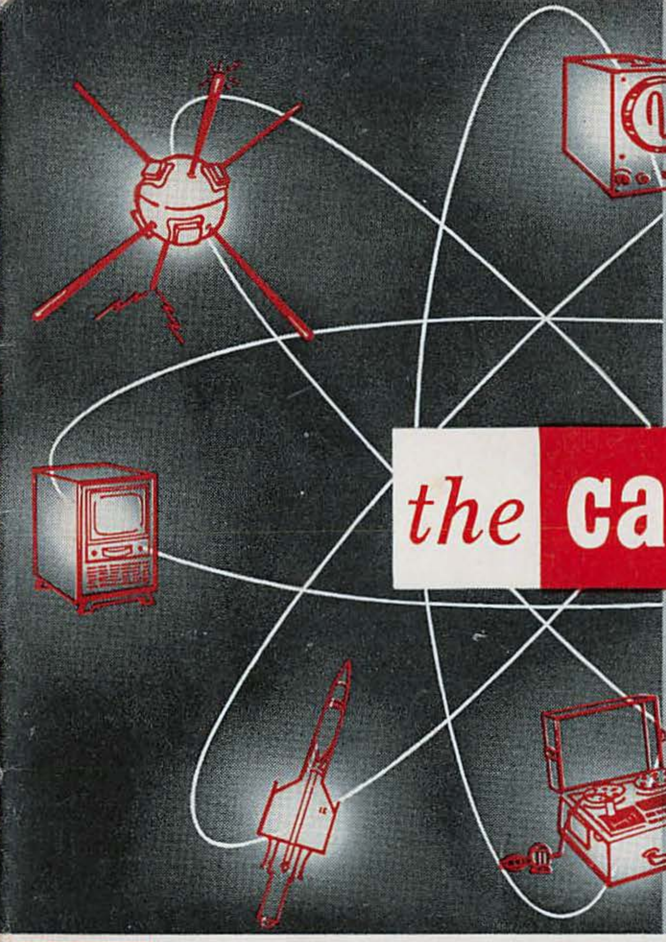

the capacitor

CDE

CORNELL-DUBILIER ELECTRONICS DIVISION
FEDERAL PACIFIC ELECTRIC COMPANY
NEWARK NEW JERSEY

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FRANK EAMES
5 RICHARDSON AVE.
ATTLEBORO, MASS.

51st Year

INDEX ISSUE

1961-

The 50th Anniversary of our company not only marked the half-century of service to the electronic and electrical industry, but also heralded our new association as a division of the multi-million dollar Federal Pacific Electric Company complex.

We are enthusiastic about the prospect that our merger holds for the future. Our combined vigorous resources promise new and exciting horizons of growth.

As "Partners-In-Progress" we enter the New Year with you convinced that together we can achieve an even greater measure of mutual prosperity, friendship and cordiality.

To that end, we wish for you and your loved ones continued health and happiness in 1961.

CORNELL-DUBILIER ELECTRONICS DIVISION
FEDERAL PACIFIC ELECTRIC COMPANY

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appearing in the

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of the C-D Capacitor

ELECTRONIC COUNTER

The area of application for electronic counting devices is not only large but steadily growing. Two decades ago, the sole industrial use was object counting. With the rapid expansion of electronics into other fields, both scientific and industrial, however, the counting of many kinds of regular and random events has been turned over to these devices. The electronic counter, unhampered by inertia, can operate at speeds far beyond the upper limits of the fastest mechanical counter and requires insignificant signal power.

Starting with the prosaic task of object counting, the long list of modern counter applications would fill several pages and would touch upon radioactivity, digital computers, frequency measurement, speed checking, voltage, current, and resistance measurement, totalizing events per unit time, measurement and indication of time intervals, predetermined counting, etc. Virtually every branch of science and industry has some use for the high-speed counter.

It is not the purpose of this article to review the applications of counting devices, but to describe the fundamental circuits used in modern counters. This survey is necessarily brief but is aimed to give the general electronics technician an over-all view of this special equipment.

Flip-Flop Element

Just as gears and ratchets are the basic elements in certain mechanical counters, the bistable multivibrator, or flip-flop, is the fundamental building block of the most widely used digital electronic counter systems. Although the flip-flop was invented approximately forty years ago, it did not come into widespread use until the advent of high-speed electronic counters.

The flip-flop is a fully electronic switch. A signal (trigger) pulse applied to its input will switch its output ON, whereupon it will remain ON until a subsequent pulse switches it OFF. The output then will remain OFF until another pulse arrives to switch it ON again. The circuit thus is stable-on or stable-off and acts as a counter of the activating signal pulses. The same operation could be performed, of course, with electromechanical latching relays (which are also bistable devices) but not at the tremendous speeds and low signal power offered by electronic circuits.

Figure 1 shows the basic arrangement of tube and transistorized flip-flop circuits. These circuits operate in a similar manner. Referring to Figure 1(A): when power is applied to the circuit, one tube will conduct more plate current than the other. This condition may result from slight assymetry or from a momentary transient. Assume that V_1 has the higher conduction. The lower current of V_2 means less voltage drop across R_5, therefore the plate of V_2 is closer to the B+ voltage. This causes a positive voltage to be applied to the grid of V_1 through the voltage divider R_6–R_3, which increases the V_1 plate current still further. The heavy plate current of V_1 increases the drop across R_1, and this lowers the positive voltage applied to the grid of V_2 through the voltage divider R_2–R_7. Since the voltage on this grid thus becomes more negative, the plate current of V_2 decreases still further. This action increases rapidly until V_1 draws the maximum plate current permitted by the limiting effect of R_1. The net result is that V_1 is conductin and V_2 cut off. This is one of the two stable states of the circuit.

Now, if a trigger pulse is applied momentarily to the INPUT terminals (with the upper terminal negative), additional current will flow through R_4 and the pulse source, and the resulting voltage drop across R_4 momentarily lowers the voltage at the junction of R_1 and R_4. This causes V_1 to draw somewhat less plate current, and the plate of V_1 rises

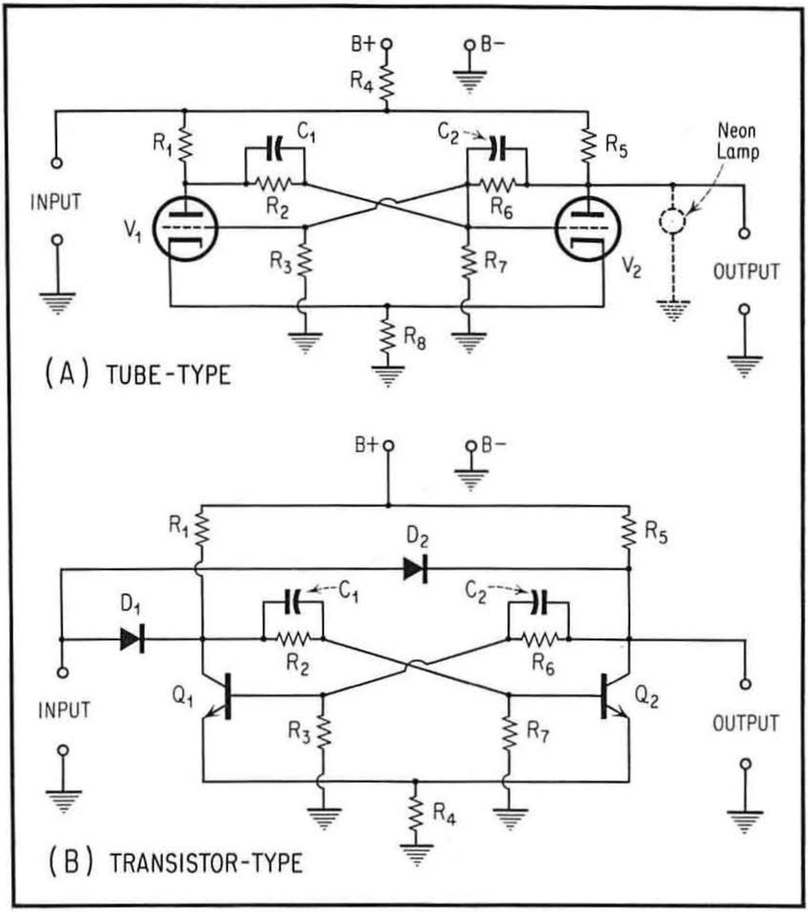

Fig. 1. Basic Flip-Flops.

toward the B+ voltage. The bias voltage applied to V_2 through the voltage divider R_2–R_7 accordingly becomes more positive, causing V_2 to draw more plate current. This, in turn, lowers the drop across R_5 and reduces the positive voltage applied to the grid of V_1 through R_6–R_3. And this action causes V_1 to draw still less plate current. Thus, V_1 draws increasingly less and V_2 increasingly more plate current. The net result is that the trigger pulse rapidly "flips" V_2 into conduction and V_2 OFF. This is the other stable state of the circuit. The commutating capacitors C_1 and C_2 speed up the flip-flop action.

From this basic action of the flip-flop, it is seen that in response to a string of pulses, V_1 is ON half of the time and V_2 half of the time. If output is taken from only one of the tubes, as shown in Figure 1(A), the output voltage will ON (high) in response to only every other input pulse. Thus, the flip-flop is a scale-of-2 counter; that is, the number of output pulses equals one-half the number of input pulses. A neon lamp connected between the V_2 plate and ground will glow in response to every second input pulse.

The transistorized circuit (Figure 1B) is similar to the tube-type, with the collector replacing the plate, emitter the cathode, and base the grid. Using NPN transistors as shown, the circuit requires steering diodes D_1 and D_2 for the positive trigger pulse. The diodes are poled to conduct the pulse to both plates readily through the low forward diode resistance but to prevent short circuit of the collectors (plates), since the collectors see the high inverse diode resistance. If high-voltage transistors are employed, a neon lamp may be used as an output indicator, as in tube-type flip-flops. But if the more common low-voltage transistors are used, some other device may be necessary. (Low-current filamentary lamps are available, and neon lamps sometimes are used with an extra transistor as a d c amplifier.)

These are the circuits which are most widely used at this writing, but flip-flops have been made with 4-layer diodes, double-base diodes (unijunction transistors), tunnel diodes, neon lamps, trigistors, magnistors, ferroresonant inductors, ferroelectric capacitors, ferrite cores, magnetic amplifiers, varactors, and electromechanical relays.

Scaler Systems

Flip-flops may be combined in numerous ways for specific counting jobs. If they are cascaded, as in the conventional RC-coupled amplifier, each stage after the first will receive a trigger pulse for each second pulse received by the preceding stage. Thus, a 2-stage counter will deliver one output pulse for every 4 input pulses, a 3-stage counter one output for each 8 input, and so on. That is, the circuit being bistable (base = 2) will divide the input number by the factor 2^n, where n is the number of flip-flops. If four stages such as shown in Figure 1(A) are cascaded, the lamp in the last stage will light once for each 16 input pulses. To determine the total number of input pulses which have passed, it is necessary only to note the **last** lighted lamp in the string; thus, in a 4-stage counter, the last (fourth) lamp indicates a

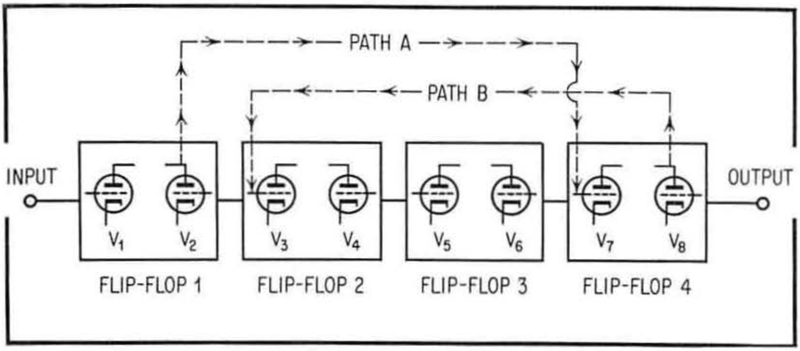

Fig. 2. Arrangement of Decimal Scaler.

count of 16, the third lamp 8, second 4, and first 2.

Such cascaded arrangements are termed **scalers.** The type just described is a **binary** scaler because its number base is 2. Such counters have many applications but since our common counting scheme is decimal (i.e., base $= 10$), greater convenience is provided by a counter based on this latter scheme. That is, we prefer a **decade** scaler, which counts 0, 1, 2, 3, 4, 5 6, 7, 8, 9 instead of the binary count 0, 2, 4, 8, 16. However, these decimal indications must be obtained with flip-flops which are base-2 devices. How this may be accomplished is discussed below.

See Figure 2. Without paths A and B, the unit is the type of scaler previously described, which counts to 16. When the paths are added, the input pulses operate the circuit in the normal manner up to the 9th pulse. The 10th pulse flips V_2 ON and this sends a negative-going voltage over path A to cut off V_7 and switch V_8 over. (Although V_2 is ON also at the 2nd, 4th, 6th and 8th pulses, the path-A signal can have no effect on V_7 until the tenth pulse.) Now, ordinarily the output pulse from V_2 would switch V_3 ON, but a negative-going voltage (fed back over path B from V_8 to the V_3 grid at the tenth pulse) bucks the signal from V_2 and maintains V_3 OFF. As a result, V_3 receives no signal and so remain OFF. At the tenth pulse, all flip-flops are OFF.

Four flip-flops arranged in this manner constitute a counter decade. The count may be indicated with ten neon lamps (numbered 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9), with the lighted lamp indicating the count. But the lamps must be connected in such a way that only the appropriate lamps will light for a particular count.

Figure 3 shows the circuit of a single, tube-type counter decade consisting of our identical flip-flops. Note the connection of the ten lamps in a bank with the odd-numbered ones in one line and the even-numbered ones in the other. In this circuit, the internal auxiliary paths are provided by C_{11}–R_{34} and C_{14}–R_{47}. Figure 4 shows a comparable transistorized counter decade using high-voltage switching transistors, such as RCA 2N398. In this circuit, the feedback paths are provided by diodes D_3 and D_6. The auxiliary d c voltages, E_1 and E_2, bias the lamps so that they are readily fired by the collector-voltage shifts. Closing the reset switch, S, "erases" the count; i.e., sets the counter back to zero. (This feature may be provided in the tube circuit by returning grid resistors R_{10}, R_{19}, R_{30}, and R_{42} to a common resistor, such as R_{10} in Figure 4, shunted by a grounding switch, instead of grounding them separately as shown.)

In a complete counter, several decades of the type shown in Figure 3 or Figure 4 are cascaded for higher counts. Thus, a four-decade counter provides a count of units in the first decade, tens in the second, thousands in the third, and ten thousands in the fourth.

A complete counter of this type sometimes is provided with a timing circuit for halting the count after an accurately-determined interval such as 0.1, 1, or 10 seconds. This enables a precise count to be made of the number of events (pulses) occurring in the unit time. Among the uses of such an instrument is the indication of frequency (cycles or pulses per second). Both regular and random pulses may be counted.

Whereas many decade scalers employ neon lamps, arranged vertically in decades, as indicators, some make use of numerical indicator tubes. These are gaseous tubes which either display an actual figure (0 to 9) or give a glowing dot to signal one of the figures (0 to 9) arranged in a circle on the instrument panel.

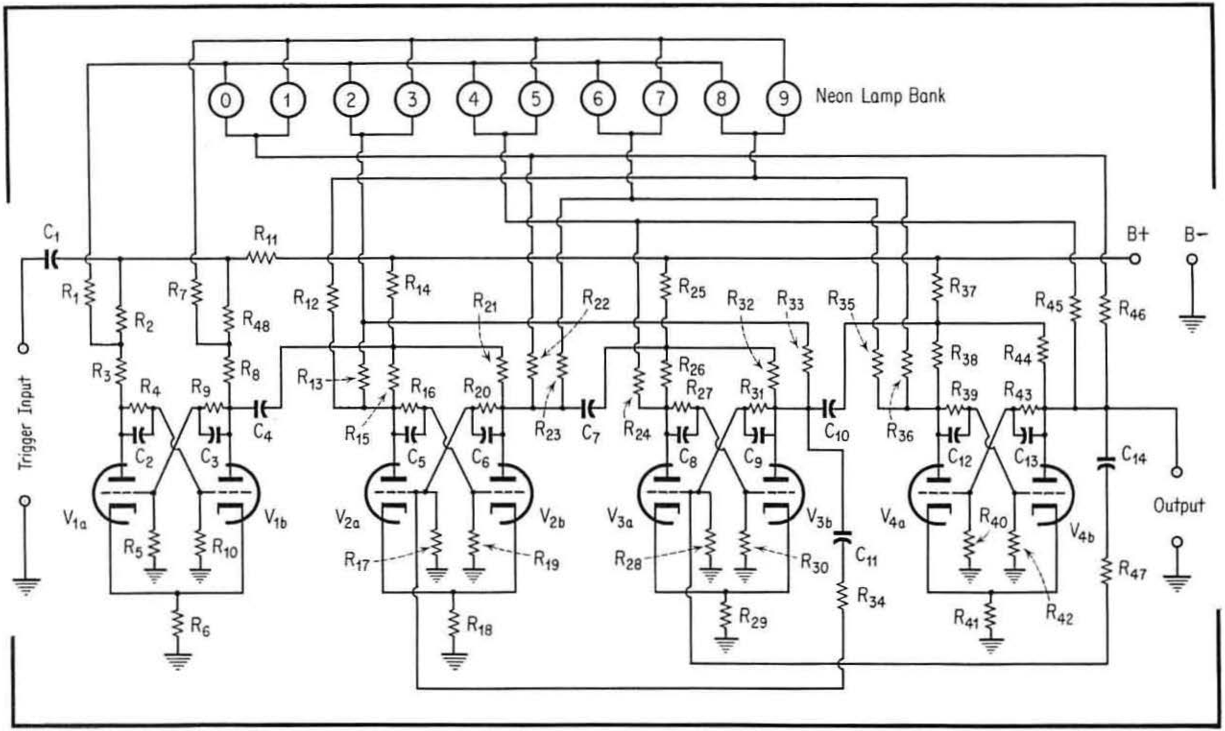

Fig. 3. Tube-Type Decimal Scaler.

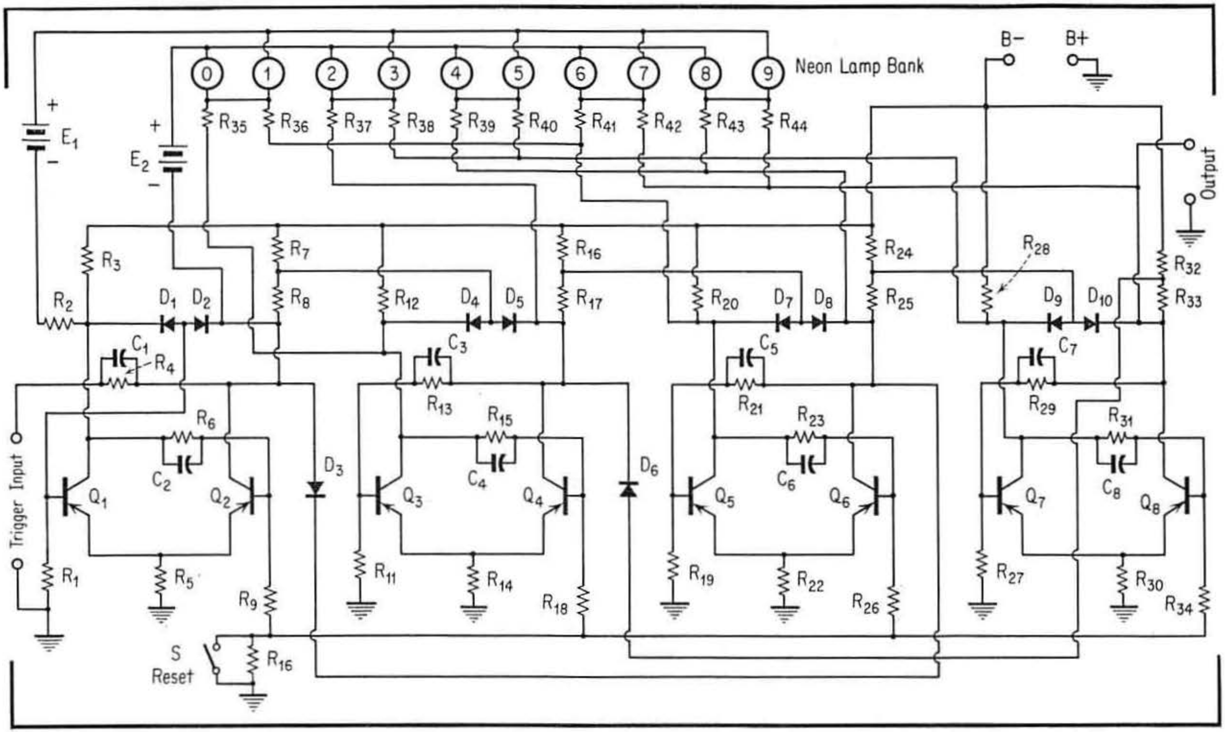

Fig. 4. Transistorized Decimal Scaler.

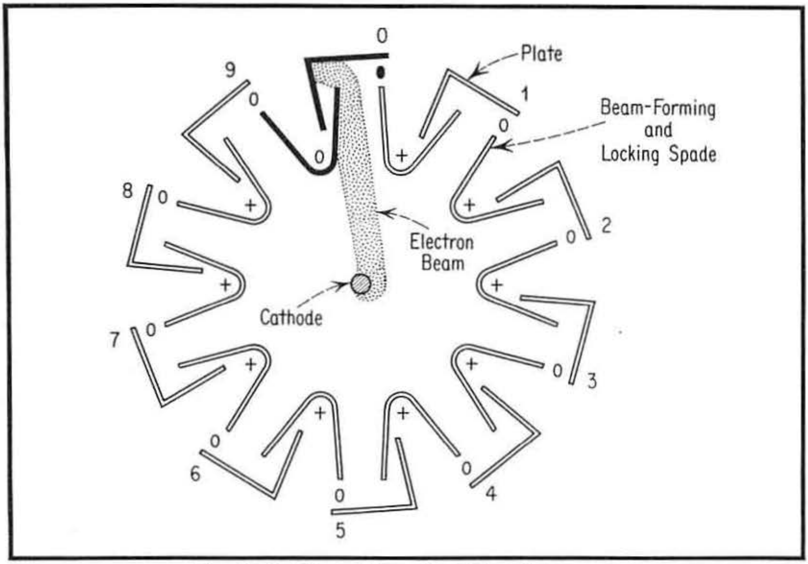

Fig. 5. Details of Beam Switching Tube.

Beam Switching Tube Decade

The Burroughs beam switching tube provides a fast and relatively simple means of decade counting. The basic structure of this tube is illustrated by Figure 5.

In this vacuum tube, which is a type of magnetron, ten sets of elements are spaced radially around a central cathode. Each set consists of a grid, plate, and spade. A strong permanent magnet surrounds the outside of the envelope and provides an axial magnetic field through the tube. The spades and plates are connected to the supply voltage through individual series resistors. The crossed magnetic and electrostatic fields give the spade a negative resistance characteristic, and this characteristic provides bistability.

Under quiescent conditions when power is applied to the tube, there is no electron beam. If the voltage of a given spade is reduced, by means of dc or a pulse, to bring the spade characteristic into its negative resistance region, the beam will form between the cathode and that spade. If nothing further is done, the beam will remain in that position (such as at the "0" elements in Figure 5) until the power is interrupted. But the beam may also be advanced to the next position. Thus, if a suitable pulse is applied to the grid so that the grid voltage is lowered, the electrostatic field between the adjacent spades will be reduced and the beam will switch to the next set of elements (as to the "1" set in Figure 5). In this way, the beam may be stepped sequentially around the ring of elements from 0 to 9. Indicators connected to the plates will show the location of the beam at any instant, and a counter decade consequently is obtained . The switching action is very fast, 0.1 microsecond being specified.

Figure 6 shows bow a beam switching tube (V_2) may be operated with a numerical indicator tube (V_1) to provide a complete high-speed counter decade. As in other counters, these decades may be cascaded for a higher total count.

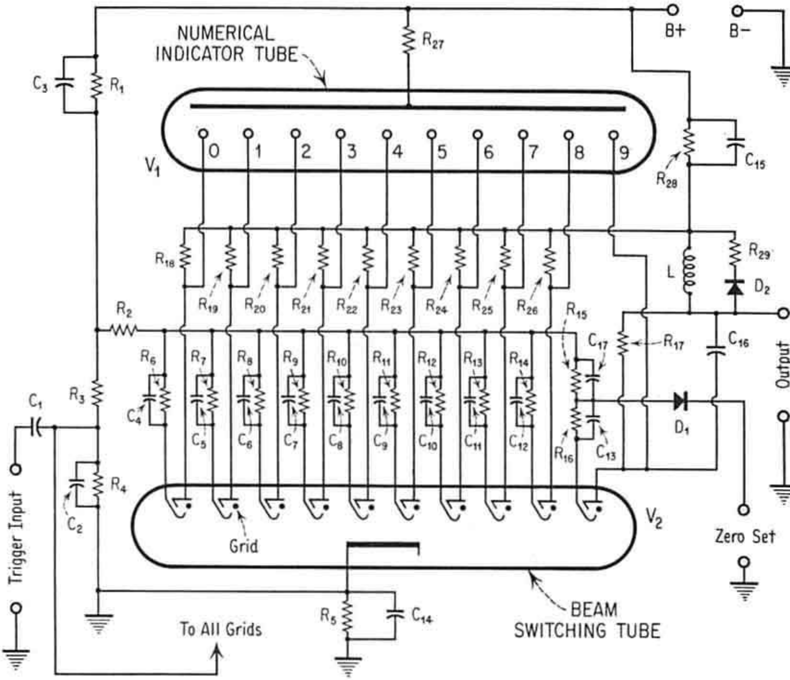

Fig. 6. Beam-Switching Counter Decade.

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