PB 161565

NBS

Technical Note 64

DESIGN AND OPERATION OF THE CEILOMETER COMPUTER

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to government agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. Research projects are also performed for other government agencies when the work relates to and supplements the basic program of the Bureau or when the Bureau's unique competence is required. The scope of activities is suggested by the listing of divisions and sections on the inside of the back cover.

Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers. These papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three periodicals available from the Government Printing Office: The Journal of Research, published in four separate sections, presents complete scientific and technical papers; the Technical News Bulletin presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: Monographs, Applied Mathematics Series, Handbooks, Miscellaneous Publications, and Technical Notes.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($1.50), available from the Superintendent of Documents, Government Printing Office, Washington 25, D.C.

NATIONAL BUREAU OF STANDARDS
Technical Note
64
OCTOBER 1960

DESIGN AND OPERATION OF THE CEILOMETER COMPUTER

Paul Meissner

DISTRIBUTED BY
UNITED STATES DEPARTMENT OF COMMERCE
OFFICE OF TECHNICAL SERVICES
WASHINGTON 25, D. C.
Price $2.00

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF ILLUSTRATIONS

ABSTRACT

The ceilometer computer has been developed to provide a display and electrical readout of cloud-height information for use with an automatic weather station. The computer receives an analog signal from the detector of a rotating-beam ceilometer, and determines the height at which cloud indications occur. A small magnetic storage drum contains ten minutes of cloud-height information which is continuously updated, and these data are analyzed for the following factors:

1) Predominant cloud height over the past ten minutes,

2) Maximum and minimum height at which significant cloud occurences were observed,

3) Number of cloud observations up to a selected critical altitude.

The computer is a wired-program machine constructed of transistorized plug-in packages. Several modes of manual operation have been incorporated for testing and maintenance purposes.

DESIGN AND OPERATION OF THE CEILOMETER COMPUTER

by Paul Meissner

1. INTRODUCTION

The ceilometer computer has been designed to provide a numerical display of cloud height information, utilizing data received from a rotating beam ceilometer. The computer has been developed to fulfill a requirement of the U. S. Weather Bureau in connection with the establishment of automatic weather stations. The output of the computer can be transmitted by teletype, together with the outputs from a variety of other weather-indicating instruments.

The rotating beam ceilometer is a device which measures the height of clouds from the ground up to about 10, 000 feet.

A light beam from a rotating searchlight is reflected by the clouds and is received by a photocell placed at a known horizontal distance from the searchlight, as shown in Fig. 1. The cloud height is calculated by simple triangulation, using the angle at which the cloud signal is received and the length of the baseline. The light source is modulated by means of a rotating shutter, and the photocell operates in conjunction with a filter and a tuned amplifier to discriminate against ambient light. The present ceilometer provides 10 scans per minute.

At present the ceilometer indications are observed by an operator who interprets a cathode-ray display and obtains answers to a variety of questions. Typical questions might be the following: At what height did most of the clouds occur over the past ten minutes? (or one minute?) What was the lowest level at which a significant number of clouds occurred? The highest level? How many clouds occurred below a certain critical level?

In order to obtain answers to these questions the cloud height equipment samples the ceilometer output and records the height at which the greatest signal is received during each scan. These data are stored in a small 100-word magnetic drum memory which retains ten minutes worth of information. After each scan there is a blank period during which no information is being received, and this time is used to perform an analysis of the stored data. The output of the equipment is a set of answers pertaining to the last ten minutes and this is then updated each scan.

1.1 Brief Description of Operation

Several portions of the equipment are time-shared, as indicated in the block diagram, Fig. 1. The input to the equipment consists of two signals. One is a shaft-position signal from the rotating searchlight, and consists of a pulse at the start of each revolution. The other is the analog signal from the photocell. This is an a-c signal at the modulation frequency of the light source. Its amplitude is determined by the reflecting cloud layer. The shaft position pulse synchronizes an altitude interval counter which counts at the power line frequency, and whose count is related to the angle of the searchlight. The angle is in turn related to cloud height. The cloud heights have been divided into intervals for convenience. The range from 0 to 10,000 feet is divided into 23 intervals, the intervals being small near the ground and becoming larger at higher altitudes. The photocell signal is passed through an analog-to-digital converter which samples the signal in synchronism with the modulated light source. The sampled analog values become pulse trains of varying length, and are compared in the peak-value detector. This determines which portion of the signal has the greatest amplitude, and provides an output signal whenever the input exceeds its previous value. This output is used to transfer the current altitude number from the counter to a buffer. Each new number replaces the previous number in the buffer. Therefore, at the end of each scan the buffer contains the altitude number corresponding to the maximum cloud signal. This number is recorded on the magnetic drum memory in one of 100 spaces. The numbers from successive scans occupy consecutive spaces on the drum. The 101'st number will replace the original number in space number one, which was recorded ten minutes earlier. Thus, the data is continually being updated.

Between scans the data is summarized in the following fashion: The altitude numbers are generated one by one with each number remaining for one revolution of the drum. During the revolution the number is compared with each of the 100 numbers on the drum. Each time this number occurs on the drum a pulse is sent to the peak-value detector. Thus, a pulse train is created for each number and these trains are compared by the peak-value detector to determine which number occurred most often. At the end of this summation the buffer contains the altitude which occurred most frequently over the past ten minutes. The other questions are answered by using counters and additional buffers. If it is desired to know the lowest altitude at which the maximum cloud signal was observed 3 or more times, a counter is pre-set to give an output at the count of 3. This counts the pulse trains and transfers the altitude number into a buffer when 3 or more counts are received, stopping when it has transferred in a number. Similarly, the highest altitude with three or

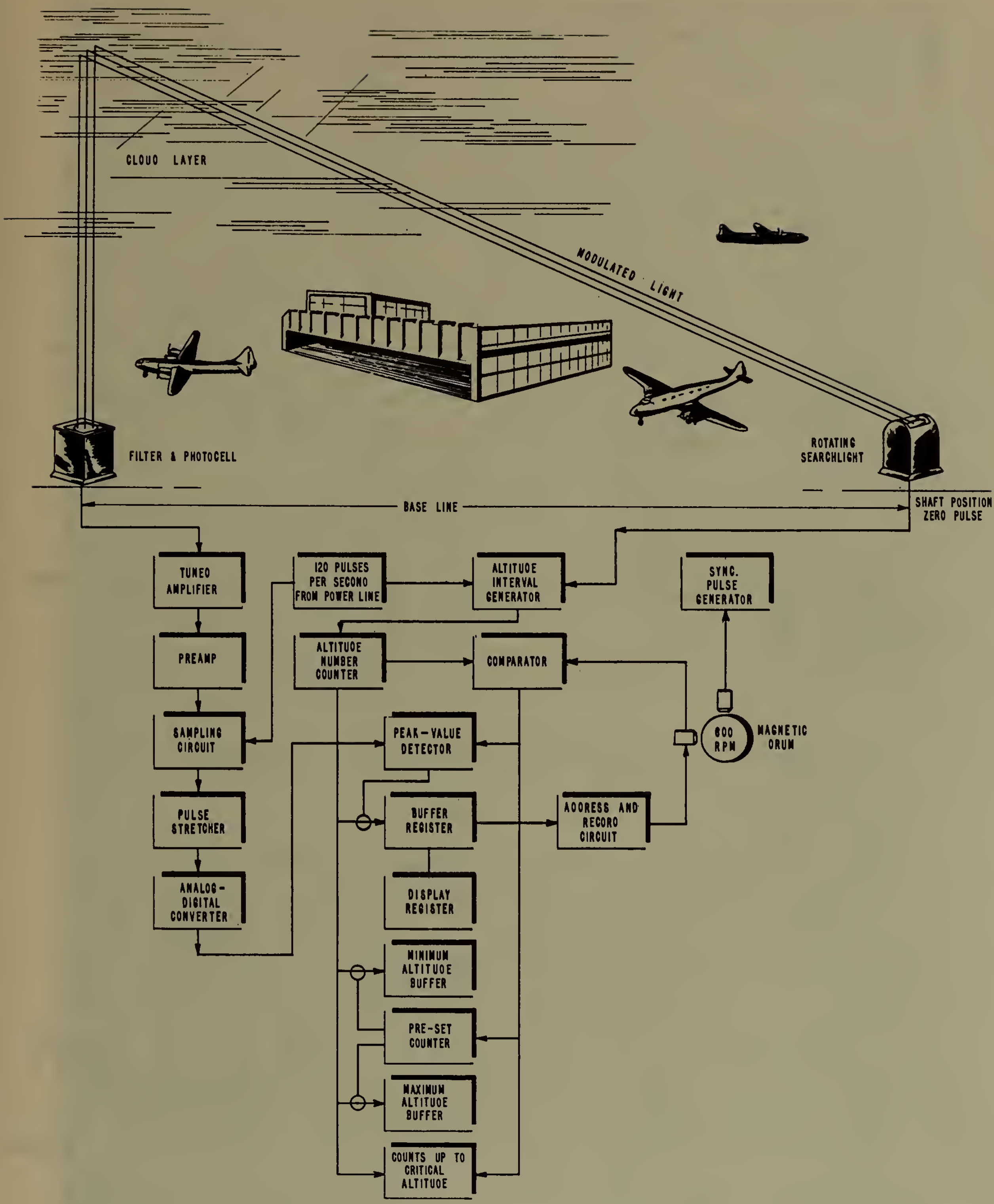


Figure 1. Block Diagram of Ceilometer Computer

more occurrences is obtained by counting the pulse trains and transferring all the altitudes with 3 or more counts into a buffer. Since the numbers are generated in ascending order, the number remaining in the buffer will be the highest altitude which occurred more than 3 times.

The various outputs from the computer are decoded to decimal numbers which are set up as switch contacts. These can be used to actuate remote displays and teletype equipment. Except for the output switches and magnetic drum, the equipment is entirely transistorized, and almost exclusively digital in operation. Thus, a high degree of reliability should be assured. The basic transistor "building blocks" are a dual flip-flop package, a package with 4 NOR circuits each having 4 inputs, a diode gating package with 8 gates, a power driver for operating larger numbers of other circuits, a timer package for accurate, stable delays, an analog switch package, and an indicator package for driving incandescent bulbs. About 145 of these packages are used. The design is flexible enough to permit modifications and additions.

Several manual modes of operation have been incorporated to facilitate testing.

A photograph of the computer appears in Fig. 2. The arrangement of packages on a recessed inner frame can be seen in Fig. 3. This frame is hinged to permit access to the wiring and the inside of the cabinet, as shown in Fig. 4. A rear view of the computer appears in Fig. 5. Several of the packages used in the computer are shown in Fig. 6.

2. DETAILED DISCUSSION OF COMPUTER OPERATION

2.1 Analog-Digital Conversion

The Analog-Digital Converter receives a modulated 120-cycle signal from a photocell in the ceilometer detector. The amplitude of this signal is proportional to the amount of light reflected from clouds passing over the ceilometer. The detector includes an amplifier which is broadly tuned around 120 cycles, in order to discriminate against ambient light. The signal received from a cloud may be very weak, depending on the density, thickness, and height of the cloud, and the presence of rain, fog, or other obstructing layers. These will attenuate both the light projected on the cloud and the reflected light. For these reasons the cloud signals may be so small as to approach the noise level of the photocell. In order to amplify these small signals to a useful value, the amplifier has sufficient

Figure 2. Front View of Computer

Figure 3. Interior View Showing Packages

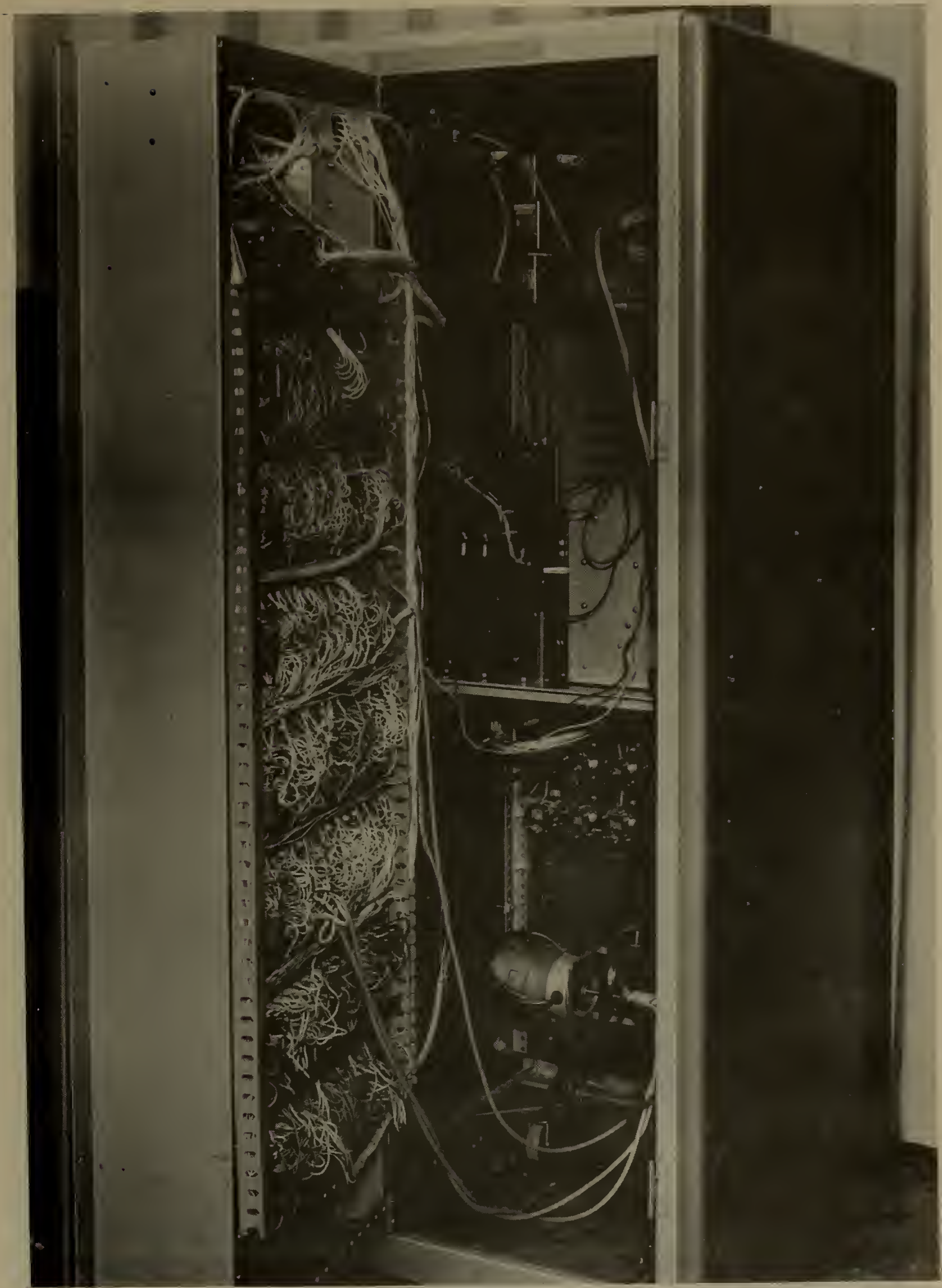


Figure 4. Interior View Showing Wiring

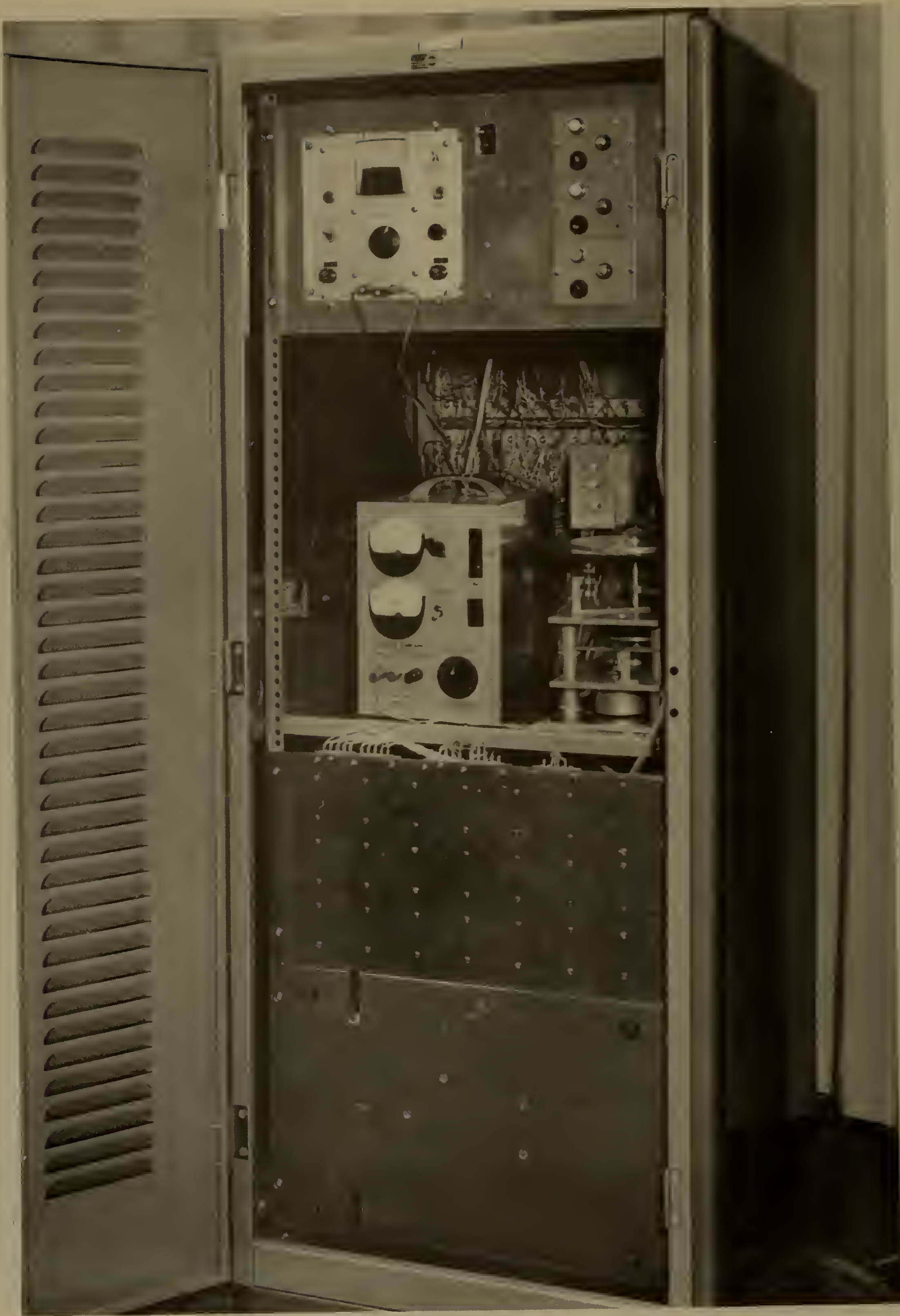


Figure 5. Rear View of Interior

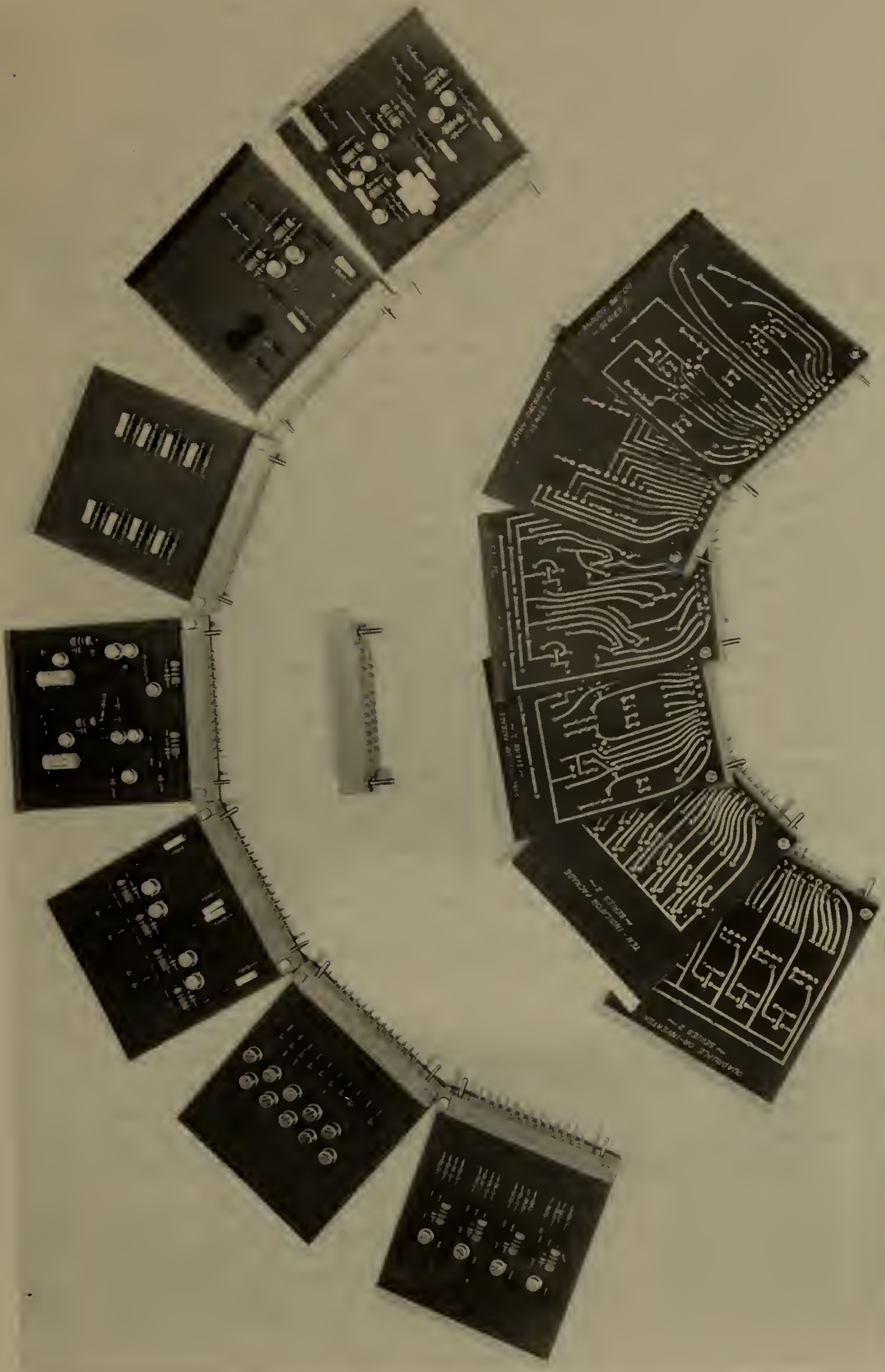


Figure 6. Photograph of Typical Packages

gain so that the noise voltage is always noticeable in the output. Because of the restricted bandwidth of the amplifier, the noise signals are similar in appearance to the 120-cycle cloud signals. However, there is an important distinction in that the 120-cycle signals are coherent from one to another, whereas the noise signals have their phases randomly displaced with respect to one another. The light source in the ceilometer is modulated by a full synchronous motor, so that the 120-cycle light signal maintains a constant phase relationship with the power line. Actually, there are two searchlights in the projector, with the light beam coming from first one and then the other. Each of these has its own lamp and rotating shutter, and it is necessary that the shutters be properly adjusted with respect to their motors so that the modulation produced by each shutter has the same phase relationship with the power line. When the shutters are properly adjusted, the cloud signals will always have the same phase relationship with the power line, whereas noise signals will occur randomly. Thus, by sampling the photocell synchronously with the power line it is possible to obtain a substantial degree of discrimination against noise. The sampling circuit is adjusted to sample the photocell signal at those instants at which the negative peaks of the 120-cycle signal occur. Since the noise is random, the peak values of the noise will seldom occur at these instants; the sampled voltages will generally be less than the peak values. The sampling process is illustrated in Fig. 7. Actually, if the sampled values were allowed to be both positive and negative, and were averaged over a sufficient time, the noise would average zero, whereas real signals would be preserved. However, with the 120-cycle signal and a 3-second scan time, there are not enough cycles over each altitude interval to permit averaging of the sampled values. Nevertheless, there is still a worthwhile amount of discrimination. First, real signals are always sampled at their peak values. Second, only the negative peaks are sampled, and for real signals this will always yield a value. However, the sampling circuit has zero output for positive voltages. Since the noise is just as likely to be positive as negative at the sampling instant, the sampled values for noise will be zero half the time. Thus, if a real signal is present, even though quite small, it has a greatly increased chance of being recognized above the noise.

2.1.1 Sampling Circuit

A signal of 120 pps (pulses per second) is derived from the 60-cycle power line, through the use of a full-wave rectifier driving a flip-flop. See Fig. 7. This circuit consists of a pair of diodes from the secondary of a 6-volt filament transformer, the centertap of which is grounded. The cathode leads of the diodes are joined

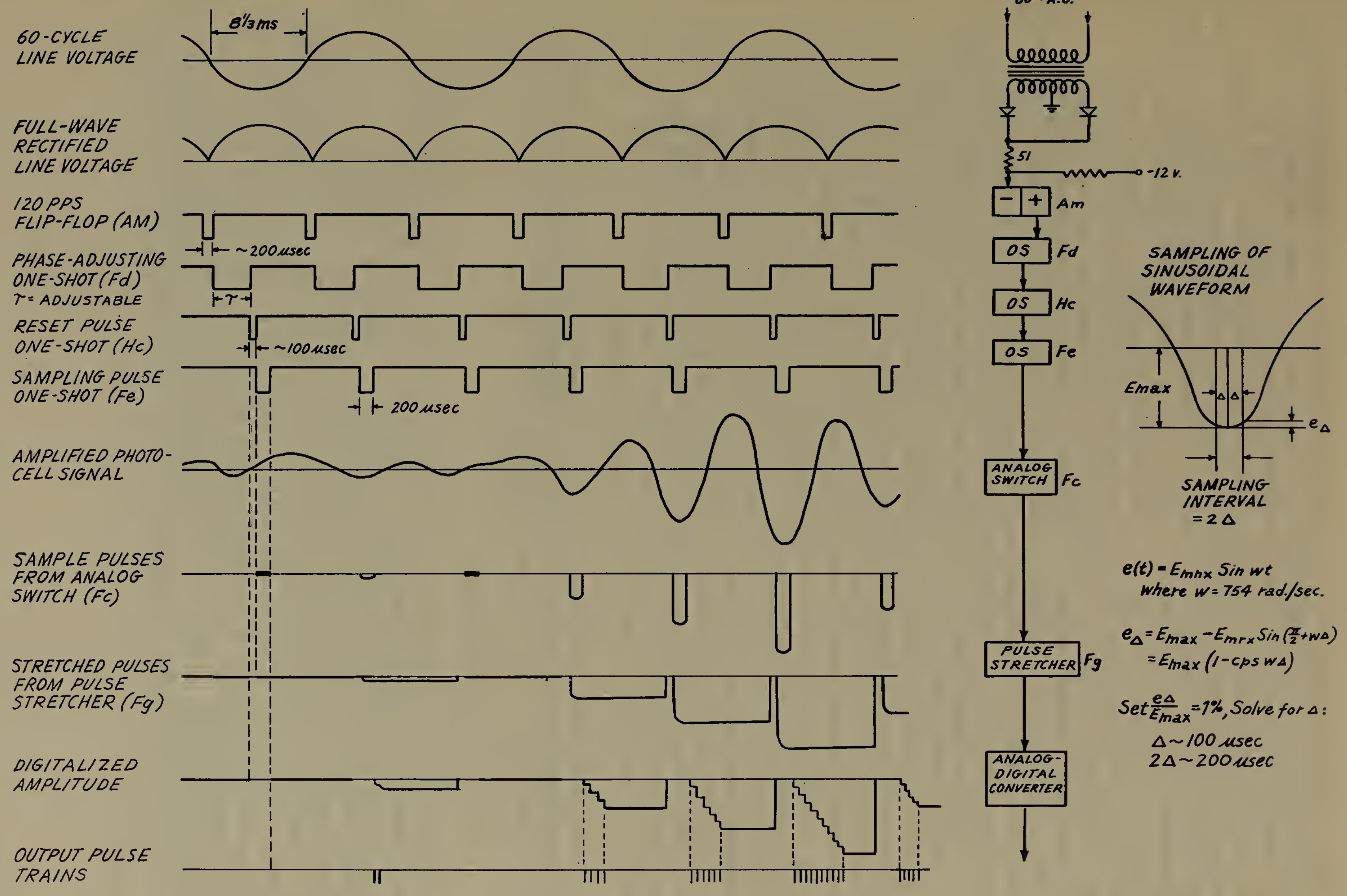


Figure 7. Sampling Process and Analog-Digital Conversion

together and fastened by means of a 51-ohm resistor to the base of the flip-flop. This point is connected to -12 volts through a 5K resistor, so that this side of the flip-flop normally tries to conduct. However, the diodes ordinarily keep the base positive, and cut off, except during the brief interval during each half-cycle when the transformer output voltage passes through zero. The output of the flip-flop is a pulse about 200 microseconds in length at a rate of 120 pps. This signal is used to trigger a one-shot (Fd) which serves as a phase adjustment, in order to permit the sampling process to be centered at the negative peaks of the 120-cycle photocell signals. This one-shot can be adjusted up to a few milliseconds. This, in turn, drives a second one-shot (Hc) which furnishes a reset pulse. This one-shot drives a third one-shot (Fe) which is adjusted for the duration of the sampling interval. The sampling one-shot (Fe) is set so that the width of the sample is as long as possible in order to permit charging of a large storage capacitor. This capacitor is used in a pulse-stretching circuit which preserves the amplitude of the sampled pulse long enough for the operation of the analog-digital converter. It is desired that the amplitude of the sampled pulse be within 1% of the peak value of the input signal. Examination of a sine wave, as shown in Fig. 7, indicates that the value of a 120-cycle signal is within 1% of the peak value for about 200 microseconds. This is the setting used for this one-shot (Fe). This one-shot operates an analog switch (Fc) which is turned on for the duration of the sampling interval. The incoming signal is applied to this switch, and the output of the switch is a sampled pulse 200 microseconds long. having an amplitude equal to the incoming signal.

The sampled pulse is applied to a pulse-stretching circuit (Fj) which preserves its value for several milliseconds in order to allow time for the value to be digitalized.

2.1.2 Pulse Stretcher

This circuit consists of an emitter-follower with a capacitor from emitter to ground (Fig. 8). Initially the capacitor is discharged by means of another transistor. When a sampled pulse is applied to the base of the emitter-follower, the capacitor is charged to a voltage which closely approaches the pulse amplitude. When the applied voltage goes to zero the transistor is turned off and the capacitor remains charged. The voltage on the capacitor is applied to the base of a second emitter-follower which acts as a high-impedance load, and which in turn provides the input to the analog-to-digital converter. The charge on the capacitor leaks off slowly through the back resistance of the charging transistor and the input resistance of the output transistor. However, it remains within a few per cent of its initial value for 2000 microseconds or so, which is the longest time that would be required for the analog-to-digital converter to reach a balance. Any error introduced by decay of the charge does not affect the relative accuracy of the final results, since the amount of decay would be the same for two signals of the same amplitude.

2.1.3 Analog-Digital Converter

The pulse stretcher output is applied to a comparator (Fh) which controls the analog-digital converter (Fig. 9). The converter is of the ramp type, which means that an accurate stairstep voltage is produced which stops increasing when it reaches the value of the unknown voltage. This stairstep is produced by means of a 7-bit binary counter which operates a set of analog switches. These in turn connect a set of carefully adjusted networks to an accurate reference voltage. The counter is driven by a blocking oscillator (Fa), which triggers a one-shot (Gp) at a rate of about 35 kc. As the counter advances, the various networks are switched in and out, in such a fashion that the output voltage increases in small, accurate increments. The converter divides the range from 0 to 10 volts into 128 steps, giving a resolution slightly greater than 1%. This stairstep voltage is applied to the comparator, together with the unknown voltage, and the stairstep is terminated when the two voltages are equal. At this point the number in the counter represents the value of the unknown voltage. The sequence of operation is as follows:

The 120 pps timing pulses which trigger the sampling process also reset the pulse stretcher and the 7-bit counter. When the phase-adjusting one-shot (Fd) goes off it triggers a reset one-shot (He) which resets the pulse stretcher (Fg) and the counter. The trailing edge of this pulse triggers the sampling one-shot (Fe). This causes the input voltage to be sampled via an analog-switch (Fc) and the voltage is applied to the pulse stretcher. The "stretched pulse" is applied to the comparator (Fh). When the sampling one-shot goes off it triggers a control flip-flop (Ff) which opens a gate (OR-inverter Fb) allowing pulses from a 35-kc blocking oscillator (Fa) to drive the counter. The counter then advances until its output just exceeds the unknown voltage, at which time the comparator puts out a pulse which resets the control flip-flop (Ff) gating off the input to the counter. Nothing further occurs until the next 120 pps timing pulse. The blocking oscillator (Fa) drives a one-shot (Gp) which serves two purposes. First, the pulse from the blocking oscillator is too narrow (about 1 microsecond) to pass through an OR-inverter. The one-shot increases this width to 20 microseconds. Also, the comparator must be triggered in order to perform a comparison, and must be held off during the switching transients which occur as the counter is advanced. The pulse

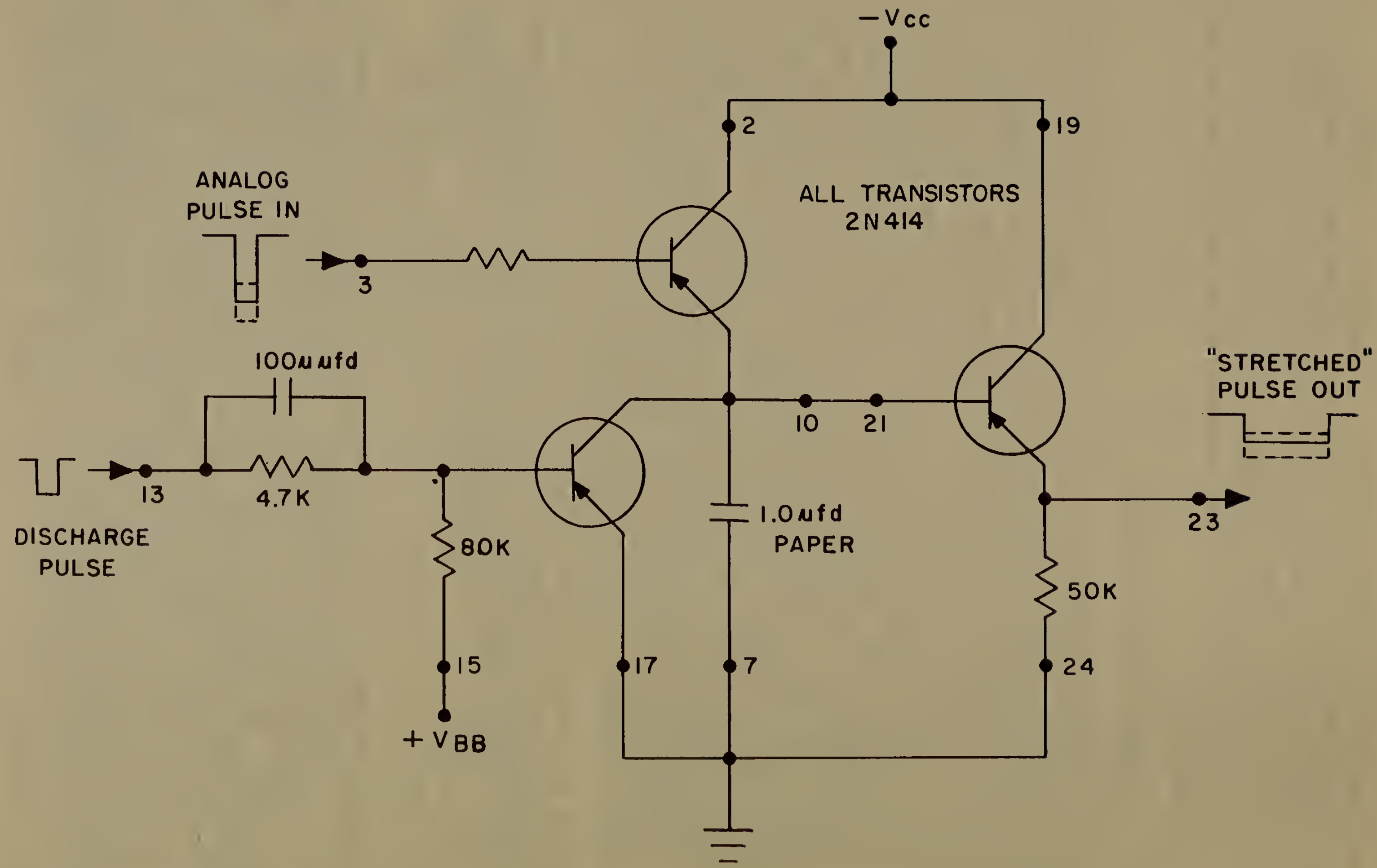


Figure 8. Pulse Stretcher

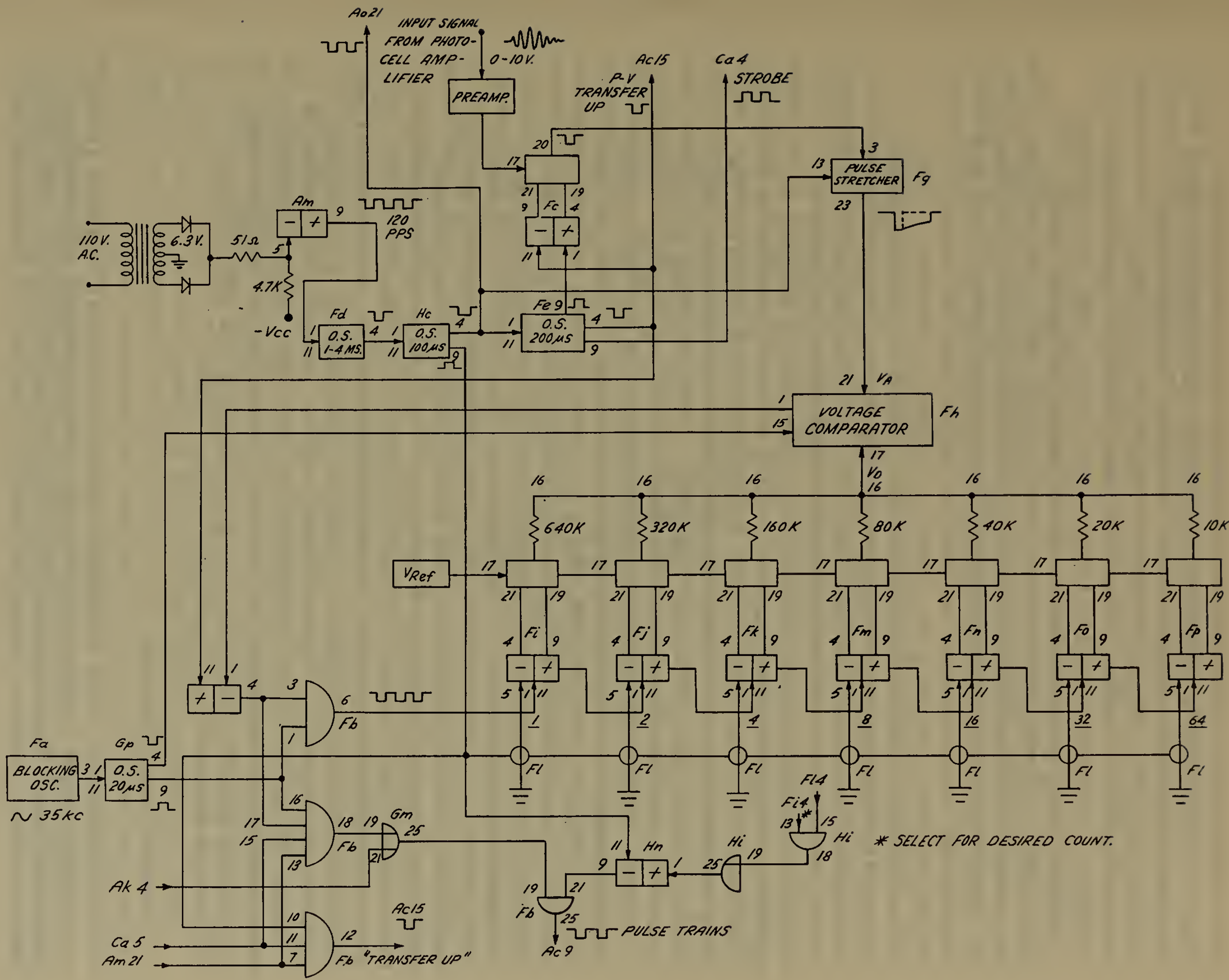


Figure 9. Analog-Digital Converter

from the one-shot inhibits the comparator at the instant the counter is advanced, and holds it off until the transients have disappeared and the output of the converter has stabilized. The one-shot then unclamps the comparator, allowing a comparison to be made. It will be noted that the input to the counter is a series of pulse trains, at a 35-kc rate, the number of pulses being proportional to the unknown voltages being digitalized. These pulse trains also constitute the output from the converter, and are sent to the peak-value detector, during the input cycle. A separate gate (OR-inverter Fb) is used for controlling these signals, so that the output may be turned on and off without affecting the operation of the converter. The converter thus functions continuously. There is an additional gating circuit in series with these output pulses which is used to establish an amplitude threshold for incoming signals. This circuit is designed so that unless the digitalized value of a signal exceeds a certain preset count the pulses will not be gated to the peak-value detector. This circuit operates in the following way: The output pulse trains from OR-inverter Fb are inverted (Gm) and sent to an additional OR-inverter (Fb) which is controlled by a flip-flop (Hn). This flip-flop is reset so as to close the gate each time that the analog-digital converter is reset. An OR-inverter (Hi) has inputs from several of the counting stages of the analog-digital converter. When the pre-selected count is reached during a pulse train, this OR-inverter puts out a pulse which triggers the gating flip-flop (Hn), thus allowing the remainder of the pulse train to be transmitted to the peak-value detector. A preselected count of 6 is presently being used, with the inputs to Hi being obtained from the second and third counting stages (Fj and Fk). One additional output signal is required from the converter. The peak-value detector requires a signal before the start of each new pulse train, in order to permit the number in the adder register to be transferred into the subtractor register. (This is explained in detail in the section on the peak-value detector.) This "transfer up" pulse is obtained from the reset one-shot (Hc) since this pulse precedes each pulse train and does not extend into the period where counts are taking place. This pulse is gated through an OR-inverter (Fb) which is open only during the input cycle.

2.2 Peak-Value Detector

This portion of the computer receives a series of pulse trains of varying length. Its purpose is to put out a signal whenever an incoming pulse train exceeds the largest previous train. It is time-shared during both the input and analysis cycles. It functions in exactly the same way during both cycles, and its output is used in the same way; namely, to transfer a number (the altitude number) from a counter to a buffer. During the input cycle it determines the point at which the maximum cloud signal occurs; during analysis it detects the most frequent altitude number.

The peak-value detector consists of two registers: an adder and a subtractor. (Fig. 10.) There is a control flip-flop (Bj) which allows incoming pulses to go into either the adder (lower halves of flip-flops (Ba-Bi) or the subtractor (upper halves). Operation of this device is as follows:

Initially both registers are at zero. The control flip-flop allows the first pulse to go into the subtractor, causing the flip-flops to change to all one's. The last "borrow" pulse flips the control flip-flop, allowing the trailing edge of this first input pulse to be counted by the adder. Succeeding pulses go only into the adder, so that at the end of this first pulse train it has a count equal to the number of pulses in the train. At the end of the train this number is transferred from the adder into the subtractor, and the control flip-flop is reset. The same number is now in both the adder and subtractor. Pulses from the next train start into the subtractor. If there are fewer pulses in this train than in the previous one, the subtractor will not go through zero; hence, the control flip-flop will not change. At the end of this train the previous number is again transferred into the subtractor. If, now, a pulse train is received which is longer than the original train, counts will be subtracted from the subtractor until it goes through zero; the balance of the pulses will then be added to the number in the adder. Thus, the number in the adder is brought up to the value of the new number. At the end of a series of such comparisons the adder has stored in it a number equal to the longest pulse train that was received. The significant fact, however, is that the control flip-flop changed state each time a new pulse train exceeded the largest previous one. These changes of state constitute the output signals from the detector, and the last one will occur during the largest pulse train that is received. One special condition should be noted. When no cloud signal is received during an input scan, the highest altitude number is recorded, namely, the binary number "23" (11101). During analysis the number of occurrences of this number will be counted along with the rest of the altitude numbers. However, it is not desirable to read out an all-clear indication unless the all-clear value occurs at least 80% of the time (or some similarly large preselected percentage). In order to achieve this result a special gate is attached to the adder register. An OR-inverter (Al) receives signals from the "16" and "64" stages of the adder register

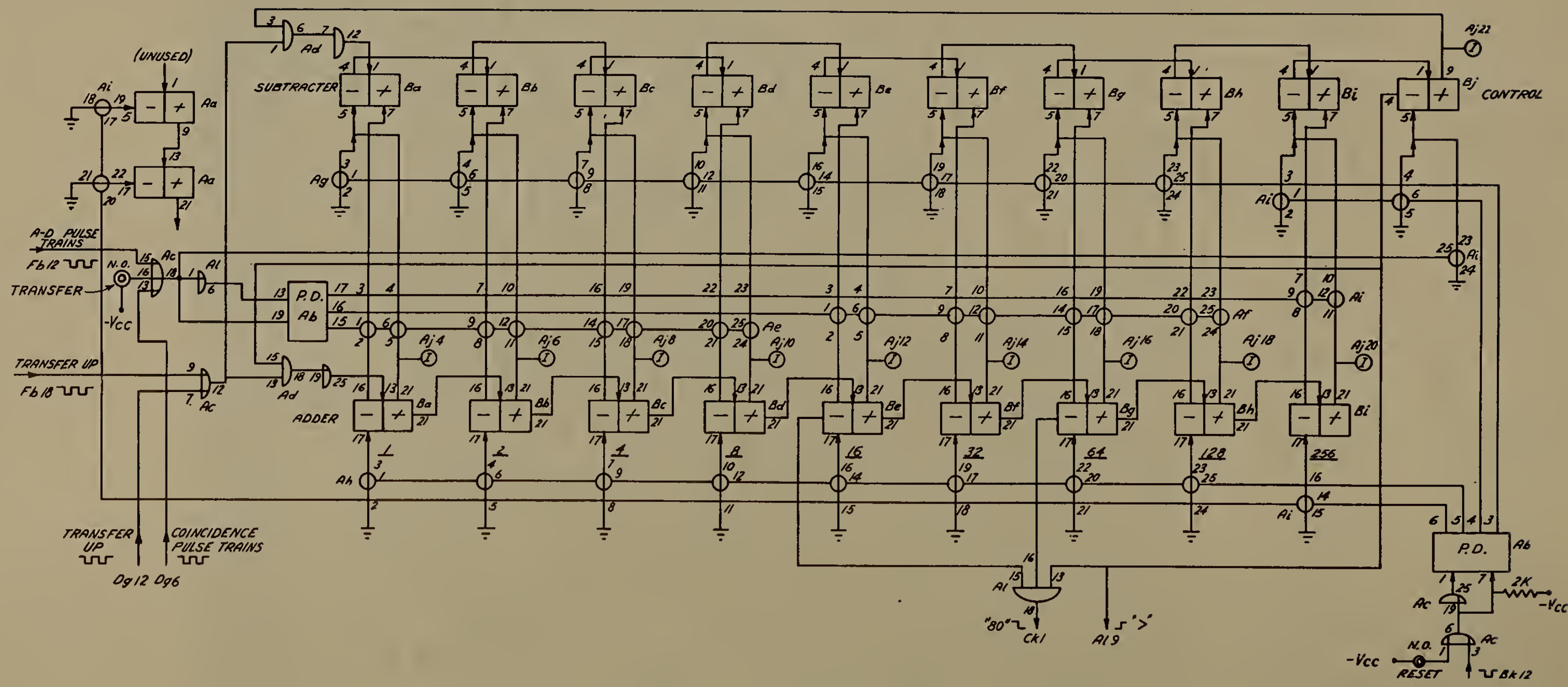


Figure 10. Peak-Value Detector

and also from the control flip-flop. The output from this gate is used when reading number "23", and will cause this number to be transferred into the buffer register if it occurs 80 or more times.

During the input cycle, pulse trains are supplied to the peak-value detector from the analog-to-digital converter. During the analysis cycle the detector receives coincidence pulses from the comparator circuit. These pulses are OR'd through an OR-inverter (Ac) and are fed to the input of either the subtractor register or the adder, as determined by the control flip-flop (Bj) and four OR-inverters (Ad). Prior to each pulse train, the contents of the adder register are transferred up into the subtractor, and the control flip-flop is reset. This is done by means of a power driver (Ab) operated from OR-inverters Ac and A1. The input for this purpose is from either the comparator circuit or the analog-to-digital converter. These signals are OR'd through an OR inverter (Ac) together with a normally-open push-button to -12 volts. Thus, the transfer can be performed manually, for test purposes. The detector is zeroed at the beginning of the input and analysis cycles by means of a power driver (Ab). This receives a reset pulse from the input-control circuit, and may also be energized by a normally-open push-button to -12 volts. Indicator lights are operated by the adder register, and indicate the number stored in this register, which is the peak value. A light on the control flip-flop comes on whenever the subtractor register goes through zero, indicating an increase in the peak value.

2.3 Altitude Number Counter

The altitude number counter generates numbers which represent the various altitude intervals of interest. There are presently 23 such intervals, as shown in the Table, Fig. 11. A five-bit binary counter is used, (Fig. 12) and hence there are potentially 32 numbers available, since $(2)^5 = 32$. However, feedback is used to reset the counter to zero at the count of 24. This counter is time-shared, and functions during both the input and analysis cycles. The analysis cycle is actually terminated when the count of 24 is reached.

During the input cycle the counter is advanced in accordance with pulses which correspond to various angular positions of the rotating searchlight, and hence represent various altitudes. At the same time, the photocell signal from the detector is being converted into pulse trains by the analog-to-digital converter, and these are being compared in the peak-value detector. Each time the peak-value detector detects an increase in the photocell signal, it develops a signal

Altitude Number	Binary Form 1 2 4 8 16	Nominal Height, Hundreds of Feet
1	10000	00 (00)
2	01000	01
3	11000	02
4	00100	03
5	10100	04
6	01100	05
7	11100	06
8	00010	07
9	10010	08
10	01010	09
11	11010	10
12	00110	12
13	10110	15
14	01110	20
15	11110	25
16	00001	30
17	10001	40
18	01001	50
19	11001	60
20	00101	70
21	10101	80
22	01101	90
23	11101	99

Limits, Hundreds of Feet	Angle, Degrees	Number of Counts, 120 pps
0	0	000
50	6 3/4	027
150	16 3/4	067
250	26 1/2	106
350	35	140
450	42	168
550	47 3/4	191
650	52 1/2	210
750	56 1/4	225
850	59 1/2	238
950	62 1/4	249
1100	64 1/2	258
1350	69 3/4	279
1750	74	296
2250	77 1/2	310
2750	79 3/4	319
3500	81 3/4	327
4500	83 3/4	335
5500	84 3/4	339
6500	85 1/2	342
7500	86 1/4	345
8500	86 3/4	347
9500	87	348

Figure 11. Table of Altitude Intervals

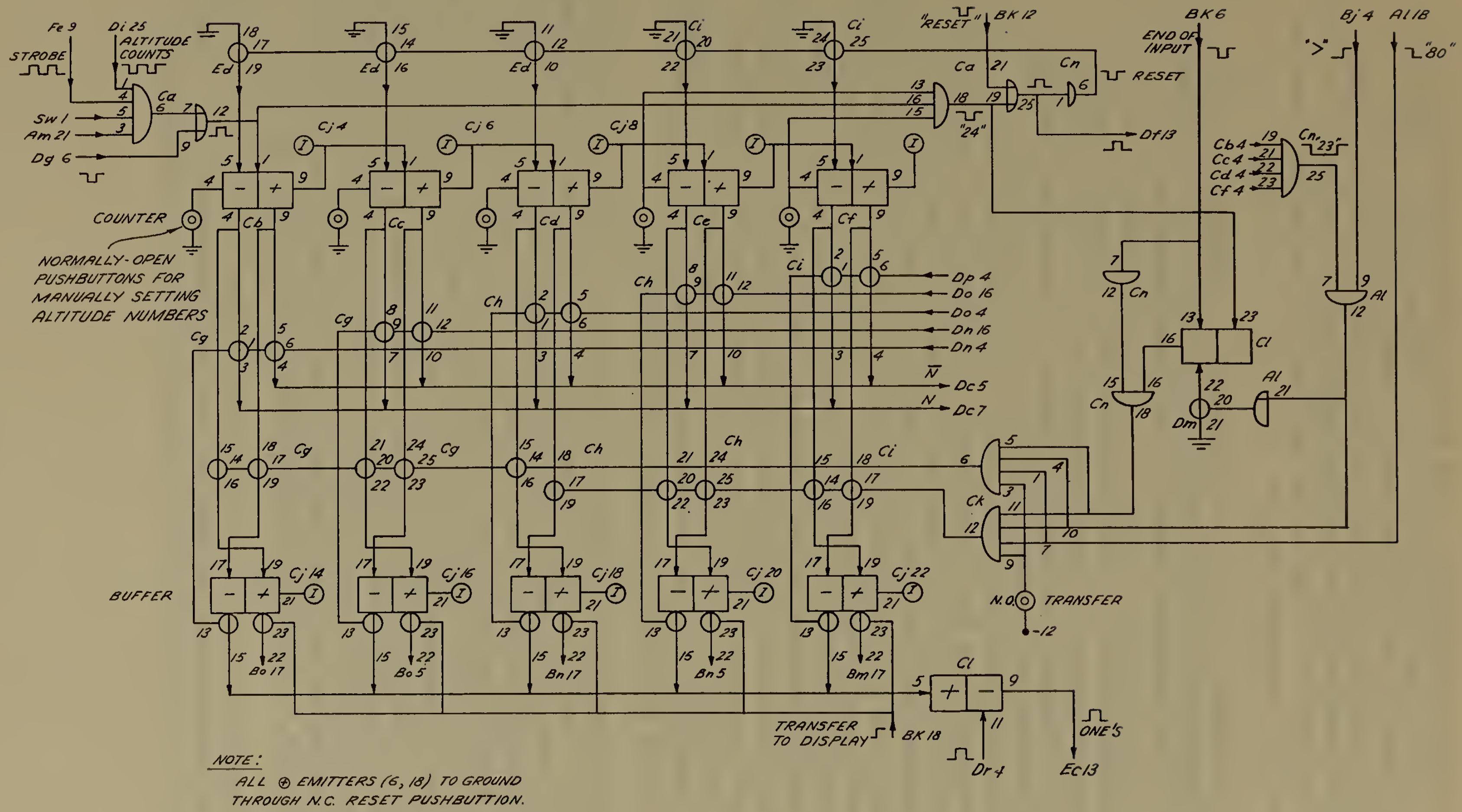


Figure 12. Altitude Number Counter and Buffer

(its control flip-flop changes state) which causes the current altitude number to be transferred into a buffer register. Thus, at the end of the input cycle the buffer contains the altitude number for which the greatest cloud signal was received. This number is then recorded on the magnetic drum in the next consecutive address. In the event that no cloud signal is received the number "23" corresponding to "all clear" is recorded.

During the analysis cycle the counter is advanced by pulses from the comparator circuit, which occur at a rate of once per revolution of the magnetic drum. Thus, all of the altitude numbers are generated, one by one, with each remaining for one revolution of the drum. A comparator circuit compares each altitude number with all of the 100 numbers stored on the drum and generates trains of coincidence pulses. These pulse trains are fed to the peak-value detector which determines which altitude number occurs most frequently. The output of the detector accomplishes the same function as during the input cycle; namely, whenever a new number occurs more frequently than a previous number, this number is transferred into the buffer register. Hence, at the end of the analysis cycle the buffer contains the altitude number which occurs most frequently on the drum. The altitude numbers are generated consecutively, in ascending order. If two altitudes occur the same number of times, the lower one will remain in the buffer, since an increase is required to produce a transfer signal. The "all clear" signal must occur at least 80% of the time in order to be transferred into the buffer. At the end of the analysis cycle the contents of the buffer are transferred to a storage register, from which they are decoded to the output display.

The above description applies to the mode, or most predominant cloud height. Two other altitude numbers are transferred out during the analysis cycle. These are the minimum and maximum altitudes at which significant activity was observed. By "significant activity" is meant a preset number of observations, such as 3 or more over the observation period. These are described more fully under the max-min circuitry. There is also a counter which counts the number of observations up to the critical height. A gate opens at the beginning of the analysis cycle and allows coincidence pulses to actuate this counter until the critical altitude number occurs, at which time the gate closes. A suitable gating structure is wired to the altitude number counter for this purpose, as described under the critical height counter.

For purposes of the comparator, the altitude number is serialized by means of commutating pulses on five lines from the sync. circuit. These pulses correspond to the bit positions on the magnetic drum, and each set of five correspond to one word on the drum. Thus, the first bit of the counter is sampled during the first bit of a word on the drum; then the second, third, and so on. The resulting outputs appear on a pair of lines marked N, $\overline{N}$. The N line will have a positive spike if the flip-flop being sampled is in the "one" state. The $\overline{N}$ line will have a positive spike if it has a "zero".

The output of the buffer goes either to the record circuit (end of input cycle) or the output storage register (end of analysis). For the record circuit it is again desirable to serialize the number, making use of the commutating lines from the sync. circuit. However, since a NRZ (non-return-to-zero) recording is used, it is only necessary to sent "one's" to the record circuit. Since the commutating lines are always active, it is necessary to gate off the serialized buffer contents, except for the single word during which it is recorded. The differentiated spikes developed by the commutating circuit (R-C-diode gates are used for this purpose) cannot be passed through an OR-inverter. Hence, they are used to trigger a flip-flop (C1) which is reset near the end of each bit by a one-shot in the comparator circuit which is triggered for each bit. Thus, the flip-flop is always in the zero state at the beginning of a bit; if the corresponding bit in the buffer is a "one", the flip-flop (C1) will be set to the "one" state, then reset to zero. If the bit in the buffer is a "zero", the flip-flop will remain in the zero state. Thus, a square pulse is obtained from the flip-flop for each "one" in the buffer, and this pulse can be passed through an OR-inverter, as required.

Counting pulses to the altitude number counter are OR'd in an OR-inverter (Ca) from the two different sources. The searchlight position pulses are passed through an extra OR-inverter (Ca) which permits them to be gated off during analysis and during manual operation. The count of 24 is recognized by combining the outputs of the 4th and 5th bits in an OR-inverter (Ca) together with the input pulses to the counter. The output from this OR-inverter is a negative pulse at the count of 24 which is equal in width to the input pulse. The trailing edge of this negative "24" pulse is used to reset the altitude number counter at the count of 24, during the analysis cycle. This is also the signal for the analysis to terminate. Note that this "24" pulse is OR'd with a reset pulse from the control circuit (OR-inverter Ca), requiring an additional OR-inverter (Cn) to regain a negative pulse. During the input cycle the counter does not reach 24, since there are only 23 altitude interval pulses. The control circuit furnishes a reset pulse at the beginning of the analysis cycle, and also at the beginning of the input cycle.

Transfer of the altitude number into the buffer is accomplished by two OR-inverters (Ck) driving gating packages, with the gates divided between them. Note that all four inputs to these OR-inverters (Ck) are used. The rules for transferring numbers into the buffer are complicated by the special way in which "all clear" signals (number 23) must be handled.

During the input cycle it is desired to transfer "23" into the buffer if there has been no cloud signal above the amplitude threshold established in the analog-digital converter. Accordingly, a control flip-flop (C1) is reset at the end of each analysis cycle and this flip-flop controls a gate (Cn) which is strobed by an "end of input" pulse. The control flip-flop (C1) has a "set" input from the peak-value detector, so that if a signal is received by the detector during the input cycle its output will trigger the control flip-flop and close the gate (Cn). Thus, if no signal is received during an input cycle, the "end of input" pulse will pass through the gate (Cn) and transfer the number "23" into the buffer. If, however, a cloud signal occurs, the flip-flop is triggered to its opposite state, and the "end of input" pulse cannot pass through. The buffer would not receive number "23", but would have the altitude at which the cloud was received.

During analysis it is desired to transfer down the "all clear" number only if it occurs 80 or more times. In the section on the peak-value detector it was explained that there is a special output signal corresponding to a count of "80 or more". This signal goes into the transfer gates (Ck) at all times. However, the normal signal, which is the "greater than" pulse, is gated off (via OR-inverter A1) during the analysis of number "23". The count of 23 is recognized by an OR-inverter (Cn) with inputs from the appropriate counter stages. Thus, it is not sufficient for the number of occurrences of "23" to merely exceed the most frequent cloud height. It must actually occur 80 or more times in order to be transferred into the buffer.

For manual operation, altitude numbers can be transferred into the buffer by means of a normally-open pushbutton to -12 volts at the input to the OR-inverters (Ck).

Note: This push-button is OR'd with the output from the control flip-flop (Bj) of the peak-value detector. If the control light is "on", the input to the OR-inverters will be held negative and the push-button will not operate. The peak-value detector must first be zeroed. Indicator lights are operated by both the altitude number counter and the buffer.

2.4 Synchronizing Pulse Generator

Communication with the magnetic drum requires a knowledge of where the information is placed on the drum. NRZ (non-return-to-zero) recording is used; hence, there is no indication as to where one bit ends and the next bit begins if the second bit is a zero. Nor is it ordinarily possible to tell where a word starts and stops. In order to establish word and bit positions on the drum, therefore, a sync. channel is added, which is entirely independent of the information channel. It feeds into a read amplifier only; there is no provision for recording on the sync. channel.

Note: Care should be used not to disturb the sync. channel. Never measure the sync. read head with an ohmmeter, as the meter current could result in an erasure. Do not bring magnetized objects near the drum. Use care not to short-circuit any instrument probe to the read circuit input connections which might apply power to the read head. Recording of the sync. channel takes only a moment with the proper equipment, but special circuits must be constructed for this purpose and they will not ordinarily be readily available.

The sync. channel has 100 six-bit words recorded on it, with one's in every bit position. The one's are uniformly spaced with a gap between words which is equivalent to two one's. This pattern is shown in Fig. 13. At a drum speed of 600 RPM, or 10 revolutions per second, the bit spacing is about 120 microseconds. The 100 words require about 96,000 microseconds, leaving a gap of about 4,000 microseconds (since each revolution takes 1/10 second or 100,000 microseconds) where no information is recorded.

The sync. circuit produces three outputs - revolution pulses, word pulses, and bit pulses. This circuit is shown in Fig. 14. The revolution pulse is produced by means of a special circuit using a one-shot (Ek) operating in conjunction with a pair of OR-inverters (Dj, Dl), which acts as a gap sensor. The one-shot is set for about 2 milliseconds and is constantly restarted by the bit pulses. It does not run through its normal time period until an interval of about 2 milliseconds elapses without any bit pulses. Then it completes it normal period and generates a step corresponding to one revolution of the drum. This step exists until the bit pulses occur again. This one-shot triggers a second one-shot (Ep) which gives a revolution pulse of about 200 microseconds, the width being not at all critical. As an indication that this circuit is running, the revolution pulses cause a flip-flop (Ea) to count at a rate of 10 pulses per second. This, in turn, operates the Revolution Pulse Light which blinks on and off, producing five flashes per second.

The remainder of the sync. circuit is a six-bit ring counter, in which each stage represents one bit-position in the words. The altitude numbers which are recorded on the drum are five-bit words. However, space has been allotted at the end of each word for a sixth bit; this bit serves as the end-of-word signal, and also allows a parity bit to be added to the numbers being recorded. This is discussed in the section on the record circuit. Every revolution the ring counter is reset to its zero condition, which consists of the first five bits being zeroes. At the first bit after the revolution pulse the first stage becomes a "one", and the sixth stage goes to zero. At the second bit, the "one" advances to the second stage, and so on. The sixth bit signifies the end of a word, and when the sixth stage comes on it triggers the word one-shot (Eb). This one-shot is in the record circuit and its timing is critical. It is discussed further in that section. The five stages corresponding to information bits actuate five commutating lines which are used to serialize numbers from the altitude number counter and the buffer register. The bit pulses perform two functions. They cause the record circuit to record one's in the proper locations, and they indicate the bit locations for purposes of the read circuit.

2.5 Address Counter

The Address Counter keeps track of the 100 word locations on the drum and causes each successive number to be recorded in the next consecutive position. In normal operation the address circuit is triggered at the end of the input cycle, signifying that a number is ready to be recorded. The address counter is then activated and produces a pulse when the appropriate drum location occurs. This pulse activates the record circuit, causing the number to be recorded. The actual circuitry is made more complex by the addition of several control functions which are needed to obtain the correct timing, and to provide several manual modes of operation for test purposes.

Basically, the address circuit consists of a two-decade counter and a gate circuit which can be opened for one revolution of the drum (Fig. 15). When this gate is triggered it admits a train of 100 word pulses into the counter, plus one additional pulse at the start. Thus, the counter cycles through its full capacity, passing through zero in the process, and returning to its original number, plus one. When the counter reaches zero the trigger pulse for the record circuit is produced. As successive numbers are recorded, the counter keeps advancing by one each time, with the 100 word positions on the drum being used consecutively. Normally, this

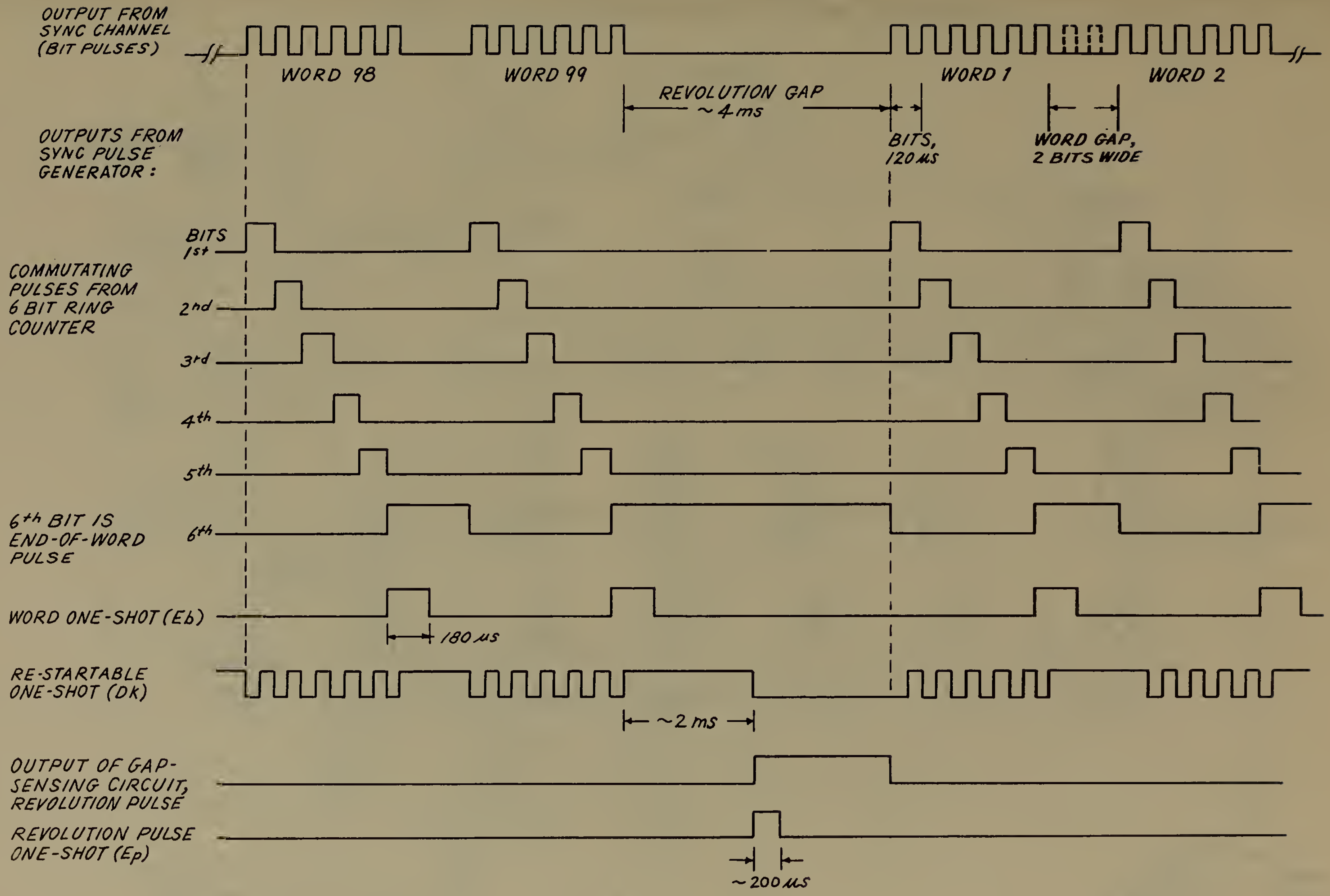


Figure 13. Synchronizing Pulse Pattern

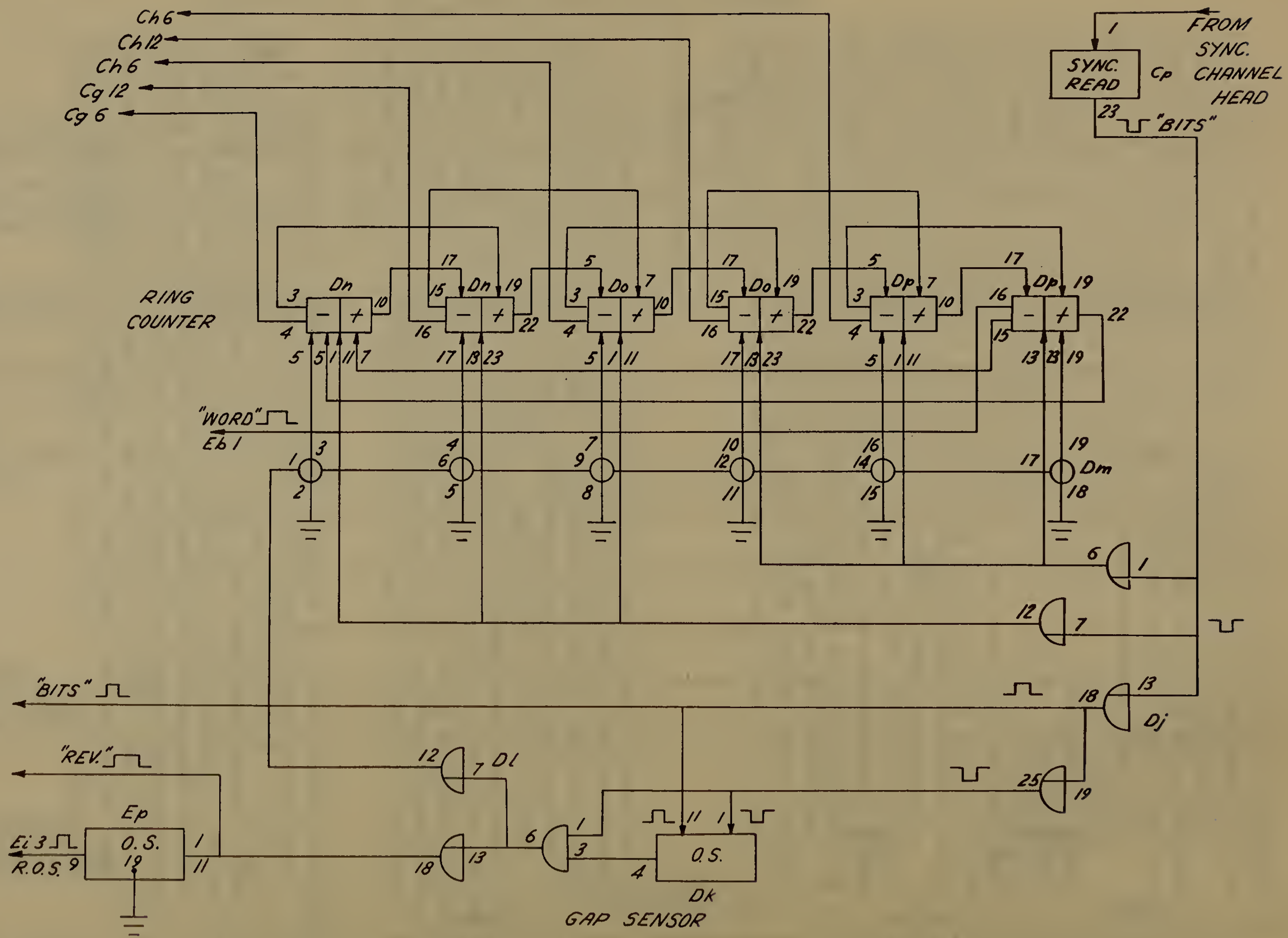


Figure 14. Synchronizing Pulse Generator

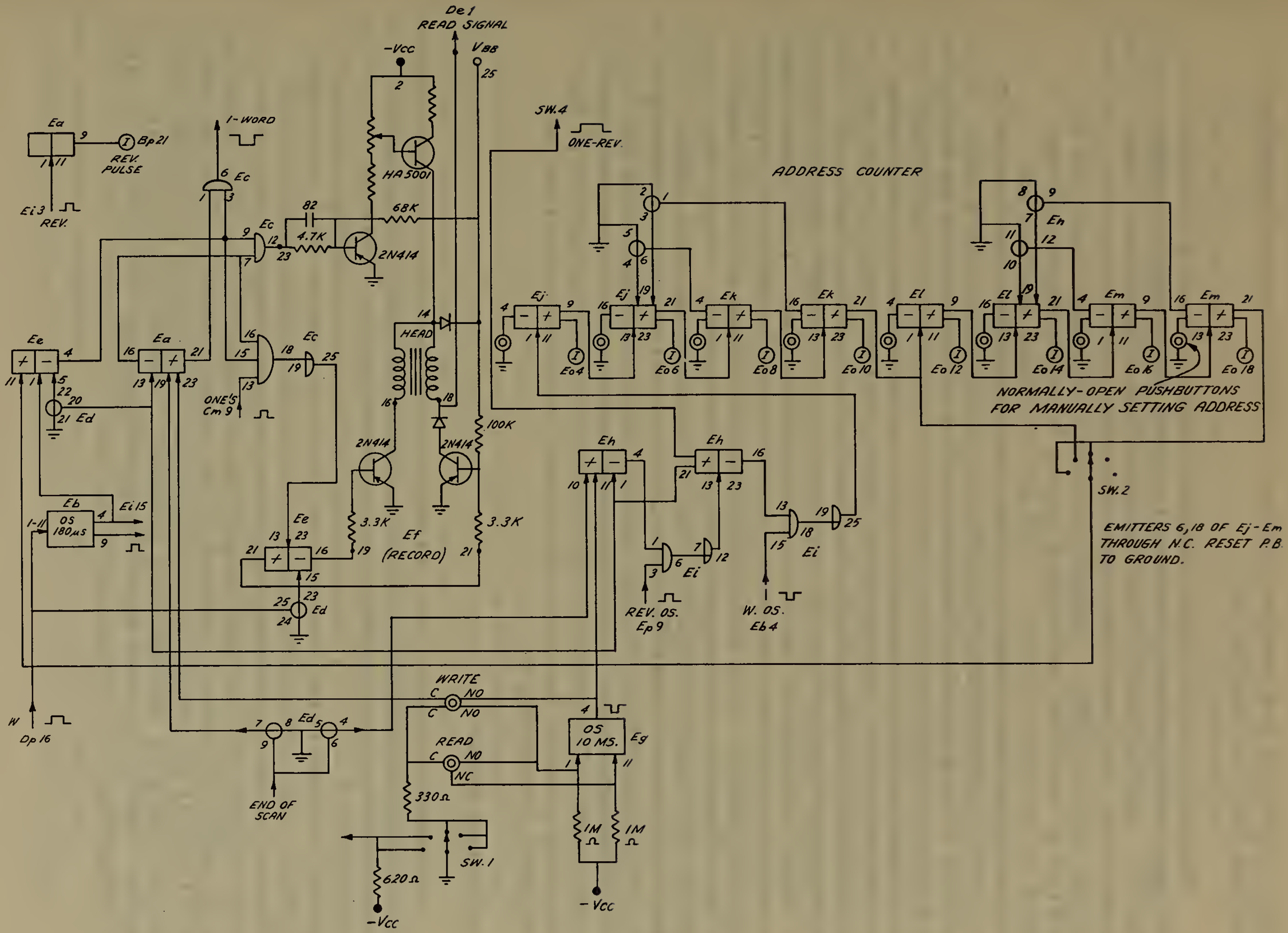


Figure 15. Address Counter and Record Circuit

would represent ten minutes of data, with each number replacing one that was ten minutes old.

The one-revolution gate operates in the following manner: The gate is triggered by means of a "set" pulse applied to flip-flop Eh, causing pin 1 of OR-inverter Ei to go positive. This permits the next revolution pulse to reach the "T" input of a second flip-flop (Eh). Triggering of this flip-flop causes pin 13 of Ei to go positive, permitting pulses from the word one-shot (Eb 4) to enter the counter. This gate remains open for one revolution, at which time the next revolution pulse reaches the "T" input of the second flip-flop. When this flip-flop reverts to its original state it gates off the word pulses and resets the first flip-flop, gating off the revolution pulses. Polarities in this circuit have been carefully selected in order to achieve the proper timing sequences for the analysis cycle and manual operation. This will be referred to in the appropriate sections. Note that the word pulse applied to pin 15 of Ei is negative-going, rather than positive, as would normally be the case for an AND circuit. This means that an output occurs as soon as the gate is opened by means of a positive signal on pin 13. It is this signal which furnishes one extra count to the 100-counter, along with the 100 word pulses. Also, the counter will count the trailing edge of the word one-shot pulse. The significance of this timing will be discussed under recording. In normal operation, the one-revolution gate is triggered at the end of the input cycle, causing one altitude number to be recorded on the drum. Closing of the one-revolution gate indicates that the recording process has been completed, and is the signal for the analysis cycle to begin.

One-Minute Mode

In order to obtain a one-minute mode of operation it is necessary to carry out the computer operation on the basis of one-minute of stored information, instead of ten minute's worth. This is accomplished in a very simple way, merely by recording each new altitude number in ten locations on the drum, rather than in a single location. Thus, the 100 locations on the drum will contain only 10 different words, corresponding to one minute of data. This is accomplished by obtaining the address signal from the first decade of the address counter, instead of the second decade. When the train of 101 pulses are supplied to the counter to initiate a recording, the first decade goes through zero ten times, furnishing ten record pulses. Thus, the first word will go in locations 1, 11, 21, ... 91; the second will go in locations 2, 12, 22 .... 92; etc.

2.6 Record Circuit

In normal operation the record circuit is triggered by a pulse from the address counter as the counter goes through zero. When triggered, the circuit functions for the duration of one word, and is then reset. Before analyzing the logic circuitry it is desirable to discuss the actual recording circuitry.

2.6.1 Record Package

NRZ (non-return-to-zero) recording is used on the magnetic drum, since it permits the circuitry to operate at one-half the speed that would be required for recording complete pulses. With NRZ recording, erasing is not necessary, no bias signal is needed, and single words can be changed without disturbing adjacent words. NRZ recording is carried out in the following way: During the time that a word is being recorded a current is maintained through the recording head which develops a field strong enough to produce saturation of the magnetic coating on the drum. Whenever a "one" occurs, the direction of the current is reversed, resulting in a crossover in the magnetization on the drum, to saturation in the opposite direction. Wherever there are "zeros", the direction of magnetization remains the same. Since the head is always producing a field strong enough to saturate the coating, in one direction or the other, any previous information is completely eliminated, and replaced by the new information. At the end of the recording the current through the head is turned off, so that it has no further effect.

In playback, each crossover in the direction of magnetization on the drum results in a rounded pulse from the read head. Since the crossovers must alternate, the pulses from the read head alternate in sign. Each pulse corresponds to a "one"; a bit location having no pulse is thus a "zero". A string of zeroes would furnish no indication as to where a bit starts and stops; therefore, it is necessary that the sync channel supply this information. The sync channel has a "one" in every bit position.

The circuitry in the record package is very simple, due to this method of recording (Fig. 16). The same head is used for both recording and reading, and actually has two identical windings which can be connected either in series or parallel. These windings are connected in series-aiding, and the unction is fed from a transistor which acts as a constant-current source. The free ends of the windings connect to two switching transistors which in turn are connected to opposite sides of a flip-flop. Thus, only one winding at a time can carry current. The direction of the magnetic

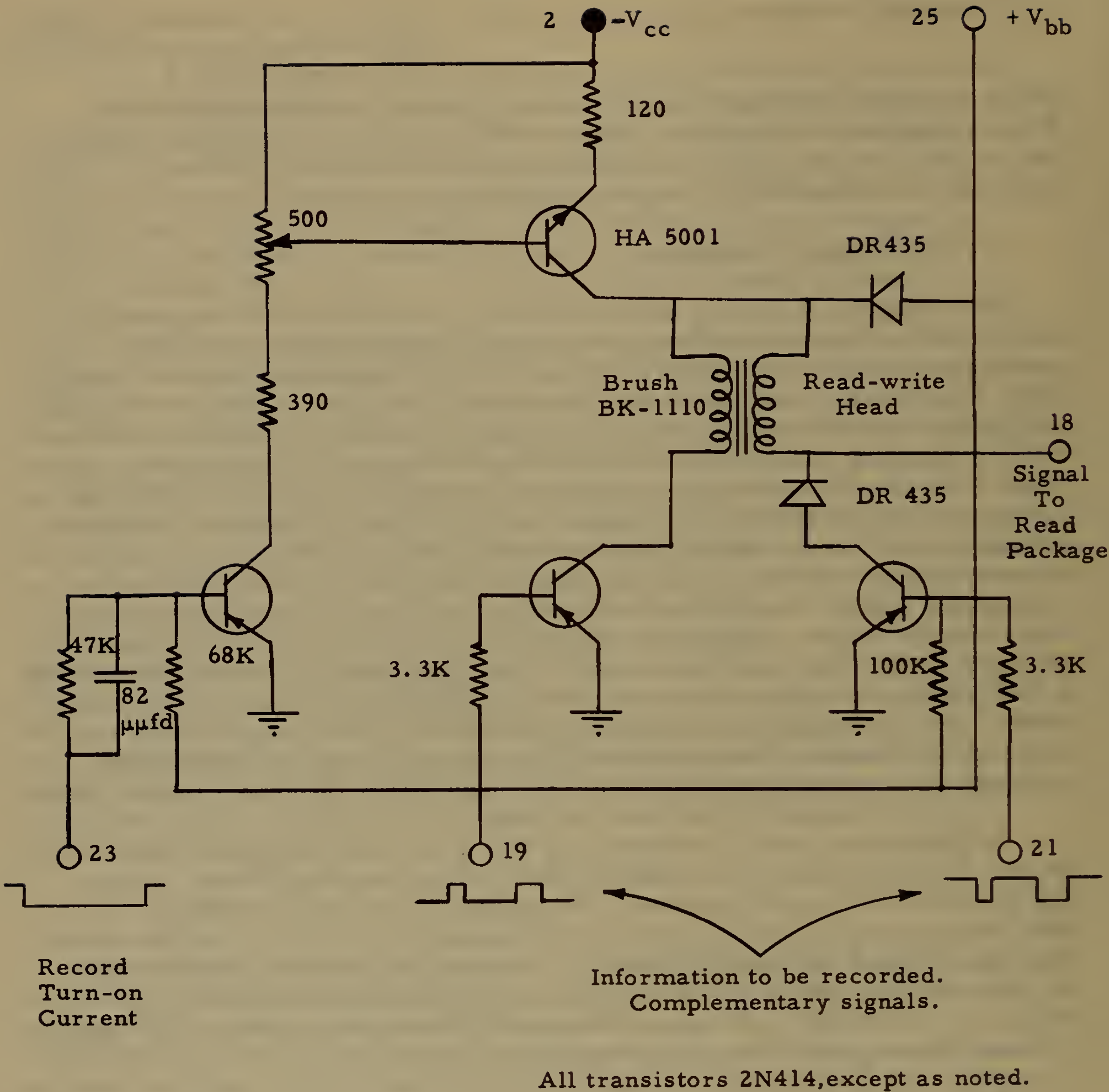


Figure 16. Record Package

field produced by one winding is opposite to that produced by the other. The constant-current transistor is operated by a switching transistor which causes it to be turned on for the duration of the word that is being recorded. Operation of this transistor as a current source is based on the fact that the variational resistance of the collector is very high when the base is driven by a voltage-source and a suitable emitter resistor is used. An NPN transistor is used in this particular circuit. This transistor will be off when its base is at -Vcc volts, which occurs when its accompanying switching transistor is turned off. Turning on the switching transistor results in a flow of current through the potentiometer which furnishes the base drive, causing the base of the NPN transistor to move positively toward ground. Since this potentiometer is only a few hundred ohms it is a reasonable voltage source for the constant-current transistor. The potentiometer is adjusted to establish a collector current of 30 to 40 ma. which is sufficient to saturate the magnetic coating of the drum.

The sequence during recording is as follows: The constant-current transistor is turned on via its switching transistor. Then, as the various bit positions reach the head the recording current is switched from one winding to the other whenever a "one" is to be recorded. It can be seen that there may be an odd or even number of reversals depending upon whether there is an odd or even number of one's in the 5-bit word being recorded. However, it is highly desirable to have the recording circuit start and stop in the same state. This is necessary in order to use the head for reading and also to prevent transients from being recorded due to switching the recording current on and off between words. The desired situation is achieved by the incorporation of a sixth bit which is used to provide even parity. If a word has an odd number of bits, the parity bit is made a "one"; otherwise, it remains a zero. Thus, in addition to the very desirable features mentioned above, the possibility of a parity check is gained, and this has been included in the read circuits. If a word being read from the drum contains an odd number of one's, an error is indicated. It will be noted that there is a diode in the lead connecting one of the switching transistors with its winding. Also, there is a pull-up resistor attached from the base of this transistor to +12 V. This transistor is normally off when the circuit is not being used for recording, and the opposite transistor is normally on. Thus, one end of the series-connected head windings is grounded, and the other end sees a high impedance. This end is connected to the read package and turns out to have twice the voltage that would be developed across a single winding. In the present equipment these signals are about 0.2 volt peak, which is well above noise, and only moderate gain is required in the read circuit. The diode connected between this point and its associated collector prevents shorting of positive pulses by the "off" transistor. This is necessary for the following reason. The collector circuit is normally energized from a negative supply (for a PNP transistor) and is back-biased for this polarity. However, it becomes a forward-biased diode for positive signals and will conduct even when turned off. The diode is therefore connected to prevent current flow for positive signals. The pull-up resistor at the base of this transistor helps to assure that it gets turned completely off, so that the transistor will not load the read signal.

Switching speeds in the record circuit are leisurely, as permitted by NRZ recording, together with ample bit spacing on the drum. By using a head with a large inductance, a large read signal is obtained, but switching speed is reduced. Two times are of interest here: the time to get the recording current turned on, and the time to switch from one winding to the other. Switching requires reversal of the flux in the head, which presents a highly inductive load. The recording current is turned on and off between words; the pattern on the sync channel provides a space of two bits for this purpose. The word one-shot (Eb) is adjusted so that its trailing edge occurs in the center of this space. Since the address counter counts on the trailing edge of this pulse, the signal to initiate a recording will occur at this time. The recording current remains on for one word and is turned off at the center of the next interval between words. The time required for the recording current to go from zero to 30 ma. is about 60 microseconds. The turn-off time is about 80 microseconds. When the recording current is turned off, a large positive voltage appears at the collector of the constant current transistor, due to the inductive load. To prevent damage, this point is clamped to +12 volts through a diode. This slows the turn-off time somewhat, but it is still well within the time allotted. In order to switch the current from one winding to the other, the flux in the recording head must be reduced to zero and built up to a maximum in the opposite direction. This requires about 110 microseconds, which is within the 120-microsecond bit spacing on the drum.

2.6.2 Operation of Record Circuit

The signal to begin a recording is derived from the address counter when it cycles through zero. This is indicated by the output of the last flip-flop of the counter going positive (pin 21 of Em). This signal triggers a flip-flop (Ee) which opens several gates for a single word (Fig. 15). One of these turns on the recording current. It will be recalled that the address counter counts trailing edges of the word one-shot (Eb) and these are adjusted to fall in the spaces between words. In order to allow time for the build-up and decay of the recording current the timing of this one-shot (Eb) is quite important. It is triggered by the sixth bit from the sync channel and should be set for 180 microseconds, $\pm$ 20 microseconds. The flip-flop (Ec) will remain in the "set" state until the trailing edge of the next word pulse. These pulses are constantly fed into the flip-flop via its internal gate (pin 1). However, a "reset" pulse is developed only when the flip-flop has been in the "set" state for more than a few microseconds. The flip-flop (Ec) thus remains on for a duration of one word, starting and ending in the intervals between words. In addition to turning on the recording current this flip-flop opens a gate which allows pulses corresponding to the one's being recorded to enter the counting input of the switching flip-flop (Ee). This flip-flop causes the recording current to flow alternately in the two separate windings of the recording head, as explained in the previous section. A third gate goes to the read circuit. During manual operation this provides a signal for reading single words. This will be explained in the section on the read circuitry. Another flip-flop (Ea) is used to establish whether the single-word circuitry is being used for reading or recording. It is automatically triggered into the record state whenever a word is to be recorded during automatic operation. It remains in the record state until the record function is ended, as indicated by the closing of the one-revolution gate. During manual operation this flip-flop is triggered by the "Write" button. When this flip-flop is in the record state it allows the single-word flip-flop (Ee) to turn on the recording current and allow one's into the switching flip-flop. When it is in the read state it gates off these signals and instead allows the single-word signal to be sent to the read circuit. Note that the switching flip-flop (Ee) is always reset at the end of a word by the leading edge of the word pulse. This flip-flop "counts" back and forth in accordance with the one's being recorded, which occupy the first five bit positions of a word. The word pulse occurs at the sixth or parity bit position. If an even number of one's has been recorded, the flip-flop will end up in the reset state and the parity bit will be a zero. If there were an odd number of one's, the word pulse will reset the flip-flop, making the sixth bit a one. Triggering of the record circuit is done by means of an "end of scan" pulse which is applied through gates (Ed) to the read-record flip-flop (Ea) and to the input flip-flop (Eh) of the one-revolution gate.

2.7 Read Circuitry and Comparator

During the analysis cycle the information stored on the magnetic drum is scanned in order to obtain answers to the various questions of interest. These are restated below, in terms of the equipment operation:

1) Which altitude number occurs most frequently on the drum?

2) What is the lowest altitude number that occurs 5 or more times?

3) What is the highest altitude number that occurs 5 or more times?

4) How many altitude numbers occur up to the critical altitude?

Answers to these questions are developed in the following way: The altitude number counter is advanced to the first altitude number and this is compared with each of the 100 words stored on the drum. A coincidence pulse is generated whenever the word on the drum is the same as the number. The output of the comparator will thus be a train of coincidence pulses, the number of pulses equaling the number of times that the particular altitude number occurs on the drum. One revolution (0.1 second) is required for this comparison, after which the altitude counter is advanced to the next number. This is again compared with the contents of the drum and another train of coincidence pulses is developed. The process is repeated until all 23 altitude numbers have been generated, after which the analysis cycle is terminated. The comparator circuit has thus furnished 23 trains of coincidence pulses, from which the answers to the various questions are to be obtained.

In order to determine which altitude number occurred most frequently, the trains of coincidence pulses are sent to the peak-value detector. This device furnishes an output whenever an incoming train contains more pulses than the longest previous train. These output pulses cause the altitude number associated with the incoming train to be shifted into a buffer register. Thus, at the end of the analysis cycle the buffer will contain the altitude number which occurred most frequently on the drum. This number is then shifted into the display register from which it is decoded to the numeric readout, as the predominant cloud height.

The trains of coincidence pulses also go to the max-min circuit and the critical height counter. The max-min circuit contains a preset counter which gives an output whenever it receives a pulse train containing more than the preset number of pulses. These output signals transfer the altitude number associated with the incoming pulse train into two buffers: the max buffer and the min buffer. However, after the first output signal the input to the min buffer is gated off, so that only the lowest altitude with five or more counts appears in this buffer. Altitude numbers continue to be transferred into the max buffer as long as their pulse trains exceed the preset count. Thus, when the analysis is completed, the max buffer contains the highest altitude which occurred five or more times. The critical height counter starts counting coincidence pulses at the beginning of the analysis and continues until a preset altitude number, corresponding to the critical height, is reached. Its input is then cut off. Therefore, its final count is equal to the number of cloud observations up to the critical height. Details of these circuits will be discussed in their respective sections.

2.7.1 Comparator Circuit

The comparator circuit makes a bit-by-bit comparison of the altitude numbers and the words on the magnetic drum. Since the words come serially from the drum it is logical to make the comparison in this fashion, and much less equipment is required than for a five-bit parallel comparator. It is required that the altitude numbers be serialized, also, and this is accomplished quite simply, by using the five commutating pulses from the sync channel. The altitude numbers are sampled, one bit at a time, by these commutating pulses and a flip-flop (Dc) is caused to set up according to whether the bit is a one or a zero (Fig. 17). A second flip-flop (Dc) is set in accordance with the bits from the drum. The outputs from these flip-flops are connected to a gating structure consisting of three OR-inverters (Dd) which are connected to give an output if the flip-flops have opposite states. This function is represented by the Boolean expression ($A\bar{B}$ or $\bar{A}B$). (This would be the sum digit for a half-adder, also called the Exclusive-OR function.) If the two flip-flops do not agree, the output of the comparator triggers a flip-flop (Df) which remains set until the end of the word. At the end of the word (start of the sixth bit) a sampling pulse is sent to a gate (Df) controlled by this flip-flop. If the flip-flop has been triggered, the gate will be closed, and the sampling pulse will not get through. If, however, all five bits of the altitude number and the word from the drum agreed, then the flip-flop would remain in its untriggered state and the sampling pulse would pass through the gate to become a coincidence pulse. The sampling pulse for this circuit is the word one-shot pulse; the trailing edge of this pulse resets the flip-flop between words, readying the circuit for the next comparison. The comparator circuit functions continuously, even during recording (during which errors might arise due to transients) but the output gate (Dj) is inhibited except while reading.

A note of explanation is necessary with regard to the timing of information read from the drum. The read circuit reads only one's from the drum, due to the use of NRZ recording. Hence, if a one does not appear in a given bit position, the bit is assumed to be a zero. However, if a one does appear in a bit position it will occur about 40 microseconds after the start of the bit, with respect to the sync channel. This is due to the appreciable time required for the record circuit to write a one on the drum. For this reason, time must be allowed for the word flip-flop to set up, before it is compared with the altitude-number flip-flop. This is achieved by means of a strobe pulse which activates the comparison. A one-shot (Da) is triggered at the start of each bit, and is set for 80 microseconds, in order to allow plenty of time for a one to occur, if it is present. This one-shot triggers the strobe one-shot (Db) which furnishes a 20-microsecond strobe pulse to the two AND-gates of the comparison circuit (Dd). Thus, the comparison circuit is strobed near the end of each bit to test whether a coincidence has occurred. The word flip-flop (Dc) is reset to its zero state at the beginning of each bit, and will remain in this state unless a one occurs. Resetting at this time cannot result in a conflict between the reset pulse and a one from the drum, since the one's are always at least 20 microseconds late.

Mention should be made of the effect of the parity bit on the comparison circuit. The altitude number flip-flop (Dc) takes on states corresponding to the five bits of the altitude number, while the word flip-flop (Dc) takes on the state of the parity bit, in addition to the five information bits. The comparison circuit operates for all six bits, which means that a lack of coincidence will be indicated whenever the parity bit is not the same as the fifth bit of the altitude number. This will not prevent a coincidence pulse from being generated, however, since the output is sampled before the occurrence of the strobe pulse for the parity bit.

2.7.2 Parity Check Circuit

The five-bit altitude numbers may have an odd or an even number of one's. However, as pointed out in the section on recording, it is desirable that all words recorded on the drum have an even number of

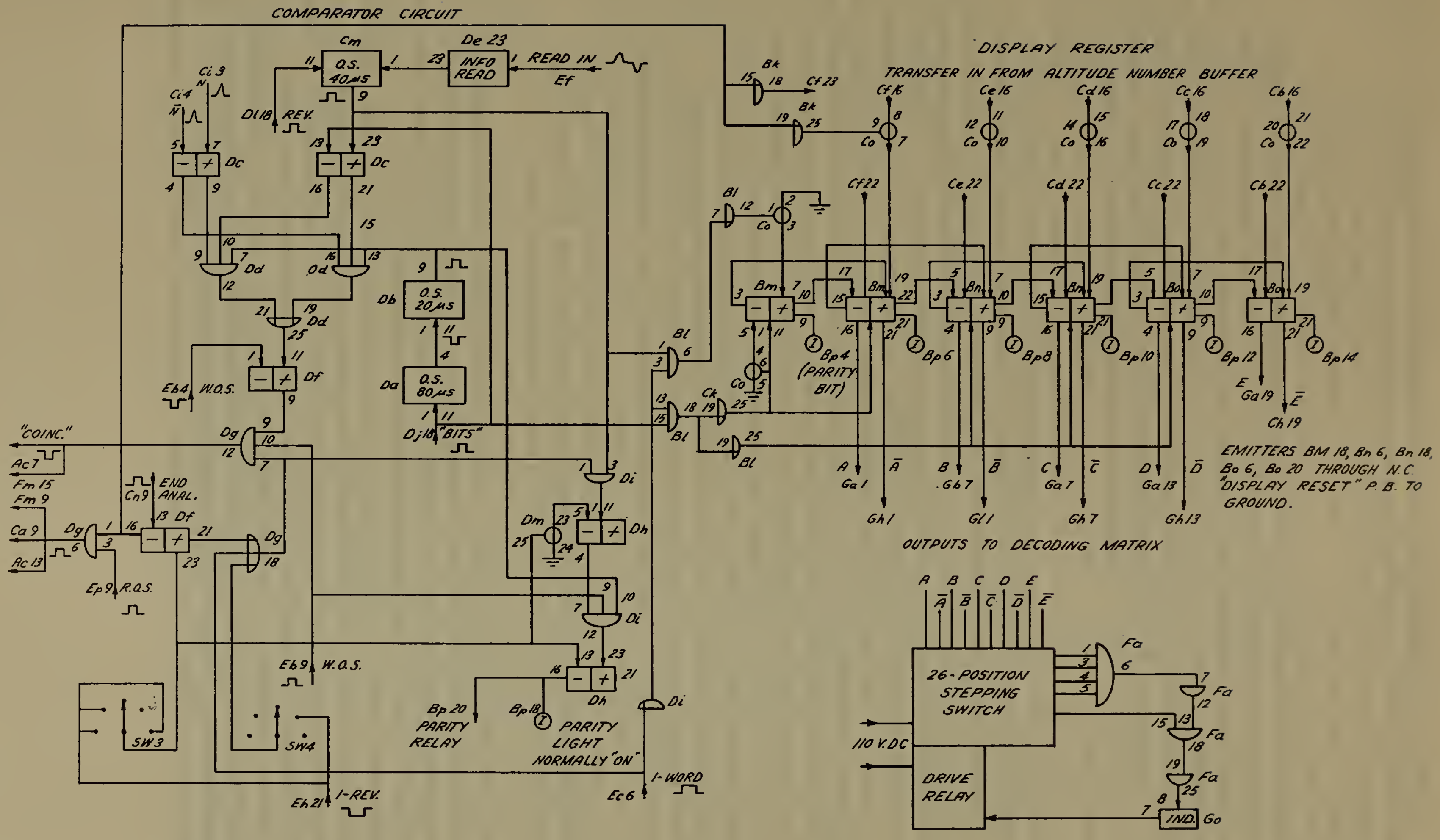


Figure 17. Comparator and Display Register

one's. (A word containing all zeroes would be acceptable; in fact, the drum can be erased by recording all zeroes.) For this purpose, space has been allowed on the drum for a sixth bit, which is the parity bit. This is made a one or a zero as needed in order to make an even number of one's in each word. This permits an even parity check to be applied during the reading process as a check against errors in recording and reading. The check consists in counting the number of one's in each word, and noting whether there was an odd or an even number. This is done by sending the one's from the drum into the counting input of a flip-flop (Dh). A Parity Reset pushbutton initially sets this flip-flop to the correct state. This flip-flop controls a gate which is sampled at the end of each word. The gate is normally kept closed by the counting flip-flop; however, if an odd number of one's has occurred during a word, the flip-flop will end up in the opposite state, and the sampling pulse will pass through, triggering the parity flip-flop (Dh). The parity flip-flop operates a relay which can be used to furnish an error signal. In the present equipment the relay causes a red background to appear behind the numeric readout. In many cases a parity error might have no effect on the actual output, but it serves as a warning that the answer may be questionable, and if it occurred repeatedly it would indicate a failure. An indicator light is also operated by the parity flip-flop, and is normally on. This provides a fail-safe indication; if the light were connected so as to be normally off, a failure in the lamp circuit would mask a parity indication. Similarly, the parity relay is normally held closed, so that a failure of the relay circuit causes the parity indication to appear. A parity error may be due to a variety of causes, including power line transients, etc., and need not mean that all succeeding results are in question. Hence, the parity circuit is reset at the beginning of each analysis cycle. This reset pulse is applied to both the parity flip-flop (Dh, pin 13) and the counting flip-flop (Dh, pin 5, via a gate on package Dm).

It will be noticed that there is a one-shot (Cm) which "squares up" the one's coming from the read circuit. Due to a peculiarity of the recording scheme it is possible to occasionally produce a double-peaked "one", instead of a single, rounded pulse. Nevertheless it is a perfectly valid, well-defined "one". The read package will, in turn, produce a double pulse. This would not affect the comparison circuitry (or the shift register described below) but would cause the counting flip-flop to count twice on a single "one". Thus, a parity error would be indicated. This is prevented by having the read circuit trigger a one-shot (Cm) which is set for 40 microseconds. This is long enough to discriminate against multiple pulses of the type described. However, the "T" input cannot be used; hence, the revolution pulse is sent to the reset side (Cm, pin 11) in case it should ever hang up.

2.7.3 Read Package

The Read Package receives digital signals from the magnetic drum and produces negative output pulses of standard amplitude. The signal developed across the Brush BK1110 head used on the magnetic drum is about 0.3 volt, peak. Thus, it is not necessary to provide significant voltage gain, but merely to provide a reasonably high input impedance. When used with NRZ recording, successive input pulses alternate in polarity, which requires that the signals be full-wave rectified.

A block diagram of the package appears in Fig. 18, together with a schematic diagram and typical waveforms. The emitter-follower stage presents a high input impedance and provides low output impedance for driving the phase-inverting transformer. This transformer has a center-tapped secondary which drives the bases of a pair of transistors having a common collector load. Both transistors are normally cut off, since their bases and emitters are at ground potential. Since they are driven in opposite phase, when one conducts, the other is cut off even further. Thus, only one transistor at a time draws current through the load resistor. The transistors conduct on negative signals; hence, the signals at the load are positive pulses for either polarity of input pulse. The emitters of these two transistors go to opposite ends of a balance potentiometer which has the sliding contact grounded. This potentiometer is adjusted to obtain equal-amplitude pulses at the load resistor.

The full-wave rectified pulses are differentiated to provide a signal which has a sharply-defined positive-to-negative zero-crossing. Since the input pulses to the differentiating network are positive, the first portion of the differentiated signal is positive. Thus, the following amplifier stage, which is normally cut off, remains off. When the peak of the pulse occurs, the derivative falls sharply to zero, and as the pulse decreases, the derivative goes sharply negative, turning on the following stage. This results in a pulse whose leading edge is closely timed to the peak of the input pulse. This signal is d-c coupled to an NPN transistor, which also is normally off and which starts to conduct when its base goes positive. Together, these two amplifier stages furnish sufficient gain to cause saturation at the collector of the NPN output transistor, resulting in 12-volt negative pulses whose leading edges coincide closely with the peaks (both positive and negative) of the input signals to the Read

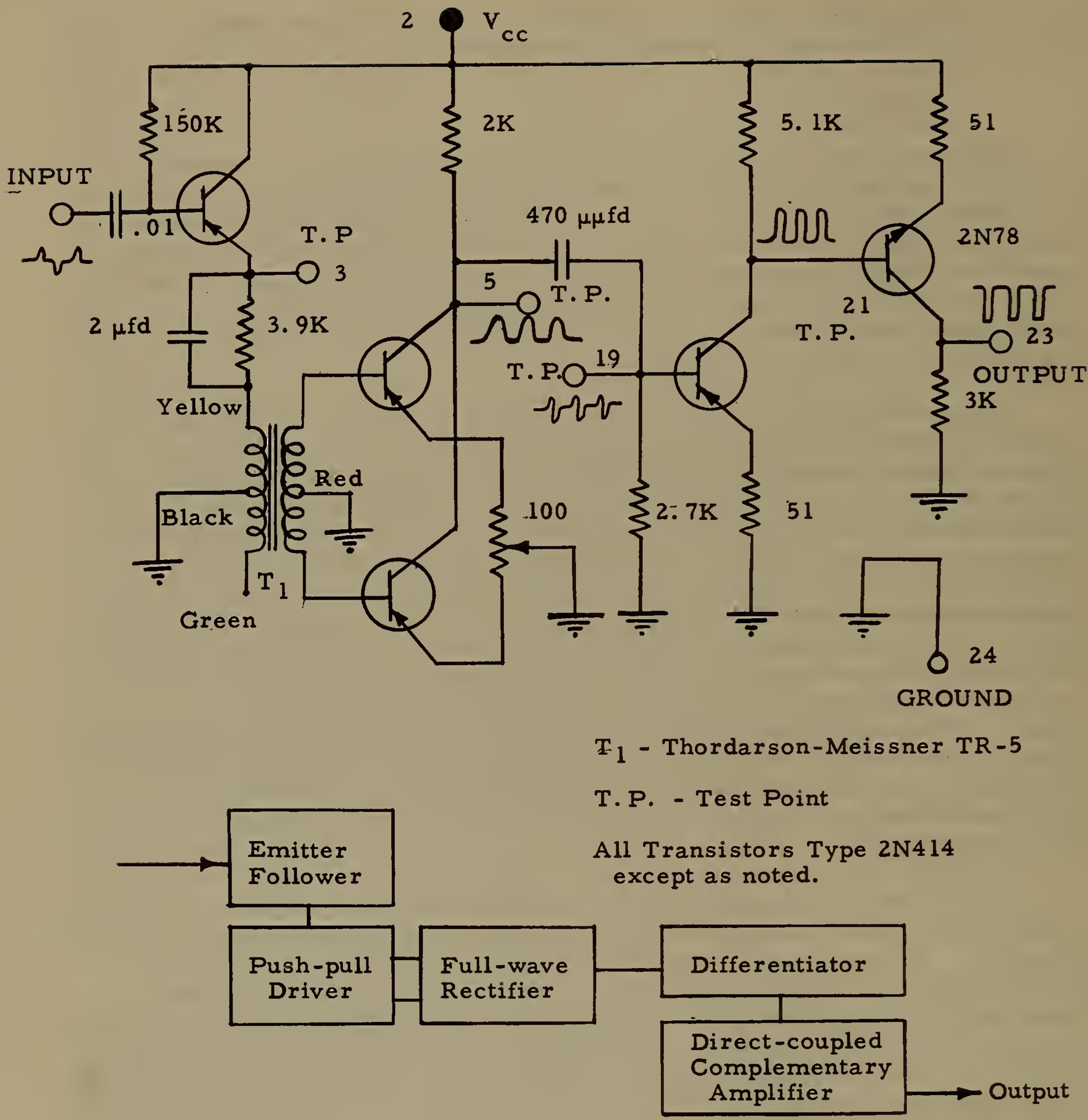


Figure 18. Read Package

Package. By passing the output pulses through an OR-inverter stage, the rise time can be speeded up to less than one micro-second, resulting in positive pulses which will readily operate flip-flops and other standard packages in this series.

2.7.4 Storage Register

At the end of the analysis cycle the altitude number occurring most frequently is stored in a buffer register. Since this buffer is also used during the input cycle the answer must be transferred into a storage register (Fig. 17), from which it can be decoded into the numeric readout. Since this register drives the output display it is also convenient to use it during manual operation. Accordingly, it has been made into a shift register, and single words can be shifted into it, from the drum. It is six bits long, so that it can include the parity bit. The Address and Record Circuit has a flip-flop (Ee) which is triggered by the address counter and which stays on for a duration of one word. When the equipment is operated manually on "Single Word", and the "Read" button is pushed, the signal from this flip-flop is gated via an OR-inverter (Ec) to a pair of gates which furnish signals to the shift register. One of these (Bl) feeds one's from the read circuit into the first stage of the register (Bm). The other gate (Bl) provides shift pulses. Simultaneously, it shifts zeroes into the first stage of the register. Thus, the first shift pulse moves the word one space to the right (to the left on the front panel) and sets the first stage to zero. If the first bit of the word being read is a one, the one will arrive a short time later, setting the stage to a one. Then the next shift pulse occurs, moving the word one more place to the right, and setting the first stage to zero. The first stage either remains at zero or is set to a one in accordance with the second bit being read. In all, there will be six shift pulses to a word, after which the new word is in the register, together with its parity bit. It then appears decoded in the numeric display.

2.7.5 Max-Min Circuit

The max-min circuit detects the highest and lowest altitudes at which the number of cloud observations are equal to or greater than a preset value.

The max-min circuit consists of two 5-bit storage registers with provisions for decoding to numeric displays, and a counter which can be preset for numbers from 1 to 16 (Fig. 19). The counter contains four flip-flops, and either side of each flip-flop can be connected to a four-input OR-inverter (Gm). The counter is driven by trains of coincidence pulses from the comparator circuit.

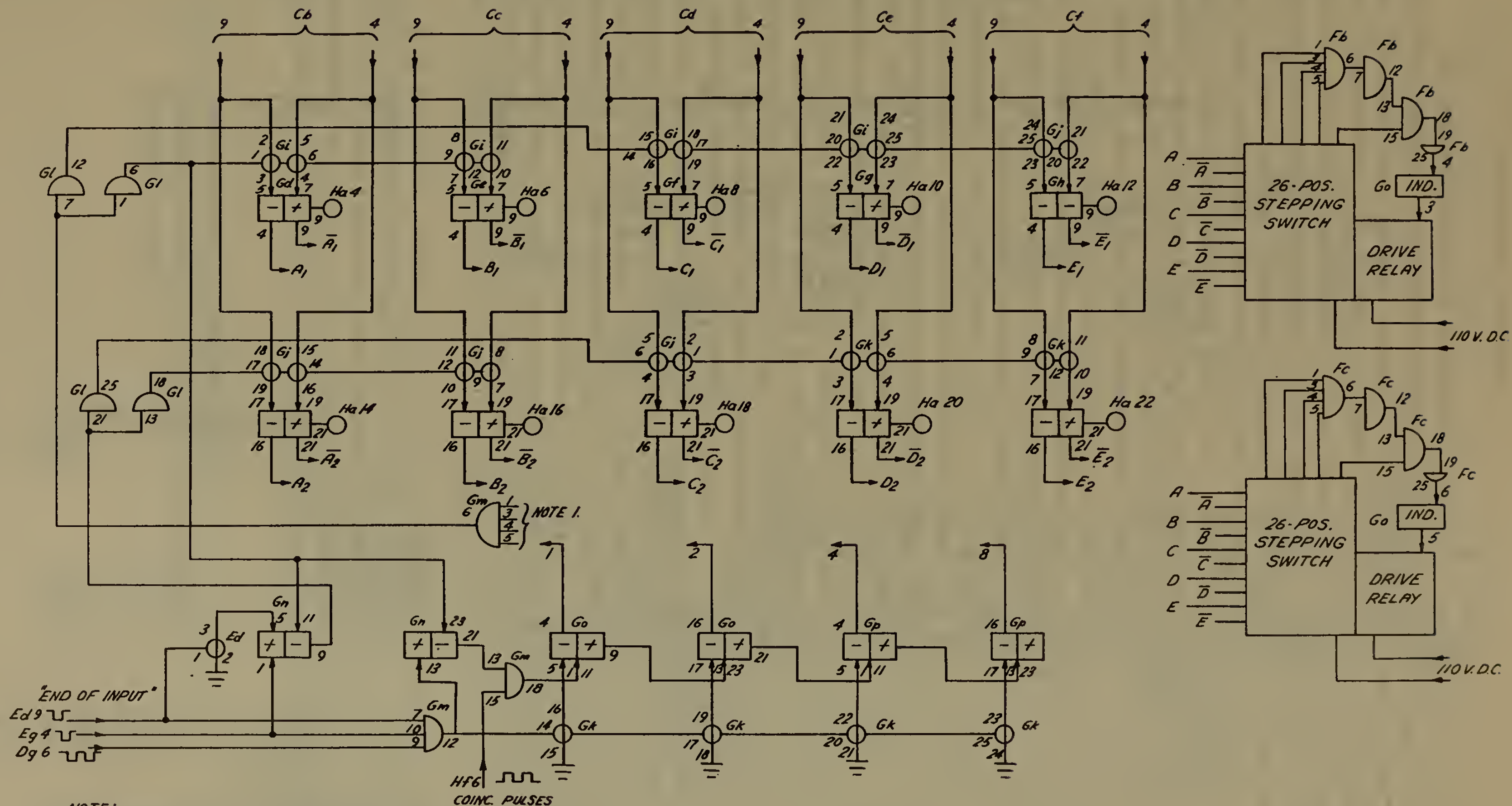
Whenever the number of pulses in a train equals the value for which the counter is preset, the OR-inverter provides an output, gating off the counter input (via flip-flop Gn and OR-inverter Gm). This output signal drives additional OR-inverters (Gl) which cause the concurrent altitude number to be shifted into the registers. The gates feeding the lower register are driven by a flip-flop (Gn) which is triggered by the first output signal, thereby transferring only one altitude number into this register, which displays the minimum altitude. After each pulse train the counter and its input flip-flop (Gn) are reset by a pulse from the analysis control circuit. The counter thus continues to furnish output pulses each time a pulse train exceeds the preset value, and altitude numbers continue to be transferred into the other register, which displays the maximum altitude.

2.7.6 Circuit for Counts Up to Critical Altitude

This circuit contains a counter which counts the number of cloud observations that occur up to a preset height. This would ordinarily be preset to the critical altitude for a given airport. Since the drum contains 100 altitude numbers, and all of these could fall below the critical altitude, the counter must be capable of registering 100 counts. This is accomplished by cascading two decade counters, the first being a units counter and the second being a tens counter (Fig. 20). They are wired to count in 1-2-2-4 fashion.

The input to the counter is the series of coincidence pulse trains from the comparator circuit. These pulses are passed through an OR-inverter (Hf) to the input of the counter. This OR-inverter is controlled by a flip-flop (He) which can be used to gate off the pulses at the appropriate time. This flip-flop (He) receives a trigger pulse from a gate circuit which is operated by the altitude number counter. When the critical altitude is reached, this gate circuit triggers the gating flip-flop (He), causing the input pulses to be gated off. Thus, at the end of the analysis cycle the counter will have registered the number of cloud observations up to (but not including) the critical altitude. (Observations up through the critical altitude can be included simply by wiring the gating circuit to recognize the next highest altitude number.)

The counter is reset to zero at the beginning of each analysis cycle by means of reset pulses applied to two OR-inverters (Hj). The reset pulses also reset the gating flip-flop (He). Pressing either the "Read" or "Write" button in manual operation will cause this reset pulse to occur, thus zeroing the counter. However, this circuit receives input pulses only during analysis.



NOTE:
1. CONNECT IN(1,2,4,8) FOR DESIRED COUNT.

Figure 19. Maximum - Minimum Circuit

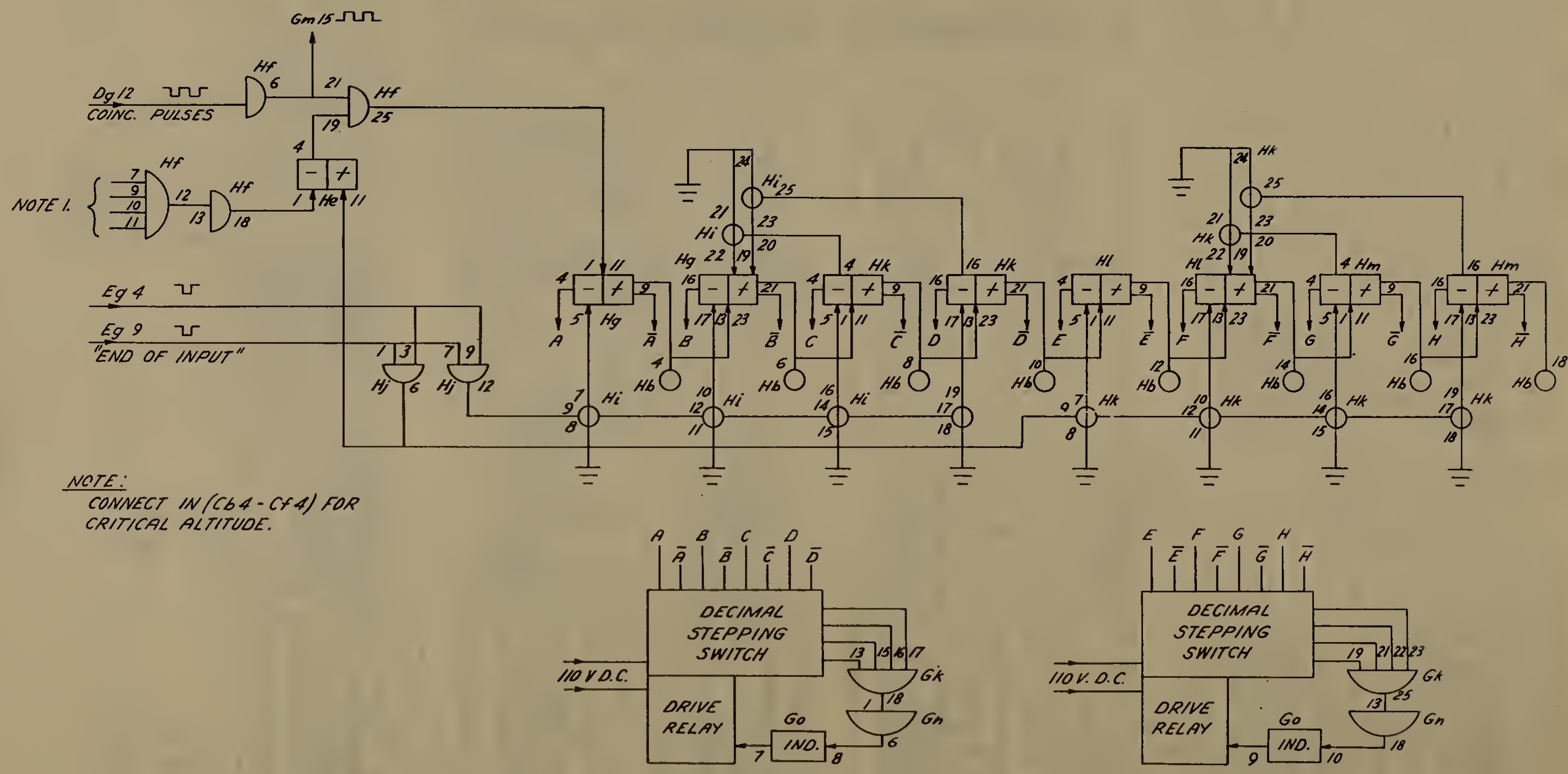


Figure 20. Circuit for Counts up to Critical Altitude

2.7.7 Analysis Control

The analysis cycle requires some 25 revolutions of the magnetic drum, consuming about 2.3 seconds. During this time the altitude number counter is advanced by one count after each revolution. In automatic operation the equipment goes through an input cycle and then produces an end-of-scan pulse. This pulse causes one word to be recorded on the drum, after which the analysis cycle is initiated. This signal is derived from the closing of the one-revolution gate and triggers the analysis flip-flop (Df). (See Fig. 18.) This flip-flop opens a gate (Dj) which allows revolution pulses to go to the input of the altitude number counter. This is also used as the "transfer up" pulse in the Peak-Value Detector, and as the reset pulse for the preset counter in the max-min circuit. This flip-flop also furnishes a negative signal to the input of an OR-inverter (Dg), the output of which goes positive, opening the output gate (Dj) for the comparator circuit, allowing coincidence pulses to be produced. The analysis ends at the moment the altitude number counter reaches 24, which causes the counter to reset to zero, simultaneously resetting the analysis flip-flop. When the analysis starts, the altitude number counter is in the zero state, since it is set to all zeroes by the end-of-scan pulse. Normally, this would not constitute a valid word, since the altitude numbers start with 10000, and the word 00000 is not used. Hence, it should not be included in the analysis. It is eliminated by the arrangement of the timing of the analysis cycle. The one-revolution gate closes at the leading edge of the revolution pulse. This furnishes the trigger signal for the analysis flip-flop, causing the gate (Dg) to open in time to allow the same revolution pulse to advance the counter immediately to the state 10000. Thus, word zero is not included in the analysis. However, should it prove desirable to include word zero, it is simply necessary to bypass one OR-inverter in the one-revolution gate circuit (Ei 7-12). This will cause the analysis trigger signal to occur on the trailing edge of the revolution pulse. The analysis will therefore start with word zero.

The analysis control circuitry is used extensively in the various manually-operated test functions of the computer. The purpose and use of these functions are described in a separate section; however, it is convenient to discuss the circuit operation at this point. The three manual modes of operation, which are selected by a front-panel switch, are:

1. Read or write single words
2. Read a single word for one revolution
3. Analysis cycle.

There is a push-button marked "Write" and one marked "Read". The "Write" push-button is only used with the single-word function, since it is only possible to record one word at a time. The "Read" push-button is used with all three manual functions. Pressing either the "Read" or "Write" button triggers a one-shot (Eg) which furnishes a "start" pulse for the selected function. This pulse activates the one-revolution gate circuit by triggering flip-flop Eh. Thus, the one-revolution gate circuit is activated for all of the manual functions. These will now be described individually.

1. Reading Single Words

The "Read" button triggers the one-revolution gate, as described above. This causes the address counter to receive 101 counts, thus cycling through zero, as described in a previous section. When the counter goes through zero, it triggers a flip-flop (Ee) in the record circuit. Notice that, since the address counter is counting the trailing edges of word pulses, this trigger will occur at the trailing edge of a word pulse. At the same time, this flip-flop is constantly receiving word pulses at its opposite input, from the word one-shot (Eb). These pulses attempt to reset the flip-flop at the trailing edge, but they are only effective after the application of a "set" pulse. Thus, the flip-flop (Ee) will provide an output signal of one word length. This signal is sent to the read circuit via an OR-inverter (Ec) and is used to gate one word into the display storage register. Pressing the "Read" button again will result in the next successive word being read.

2. Writing Single Words

Pressing the "Write" button triggers the one-shot (Eg) as described above, but in addition to triggering the one-revolution gate, the "start" pulse is passed through an extra set of contacts on the "Write" switch. This pulse triggers the read-record flip-flop (Ea) into the record state. Now when the selected address occurs, the record package is activated for one word, and the altitude number residing in the altitude buffer is recorded. At the end of the selected word the one-word flip-flop (Ee) is reset, gating off the recording process. At the end of the revolution the read-record flip-flop is returned to the "read" state.

3. Reading for One Revolution

In this mode a pulse for the duration of one revolution is sent to the read circuit. This pulse is obtained from one of the flip-flops (Eh) in the one-revolution gate. The trigger signal from the address counter is interrupted by a switch, so that the one-word gate is not actuated in this mode.

4. Analysis

This function takes about 24 revolutions of the drum. It is necessary that the analysis start at the beginning of a revolution. This is achieved by using the pulse from the one-revolution gate to trigger the analysis flip-flop (Df) in the read circuit. Pressing the "Read" button causes the one-revolution gate to produce an output signal for one revolution; the trailing edge of this pulse initiates the analysis cycle, which then continues for 23 revolutions.

2.8 Altitude Interval Generator and Control Circuit

The rotating searchlight of the Ceilometer is driven by a synchronous motor at a speed of exactly 5 revolutions per minute. A switch actuated by the rotating shaft produces a pulse once each revolution. This pulse is used to synchronize a counter which counts pulses at the power line frequency. Thus, the counter is in step with the rotating searchlight, and its count is related to the angular position of the searchlight. The counter consists of three 1-2-2-4 decade units, giving it a capacity of 1000 counts (Fig. 21). It is pulsed at a 120-cycle rate, receiving 2 pulses for each cycle of the line frequency. The active portion of each input scan is three seconds in duration, representing a count of 360. Each decade of the counter drives a decimal-decoding package, which has ten separate ouptuts for the numbers 1-10. These in turn drive a number of 3-input diode AND-gates which put out pulses corresponding to the various altitude intervals. There are 23 of these gates, and their outputs are all combined in a single OR-gate which supplies pulses to the altitude number counter. Therefore, the altitude number counter is advanced each time that the start of a new interval is indicated by the altitude interval generator.

2.8.1 Detailed Operation of Altitude Interval Circuit

The altitude intervals are shown in the accompanying table, Figure 11. The required resolution is shown by the highest interval, 8500 to 9500 feet, which corresponds to about $1/4^o$ of angular rotation. The searchlight rotates 90^o in three seconds, so there are $3 \times 60 = 180$ cycles at 60 cps for one scan. This is 2 cycles per degree of rotation. By counting both positive and negative half-cycles of the line voltage (using a full-wave rectifier) it is possible to get 4 counts per degree, each count equaling 1/4° of rotation. Thus, the interval from 8500 to 9500 corresponds to one count at the 120 pps rate. In the table, the angles corresponding to the various altitude intervals have been rounded to the nearest 1/4 degree, and in most cases the approximation was quite close. The various counts corresponding to the 23 intervals are shown in the table.

The source for the 120 pps signal is the same as that used to trigger the sampling process for the analog-digital converter. This consists of a flip-flop (Am) triggered by pulses from a full-wave rectifier, with the pulses occurring at the zero-crossings of the 60-cycle line voltage. The flip-flop (Am) triggers a string of three one-shots (Fd, Hc, Fe) which furnish signals for the analog-digital converter. The output from the second of these one-shots (Hc) is used to drive the altitude interval counter, via an OR-inverter (Ao). (This OR-inverter is used to inhibit counts which might occur during the occurrence of a synchronizing pulse from the ceilometer. This is discussed in the following section.) Attached to each decade of the altitude interval counter is a decimal decoding package, and these packages drive the 23 three-input diode AND-gates whose outputs correspond to the various altitude intervals. The diode gates are on special package with six gates per package. The outputs of these gates are combined in a 23-input diode OR-gate, constituting an additional package. The output of this package is a series of negative pulses which are passed through an OR-inverter (Di) in order to increase the amplitude and shorten the rise time. One problem arises in counting these pulses, in that the last two correspond to consecutive states of the counter. Thus, the output of the OR-gate is a single pulse two counts in length, whereas all the other pulses are distinct and are one count in length (8.3 milliseconds). This is resolved by the use of a strobe pulse, applied to the input of an OR-inverter (Ca), together with these signals. The strobe pulses are obtained from one of the one-shots (Fe) which is operating at the 120 pps rate.

2.8.2 Control Circuit

The control circuit determines whether the computer is in the input cycle, or the analysis cycle. This circuit furnishes the proper signals to the various portions of the computer, and also handles the synchronizing pulse from the rotating searchlight. The control circuit receives three-second pulses from the altitude interval generator which are developed in the following way:

An extra AND-gate is included in the altitude interval generator and is set for a count of 359. When this count is reached, a one-shot

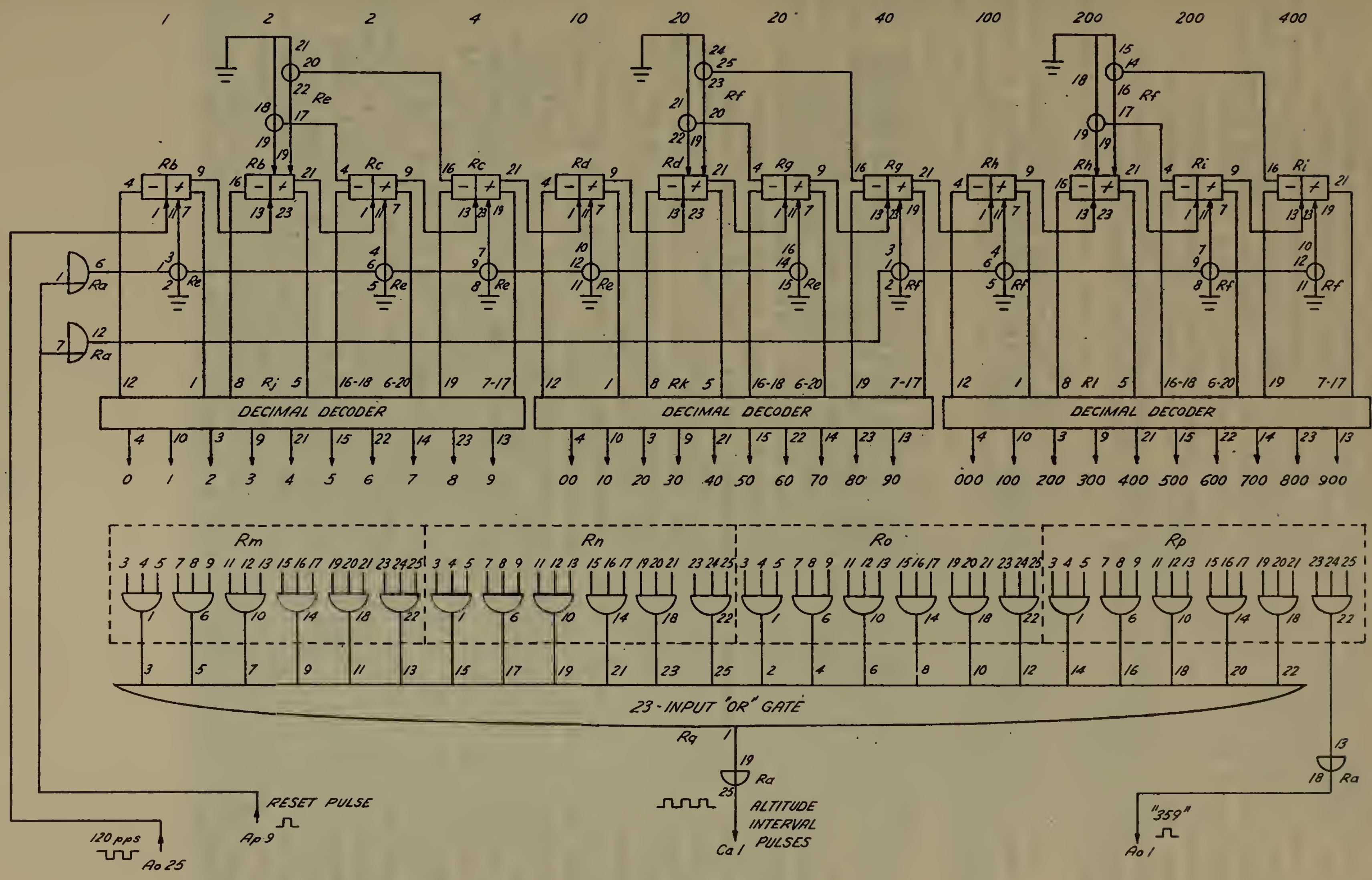


Figure 21. Altitude Interval Generator

(Ap) is triggered (Fig. 22). This one-shot is set for about 20 microseconds, and the trailing edge of its output pulse is used to set the interval counter to all one's. (Were the counter stages set to zero, instead of one, false carries might occur, with uncertain results.) The next input pulse then resets it to all zeroes, causing the counting sequence to be repeated. Each three-second input scan is followed by three seconds during which the Ceilometer is inactive; therefore, only alternate sets of altitude pulses are desired. The inactive time is used by the computer to analyze the stored data. The "359" pulse is used, therefore, to trigger the computer back and forth between the "input" and "analysis" cycles.

The "359" pulse triggers a flip-flop (Am) which determines the mode of operation of the computer. Several functions are affected by the control circuit. The control circuit operates in the following way:

Assume that the computer is in the input cycle. Pin 21 of flip-flop Am is positive, holding OR-inverter Ca open and allowing counts from the altitude interval generator to be sent to the altitude number counter. Also, two OR-inverters in the Analog-digital converter are held open. One of these (Fb) allows "transfer up" pulses to be sent to the peak-value detector. The other (Fb) allows the pulse trains from the converter to be sent to the peak-value detector. The converter runs continuously, but its output signals are used only during the input cycle. When the "359" pulse occurs, it triggers flip-flop Am into the "analyze" state, causing pin 21 to go negative, thereby gating off signals from the converter. As pin 16 becomes positive it opens an OR-inverter (Bh) allowing the "359" pulse to pass through. The output of this OR-inverter is a negative signal referred to as the "end-of-input" pulse. It triggers the address and record circuit, causing the new altitude number to be recorded, after which analysis takes place. The "359" pulse would normally persist for 1/120 of a second, since this is the rate at which pulses are sent to the altitude interval counter. However, the "359" pulse triggers a one-shot (Ap), as explained previously, which sets the counter to all one's. As soon as this happens, the count of 359 no longer exists, and the "359" pulse ends. Thus, the width of the "end-of-input" pulse is equal to the pulse from one-shot Ap, which is about 20 microseconds. Note that this gate only passes every other "359" pulse. All of the "359" pulses are present at the input to this gate; however, the next pulse will trigger flip-flop Am at its leading edge, causing Am to close the gate in time to prevent passage of the pulse. Every "359" pulse triggers the one-shot (Ap) which leads to the resetting of the altitude interval generator. The pulse from Ap serves as a reset pulse for several portions of the computer as it cycles back and forth between the "input" and "analysis" cycles. These "reset" pulses are sent to the peak-value detector, where both the adding and subtracting registers are set to zero. They also reset the altitude number counter, the max-min counter, and the critical altitude counter.

2.8.3 Synchronizing Pulse from Ceilometer

Synchronizing of the altitude interval generator with the pulse from the rotating searchlight is somewhat intricate, because of the associated control circuitry. This "rotation pulse" only occurs once per rotation of the searchlight shaft, whereas there are two active scans during this time, since there are two searchlights mounted back-to-back on the shaft. It is necessary, then, that the equipment cycle back and forth between input and analysis whether the synchronizing pulse occurs or not. This enables the equipment to remain in operation even if a sync pulse should fail to occur. The sync pulse, where it occurs, represents the start of an active scan and the computer should be set to the start of the input cycle. This means that the altitude interval counter should be reset and flip-flop Am should be set to its "input" state. There are four possible conditions to consider:

1) absence of sync pulse,

2) sync pulse at correct time (normal condition),

3) sync pulse occurring early,

4) sync pulse occurring late.

If no sync pulse occurs, the "359" pulse will continue to trigger the equipment back and forth between the input and analysis cycles. One pulse will signify the start of an input cycle; the next, the start of an analysis cycle. When a sync pulse occurs, it closes a relay of the type normally used in the Ceilometer indicator units. This is a Western Electric 276-B with mercury-wetted contacts, and does not exhbit contact bounce. When the relay closes, it grounds the input of a one-shot (An) which is normally held negative through a high resistance (Fig. 22). This positive-going impulse triggers the one-shot, developing a synchronizing pulse. The leading edge of this pulse triggers flip-flop Am to its "input" state, by means of an external gate. It also starts the one-shot (Ap) which prepares the altitude interval generator to be reset, also furnishing a reset pulse for the computer. The sync pulse one-shot (An) performs two "inhibit"

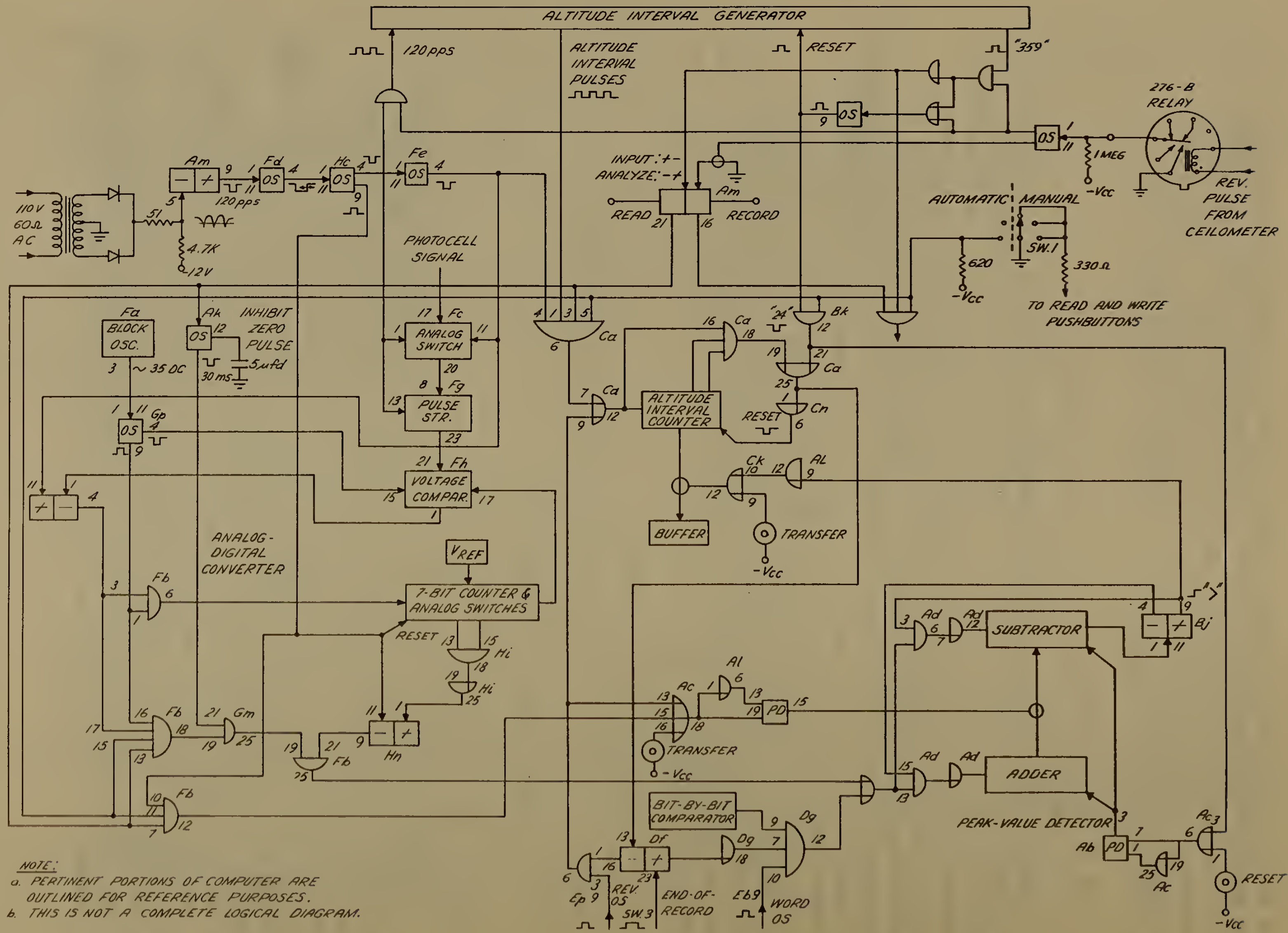


Figure 22. Control Circuit

functions, which are necessary to prevent the occurrence of conflicting pulses from the control circuit. The 120-cycle pulses to the altitude interval generator are cut off, via OR-inverter A1, in order to allow one-shot Ap to complete its cycle and set the counters to all one's without any conflicting counts. Also, the "359" pulse is inhibited, since it should be replaced by the sync pulse when it is available. The duration of An is at least 20 microseconds greater than Ap, in order to allow the altitude interval counters to settle down before additional counts are let in. (An $\approx$ 50 microseconds.)

Operation of the control circuit in terms of the arrival of the sync pulse can now be discussed. If the pulse arrives early, the altitude interval generator will not have reached 359, and the computer will still be in the analysis cycle. The sync pulse will trigger the sync one-shot (An). The leading edge of this pulse will set flip-flop Am to its input state, and will also trigger one-shot Ap, resetting the computer and terminating the analysis. (Analysis takes about 2.4 seconds, so the sync pulse could be 0.6 seconds early without chopping into the analysis.) The altitude interval counter will not be set to all one's until Ap goes off, requiring about 20 microseconds. During this time there is a small possibility that the count of 359 will occur. This would result in the production of a "359" pulse which would switch flip-flop Am away from its input state. For this reason the "359" pulse is inhibited during this time. The sync pulse will always trigger one-shot Ap, unless it happens to be already triggered, in which case the equipment may be considered to be in sync. Since this 20-microsecond interval is very small with respect to the time scale of the ceilometer, it is unlikely that the sync pulse will occur during this time; hence, the sync pulse will usually trigger this circuit. However, the equipment will generally be within one pulse at the 120-cycle rate, since this represents an interval of 8.3 milliseconds. Since the control circuit is using the 120-cycle pulses as a clock, it cannot, in fact, be set closer than 8.3 milliseconds, which therefore, constitutes being in sync. If the sync pulse is early, the altitude interval counters are reset to all one's before reaching 359, and hence 359 will not occur, since the counters will start again from zero. However, if the sync pulse is late, the count of 359 will have occurred and the control circuit will have automatically switched to the input cycle. The sync pulse simply serves to restart the altitude number generator and to reset the computer to zero.

The flip-flop, Am, which controls whether the computer is in the "input" or "analysis" state, is connected to two indicator lights.

One of these lights, located above the "Write" pushbutton, is on during the input cycle. The light above the "Read" pushbutton is on during the analysis cycle.

2.9 Output Decoding and Display

Several quantities are displayed by the computer as answers to the various factors which it analyzes. These are:

1) The altitude at which the most frequent cloud activity occurred.

2) The minimum altitude at which five or more counts were observed.

3) The maximum altitude at which five or more counts were observed.

4) The number of cloud occurrences up to the critical altitude.

The first three quantities are altitude numbers and are represented in the machine as five-bit binary words. The last quantity appears as a binary-coded decimal number (1-2-2-4 code) in two decade registers. There are two requirements for displays. First, there must be illuminated decimal numbers at the computer (Fig. 23), and second, there must be contacts available for activating a remote read-out device, which should be electrically separate from the local display. The four quantities can each be represented by two decimal numbers, the three altitude numbers being heights in hundreds of feet from 00(00) to 99(00) and the critical counts being represented directly from 00 to 99. For both the local and remote devices it is desirable that each decimal number be represented as a contact closure on one of ten lines. From the standpoint of the number of contacts required, and the decoding involved, the most economical solution was through the use of stepping switches. There are 24 possible values for the altitude numbers, permitting the use of a 26-point switch for each altitude number. The two decade numbers for the critical-counts counter were handled by an 11-point switch for each decade.

2.9.1 Altitude Number Stepping Switches

There are 3 of these 26-point switches, each for a separate altitude number. They have 10 banks of contacts which are wired in

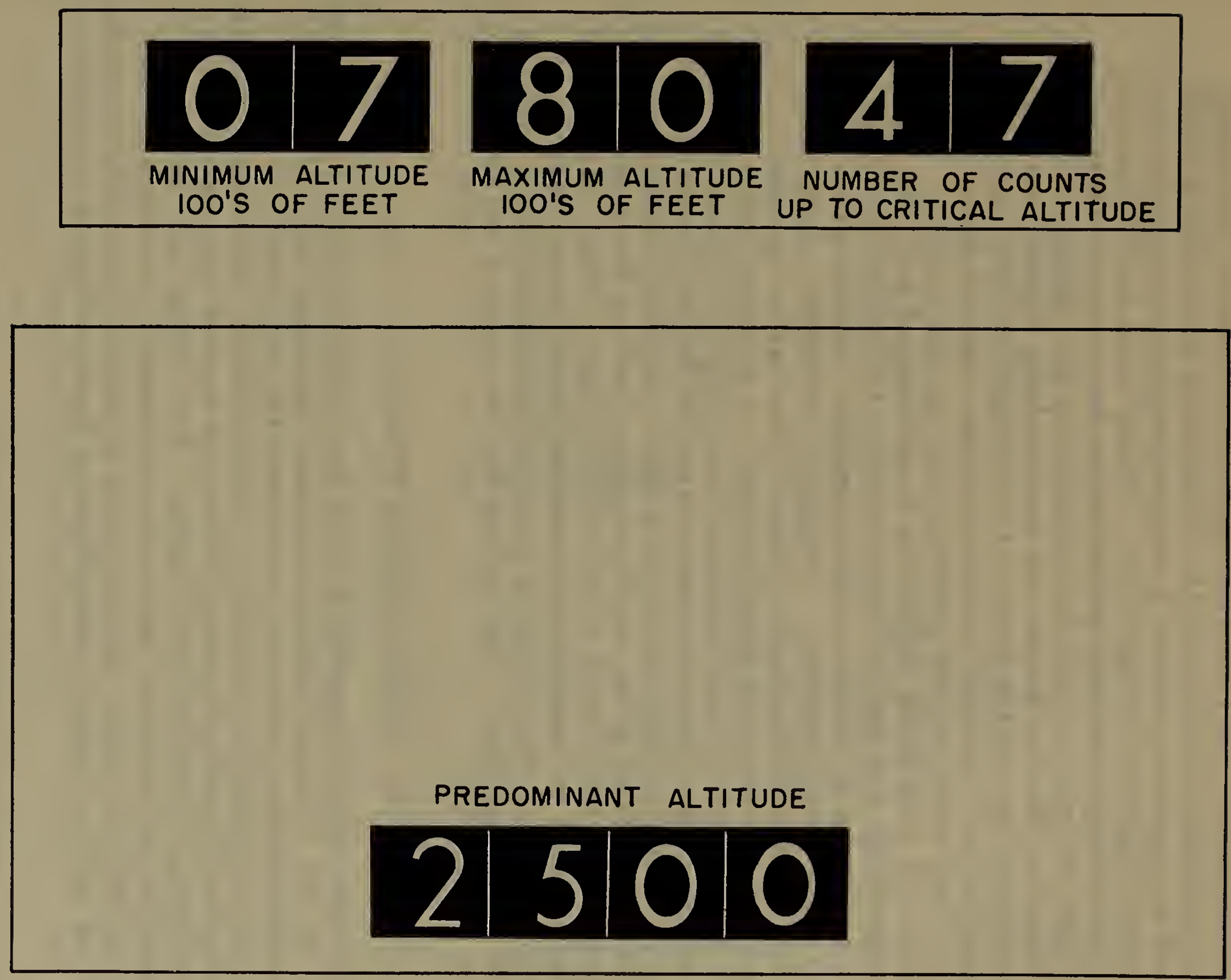


Figure 23. Arrangement of Displays.

the following way: The first five banks are wired to represent the binary numbers from 0 to 23. Two leads are brought from each bank to opposite sides of a corresponding flip-flop in one of the buffer registers (Figure 24). These lines are filtered to remove switching transients produced by the stepping switches, which might otherwise alter the numbers in the buffers. The wiper arms for the five banks are connected to an AND circuit. If the setting of the switch does not correspond to the state of its associated buffer, the AND circuit will have one or more negative inputs and will energize the drive circuit for the switch. Thus, the switch will step along until it is in agreement with the buffer. Of the remaining five banks on the switch, two banks are used for driving the local display at the computer and two are available for the remote requirements. One bank is unused. Each bank represents a decimal numeral. Hence, two banks together comprise a ten's bank and a unit's bank. It is these banks which actually decode the altitude numbers into heights. Thus, the word 01110, which is the binary representation of 14, corresponds to 20(00) feet. At this position of the switch, the unit's contact would connect to the 0 digit of the unit's display, and the ten's contact would connect to the 2-digit of the ten's display. The 0 digit of the unit's bank would be energized in several other cases, namely 00, 10, 20, ... , 90; for all of these positions the unit's contacts would be wired together. The wiring for the contact assembly is shown in Figure 24.

2.9.2 Critical Counts Stepping Switches

The two decimal numbers from the critical-counts counter are decoded by the 11-point switches in much the same way. However, only a single decimal number is obtained for each switch, rather than a pair of numbers, as above. Furthermore, the decade counters have only four flip-flops instead of five as for the altitude numbers. These stepping switches have 6 banks. Four banks are wired to correspond to the states of the 1-2-2-4 counters, one bank is used for a local decimal digit, and one bank is used for the remote output. The wiring for the contact assemblies of these switches is shown in Figure 25.

2.9.3 Stepping-Switch Drive Circuit

The drive circuit for the stepping switches is complicated by the fact that the actual stepping of the wiper arms occurs as the coil is de-energized. Thus, if they are being operated in a self-interrupting mode, the drive contacts will already have closed, and be starting to re-energize the switch by the time the contacts move to the new position. Then if the new position is found to be the desired one, it will be

N	A_n	B_n	C_n	O_n	E_n		L_{10}	L_1	X_{10}	X_1	N
1	A	$\bar{B}$	$\bar{C}$	$\bar{O}$	$\bar{E}$	UNUSEO	0	0	0	0	1
2	$\bar{A}$	B	$\bar{C}$	$\bar{O}$	$\bar{E}$		0	1	0	1	2
3	A	B	$\bar{C}$	$\bar{O}$	$\bar{E}$		0	2	0	2	3
4	$\bar{A}$	$\bar{B}$	C	$\bar{D}$	$\bar{E}$		0	3	0	3	4
5	A	$\bar{B}$	C	$\bar{O}$	$\bar{E}$		0	4	0	4	5
6	$\bar{A}$	B	C	$\bar{D}$	$\bar{E}$		0	5	0	5	6
7	A	B	C	$\bar{O}$	$\bar{E}$		0	6	0	6	7
8	$\bar{A}$	$\bar{B}$	$\bar{C}$	O	$\bar{E}$		0	7	0	7	8
9	A	$\bar{B}$	$\bar{C}$	O	$\bar{E}$		0	8	0	8	9
10	$\bar{A}$	B	$\bar{C}$	O	$\bar{E}$		0	9	0	9	10
11	A	B	$\bar{C}$	O	$\bar{E}$		1	0	1	0	11
12	$\bar{A}$	$\bar{B}$	C	O	$\bar{E}$		1	2	1	2	12
13	A	$\bar{B}$	C	D	$\bar{E}$		1	5	1	5	13
14	$\bar{A}$	B	C	D	$\bar{E}$		2	0	2	0	14
15	A	B	C	O	$\bar{E}$		2	5	2	5	15
16	$\bar{A}$	$\bar{B}$	$\bar{C}$	$\bar{O}$	E		3	0	3	0	16
17	A	$\bar{B}$	$\bar{C}$	$\bar{O}$	E		4	0	4	0	17
18	$\bar{A}$	B	$\bar{C}$	$\bar{D}$	E		5	0	5	0	18
19	A	B	$\bar{C}$	$\bar{O}$	E		6	0	6	0	19
20	$\bar{A}$	$\bar{B}$	C	$\bar{O}$	E		7	0	7	0	20
21	A	$\bar{B}$	C	$\bar{O}$	E		8	0	8	0	21
22	$\bar{A}$	B	C	$\bar{D}$	E		9	0	9	0	22
23	A	B	C	$\bar{O}$	E		9	9	9	9	23
24	$\bar{A}$	$\bar{B}$	$\bar{C}$	O	E						24
25	A	$\bar{B}$	$\bar{C}$	O	E			UNUSEO			25
26	$\bar{A}$	$\bar{B}$	$\bar{C}$	$\bar{O}$	$\bar{E}$						26

NOTE :

A TOTAL OF THREE OF THESE SWITCHES ARE USED, FOR THE PREDOMINANT, MAXIMUM, AND MINIMUM ALTITUDES.

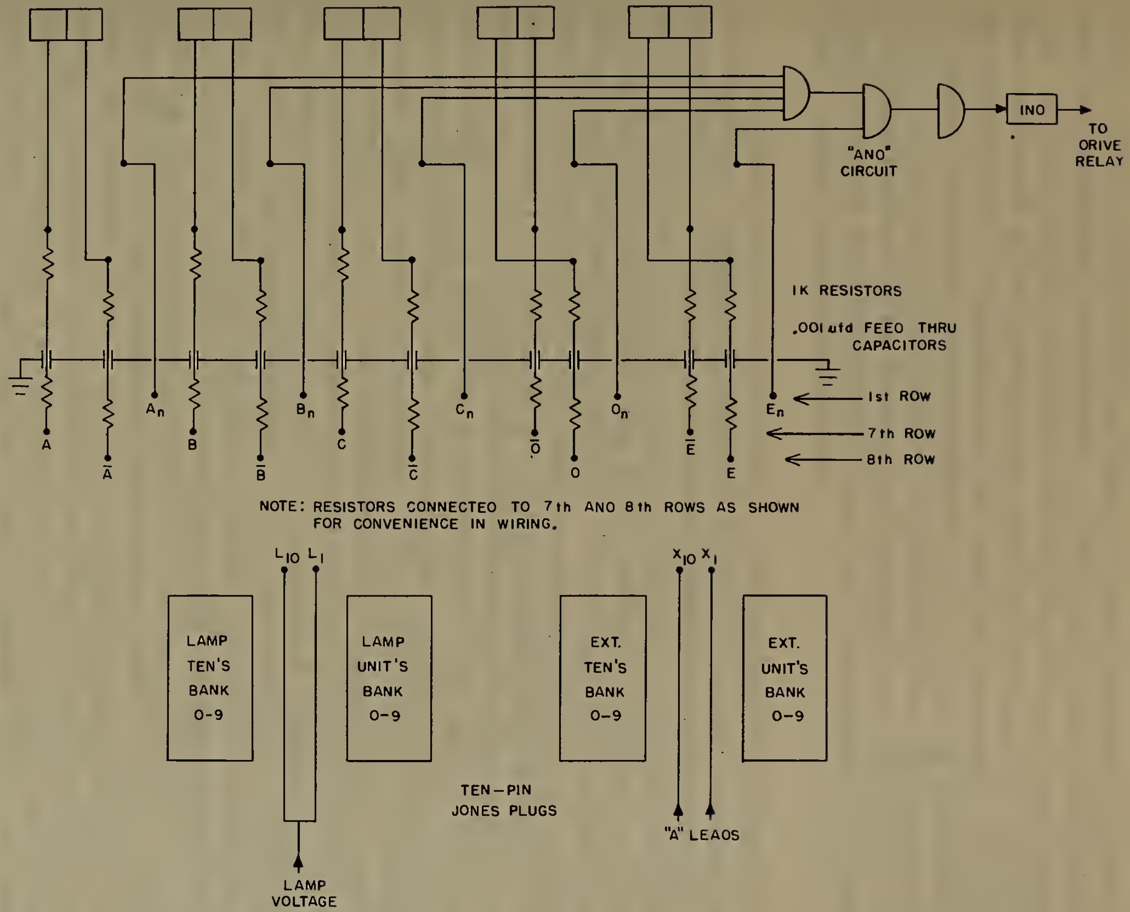
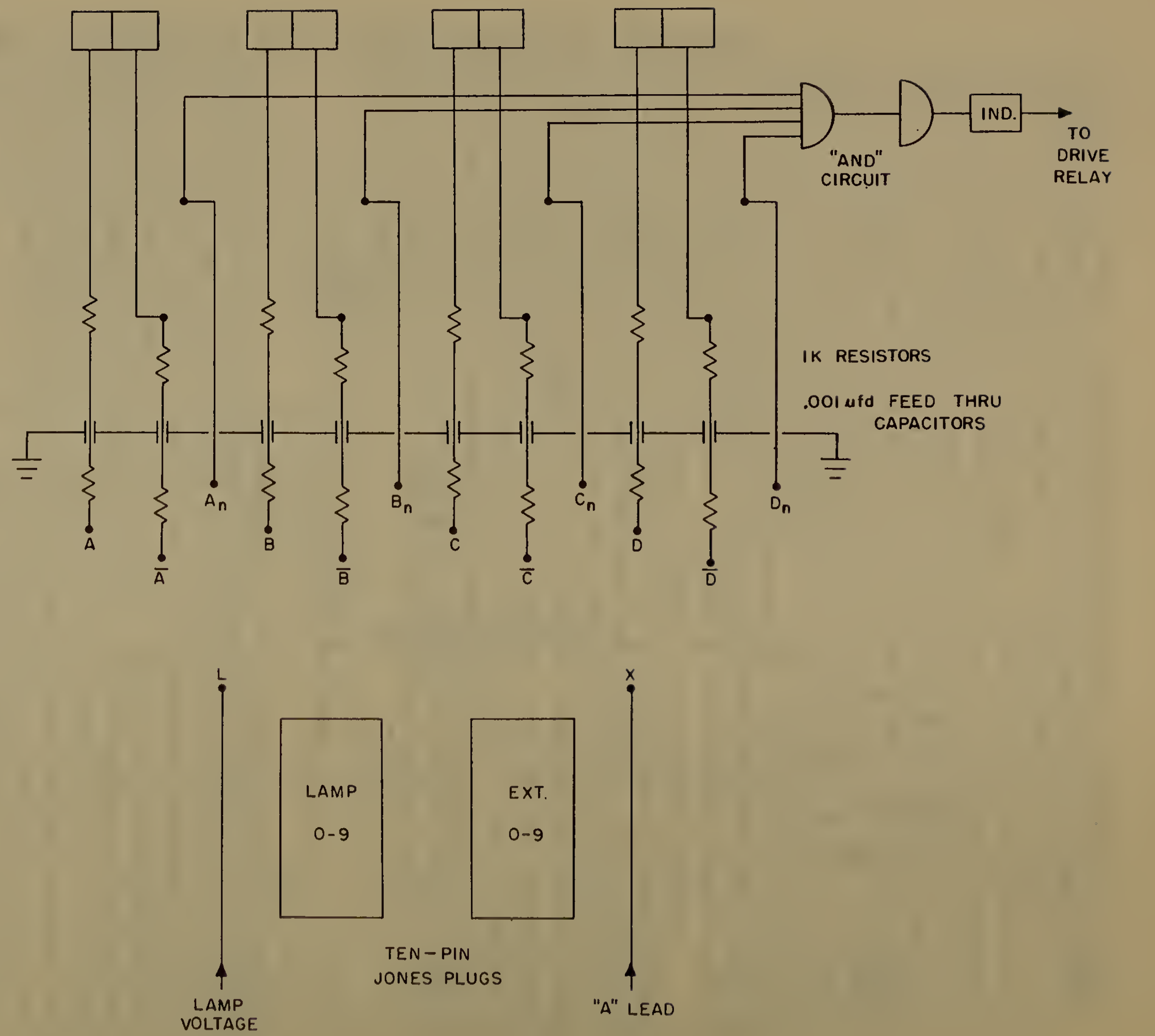


Figure 24. Wiring of 26 - Point Stepping Switches



N	A_n	B_n	C_n	D_n	L	X
1	A	B	C	D	0	0
2	A	B	C	D	1	1
3	A	B	C	D	2	2
4	A	B	C	D	3	3
5	A	B	C	D	4	4
6	A	B	C	D	5	5
7	A	B	C	D	6	6
8	A	B	C	D	7	7
9	A	B	C	D	8	8
10	A	B	C	D	9	9
11	A	B	C	D	9	9

NOTE:

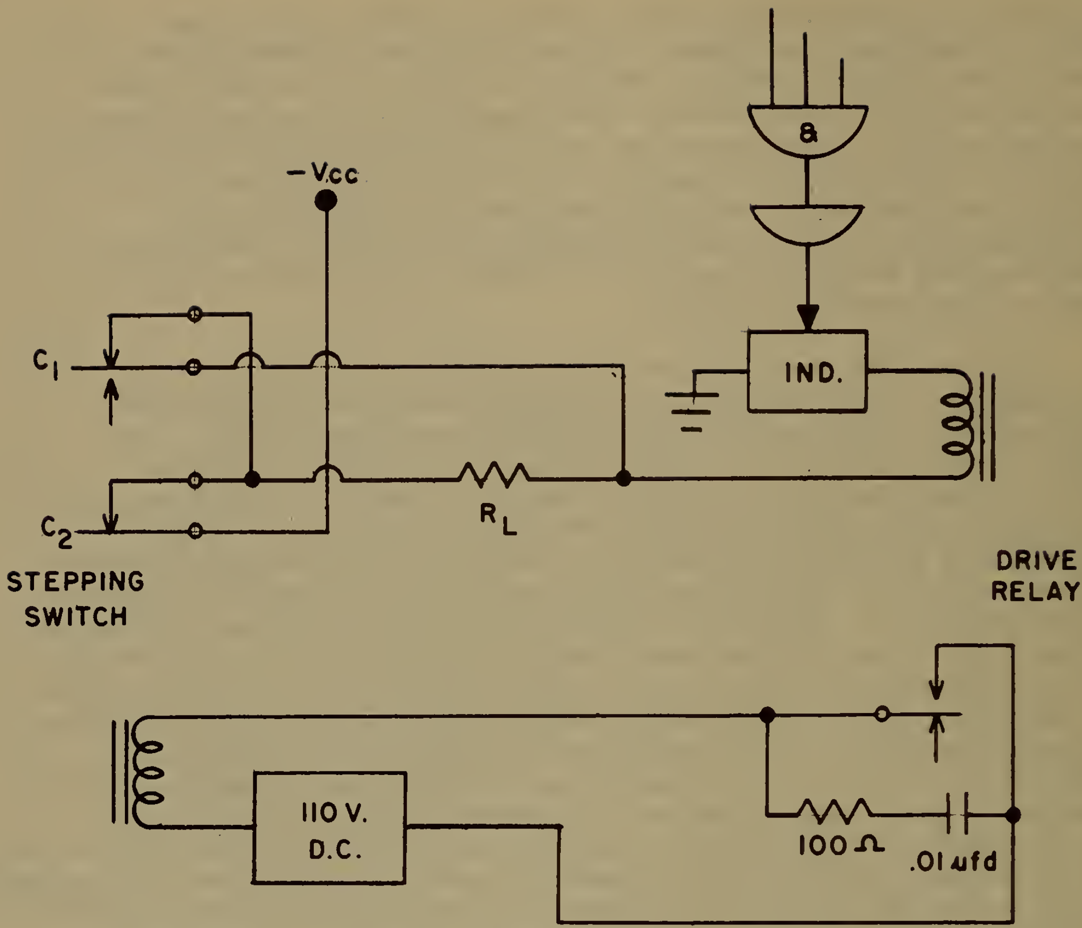
TWO OF THESE SWITCHES ARE USED, ONE FOR THE UNIT'S DIGIT AND ONE FOR THE TEN'S DIGIT, OF THE COUNTS UP TO CRITICAL ALTITUDE.

Figure 25. Wiring of 11 - Point Stepping Switches

necessary to interrupt the drive circuit quickly, before the coil is completely energized. This can be solved through the use of fast relays; however, the drive relay for this application was selected to be compatible with the transistor packages used throughout the computer and as such it was not a high-speed type. In order to assure that adequate time would be available for the AND circuit and drive relay to function, the drive relay and stepping switch were connected together as a sort of oscillator. The stepping switch drive circuit is illustrated in Figure 26. This circuit works as follows:

Assume that one or more of the inputs to the AND circuit is negative, indicating that the stepping switch setting does not correspond to the number stored in its respective buffer. The AND circuit will send a negative signal to an indicator driver which in turn energizes the drive relay. The drive relay closes, energizing the stepping switch. Note that the current for the drive relay must pass through two contacts on the stepping switch. Current can flow through the first contact and through a resistor to the relay coil, and it can flow through the second contact directly to the coil. The resistor has a value such that it will pass enough current to hold the relay closed, but it will not pass enough current to close the relay if it is open. This resistor, therefore, provides a latching action. The stepping switch contacts are adjusted to operate in sequence. As soon as the stepping switch starts to move, the direct path to the relay coil is opened, leaving only the path through the latching resistor. As the stepping switch reaches the end of its cocking stroke the next contact opens, breaking the latching path. This causes the drive relay to drop out, deenergizing the stepping switch. Now the stepping switch armature begins to drop back, stepping its wiper contacts to the next point. As soon as it starts back the contact in the latching circuit closes, but this does not pass enough current to close the drive relay. Not until the switch drops back far enough for the wipers to reach the next point does the second contact close, completing the direct path to the drive relay. By this time the AND circuit will have had a chance to function, if the new position is the desired one, and the drive for the relay will be cut off, before another step is initiated. If the new position is still not correct, the AND circuit will continue to furnish a signal to the drive relay, and the stepping action will continue. The stepping rate is about 15 to 20 steps per second with this circuit.

Contact protection for the drive relay contacts, which must interrupt the stepping switch current, is provided by an R-C network of 100 ohms in series with a 0.1 μfd capacitor across the contact. (Fg.27) The stepping switches require 110 volts, d-c, and the coil resistance

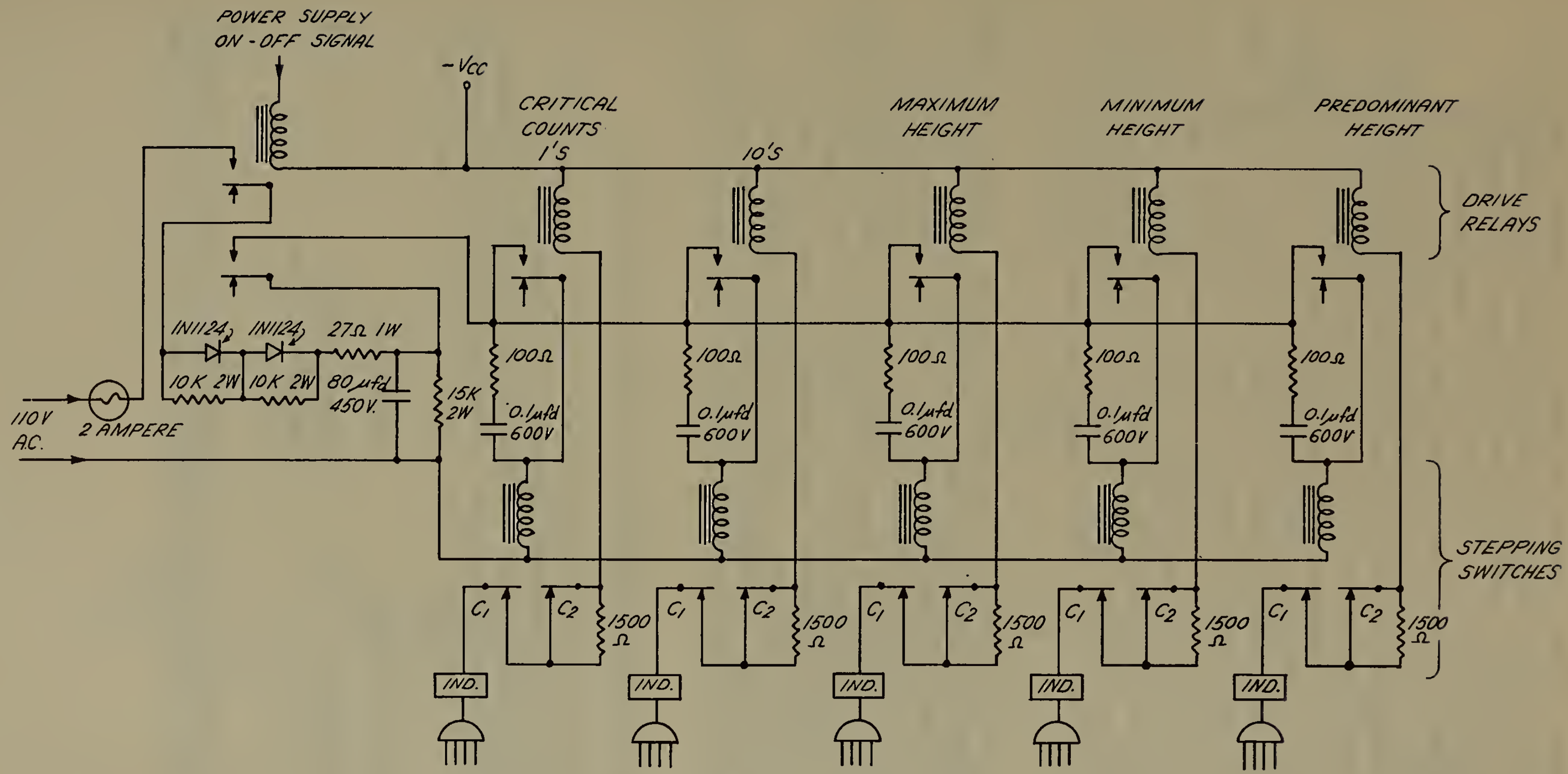


R_L – LATCHING RELAY (1500 Ω FOR 1000 Ω, 10 ma. COIL)

CONTACT C_1 ADJUSTED TO OPEN AS SOON AS ARMATURE STARTS TO MOVE.

CONTACT C_2 ADJUSTED TO OPEN AS ARMATURE BECOMES FULLY COCKED.

Figure 26. Stepping Switch Drive Circuit



NOTES:
1. CONTACT C_1 OPENS FIRST, AT START OF COCKING STROKE.
2. CONTACT C_2 OPENS WHEN SWITCH IS FULLY COCKED.
3. BOTH CONTACTS ARE NORMALLY CLOSED WHEN SWITCH IS DE-ENERGIZED.

Figure 27. Stepping Switch Chassis Wiring.

is about 400 ohms. The Current is about 0.3 amperes per coil and since there are five stepping switches the power supply must be able to furnish a peak current of about 1.5 amperes. The power supply, which is mounted on the stepping switch chassis, consists of a half-wave rectifier using two silicon diodes in series. No transformer is used, so one side of the d-c output is connected to the a-c line. The rectifiers used are 1N1124's with a current rating of 5 amperes (with proper heat sink) and a peak inverse voltage of 200 volts. This is not sufficient to allow a single rectifier to be used, since the peak value of the 110 volts line is about 160 volts, and this is the value which the filter capacitor will attain. Thus, during the non-conducting half-cycles, the rectifier has across it the 160 volt d-c output voltage plus the 160-volt peak voltage of the line, or 320 volts. For this reason, two rectifiers are used in series, with 10K ohms resistors across them to assure equal voltage division in the back direction. The power supply is protected by a 2-ampere fuse.

One additional feature was included with the stepping switches to prevent excessive display changes. Certain of the buffers change several times during the analysis cycle, and it is undesirable that these momentary changes appear in the display. For this reason, a relay has been added to the power supply which turns it off during the analysis cycle. Since a double-pole relay was available for this purpose, one contact is placed in the a-c line and one in the d-c output. Thus, the power supply is not energized continuously, reducing the dissipation on the power supply components. This relay is closed for all manual modes of operation.

3. MANUALLY OPERATED TEST FUNCTIONS

In normal operation the Ceilometer computer operates in the automatic mode, either one-minute, or 10-minute, as determined by the appropriate switch setting. However, there are several manual settings of this switch, to provide for testing of the computer (Figure 28). The switch settings are as follows:

AUTOMATIC	MANUAL
One-Minute	Single Words
Ten-Minute	One Revolution
	Analyze

Just above this switch are two push-buttons labelled "Write" and "Read". The "Write" push-button is used only for recording

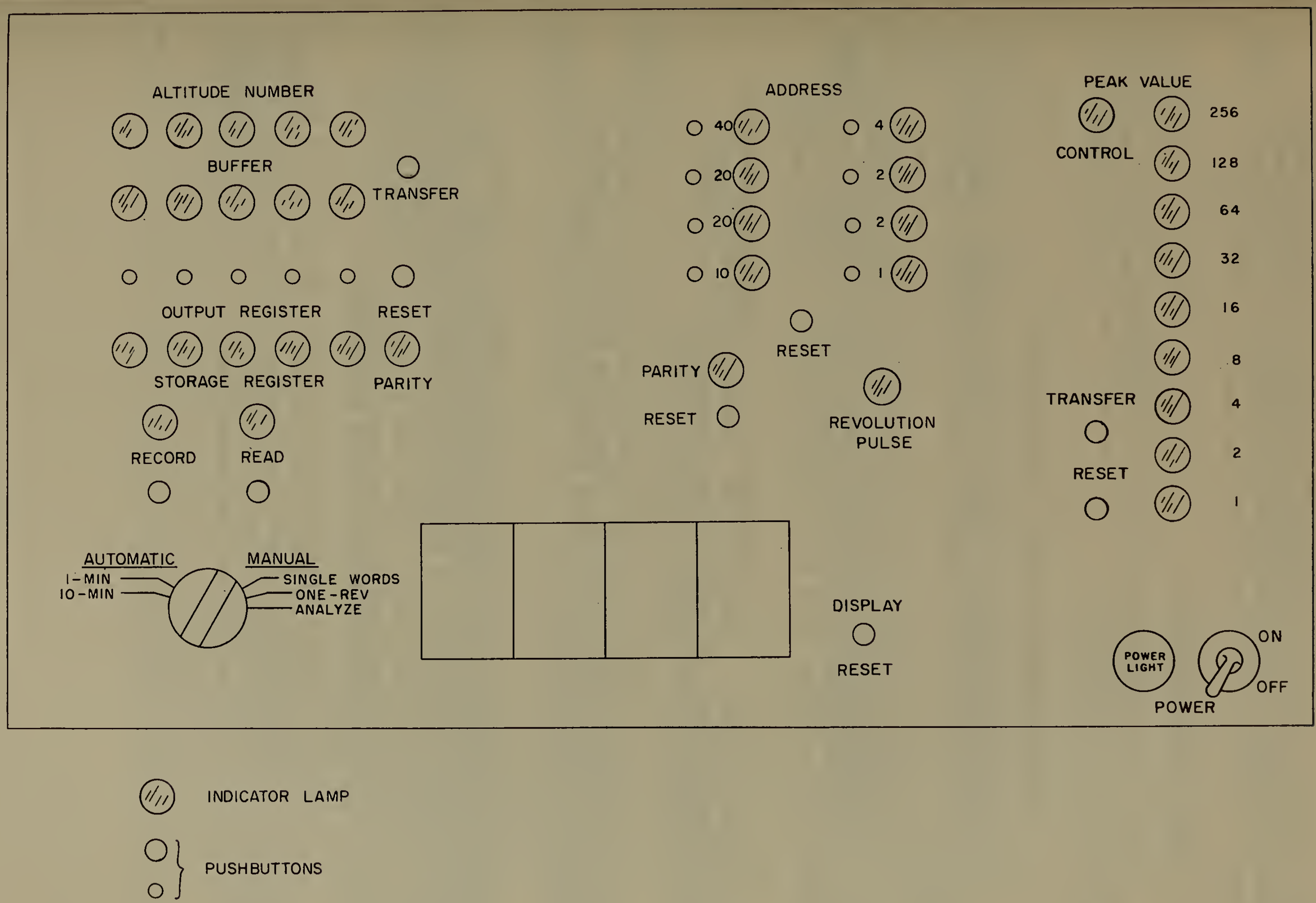


Figure 28. Front Panel

single words. The "Read" push-button is used for reading single words, reading for one revolution, or analyzing. (NOTE: These buttons should not be pressed faster than about 2 or 3 times per second. This limit is imposed by the access time of the drum.

3.1 Single Word Operation

This function permits any of the 5-bit altitude numbers (including 00000) to be recorded or read in any desired location on the drum. The procedure is as follows:

1) The mode switch is set to "Single Word".

2) The Altitude Number Counter, Address Counter, and Peak-Values Detector are zeroed by means of their respective reset buttons.

3) The desired word is set up in the Altitude Number Counter (top row of lights) by means of the five small buttons beneath it. These buttons cause the lights to turn on, indicating one's. (NOTE: Internal feedback does not allow the 8 and 16 lights to be on simultaneously.)

4) The selected word is transferred to the Buffer by means of the "Transfer" button. (NOTE: If the Control light on the Peak-Value Detector is on, the word will not transfer into the Buffer. Hence, the Peak-Value Detector should be reset.)

5) The desired address is selected by pushing the small buttons next to the address lights. (NOTE: These are 1-2-2-4 counters, connected in such a way that if either of the upper two lights are on, the second light will be on also.)

6) The desired word and address have now been selected. Pressing the "Write" button causes the word to be recorded. The Address Counter lights will be seen to blink momentarily, indicating that 101 counts are being gated to the counter. The address will be seen to advance by one. Thus, if the "Write" button is pressed again it will record the same word in the succeeding address, and so forth. The word may be recorded as many times as desired.

7) To read a single word it is only necessary to select the address and press the "Read" button. Again, the address advances by one each time a word is read. The word will be displayed in the Storage Register, in binary form, and decoded into the Output Display in decimal numbers.

8) The drum may be erased by recording all zeroes in every address. This is done by resetting the buffer to zero and recording 100 times.

The max-min and critical count circuitry do not obtain signals in this mode of operation, but they are reset to zero when the "Write" or "Read" buttons are pressed.

3.2 One-Revolution

This function permits the read circuitry to be operated for a single revolution of the drum. During this operation the read circuitry will compare each of the 100 words on the drum with the contents of the Altitude Number Counter, and the resulting coincidence pulses will be fed to the Peak-Value Detector. The Peak-Value Detector will then indicate the number of times that this word occurred. Also, if the word occurs at least once, the Control Light will come on, and the word will be transferred into the Buffer. If the word does not occur, it will not appear in the Buffer, and the Peak-Value lights will remain off.

The procedure is as follows:

1) The mode switch is set to "One-Rev.".

2) The Altitude Number Counter and Peak-Value Detector are zeroed by means of their respective reset buttons. The Address Counter plays no part in this operation and need not be reset.

3) The desired word is placed in the Altitude Number Counter by means of the five small buttons. Word "zero" (00000) may be counted, if desired. It should occur 100 times if the drum has been erased.

4) The "Read" button is pressed. If the word occurred on the drum it will now appear in the Buffer. In this case the Control Light will be on, and the number of times that the word occurred can be read from the Peak-Value lights.

The "Write" button should not be used with this function.

The max-min and critical count circuitry are not activated during this function.

3.3 Analyze

This function permits the computer to be triggered manually to perform the analysis cycle. The analysis is identical with that performed during the "analysis" cycle under automatic operation. Answers will be developed for all of the pertinent factors, as listed below:

a) What altitude number occurs most frequently, and how many times?

b) What are the lowest and highest altitude numbers which occur five or more times?

c) How many times did altitude numbers appear which were less than the critical altitude number?

In this mode of operation the read circuitry counts the number of times that each of the altitude numbers from 1 to 23 occurs on the drum. Trains of coincidence pulses are generated and sent to the Peak-Value Detector, which causes a new altitude number to be transferred into the Buffer any time it occurs more frequently than any previous number. The 23 numbers require 23 revolutions of the drum, or 2.3 seconds. During this time the Altitude Number Counter can be seen to count in binary fashion as the altitude number increases, indicating that the analysis is in progress.

The procedure is as follows:

1) The mode switch is set to "Analyze".

2) The Altitude Number Generator and the Peak-Value Detector are zeroed by means of their respective reset buttons. The address counter plays no part in this operation and need not be reset.

3) The "Read" button is pressed, to initiate the analysis. The analysis requires 2.3 seconds, during which time the Altitude Number lights will be blinking. At the end of this time the displays will contain answers to all of the questions listed above. The analysis may be repeated any number of times, and the answers should always be the same, as long as the data is unchanged. Once an analysis cycle has been initiated, the "Read" button should not be pressed again until it is completed.

The "Write" button should not be used with this function.

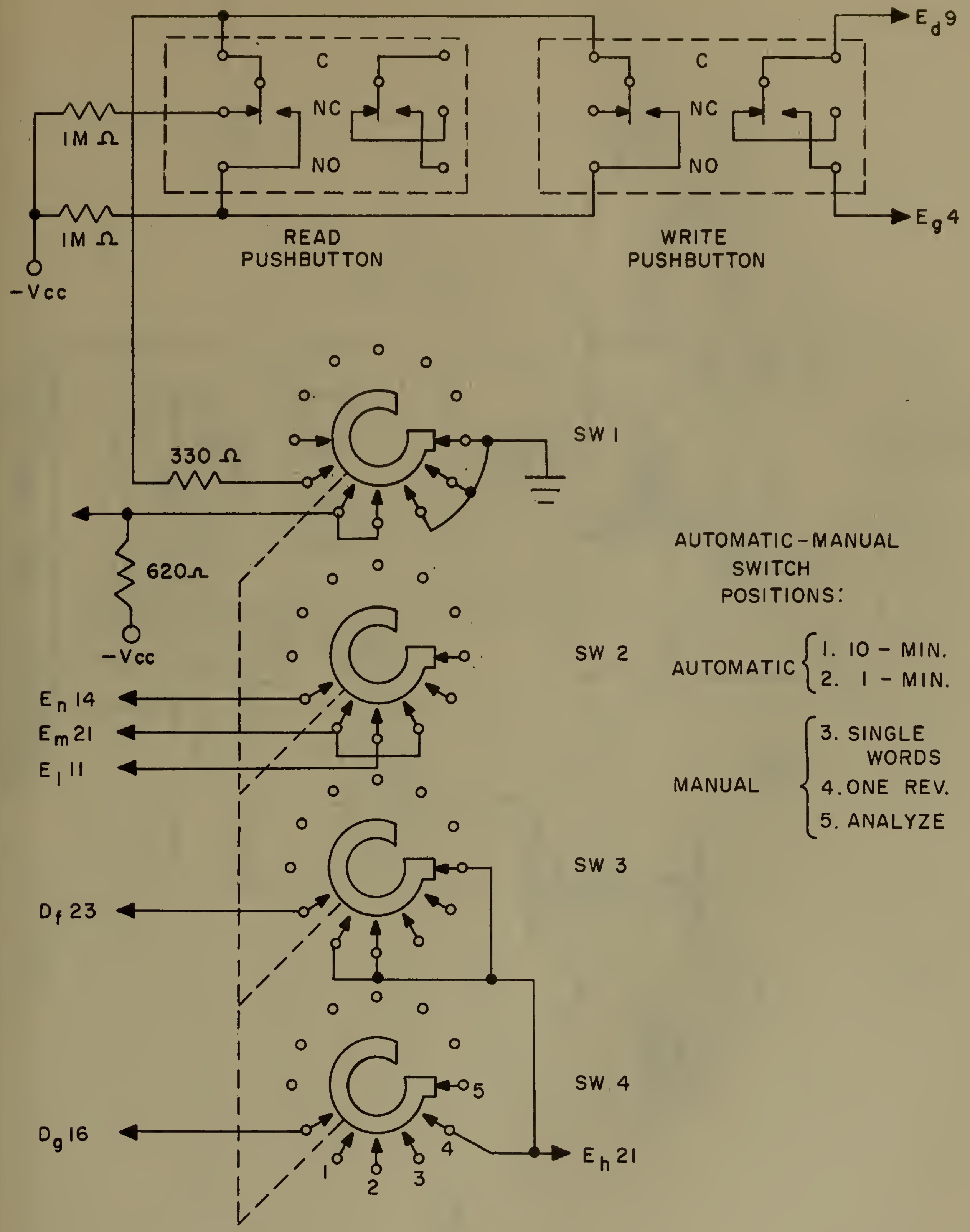


Figure 29. Switch and Pushbutton Wiring

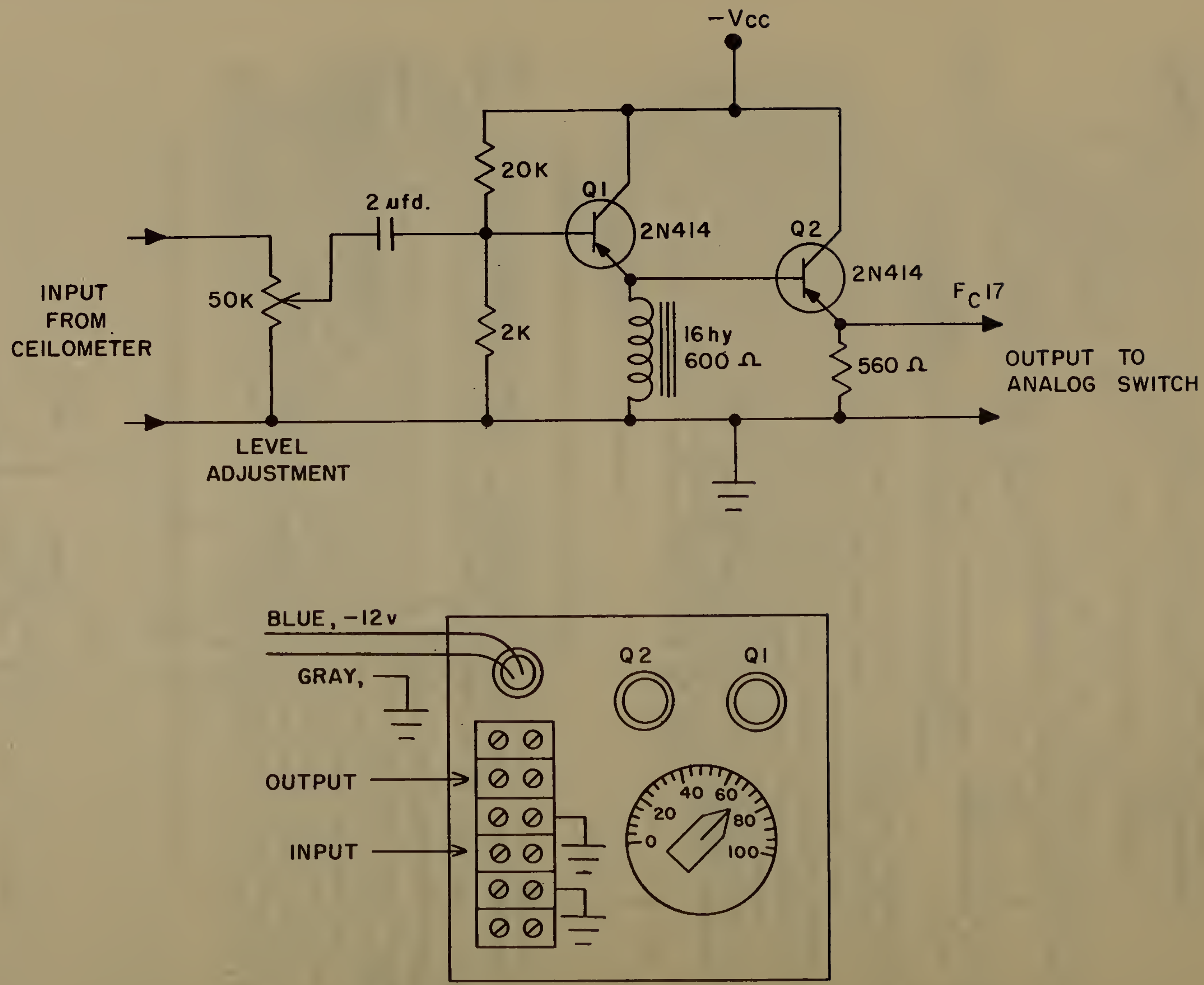


Figure 30. Input Amplifier

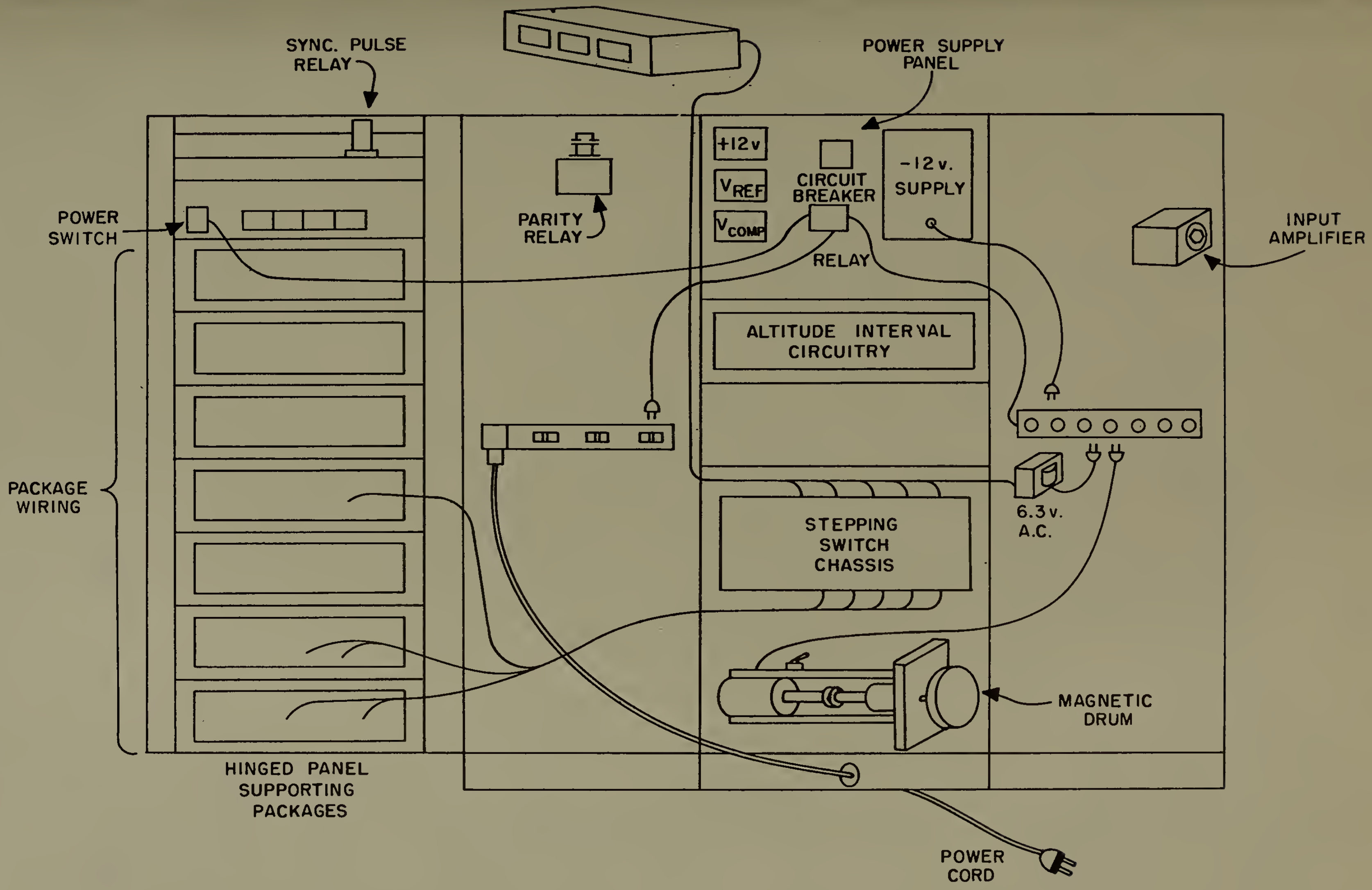


Figure 31. Developed View of Cabinet Interior

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, Secretary

NATIONAL BUREAU OF STANDARDS
A. V. Astin, Director

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colo., is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D.C.

ELECTRICITY. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics.

METROLOGY. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

HEAT. Temperature Physics. Heat Measurements. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research. Equation of State. Statistical Physics. Molecular Spectroscopy.

RADIATION PHYSICS. X-Ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

CHEMISTRY. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

MECHANICS. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Combustion Controls.

ORGANIC AND FIBROUS MATERIALS. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

METALLURGY. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

MINERAL PRODUCTS. Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

BUILDING RESEARCH. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials.

APPLIED MATHEMATICS. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

DATA PROCESSING SYSTEMS. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Applications Engineering.

ATOMIC PHYSICS. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics.

INSTRUMENTATION. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Office of Weights and Measures.

BOULDER, COLO.

CRYOGENIC ENGINEERING. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

IONOSPHERE RESEARCH AND PROPAGATION. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

RADIO PROPAGATION ENGINEERING. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

RADIO STANDARDS. High frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

RADIO SYSTEMS. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Space Telecommunications.

UPPER ATMOSPHERE AND SPACE PHYSICS. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

NBS