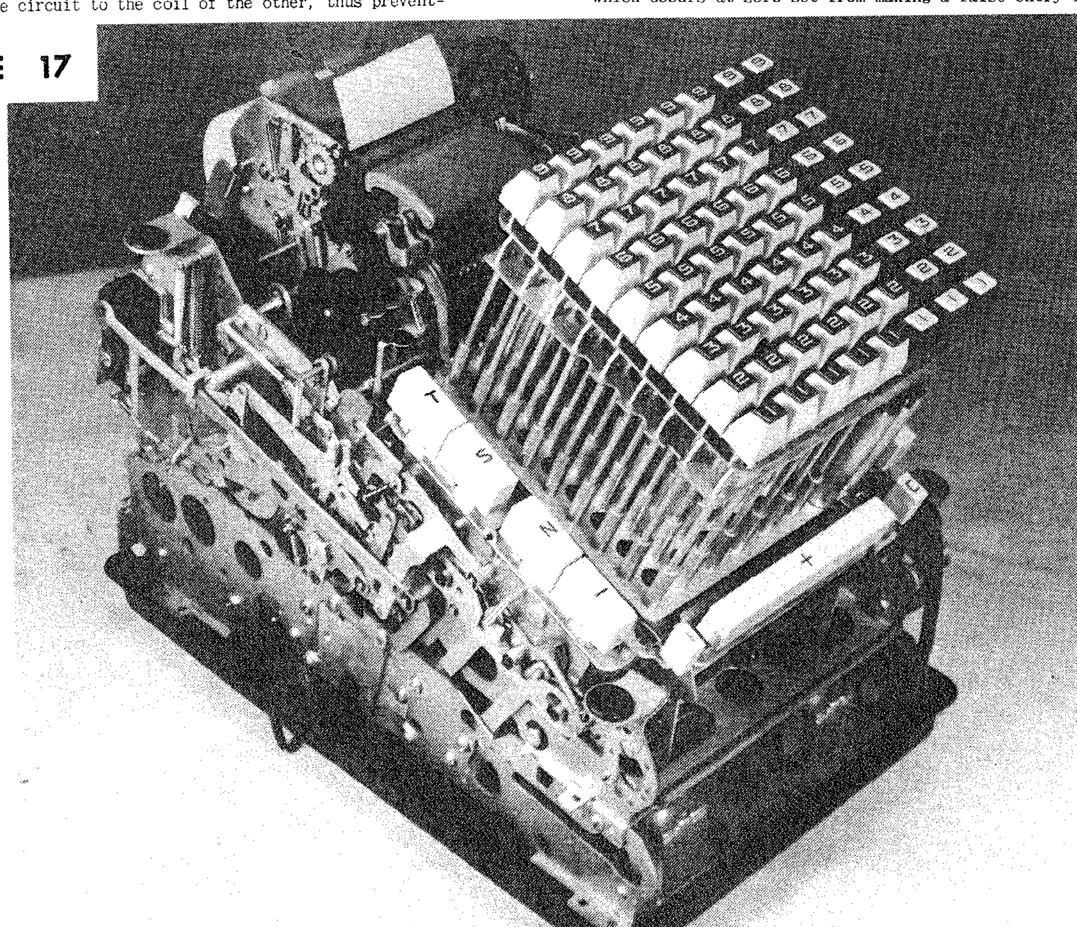


FIGURE 16

in the event that carry pulses leave the counters simultaneously or within an interval of time less than that required for the machine to cycle. This task is accomplished by storing each of the carry pulses in a 5823 gas tube. If the adding machine is busy the machine feed back relay is energized and the break contacts are open preventing operation of either the add or subtract relays. However, as soon as the machine completes the job it is doing, the contacts on the machine feed back relay close and permit either the add or the subtract relay to be energized. One of these relays operates and opens the circuit to the coil of the other, thus preventing the opposite relay from operating, and at the same time it extinguishes the gas tube which caused its operation by removing the anode supply voltage. The machine then cycles and enters the data. This allows the relay which was locked up to drop out thus permitting the remaining relay to operate and enter its data.

The contacts which are on the trigger relay and are in series with the cathode circuits of the 5823 tubes open when the counters are reset to zero. This prevents the carry pulse which occurs at zero set from making a false entry into the

FIGURE 17



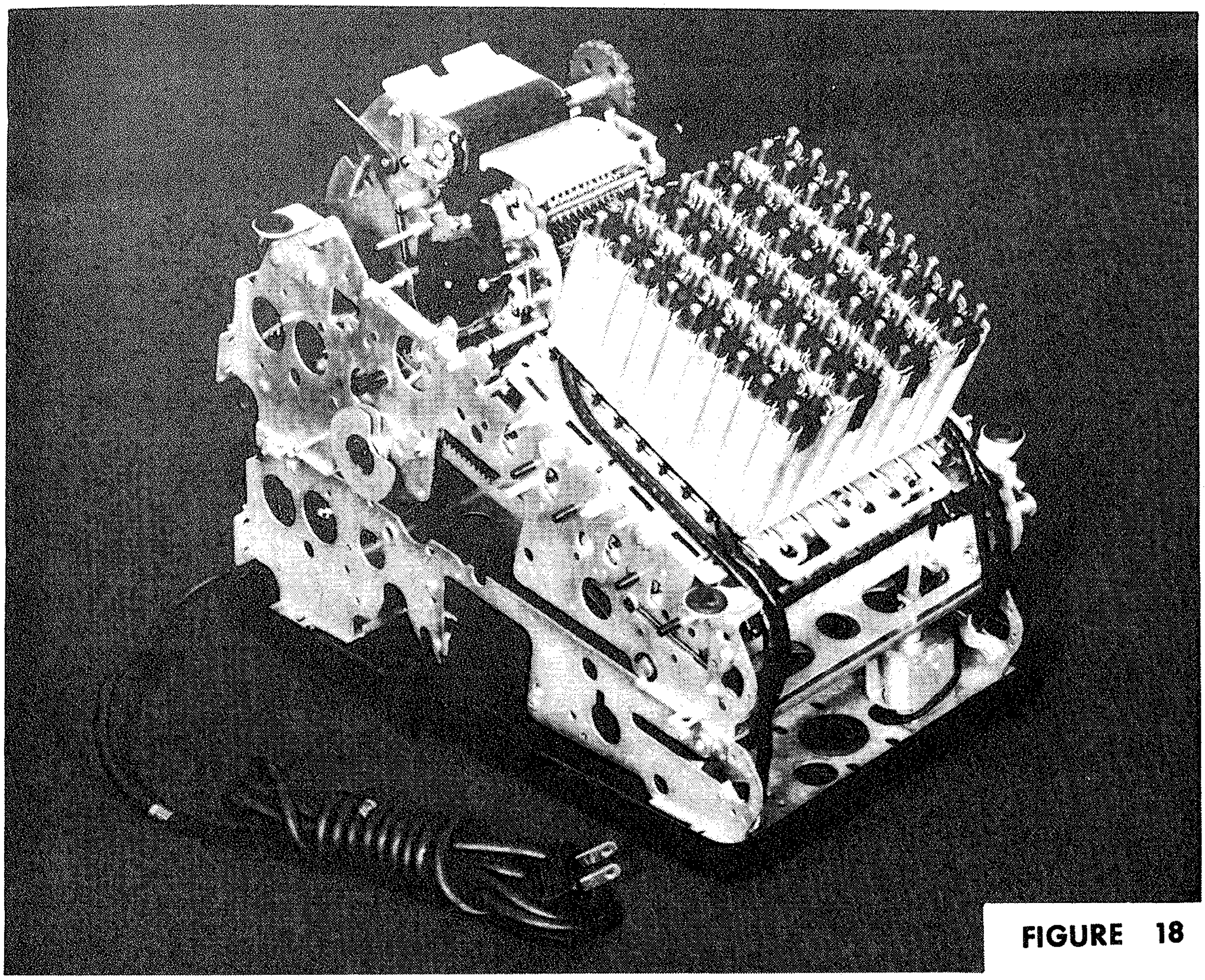


FIGURE 18

add and subtract memory units. (Resetting the counters to zero would have the same effect on the add-subtract memory units that a normal carry or overflow pulse would).

The 100's add-subtract memory and interlock circuit makes it possible to operate both add and subtract counter decades simultaneously or alternately without loss of pulse count.

FIG. 12 is a chart showing the underlying principle used in the binary to decimal decoder. The diagonals connecting horizontal and vertical lines represent "and gates" that must be operated by the horizontal binary inputs in order to energize the connecting vertical decimal lines. For example, in order to have an output on the decimal 7 line binaries one and two and four must be operated. In the system used, the gates themselves are relay contact.

FIG. 13 is a schematic of the relay decoder showing also the buffers that drive the relay coils. All four of the buffer triodes are biased to cut off. The input leads to the four grids when connected to the cathodes of the gas tube counter binaries will cause operation of their respective relays if the gas tubes to which they connect are ionized. A counter tube which is not ionized (binary "1") will leave the corresponding relay dropped or de-energized. Thus, the amount key solenoid in the adding machine which will be energized when power is applied to the common solenoid leads is the one which has a numerical value equal to the sum of the binaries which have dropped or de-energized relays in the decoder.

FIG. 14 is a schematic diagram of the basic scanning circuit. It consists of a linear type counter in which the counting elements are relays. The relays in the chain are operated one at a time in sequence from left to right. The counter chain is stepped or driven from the pulse generator relay. This relay is part of an oscillatory circuit. The scan pulse rate is approximately 8 cycles per second. The scan is initiated, by momentarily placing the trigger relay initiate lead at or near ground potential. This is done by a gas tube trigger. A detailed description of the scan operation is included in the appendix to the report.

The gas tube trigger circuit which initiates the scanning operation is shown in FIG. 15. Two type 5823 tubes are used in the circuit so that triggering can be initiated by either a positive or a negative going pulse. A positive pulse causes the right hand tube to be ionized and operate the relay. A negative pulse forces the cathode of the left hand tube negative sufficiently to ionize this stage. This stage in turn couples a positive pulse to the ignitor of the right hand stage and operates the trigger relay. The trigger relay when it operates places ground on the anodes of both gas tubes and extinguishes them so that they are ready to accept another read out signal.

FIG. 16 is a rear view of the electronic unit with all sub-assemblies in place.

FIG. 17 is a view of the solenoid controlled machine similar to FIG. 3 except that call outs of the electrical units has been omitted.

FIG. 18 is a view of the machine which is equipped with a full complement of amount key solenoids. This machine was mentioned at the end of the second section of the paper. This view shows the keyboard removed. This machine has 8 orders of solenoids and a relay selector system in the base of the machine which permits operation of any one of the 72 solenoids with only eighteen control leads. A machine similar to this with six orders of solenoids when operated through Clary scanning and decoding equipment that looks into a counter such as the Potter Instrument Company's Model 801 Megacycle - Frequency - Time - Counter permits decimal printing of high speed input data (up to 1 megacycle/second). In such an application the unit can scan six decades and print the result in approximately 8/10 seconds.

IV. APPENDIX
   A. Detailed description of gas tube counter
   B. Detailed description of scanning system
   C. Gate circuit which permits switching between input pulses
   D. Circuit of machine having 8 orders of amount key solenoids and relay selector system.

APPENDIX

A. Detailed description of gas tube counter.

FIG. 9 shows the circuit of a typical decade. The 170 volt bus is momentarily raised to 250-300 volts. This places each of the four stages in the conducting condition and the potential at the cathode of each stage is about 120 volts. The binary "0" is represented by the stage being in the conducting state. The binary "1" is represented by the stage being in the non-conducting state.

A positive pulse with an amplitude of 120 volts, a rise time of 20 microseconds or less, and a duration of 400 microseconds or more is supplied to the input terminal. The positive rise of the pulse causes ionization of a stage while the long duration causes deionization.

The first pulse puts stage one in the "1" condition.

The second pulse puts stage one in the "0" condition. The carry pulse from stage one puts stage two in the "1" condition.

The third pulse puts stage one in the "1" condition. No carry occurs from stage one therefore stage two remains in the "1" condition.

The fourth pulse puts stage one in the "0" condition. This gives rise to a carry from stage one to stage two and stage two goes to the "0" condition. Stage two gives a carry output to stage three and stage three is placed in the "1" condition.

The fifth pulse puts stage one in the "1" condition. Since there is no carry from stage one, stages two and three remain in the same condition.

The sixth pulse puts stage one in the "0" condition. A carry occurs from the first stage which puts the second stage in the "1" condition.

The seventh pulse puts stage one in the "1" condition. There is no carry pulse from stage one so stages two and three remain in the "1" condition.

The eighth pulse puts stage one in the "0" condition. This gives rise to a carry which puts stage two in the "0" condition. Stage two has a carry which puts stage three in the "0" condition. The carry from stage three puts stage four in the "1" condition.

The ninth pulse puts stage one in the "1" condition. There is no carry from stage one so stages two, three, and four remain as set by the eighth pulse.

The tenth pulse puts stage one in the "0" condition. This results in a carry. This carry pulse is coupled to the ignitor of stage four and returns stage four to the "0" condition. When stage four returns to the "0" condition a positive pulse is applied to the ignitor terminal of the fifth stage or feedback tube. The output of the feedback tube is a negative pulse. This negative pulse is fed back to the cathode circuits of stages two and three and holds these tubes conducting even though the carry from stage one would normally put a "1" in the second stage. All four stages are now returned to the conducting or "0" condition.

B. Detailed Description of Scan System.

The basic scanning system consists of a linear type counter in which the counter elements are relays.

FIG. 14 is a schematic diagram of the basic scanning scheme.

Normally all relays are de-energized. Operation of the scan system is as follows:

1. The trigger initiate line going to the trigger relay is momentarily grounded. This causes the trigger relay to lock up through its own make contact to ground.
2. The locking up of the trigger relay transfers the capacitor C1 from its charging circuit to contacts which will permit it to discharge through the coil of relay CH1 after the pulse generator relay is energized.
3. When the trigger relay locks up, the battery is also applied to the chain battery bus. This starts the pulse generator relay into operation. The pulse generator relay is part of an oscillatory circuit. The resistor R_2 and capacitor C_2 in combination with the pulse generator relay determine the frequency of operation. The frequency is adjusted for a convenient scan rate (approximately 6-10CPS).
4. As soon as the pulse generator relay is energized and operated, the discharge path for C_1 is completed. Capacitor C_1 discharges into relay coil CH_1 causing relay CH_1 to operate and lock up through its make contact to ground. Capacitor C_1 is chosen to be just large enough to reliably operate relay CH_1.
5. The operation and lock up of relay CH_1 also closes the chain pulse bus to the coil of relay CH_2 and closes make contacts which apply battery to the polarity switch control bus.
6. The second half of the first cycle of operation of the pulse generator returns the pulse generator relay to its de-energized position and applies power to the external circuit which has been set up by the operation of relay CH_1. Also break contacts on the pulse generator relay connect the polarity switch control bus to the polarity switch relay coil. This energizes the polarity switch relay causing it to lock up through its own make contact to the polarity switch bus. Operation of the polarity switch relay transfers the chain pulsing contact on the pulse generator relay from ground to battery so that on the second operation of the pulse generator the chain pulse bus is connected to battery instead of to ground.
7. The second cycle of operation of the pulse generator relay does three things:
   (1) it removes power from external circuits;
   (2) it places battery on the polarity switch relay coil so that this relay will not de-energize upon drop out of relay CH_1;
   (3) it places battery on the chain pulse bus causing operation of relay CH_2;.
8. Operation of relay CH_2 does the following:
   (1) it locks up through its own make contact to the battery bus;
   (2) it opens the circuit to the coil of relay CH_1 and permits this relay to de-energize.
   (3) it connects the chain pulse bus to relay CH_3;
   (4) it sets up external circuits which will be energized upon the second half of the second cycle of operation of the pulse generator relay.
9. On the second half of the second cycle of the pulse generator relay, the following takes place:
   (1) the pulse generator relay removes battery from polarity switch relay coil. This causes the polarity switch relay to de-energize since battery has been removed from polarity switch control bus by relay CH_1 being de-energized;
   (2) it removes battery from the chain pulse bus;
   (3) it connects the polarity switch relay coil to the polarity switch control bus;
   (4) it closes external circuits that were set up by operation of relay CH_2;
   (5) it connects the capacitor C_1 across the coil of relay CH_1. This does not cause operation of relay CH_1 however, because C_1 is so chosen that it discharges on the first operation of the pulse generator relay.
10. Operation of relays CH_3 through CH_6 occurs in the same manner as relays CH_1 and CH_2. It should be noted that the polarity switch relay operates on every other cycle of the pulse generator. This alternately places ground and battery on the chain pulse bus through the pulse generator relay contact.
11. After operation of the end chain relay CH_6, the seventh operation of the pulse generator relay places ground on the chain pulse bus, and through the make contact on relay CH_6, this ground shorts out the coil on the trigger relay causing it to de-energize.
12. De-energizing the trigger relay does the following:
   (1) it removes battery from the chain battery bus;
   (2) it places capacitor C_1 across the battery and charges it so that it is ready to operate relay CH_1 upon the next trigger pulse.

C. Gate circuit which permits switching between input pulses.

This gate circuit permits continuous pulse counting with read out from counters at any time and as often as every half second.

This gate circuit permits pulses to be counted continuously without loss of pulse count while at the same time it permits frequent decimal read out of the total pulse count.

Each time a read signal is applied to the gate input terminal marked read the output pulses are switched so that they now enter a second counter. The switching is arranged so that switching can occur only immediately following a counted pulse. This insures that the next pulse will be counted in the second counter.

While the pulses are being counted by the second counter the first counter is scanned and the data entered into the adding machine.

The next read signal switches the pulse output back to the first counter and reads the second counter, etc.

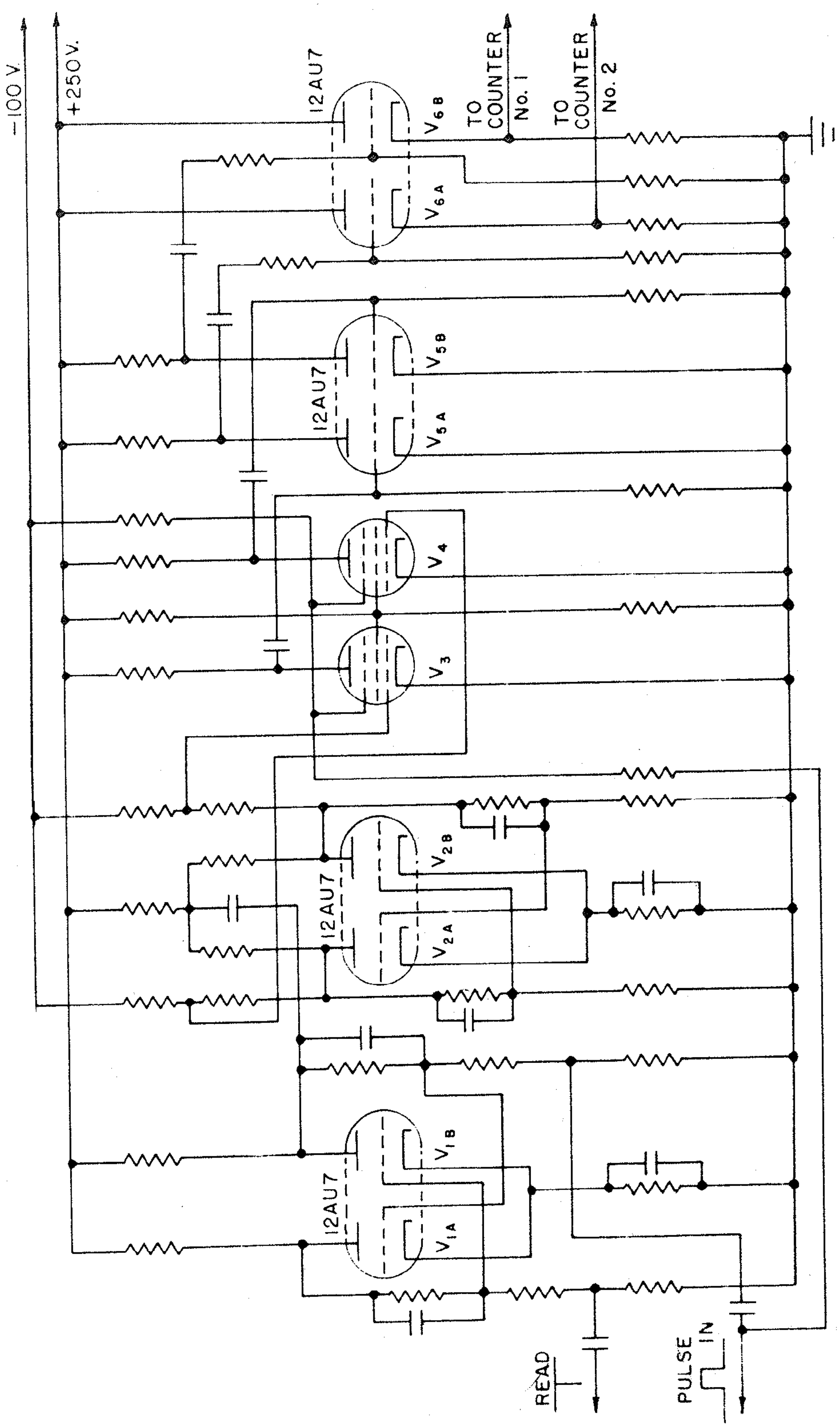
The pulse input is plus 40 volts with a rise time of 10 microseconds and a duration of 400 microseconds. The read pulse is a negative pulse of minus 100 volts and a fall time of 10 microseconds.

The output pulses to the #1 and #2 counters are positive going pulses with an amplitude of plus 115 volts, a rise time of 10 microseconds and a duration of approximately 400 microseconds.

D. Circuit of machine having 8 orders of amount key solenoids and relay selector system.

APPENDIX C

GATE CIRCUIT PERMITTING CONTINUOUS PULSE COUNTING WITHOUT LOSS OF PULSE COUNT AND WITH FREQUENT DECIMAL READOUT.



APPENDIX D

SELECTOR SYSTEM FOR MACHINE WITH EIGHT DECIMAL ORDERS OF KEYBOARD SOLENOIDS