Digital Computer Laboratory
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SUBJECT: <u>THE FERROELECTRIC SWITCH</u>

To: Norman H. Taylor

From: Dudley A. Buck

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Abstract: A multi-position ferroelectric switch is proposed which can accomplish many of the switching tasks in an information handling system; in particular, it can select among the rows and columns of a ferroelectric memory. The logical circuitry of the ferroelectric switch can be painted directly onto the two sides of a thin ferroelectric sheet.

The non-linear electric displacement-versus-field characteristics of a <u>ferroelectric</u> dielectric can be utilized to construct a condenser whose capacitance is a function of the applied voltage.[1,2] This phenomenon, which makes possible dielectric amplifier operation, is the basis for operation of the switch to be here described. Figure 1 illustrates the operation of the basic switch element--a simple R-C filter which uses a non-linear condenser as its series branch. With no direct voltage across the condenser (Fig. 1A) the circuit behaves like any ordinary π-section R-C filter with the exception that distortion will result if the input voltage is large enough to drive the dielectric out of its linear region. Transfer characteristics are shown for sinusoidal excitation. If a bias voltage, V_c, is inserted in the circuit as shown (Fig. 1B), the operating point for the transfer characteristic is shifted to a new point on the charge-versus-voltage characteristic of the non-linear condenser. At this new point, the condenser has a much lower capacity and, therefore, the [illegible] characteristics are changed in such a way that the [illegible] in amplitude [illegible] input voltage. Then, the output voltage can be changed by varying the bias voltage, V_c. For ferroelectric switch operation [illegible] V_c [illegible] enough to bias the dielectric well [illegible]

Figure 2 illustrates a two-position ferroelectric switch. The two non-linear condensers are made as a single unit by [illegible] a large electrode on one [illegible] sheet and two smaller electrodes on the opposite side. [illegible]

[illegible]

[illegible]

In the opposite position, output 2 is ON.

Figure 2B illustrates an eight-position ferroelectric switch. Operation of the first stage, controlled by S_1, is the same as the two-position switch. Subsequent stages, however, have the lower ends of their resistors connected so that the even resistors are connected to ground when the odd resistors are connected to V_c and the even resistors are connected to V_c when the odd resistors are connected to ground. There are eight possible paths through the switch (Fig. 3) only one of which will have all of its condensers ON. With S_1, S_2 and S_3 of the eight-position switch set as shown, output zero is ON. Outputs 1, 3 and 7 have one condenser OFF, outputs 2, 4 and 6 have two condensers OFF, and output 5 has all three condensers OFF. The number of OFF condensers among the outputs follows a binomial distribution:

	All On	One OFF	Two OFF	Three OFF	Four OFF	Five OFF
4-position switch	1	2	1			
8-position switch	1	3	3	1		
16-position switch	1	4	6	4	1	
32-position switch	1	5	10	10	5	1

Successful operation of the switch postulates that a single OFF condenser leading to an output will cause that output to be OFF. To test this, an eight-position switch was constructed (Fig. 4) using a thin (.025") sheet of barium tinanate ceramic (Glenco body "X-18"). All of the non-linear condensers are placed on the same sheet by firing electrodes on the two sides as shown. The signal enters the sheet via a large fired electrode (back view). Two electrodes match this input electrode on the opposite side (front view). Among the two condensers thus formed, one will always be OFF and one will always be ON. Each of these two electrodes is enlarged to match up with two electrodes on the opposite side which are alongside the input electrode. One of each pair of this third set of electrodes will be OFF. Finally the signal goes through the dielectric a third time coming out on one of the eight small electrodes (front view).

The operation of the switch is illustrated graphically by Fig. 5. With a constant-amplitude, sine-wave input of variable frequency, the RMS output at terminal 7 was measured as a function of frequency for each of the eight possible combinations of S_1, S_2 and S_3. At 800 cps, the best operating frequency for this particular design, the ratio of ON voltage to the highest OFF voltage is greater than three to one. This operating frequency can be shifted higher or lower by changing the size of the condensers and resistors. Both steady-state and pulse tests on this dielectric indicate that the operating frequency can be shifted up to several megacycles per second. If the resistors are replaced by inductors, the output-versus-frequency characteristics can be improved and losses are lowered.

For pulsed operation of this switch, a non-linear condenser is used in both the series and shunt arms of the filter. Fig. 6A illustrates such a switch which is so arranged that when the series condenser is ON, the shunt condenser is OFF (Fig. 6B); and when the series condenser is OFF, the shunt condenser is ON (Fig. 6C). The filter looks like a condenser voltage-divider to the rising edge of a pulse. The divider has either a large condenser in its upper leg and a small condenser in its lower leg or vice-versa, depending on whether the switch is ON or OFF.

The ferroelectric switch is proposed as a means for driving the rows and columns of a ferroelectric memory and for switching within an information-handling system. Its unique packaging makes it promising in applications where size, weight and cost are important considerations.

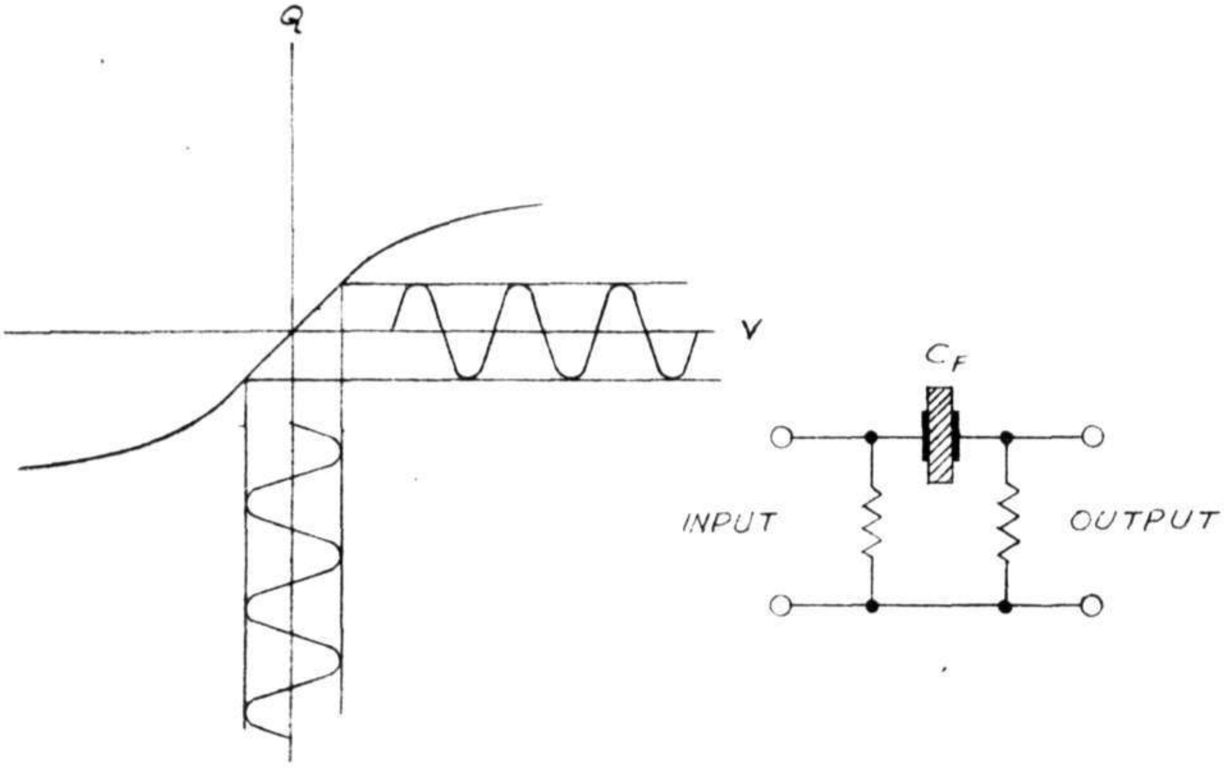
Signed Dudley A. Buck
Dudley A. Buck

Approved William N. Papian
William N. Papian

DAB/jk

Drawings attached:

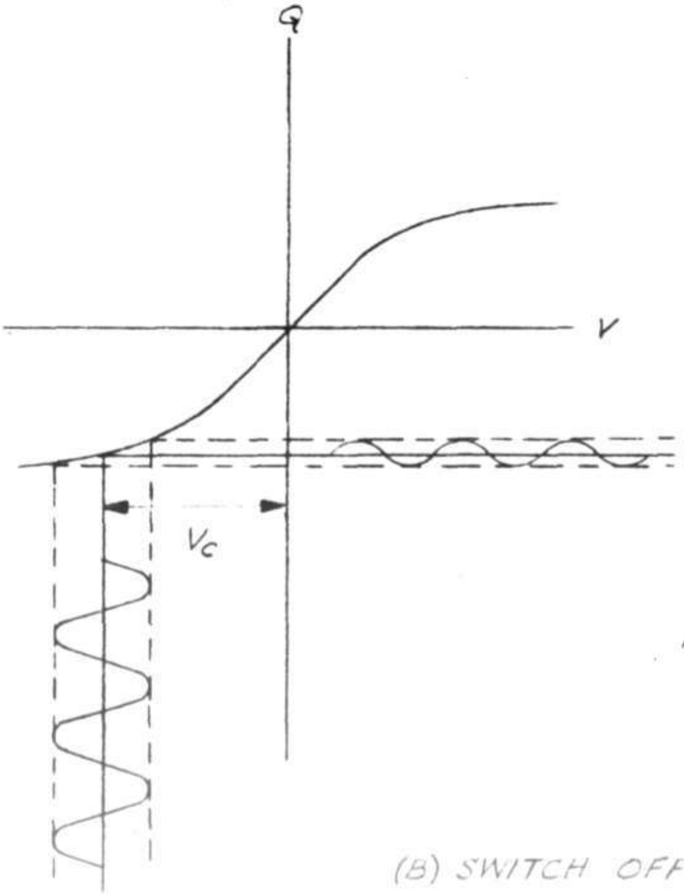
Fig. 1 - A-51155
Fig. 2 - A-51144
Fig. 3 - A-51151
Fig. 4 - A-50906
Fig. 5 - A-51148
Fig. 6 - A-51152

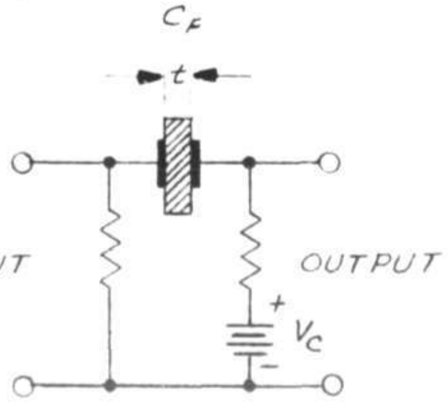


(A) SWITCH ON

NOTE:

C_F IS A CONDENSER WITH FERROELECTRIC MATERIAL AS DIELECTRIC.





(B) SWITCH OFF

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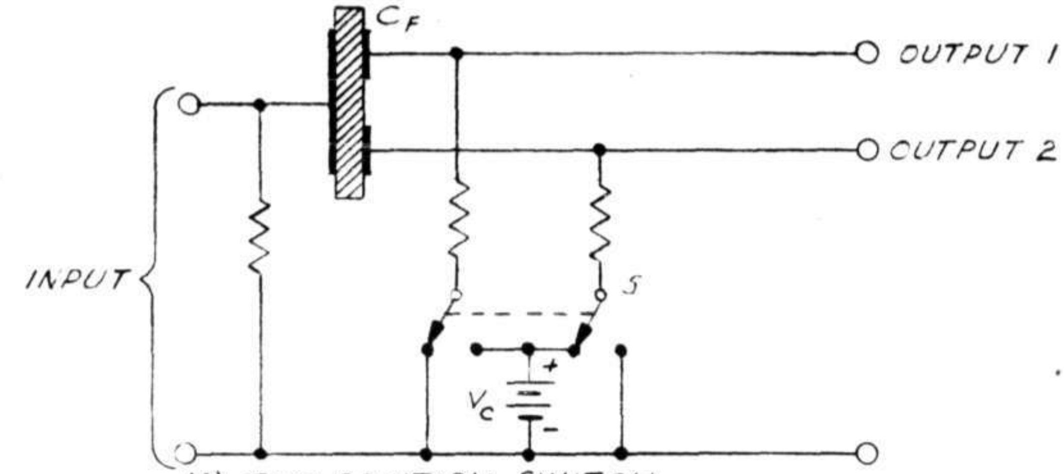
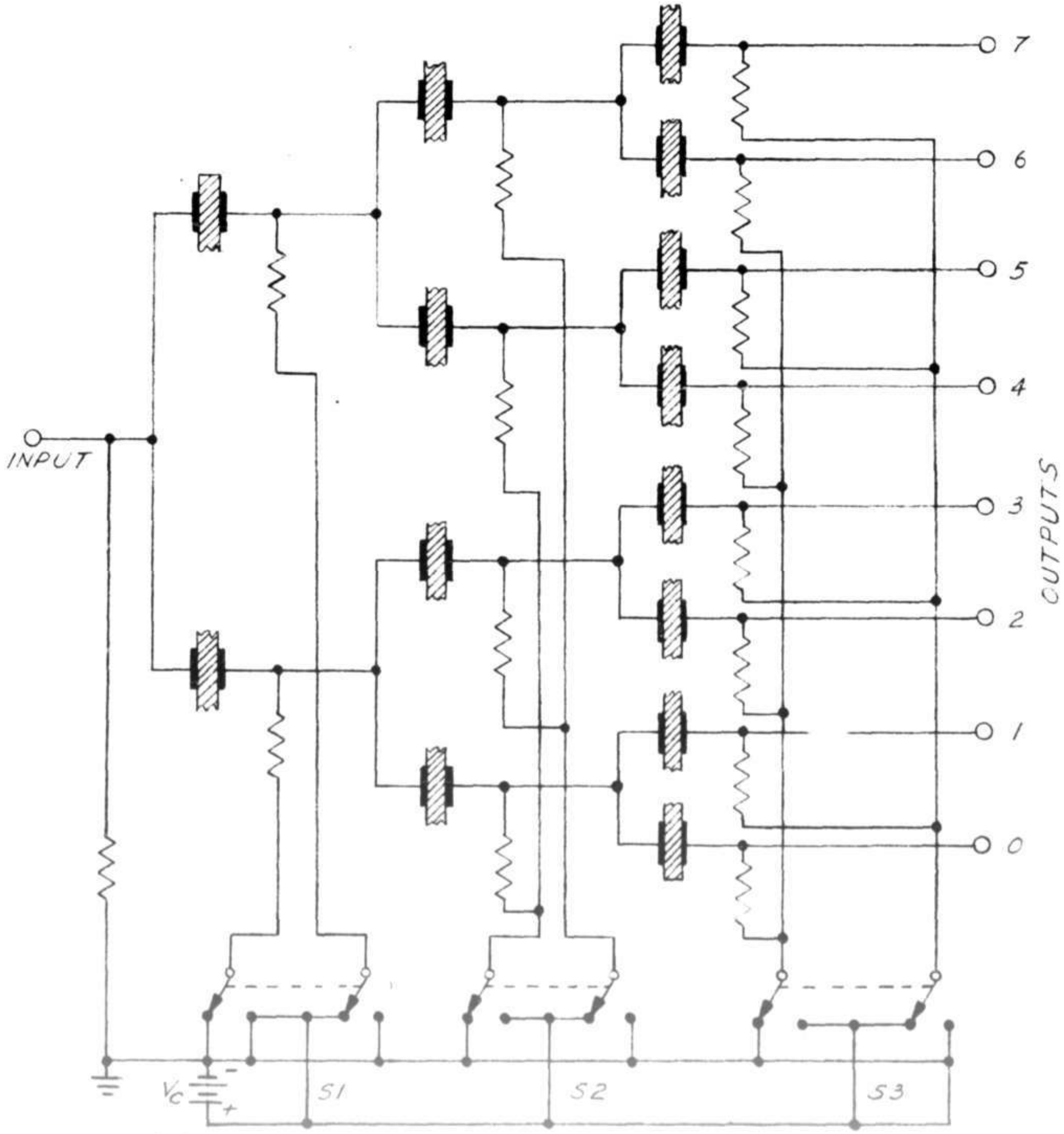
FERROELECTRIC SWITCH OPERATION



(A) TWO-POSITION SWITCH



(B) EIGHT-POSITION SWITCH

FERROELECTRIC SWITCH SCHEMATIC DIAGRAM

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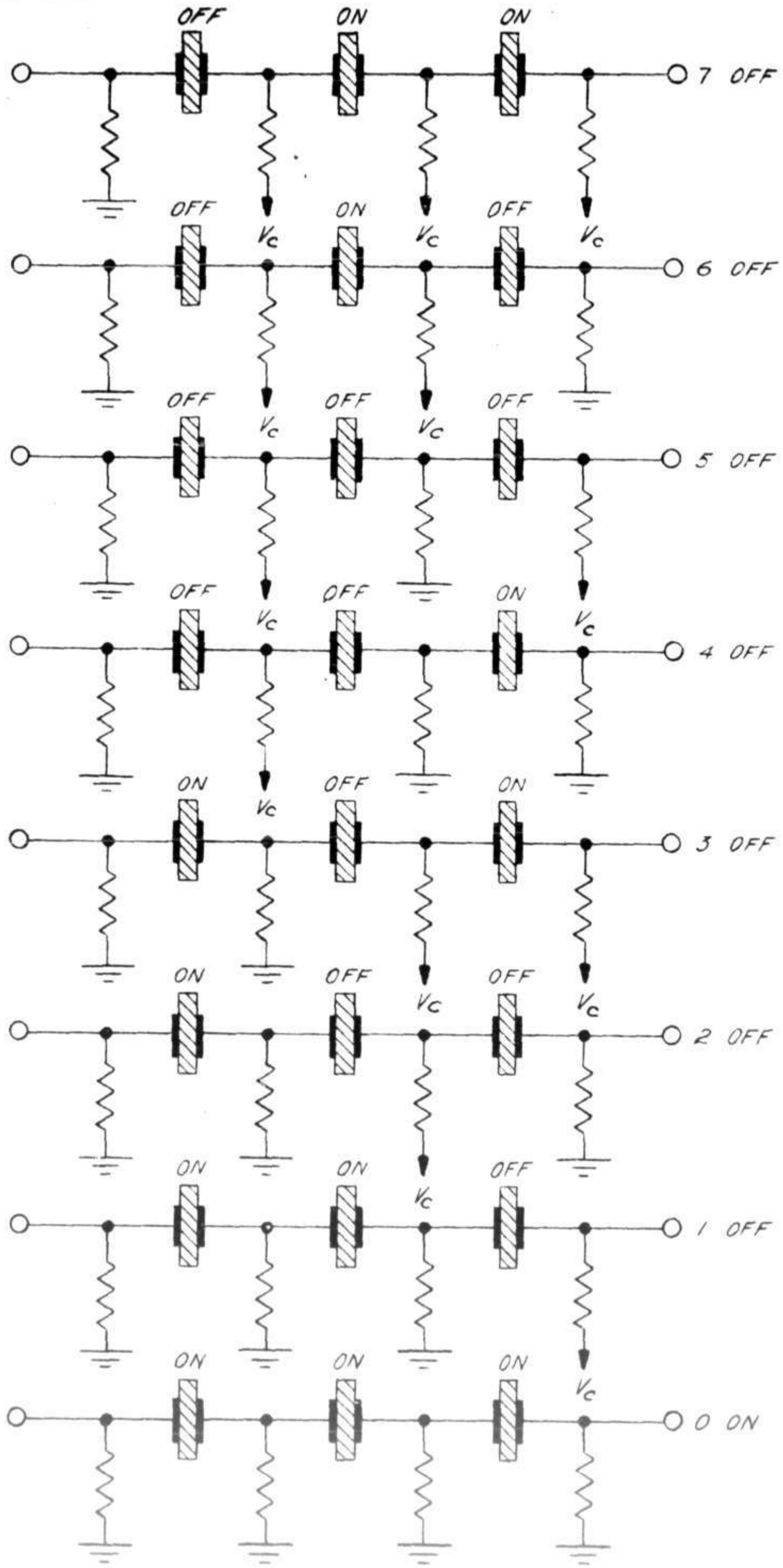

EIGHT-POSITION SWITCH ANALYSIS

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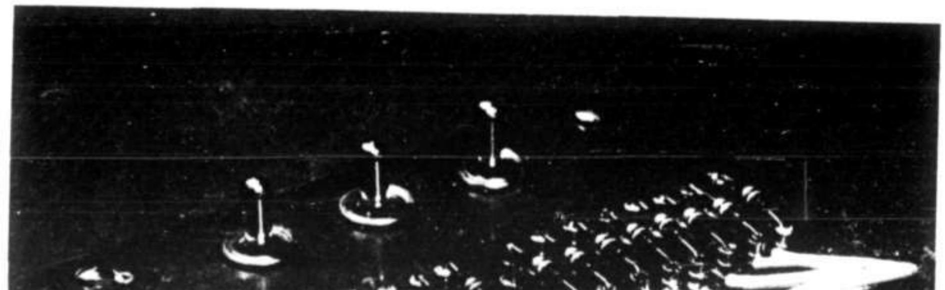
(FRONT VIEW)



(BACK VIEW)

FERROELECTRIC MULTI-POSITION SWITCH

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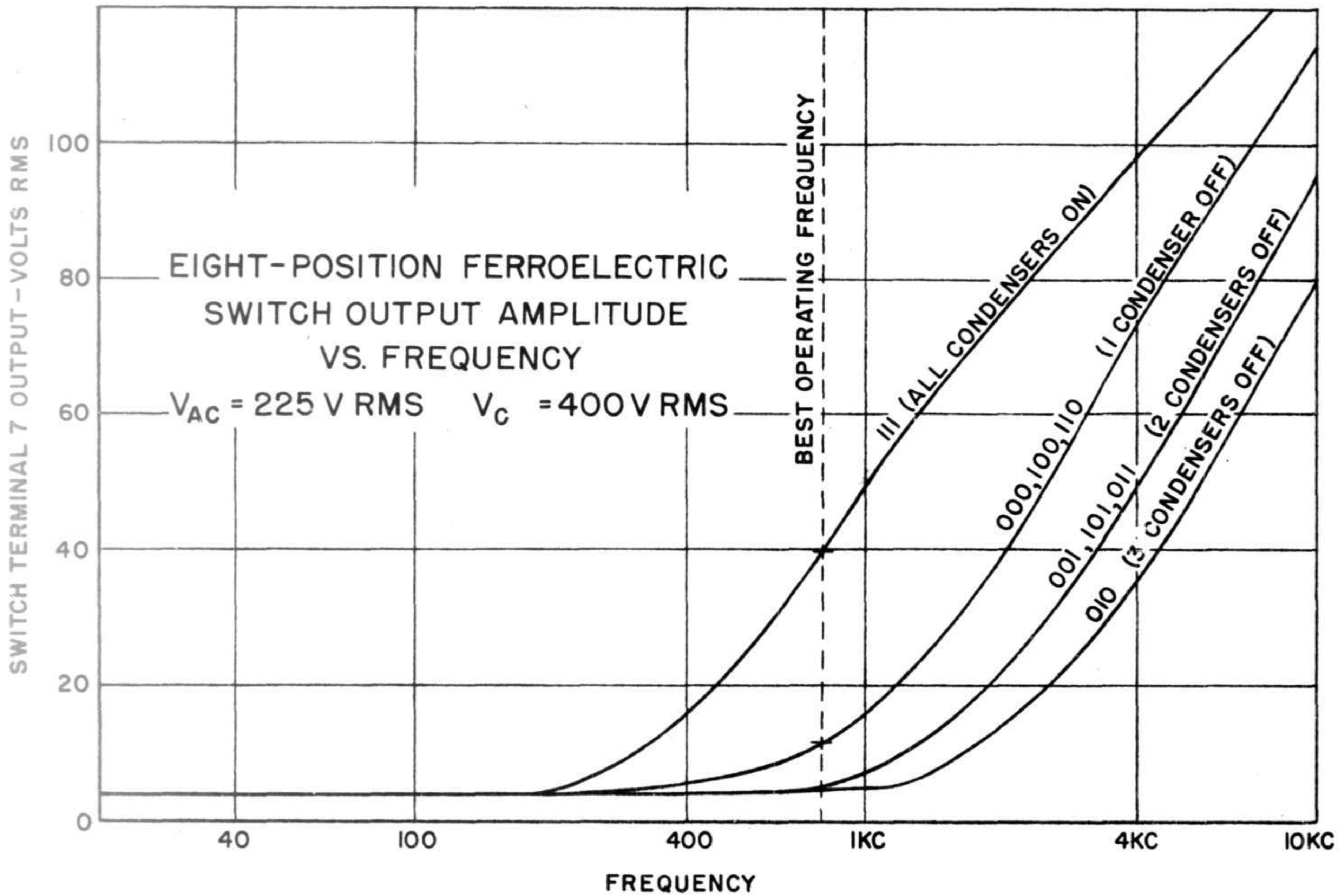

EIGHT-POSITION FERROELECTRIC
SWITCH OUTPUT AMPLITUDE
VS. FREQUENCY
V_{AC} = 225 V RMS V_C = 400 V RMS
BEST OPERATING FREQUENCY
111 (ALL CONDENSERS ON)
000,100,110 (1 CONDENSER OFF)
001,101,011 (2 CONDENSERS OFF)
010 (3 CONDENSERS OFF)
SWITCH TERMINAL 7 OUTPUT-VOLTS RMS
0
20
40
60
80
100
40
100
400
1KC
4KC
10KC
FREQUENCY