Ten-Pulse Control

Up to the time the multiplier carries, no other operation takes place. When a carry occurs, it is a signal to start rolling the multiplicand counter. Before discussing the multiplicand read-out, it is necessary to establish the 10-pulse control circuit together with its associated circuits. Since several of these circuits are interconnected, they will all be discussed at this point.

First, consider the A33 switch tube (Section 24A) which produces negative pulses at 10 and 14 to turn trigger B3 (Section 27B) ON and OFF. The status of B3 trigger is indicated by indicator light 5 on the socket B7. The circuits for A33 and B3 are shown in Figure 112.

Switch A33 can conduct only when both the grid and suppressor are above cutoff. The grid of A33 is normally at about −35 volts and will rise above cutoff when it receives a positive pulse from tube $A27_1$ of trigger A27, the second stage of the primary timer. This positive pulse will come every time A27 goes ON, i.e., at 2, 6, 10, and 14 of each primary cycle. However, the tube cannot conduct unless the suppressor also rises above cutoff. The suppressor is directly coupled to the anode of tube $A34_1$, which is a follower for the OFF side of trigger A29, the fourth stage of the primary timer. As long as A29 is OFF, $A34_1$ is conducting, and its anode potential is low (approximately +50 volts). As long at $A34_1$ conducts, then the suppressor of A33 is at approximately −50 volts which is below cutoff for this element. When A29 goes ON, $A34_1$ stops conducting, and its anode potential rises to approximately +150 volts. The suppressor A33 is then above cutoff, and conduction occurs through A33 subject to the pulses applied to the grid. Since the suppressor will be conditioned to conduct by $A34_1$ from 8 through 0, of the four pulses received by the grid, only two can cause conduction, those at 10 and at 14.

When A33 conducts at 10 and at 14, it produces negative pulses at its anode. These negative pulses are fed to both sides of trigger B3 from the midpoint of the A33 load resistor. The −10 pulse turns B3 ON, which is initially OFF by cancelling. The −14 pulse again turns B3 OFF. Therefore B3 goes ON at 10 and OFF at 14 of each primary cycle.

Trigger B3 through its followers $B9_1$ and $B9_2$ controls several circuits among which is the 10-pulse control. Follower $B9_1$ follows the ON side of trigger B3 and thus produces a −10 pulse and +14 pulse. The purpose of these pulses will be explained later. Follower $B9_2$ follows the OFF side of B3; consequently, it is conducting at all times except from 10 through 14. From 10 through 14 the anode potential of $B9_2$ is high to condition certain switches. At 14 the negative pulse produced at the midpoint of the $B9_2$ load resistor is passed on to the secondary timer to advance it 1 for each primary cycle.

One of the switches conditioned by $B9_2$ is B10, as shown on the B chassis diagram (Section 28B) and in Figure 113. In other words, B10 is receptive to pulses applied to its suppressor from 10 through 14. A constant stream of B pulses is applied to the suppressor of B10, and remembering that B pulses are negative at index points and positive at mid-index points, it is obvious that B10 will conduct on every *positive* B pulse from 10 through 14, or at 10.5, 11.5, 12.5, and 13.5, as shown on the timing chart in Figure 113. Before discussing the purpose of these pulses, examine B4 switch (Figure 113) which works with B10 switch to control B16 trigger. B4 also receives a constant stream of B pulses at its suppressor, but its grid is conditioned by $A34_2$, which is a follower for the ON side of trigger A29 (the fourth stage of the primary timer). The anode of $A34_2$ is at high potential as long as A29 is OFF, i.e., from 0 through 8; hence B4 switch is conditioned to conduct from 0 through 8 and will conduct on the positive shifts of the B pulses at 0.5, 1.5, etc., through 7.5, as indicated on the timing chart in Figure 113. At each of these points a negative pulse is produced at the anode of B4. This pulse is taken from a tap on the load resistor of B4 and fed to the OFF side

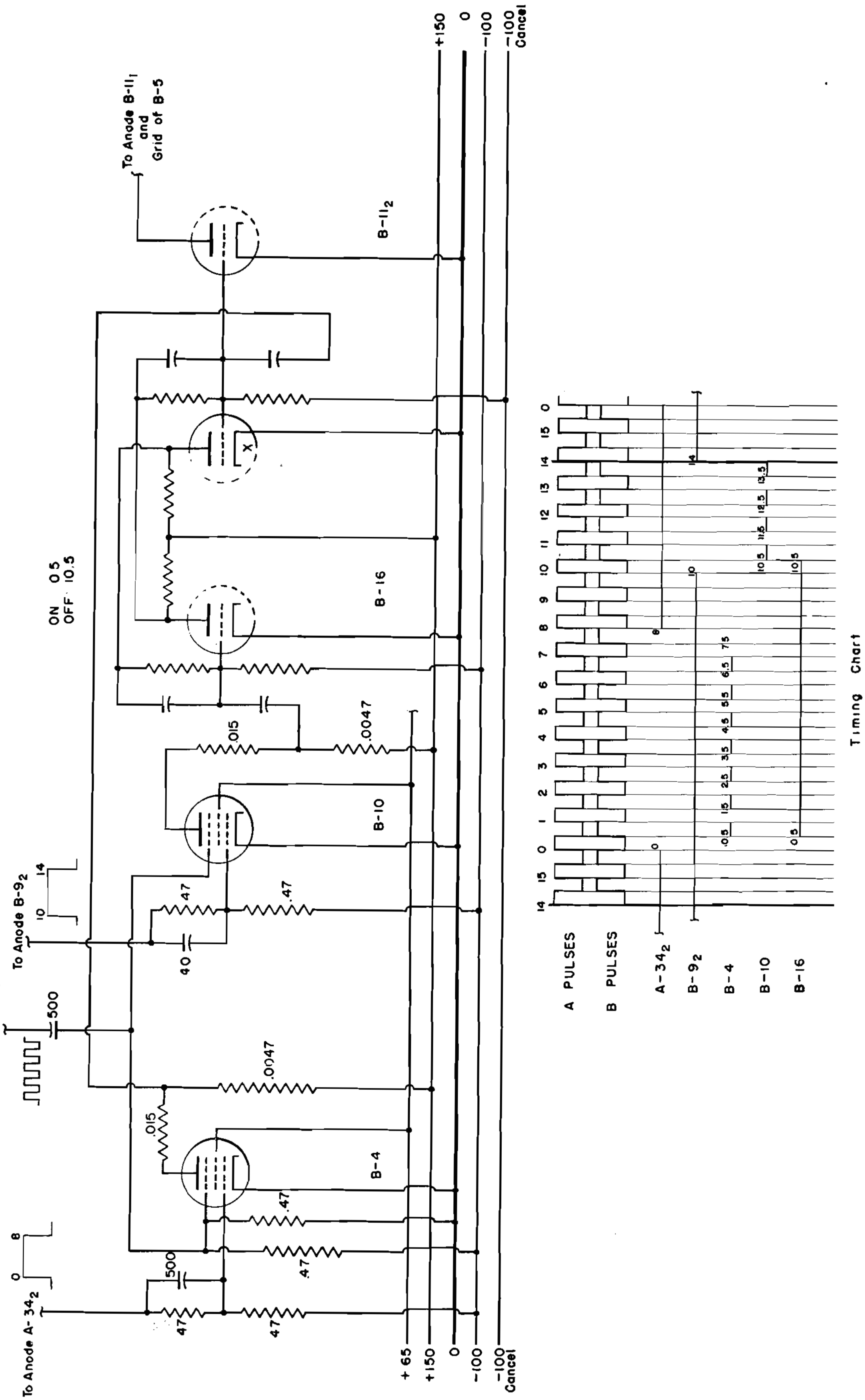

Figure 113. Ten-Pulse Control Trigger

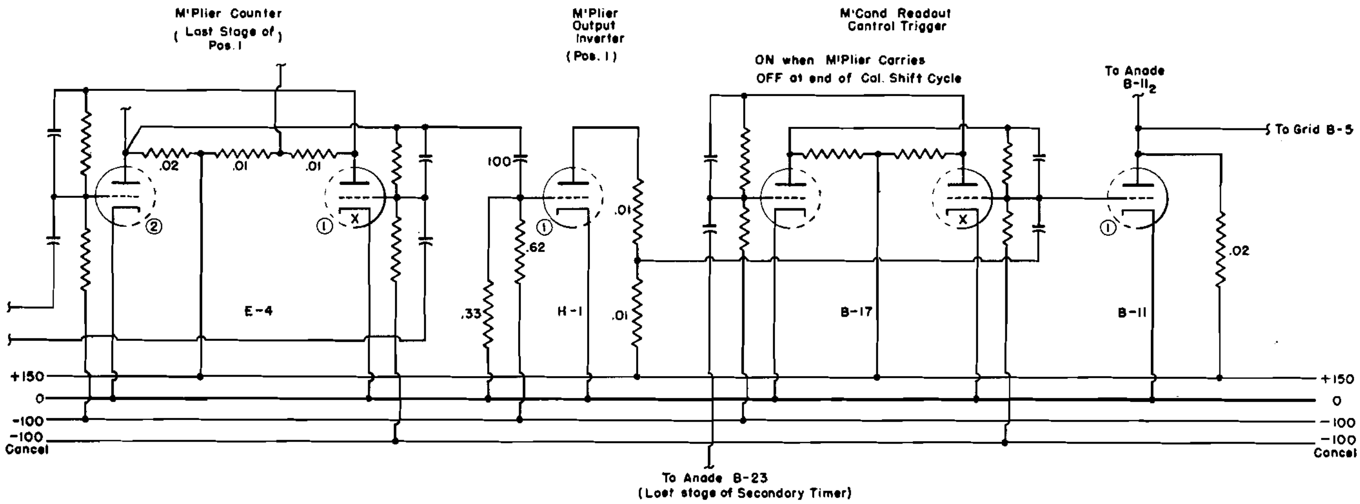

Figure 114. Multiplier Output Circuit

of trigger B16 which is initially OFF by cancelling. The first of the series of pulses at 0.5 will turn B16 ON and the others will have no effect until B16 is again turned OFF. Since B16 does not turn OFF before 8, only the 0.5 pulse is used, and it turns B16 ON.

Now observe that the ON side of B16 is coupled to the output of switch B10 which was just discussed. It has been shown that B10 produces negative pulses at 10.5, 11.5, 12.5, and 13.5. The first of these pulses, –10.5, will turn B16 OFF, and the others will have no effect. It has been determined then that B16 turns ON at 0.5 of each primary cycle and turns OFF at 10.5 of each primary cycle, thus providing the timing control for producing 10 adding pulses each primary cycle.

Multiplicand Counter Rolling Control

It has been shown that B16 provides a means of producing 10 pulses for rolling the multiplicand, but it must be remembered that these 10 pulses cannot be fed to the multiplicand counter *every* primary cycle, but *only on those primary cycles following a carry-over in the multiplier position determined by the column shift control.* Consequently, it is evident that some means must be provided to signal when this is to happen.

Figure 114 shows the circuits for multiplier read-out control using the first position of the multiplier counter. As noted in Figure 114 the multiplicand rolling control trigger, B17, is in the B chassis and is located in Section 28B of the wiring diagram. Indicator light 3 in socket B7 indicates the status of this trigger. The multiplier output inverters are in the H chassis which consists of three 12SN7's. One triode section of each tube in the H chassis is used for each position of the multiplier counter.

Observe that no load resistors are shown in the H chassis circuit diagram (Section 41). All six triode inverters use the same load resistor, which is shown to the right of B17 trigger in the B chassis diagram. This common load resistor is permissible, because only one multiplier position can be active at any one time; hence only one tube in the H chassis can use the load resistor at any one time. The common load resistor also permits all six multiplier output inverters to control the same trigger.

Referring now to Figure 114, note that only the last stage trigger of the multiplier counter position 1 is shown. Observe also that the grid of $H1_1$ is at approximately –35 volts, as determined by the voltage divider between the –100 volt line and ground. This means that $H1_1$ is normally cut off, and its anode is at high potential. When the multiplier counter position being advanced goes from 9 to 0, trigger E4 goes OFF and a positive pulse appears at the anode of tube $E4_2$. This positive pulse is transmitted through the 100 mmfd coupling capacitor to the grid of $H1_1$, momentarily driving it above cutoff and causing $H1_1$ to conduct. When $H1_1$ conducts, a –100 volt negative pulse is produced at its anode. From the midpoint of the load resistor of $H1_1$ a –50 volt negative pulse is fed to the OFF side of trigger B17, which is initially cancelled OFF. This negative pulse turns B17 ON, and the follower tube $B11_1$ is in turn cut off. B17 remains in the ON status until turned OFF at 14 of the last primary cycle in the given column shift cycle. B17 is turned OFF by a negative pulse produced at the anode of tube $B23_1$, which is the OFF side of the last stage of the secondary timer. The negative pulse at the anode of $B23_1$ appears when the secondary timer advances from 9 to 0, signalling a column shift.

From the foregoing description, it may be seen that B17 turns ON at 12 of the primary cycle during which the active multiplier position advances from 9 to 0, and B17 stays ON until the end of that column shift cycle. B17, then, determines the number of primary cycles during which 10 rolling pulses are applied to all positions of the multiplicand counter. Follower tube $B11_1$ for B17 trigger and follower tube $B11_2$ for B16 trigger work together as blocking tubes to control the 10-pulse control switch B5, as shown in Figure 115 and in Section 28A of the circuit diagram. $B11_2$ is at high potential from 0.5 through 10.5 of *every primary cycle*, since it follows the OFF side of B16 trigger, the 10-pulse control trigger. However, $B11_1$ does not permit $B11_2$ to be effective until after trigger B17 turns ON, indicating that the multiplicand must start receiving rolling pulses. Then, during every primary cycle after B17 turns ON, the anode potential of both $B11_2$ and $B11_1$ is high from 0.5 through 10.5, and the grid of B5 switch is conditioned to conduct accordingly. Observe that the grid of B5 is at approximately –50 volts as long as either $B11_2$ or $B11_1$ is conducting. When both $B11_2$ and $B11_1$ are cut off, the grid of B5 rises well above cutoff and B5 is conditioned to conduct subject to the positive pulses applied to the suppressor.

The suppressor of B5 is normally at –50 volts as determined by the voltage divider between ground and –100 volts. The suppressor B5 is coupled by means of a 250 mmfd capacitor to the anode of A16, where A pulses are produced; hence the suppressor of B5 receives a constant stream of A pulses at its suppressor, and B5 will conduct on every positive shift of the A pulses from 0.5 through 10.5. As indicated on the timing chart in Figure 115, B5 will produce 10 negative B pulses at its anode during each primary cycle that it is active. These negative pulses at 1, 2, 3, etc. through 10 are fed by way of a 50 mmfd coupling capacitor to the grid of the 25L6 power tube, B6. The grid of B6 is tied to +150 volts through a .47 megohm resistor and consequently B6 is normally conductive. Each time B5 conducts, a negative pulse is passed to the grid of B6, cutting off B6 momentarily and producing a positive pulse at the anode of B6. Thus, 10 positive A pulses are produced at the anode of B6 during each primary cycle that B17 is turned ON. These are the 10 pulses used to roll the multiplicand counter.

From the section on *Read-In Circuits* it will be remembered that the D chassis contains the inverters controlling the read-in of the 10 rolling pulses. There is one inverter for each position of the multiplicand counter, and each consists of one triode section; therefore only three 12SN7's are required. These are D5, D11, and D14. The inverter grids are normally at –35 volts, and each time a positive A pulse from B6 is fed to the grids of the six inverters through the 250 mmfd coupling capacitor, all six inverters conduct and produce negative pulses at their anodes. These negative pulses are taken from the midpoint of the inverter load resistors and passed to the six positions of the

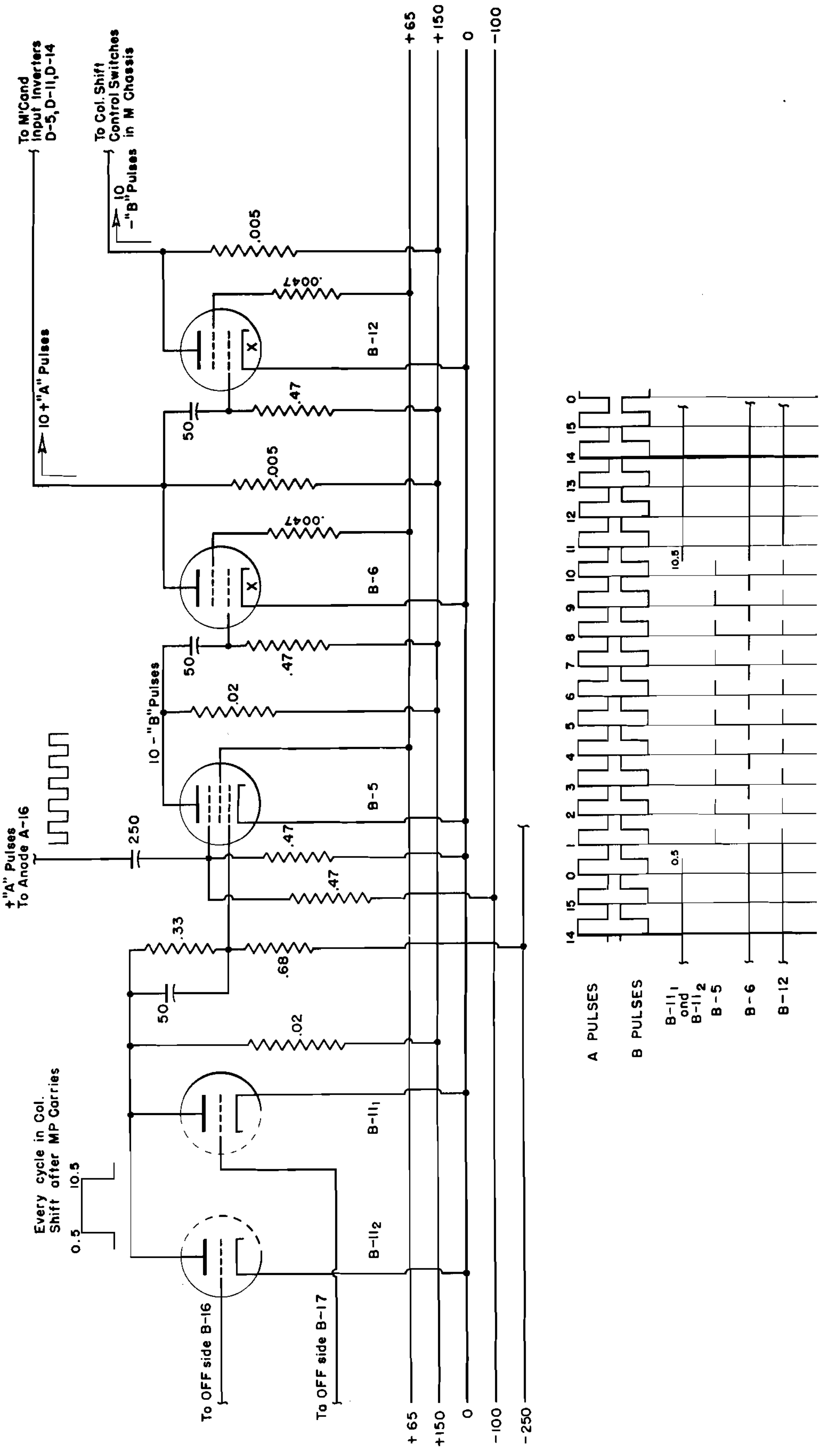

Figure 115. Ten-Pulse Control Switch and Power Tubes

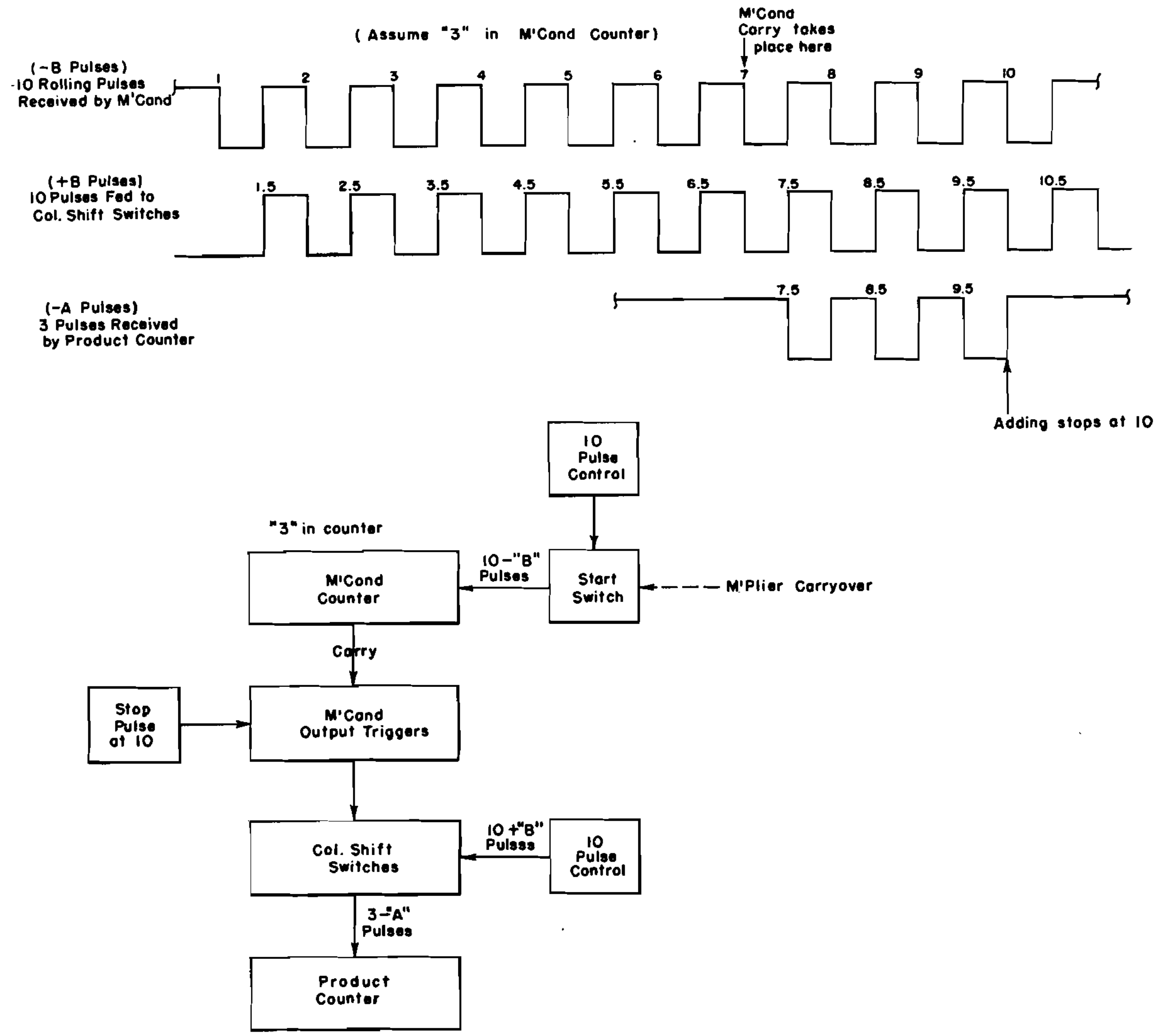

Figure 116. Multiplicand Output to Product

multiplicand counter. Thus, each position of the multiplicand counter receives 10 rolling pulses during each primary cycle that trigger B17 is ON.

Power tube B12 operates exactly as does B6 except that it inverts negative A pulses to positive B pulses to feed the column shift control power tubes. The column shift control will be discussed in succeeding sections. B12 is shown at 27A of the wiring diagram.

Multiplicand Read-Out

The number of entry pulses required to advance a counter position to zero is the ten's complement of the number standing in the counter. When the multiplicand is transferred to the product counter, entry pulses to the product counter start at half a cycle point after the multiplicand position being read out arrives at zero, and terminates at 10 of the cycle. For instance, if a multiplicand counter position contains a 2, the eighth entry pulse applied to this position (at 8 of the cycle) advances it to 0. This enables 2 entry pulses to be applied to the product counter, one pulse at 8.5 and another at 9.5 of the adding cycle. Similarly, a 3 standing in the multiplicand enables the product counter to receive 3 pulses, at 7.5, 8.5, and 9.5. This is shown

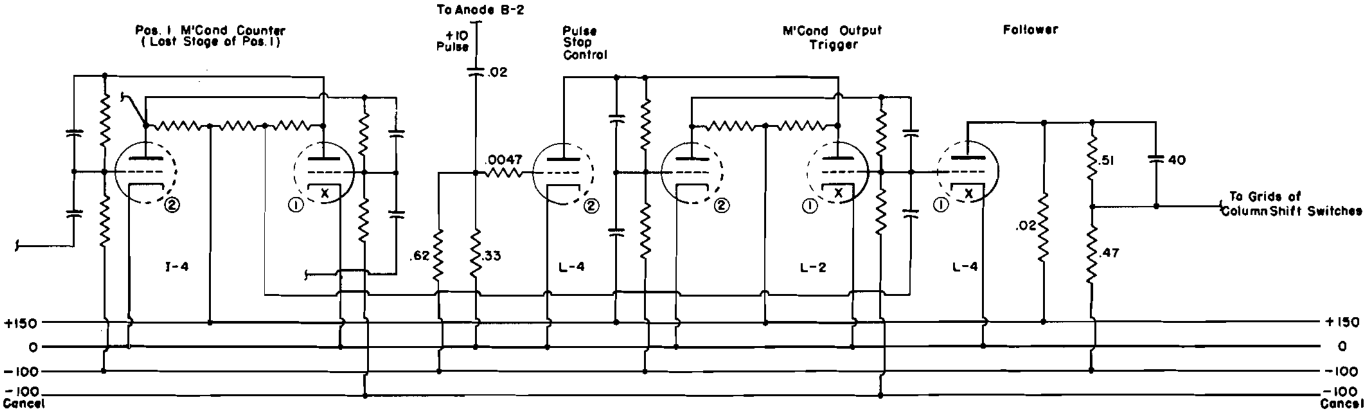

Figure 117. Multiplicand Read-out Controls

in Figure 116 which is a block diagram of the multiplicand read-out operations. Remember that positive A pulses are fed to the multiplicand input inverters, which in turn invert them to negative B pulses to operate the multiplicand counter triggers. This means that the multiplicand carry-over occurs at index points of the primary cycle. However, the pulses fed to the product counter by the column shift control switches are negative A pulses coming at mid-index points of the primary cycle. This arrangement permits the multiplicand read-out triggers to turn ON and condition the column shift switches one-half cycle point before any pulses are passed by the switches.

Figure 117 shows the multiplicand read-out circuit for the first position of the multiplicand counter. Only the last stage of the counter position is shown. When the first position of the multiplicand counter advances from 9 to 0, trigger I4 goes OFF, and a negative pulse appears at the anode of tube $I4_1$. A −50 volt pulse at the midpoint of the load resistor for $I4_1$ is passed on to the OFF side of trigger L2, turning it ON. When L2 goes ON, tube $L2_1$ cuts off, and follower tube $L4_1$ does likewise. As long as $L4_1$ is cut off, its anode is at high potential, and the midpoint of the voltage divider in parallel with the load resistor $L4_1$ is at approximately +25 volts. This midpoint is connected to the grids of all the column shift switch tubes for the first position of the multiplicand. Thus, the column shift switches are permitted to conduct when L2 trigger goes ON. It might be noted that on the main wiring diagram the .51 megohm resistors are shown in the L chassis circuit, while the .47 megohm resistors are shown on the O chassis circuit. This arrangement permits the grids of the 6SK7 switches in the O chassis to be tied down below cutoff in case jumper wires between chassis are removed.

At a given point in the cycle all adding in the product counter must be stopped, so that only the correct number of pulses enter the product counter. The adding is stopped by turning the multiplicand read-out triggers OFF at *10*. As shown in Figure 117, a +10 pulse is fed through the .02 mfd coupling capacitor to the grid of $L4_2$, which is normally cut off. The +10 pulse causes momentary conduction through $L4_2$. Observe that the anode of $L4_2$ is tied to the anode tube 1 of trigger L2, indicating that $L4_2$ uses the same load resistor as the $L2_1$ tube. When $L4_2$ conducts, the potential at its anode drops, and the potential at the anode of tube $L2_1$ also drops. This causes $L2_2$ to stop conducting and triggering results. Therefore, causing $L4_2$ to conduct will turn L2 OFF, if it happens to be ON.

In addition to turning L2 OFF at 10, $L4_2$ serves as a blocking tube to prevent L2 from turning ON when a 0 is transferred. When a 0 is transferred, no pulses should get to the product counter; con-

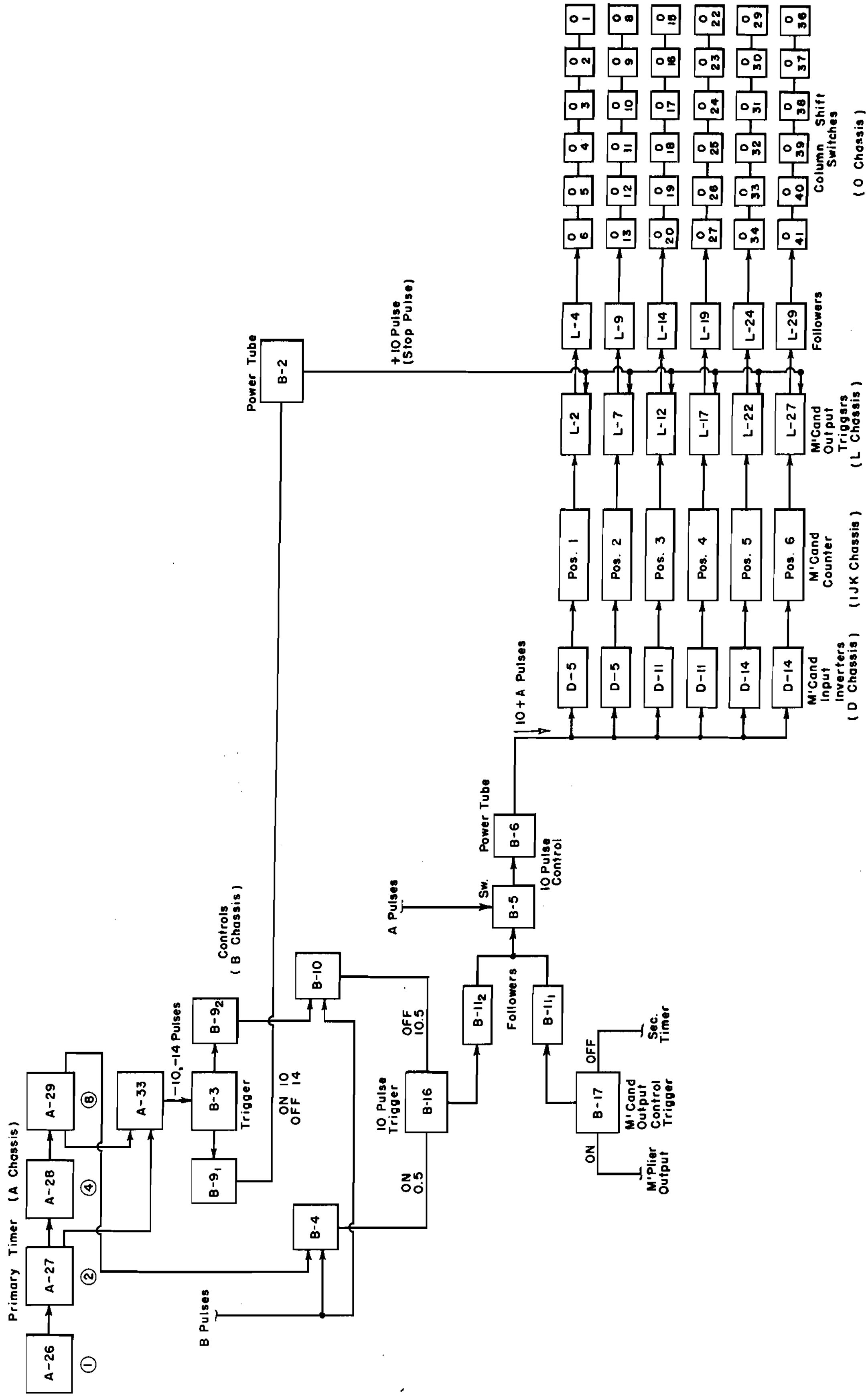

Figure 118. Block Diagram of MC Rolling and Output Circuits

sequently, trigger L2 should not turn ON. With a 0 in the first position of the multiplicand, the multiplicand counter position will signal a carry at 10 of the cycle. This would normally turn L2 ON. At 10, however, L4 is conducting because of the +10 stop pulse. This means that L2 is blocked from turning ON, since the potential at the anode of the tube $L2_1$ cannot rise as long as $L4_2$ is conducting.

The +10 pulse mentioned is produced by tube B2 in the B chassis (Section 27A). It will be remembered from the discussion of trigger B3, that follower $B9_1$ follows the ON side of trigger B3, which is ON from 10 through 14. Consequently, $B9_1$ will produce a negative pulse at 10 and a positive pulse at 14. The −10 pulse is passed to the grid of B2 via a 50 mmfd coupling capacitor. B2 is normally conducting, since its grid is tied to +150 volts through a .47 megohm resistor. The −10 pulse from $B9_1$ momentarily cuts B2 OFF, and its anode potential rises abruptly from about +50 volts to +150 volts. This positive pulse at 10 is passed to the L chassis to turn all the multiplicand read-out triggers OFF.

Figure 118 is a block diagram showing tube arrangement and operation of multiplicand rolling and output circuits. This diagram should be studied in conjunction with the block diagram in Figure 111.

Column Shift Switches

When the multiplicand factors are transferred to the product counter, they must be entered in different positions of the product counter during each column shift cycle. Since the sixth position of the multiplier counter is active first, the multi-

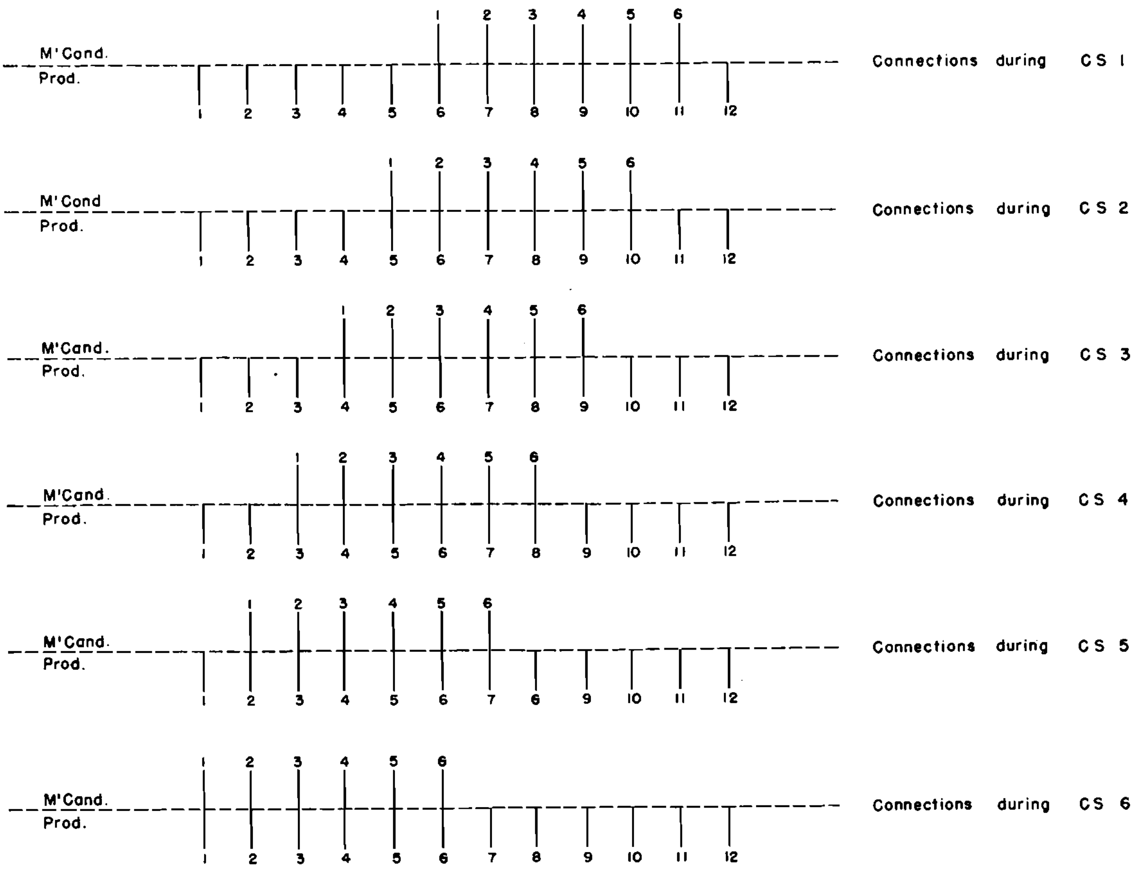

Figure 119. Principle of Column Shift

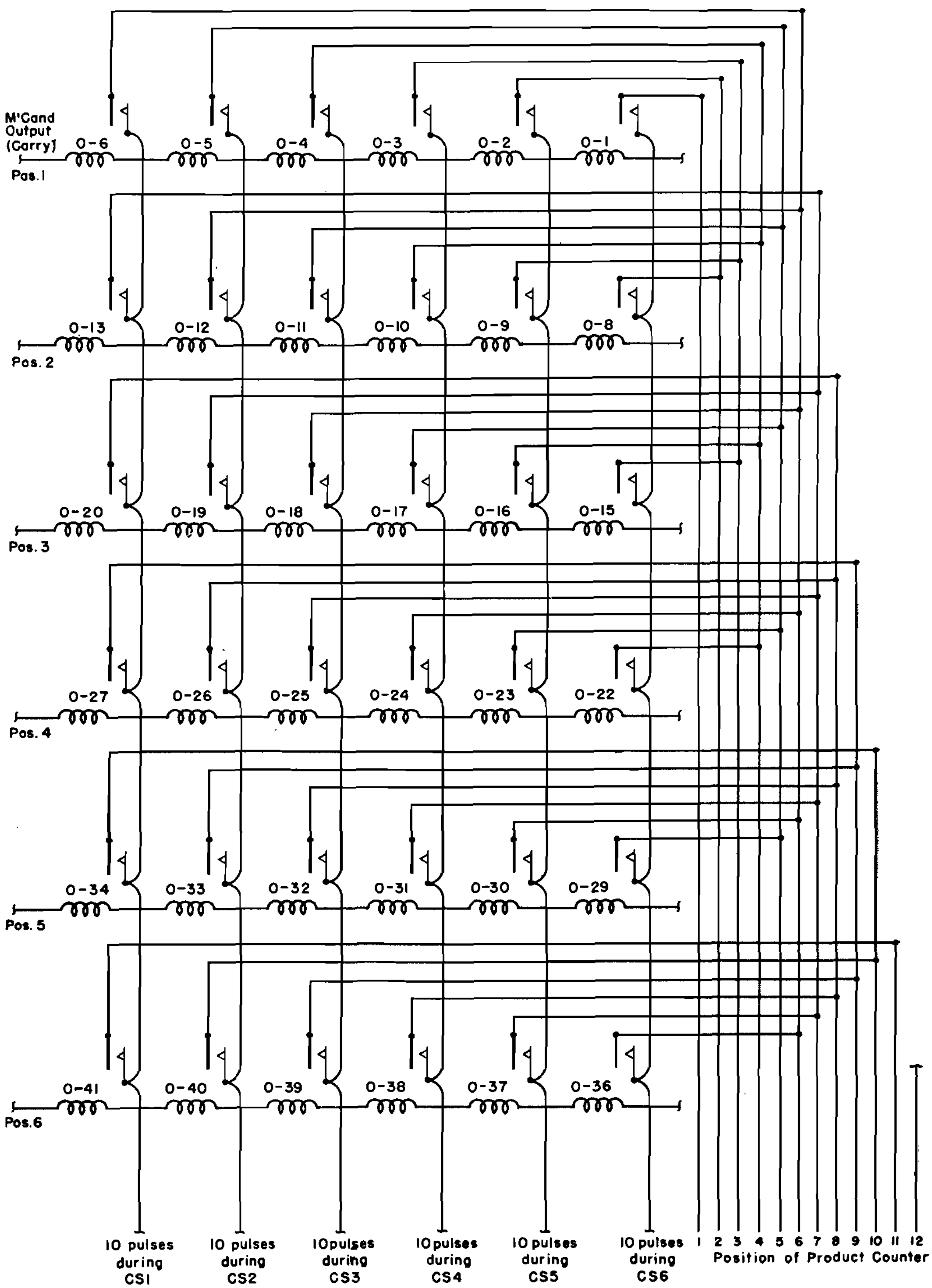

Figure 120. Schematic of Column Shift Switches

plicand counter positions 1 through 6 must be connected with product counter positions 6 through 11. The 12th position of the product counter is used to accumulate carry-overs only. During the 2nd column shift cycle, the multiplicand connects to product counter positions 5 through 10, etc. Figure 119 shows the successive connections through the six column shift cycles. The problem is to provide a means of accomplishing this successive shifting of the connections between the multiplicand counter and the product counter.

A schematic of the column shift switches using relays instead of tubes is shown in Figure 120. This schematic illustrates how connections are transferred on successive column shift cycles. One relay is shown for each tube. The contact directly above the relay coil is operated by the relay. The relays are labelled the same as the tubes to permit a closer analogy between the schematic and the actual circuits for the column shift switches in the O chassis.

Observe that the relay points in each vertical row are tied together on one side. Each vertical row successively receives a train of 10 pulses each primary cycle during which addition is to occur, but only during *one column shift cycle.* Consequently pulses can only be recognized by one vertical row at the time.

Each horizontal row of relays is associated with one position of the multiplicand counter. When the corresponding position of the multiplicand counter carries, all relays associated with that position pick up and hold until the end of the adding cycle. This permits all pulses between carry time and 10 to pass to the product counter in the position determined by the column shift. If there is a 7 in the multiplicand counter position 1, then multiplicand carry occurs at 3, and 7 pulses enter the product counter.

When the first position of the multiplicand carries, relays O-1 through O-6 pick up. However, pulses can pass through only *one* contact, depending upon the column shift cycle. The contacts O-1 through O-6 are connected with product counter positions 1 through 6, indicating that the first position of the multiplicand can be connected to product counter position 1 through 6. This corresponds to the connections shown in Figure 119. Similarly, the second position of the multiplicand can be connected to product counter positions 2 through 7 by means of relay points O-8 through O-13, etc.

In practice each relay represented in the schematic of Figure 120 is actually a 6SK7 pentode switch tube. The relay coils picked up by the multiplicand carry are representative of the grids of the switch tubes, and the relay contacts themselves are representative of the suppressors. The actual connections to the product counter entry are made at the anodes of the switch tubes. This is evident on examination of the O chassis circuit diagram. Ignoring for the moment tubes O-14, O-21, O-28, O-35, and O-42, shown to the right in the O chassis circuit diagram, it will be seen that the layout of the O chassis is essentially as shown by the schematic drawing. Each horizontal row of switch tubes is conditioned to conduct by one position of the multiplicand output trigger follower. Each vertical row of tubes receives pulses at the suppressors from the column shift control chassis.

Each horizontal row of grids is controlled by one of the multiplicand trigger followers as explained under *Multiplicand Read-Out.* Observe that all the grids in one row are tied together and that one .47 megohm resistor ties the entire group down to the −100 volt line. It will be remembered from the discussion of the multiplicand read-out that these .47 megohm resistors in the O chassis are part of the voltage dividers between −100 volts and the anodes of the multiplicand read-out trigger followers. There is a 4700 ohm resistor in each of the individual grid circuits. As previously explained, these resistors suppress parasitic oscillations which might easily appear with so many grids in parallel.

Observe that each vertical row of 6SK7's has one voltage divider for the entire row. These voltage dividers are shown under the O-1 through O-6 tubes, and they maintain all suppressors at −50 volts normally. There is also a 4700 ohm resistor in each suppressor circuit to eliminate parasitic oscillations. When B pulses are applied to the .02 mfd coupling capacitors, all the suppressors in one entire vertical row of switches rise above cutoff on each positive shift of the B pulses. However, conduction cannot occur until the grid of a switch is conditioned to conduct by a carry-over in the multiplicand. Then each positive shift of the B pulses causes conduction through the switch tube.

Since the multiplicand may contain any number from 0 through 9 in any of its six positions, the corresponding column shift switches may be conditioned anywhere from 1 through 10 of each primary cycle. The ten B pulses fed to the suppressors come at 1.5 through 10.5. However, only the pulses from 1.5 through 9.5 can be used because the multiplicand read-out triggers are turned OFF at 10. The actual number of pulses that a particular switch will accept depends upon the number standing in the multiplicand counter position which controls that switch.

Observe that each diagonal row of switch tubes is common to one position of the product counter. Since only one vertical row can be in operation at once, only one tube in each diagonal can be conducting at once. This permits the use of only one load resistor for each diagonal row of switch tubes. The load resistors for the switch tubes corresponding to product counter positions 1 through 6, along with the clippers and inverters for those positions, are located in the N chassis. The terminals 56-61 on the O chassis correspond to product counter positions 1-6 respectively. Each terminal post connects to the anodes of all the switch tubes associated with the corresponding product counter position. Terminal post O-56, for example, connects to the anode of tube O-1 only, while terminal post O-61 connects to the anode of tubes O-6, O-12, O-18, O-24, O-30, and O-36.

The load resistors for the switch tubes corresponding to product counter positions 7 through 11 are shown at the right of the O chassis circuit. No switch tubes connect to the 12th position of the products counter as this position is reserved exclusively for carry-overs. It will be observed that the output of the column shift switches does not go directly to the product counter. Instead the output passes through a clipper and inverter before entering the product counter. Because of the large interelectrode capacitance resulting from many tubes in parallel, the output from the column shift switches is not a square wave. Also, the amplitude of the pulse output varies from one position to another owing to the different number of tubes in parallel. In order to overcome these difficulties, clippers are inserted between the column shift switches and the product counter to square the tops of the waves. Since the clipper inverts the pulses applied to it, an inverter tube follows the clipper to restore the output to its original phase. The inverter also clips the other half of the output waves from the column shift switches. With this arrangement, the output to the product counter is uniform regardless of the variations in the output of the column shift switches. It might be mentioned that the clippers would not be necessary if machines were laboratory models in which proper compensating circuits could correct the variations in the pulses to the product counter. However, in production models it is difficult to make these compensations, and the clippers are used to provide uniform input to the product counter.

Figure 121 shows the clipper and inverter for the 8th position of the product counter. Note that four switch tubes are associated with the 8th position of the product counter and that all use the same .02 megohm load resistor. As long as any one of the switch tubes is conducting, the potential at the top of the .02 megohm resistor is

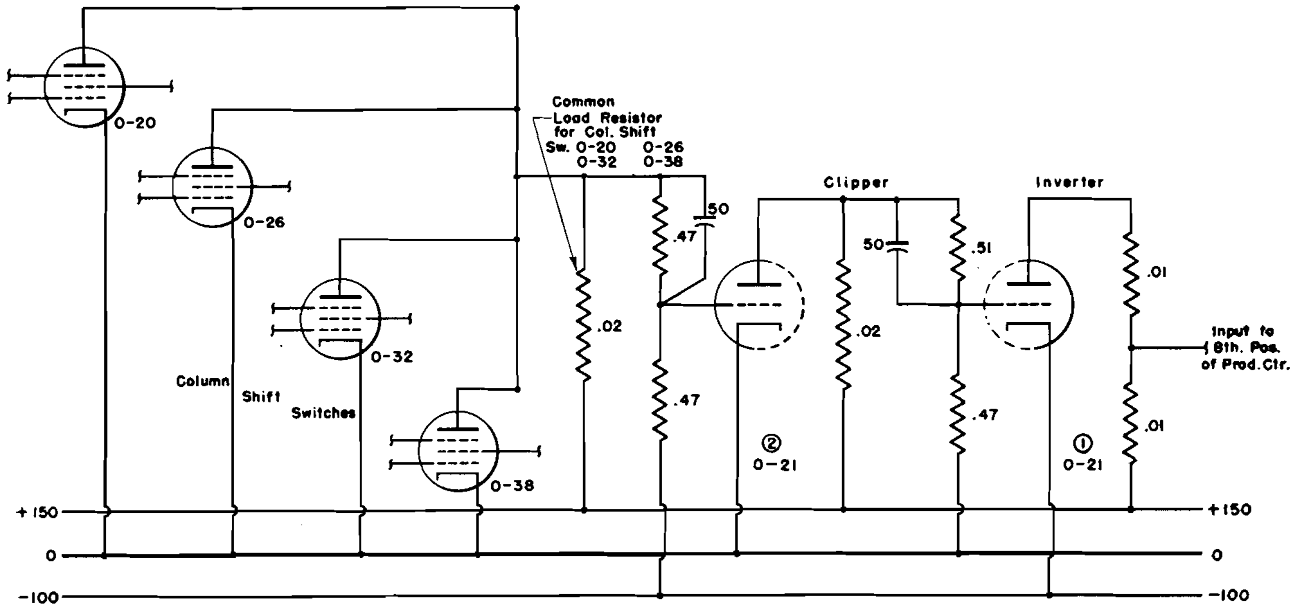

Figure 121. Clipper and Inverter between Column Shift Switches and Product Counter

approximately +50 volts. This means that the grid of $O\text{-}21_2$ is at −25 volts as long as any of the four switch tubes is conducting. When none of the four switch tubes is conducting, the potential at the top of the .02 megohm resistor is approximately +150 volts and the grid of $O\text{-}21_2$ rises above cutoff. Consequently, as the negative B pulses appear at the load resistor, they are clipped and appear at the anode of $0\text{-}21_2$ as positive A pulses, which are in turn applied to the grid of inverter $O\text{-}21_1$, where the process is repeated to produce negative B pulses at the anode of $O\text{-}21_1$. The pulses at the anode of $O\text{-}21_1$ are 100 volt pulses, whereas a counter requires only 50 volt pulses. Therefore, the counters are fed from the midpoint of the load resistors for the inverters.

Figure 122 shows a block diagram of the column shift switch operation. The column shift controls in the M chassis are discussed in the following paragraphs.

Tertiary Timer and Column Shift Control

As has been previously mentioned in connection with the electronic timers, the tertiary timer controls the column shift. Each time the secondary timer goes from 9 to 0, a negative pulse is passed to the tertiary timer to advance it 1. The tertiary timer is a conventional 3-stage binary counter, consequently it will count to 8 and then return to 0. Actually computation stops after the end of the 6th column shift cycle, so the tertiary timer is at 7 when the computation is finished. The tertiary timer is cancelled to 1, so that by observing the indicator lights the column shift position can be determined.

The circuits for the tertiary timer and all the column shift controls are shown on the two sections of the M chassis. Section 1 of the M chassis circuit shows the tertiary timer, its followers, and the interpolating tubes. Section 2 shows the column shift control power tubes and the switches and power tubes for producing the pulses to feed to the column shift switches.

The three triggers comprising the 3-stage tertiary timer are M5, M3, and M2. The indicator lights in socket M7 indicate the status of the tertiary timer. Note that the input wire from the secondary timer to the M5 trigger is shielded to prevent undesired cable coupling to the grids of M5 trigger. The two triode sections of M6 serve

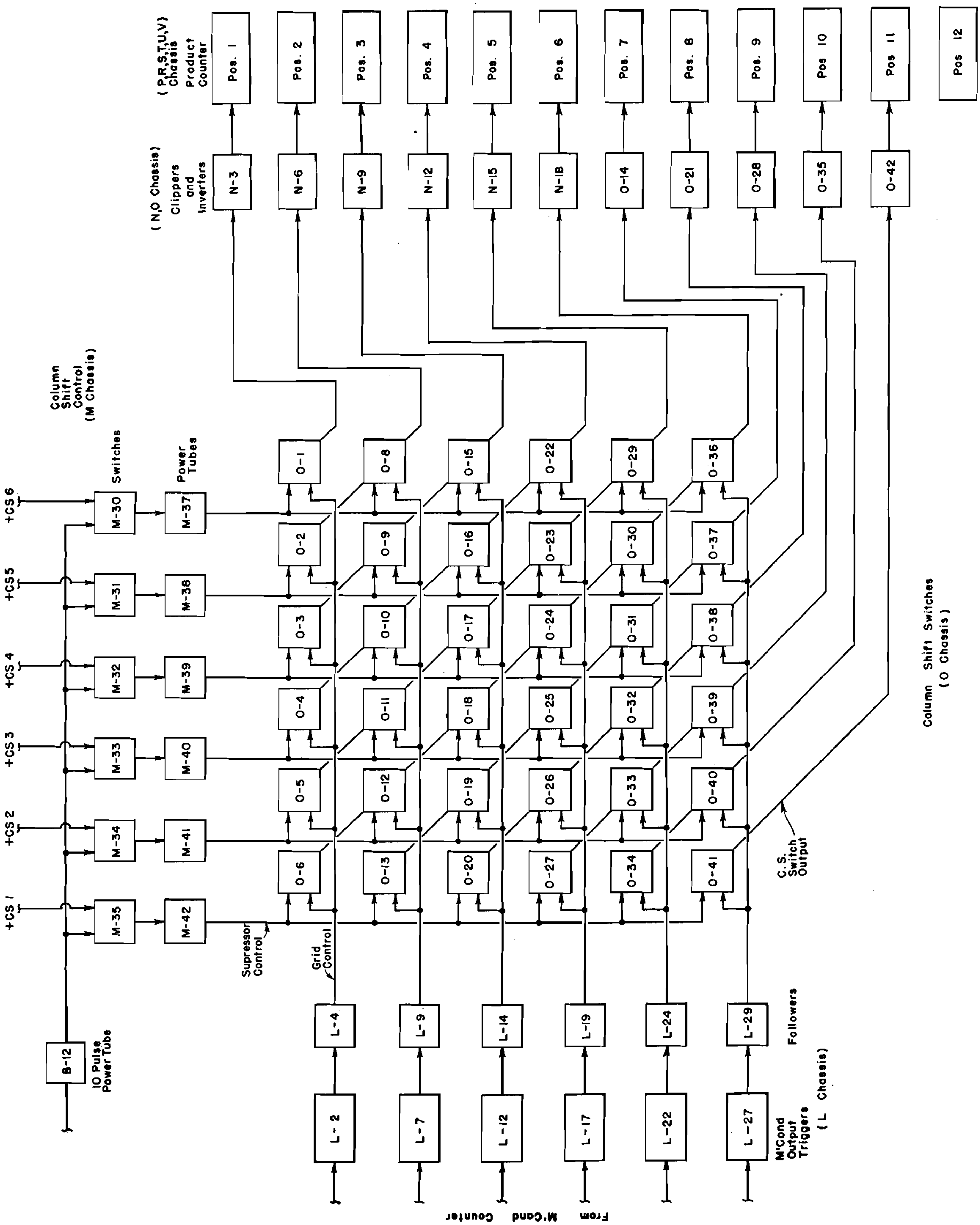

Figure 122. Block Diagram of Column Shift Switches

as followers for trigger M5, the first stage of the tertiary timer. M3, the second stage of the tertiary timer, uses the two sections of M4 as followers, while the two sections of M1 serve as followers for the third stage trigger M2. The trigger stages are mounted in reverse order to simplify wiring.

The triggers M2, M3 and M5 are slow-speed triggers because the frequency of pulses to these triggers is quite low even when computing at 35,000 kc frequency of the multivibrator. The slow-speed trigger gives more stable operation at the frequency at which the tertiary timer operates.

Observe that each trigger in the tertiary timer has two followers, one for the ON side and one for the OFF side. This is done to prevent loading the triggers. Each follower has a voltage divider between its anode and the −100 volt line. The midpoint of these voltage dividers is at −25 volts as long as the corresponding follower is conducting, and at +25 volts as long as the corresponding follower is non-conducting. The midpoint of each voltage divider is connected to the associated grids of the interpolating tubes. By this means, the interpolating tubes determine which trigger (or triggers) in the tertiary timer is ON and thereby establish the column shift position.

The tertiary timer is cancelled to 1, so as to indicate the column shift cycle in which the machine is operating. Since the tertiary timer operates as a binary counter, the following conditions will exist during successive column shift cycles:

	ON	OFF	CODE
1st column shift	M5	M2, M3	1
2nd column shift	M3	M5, M2	2
3rd column shift	M5, M3	M2	1, 2
4th column shift	M2	M5, M3	4
5th column shift	M5, M2	M3	1, 4
6th column shift	M3, M2	M5	2, 4

The followers for the triggers will follow their respective tubes; the conditions existing at the midpoints of the voltage dividers connected to the followers is as follows:

	$M\text{-}6_2$ (M-5 ON)	$M\text{-}6_1$ (M-5 OFF)	$M\text{-}4_2$ (M-3 ON)	$M\text{-}4_1$ (M-3 OFF)	$M\text{-}1_2$ (M-2 ON)	$M\text{-}1_1$ (M-2 OFF)
1st column shift	−	+	+	−	+	−
2nd column shift	+	−	−	+	+	−
3rd column shift	−	+	−	+	+	−
4th column shift	+	−	+	−	−	+
5th column shift	−	+	+	−	−	+
6th column shift	+	−	−	+	−	+

The triode sections $M21_1$ through $M16_1$ (Section 52 of wiring diagram) signal the column shift cycle in which the machine is operating. $M21_1$ conducts during the first column shift cycle, $M20_1$ during the second, $M19_1$ during the third, etc. Observe that the grids of triodes $M21_1$ through $M16_1$ are each connected to a voltage divider between the −100 volt line and the anodes of the three corresponding interpolating tubes. $M21_1$ for example, can conduct only if $M14_1$, $M14_2$, and $M21_2$ are all cut off. $M14_2$ is controlled by $M6_2$; $M14_1$ is controlled by $M4_1$; $M21_2$ is controlled by $M1_1$. By examining the table in the preceding paragraph it will be seen that all three of the interpolating tubes controlling $M21_1$ are cut off during the first column shift cycle; hence, $M21_1$ conducts during the first column shift cycle. By examining the above table and observing the grid connections of the other interpolating tubes, it will be found that $M20_1$ conducts during the second column shift cycle, $M19_1$ during the third column shift, $M18_1$ during the fourth, etc.

The table below shows the tubes conducting during the successive column shift cycles:

	Tertiary Timer	Followers	Interpolating Tubes	Column Shift Control
1st CS	$M5_2$	$M6_2$	$M13_1$; $M18_2$; $M9_1$	$M21_1$
	$M3_1$	$M4_1$	$M13_2$; $M12_1$; $M9_2$	
	$M2_1$	$M1_1$	$M11_2$; $M17_2$; $M16_2$	
2nd CS	$M5_1$	$M6_1$	$M14_2$; $M12_2$; $M10_2$	$M20_1$
	$M3_2$	$M4_2$	$M14_1$; $M11_1$; $M10_1$	
	$M2_1$	$M1_1$	$M11_2$; $M17_2$; $M16_2$	
3rd CS	$M5_2$	$M6_2$	$M13_1$; $M18_2$; $M9_1$	$M19_1$
	$M3_2$	$M4_2$	$M14_1$; $M11_1$; $M10_1$	
	$M2_1$	$M1_1$	$M11_2$; $M17_2$; $M16_2$	
4th CS	$M5_1$	$M6_1$	$M14_2$; $M12_2$; $M10_2$	$M18_1$
	$M3_1$	$M4_1$	$M13_2$; $M12_1$; $M9_2$	
	$M2_2$	$M1_2$	$M21_2$; $M20_2$; $M19_2$	
5th CS	$M5_2$	$M6_2$	$M13_1$; $M18_2$; $M9_1$	$M17_1$
	$M3_1$	$M4_1$	$M13_2$; $M12_1$; $M9_2$	
	$M2_2$	$M1_2$	$M21_2$; $M20_2$; $M19_2$	
6th CS	$M5_1$	$M6_1$	$M14_2$; $M12_2$; $M10_2$	$M16_1$
	$M3_2$	$M4_2$	$M14_1$; $M11_1$; $M10_1$	
	$M2_2$	$M1_2$	$M21_2$; $M20_2$; $M19_2$	

Triodes $M21_1$ through $M16_1$ in turn control six 25L6 power tubes, M28 through M23 (Section 53). Obviously, the operation of the power tubes will be in reverse to that of the triodes, that is, M28 is non-conducting when $M21_1$ is conducting. The grid of M28 is at the midpoint of a voltage divider between −100 volts and the anode of $M21_1$ so that when $M21_1$ is conducting, the grid of M28 is at −25 volts, M28 is cut off, and the potential at its anode rises to +150 volts.

The power tubes M28 through M23 control the multiplying control switch tubes in the C chassis (C3, C6, C9, C12, C15, C18) as well as the switch tubes M35 through M30 (Section 54) which provide the 10 pulses to the corresponding row of column shift switches. Two voltage dividers are connected to the anode of M28, one to control the grid of C18 switch and one to control the suppressor of M35 switch. The ones controlling the multiplying control switches are shown in the C chassis. During the 1st column shift cycle M28 is cut off and the potential at its anode is +150 volts. This permits the suppressors of both C18 and M35 to rise above cutoff and to accept whatever pulses are applied to their grids. C18 accepts the + pulses at 12 of each primary cycle to advance the 6th multiplier counter position, while M35 accepts the 10 B pulses fed to its grid through the .02 mfd coupling capacitor at post M12. The 10 B pulses are produced by tube B12 in the B chassis. These 10 B pulses produce 10 A pulses of 100 volts amplitude at the anode of switch tube M35 and are fed to the grid of power tube M42 through a 250 mmfd coupling capacitor. M42 is normally conductive since its grid is tied to the midpoint of a voltage divider between +150 and −100 volts. Each of the negative shifts at the anode of M35 cuts off M42 and produces a positive shift in voltage at the anode of M42. Thus the 10 A pulses at the grid of M42 are reproduced as 10 B pulses at the anode. These 10 B pulses at 100 volts amplitude from M42 are passed on to the suppressors of all the column shift switch tubes (O chassis) which are associated with the 1st column shift.

In the same manner described above, M41 power tube produces 10 B pulses to pass on to column shift switches during the second column shift cycle; M40 does the same during the third column shift, etc. Also, in a manner already described, power tubes M27 through M23 successively condition the multiply control switches, C15, C12, C9, C6, and C3 to permit successive positions of the multiplier counter to become active. As will be explained later, the M23 power tube also controls the half-entry circuits and provides the compute stop impulse.

Figure 123 is a block diagram of all the column shift controls showing a timing chart of the operations. A careful study of this diagram will assist in understanding the column shift operations.

> NOTE: The voltage divider for establishing the normal grid bias for tubes M35 through M30 is shown connected directly to the grid of M35. This divider should be connected on the common bus on the other side of the .0047 megohm grid resistor. Some machines were erroneously wired as shown on the wiring diagram and should be corrected in the field.

Carry Control and Carry Circuits

Since the multiplicand factor must be added over and over in the product counter, it is necessary to provide a means for carrying from one position to the next higher order. To keep the counter chassis standard and thus permit the same chassis to be used in all counter positions, the carry circuits are not incorporated in the same chassis as the counter. The W and X chassis contain the carry triggers and carry switches. Only the first two rows of tubes in these chassis are used. The rest of the positions contain indicator sockets, blanks, or spare tubes. The tubes in the first vertical row of the W and X chassis are the carry triggers, while the second row contains the carry switches. The indicator socket in W13 indicates the status of the carry triggers 1 through 6, while

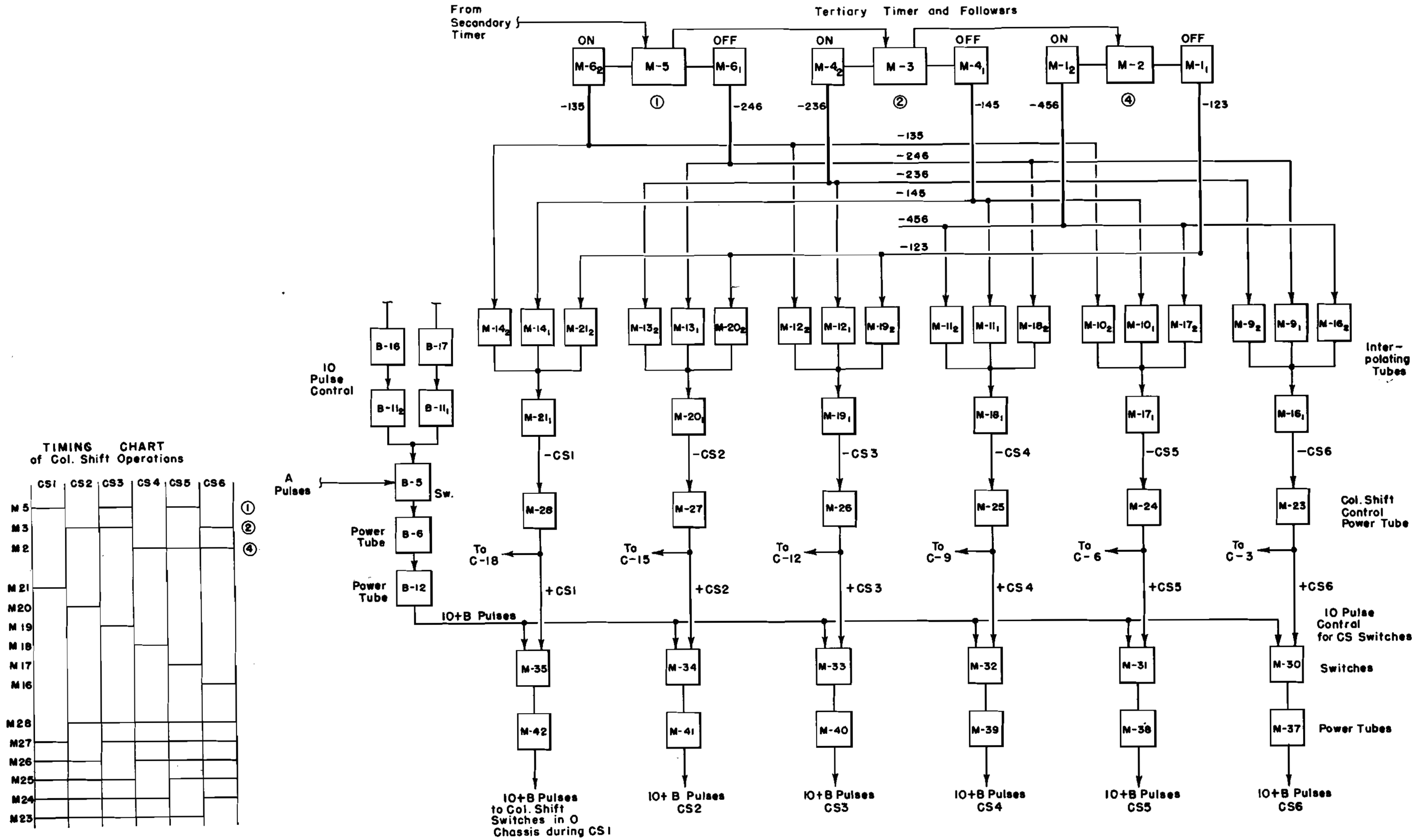

Figure 123. Block Diagram of Tertiary Timer and Column Shift Controls

indicator X3 shows the status of triggers 7 through 12. Since there is no carry back from the 12th position to the 1st position, the 12 carry trigger is not necessary for carrying. However, the carry triggers are used in reading out and therefore the 12 carry trigger must be provided for this purpose.

The basic operation of carrying was discussed in connection with counters. Figure 92 shows the carry operation in block diagram form. It must be remembered that a carry may occur anywhere during the adding portion of a cycle. Consequently, all carry operations must be delayed until all adding is complete. Adding is not complete until 10 of the primary cycle, therefore carrying must be delayed beyond this point. Actually, carry occurs at 10.5 of each primary cycle.

When any position of the product counter passes from 9 to 0, a −50 volt pulse at the output of the product counter turns the corresponding carry trigger ON, which in turn conditions the grid of the corresponding carry switch. However, nothing further happens until 10.5 of the primary cycle when the carry control causes a rise in potential at the suppressors of all carry switches. Then, any of the carry switches which have previously been conditioned will conduct and provide a negative pulse to pass on the next higher order counter position.

If a counter position stands at 9 when it receives a carry, the carry pulse from the previous position causes this position to advance to 0, thereby turning its carry trigger ON and conditioning its carry switch. Since the suppressors of all carry switches are above cutoff at carry time, when the grid of any carry switch rises above cutoff, the carry switch will conduct and pass a negative pulse to the next higher order counter position. With 12 counter positions, it is possible to have 11 such operations in succession. For example, if the counter contains 999999999994, and 6 is added, only one counter position goes from 9 to 0, yet it is necessary to add 1 to all positions except the units. The first carry trigger will be the only one turned ON at carry time; therefore, at 10.5 a carry pulse passes to the 2nd position, advancing it to 0 and turning ON the 2nd carry trigger, which in turn causes the 2nd carry switch to pass a carry pulse to the third position, advancing it to 0, etc. This continues through the 12th position. Obviously, sufficient time must be provided to complete this operation through 12 positions. To allow plenty of time for all carry operations to be completed, the carry control keeps the suppressors of all the carry switches above cutoff until 14. Since 14 is the end of a primary cycle, all carry triggers must also be turned OFF at this point in preparation for a new adding cycle.

The carry control circuits and the carry circuits for one position are shown in Figure 124. It will be observed that the carry control circuits are in the B chassis. B15 switch and B14 power tube provide the carry control from 10.5 through 14, while the B8 power tube provides a −14 pulse to turn all carry triggers OFF.

The OFF side of the carry trigger receives a −50 volt pulse from the carry output of the corresponding product counter position. This negative pulse turns the carry trigger ON. In Figure 124 the carry trigger is trigger W1. Since the grid of switch W2 is connected to the grid of tube $W1_2$, switch W2 follows $W1_2$ in potential. That is, W2 is conditioned to conduct as long as W1 is ON. However, nothing further happens until the suppressor of W2 rises above cutoff. During the adding portion of each primary cycle, the suppressor of W2 is below cutoff since it is connected to a voltage divider between −250 volts and the anode of power tube B14 which is conducting during the adding portion of each cycle. B14 is controlled by switch tube B15, which is cut off during the adding portion of each primary cycle. B15 is controlled by the ON side of trigger B16 and by triode $B9_2$ which follows the OFF side of trigger B3. The grid of B15 is tied to the grid of tube $B16_1$ (OFF side of trigger B16), therefore B15 can conduct only when B16 is OFF (from 10.5 through 0.5).

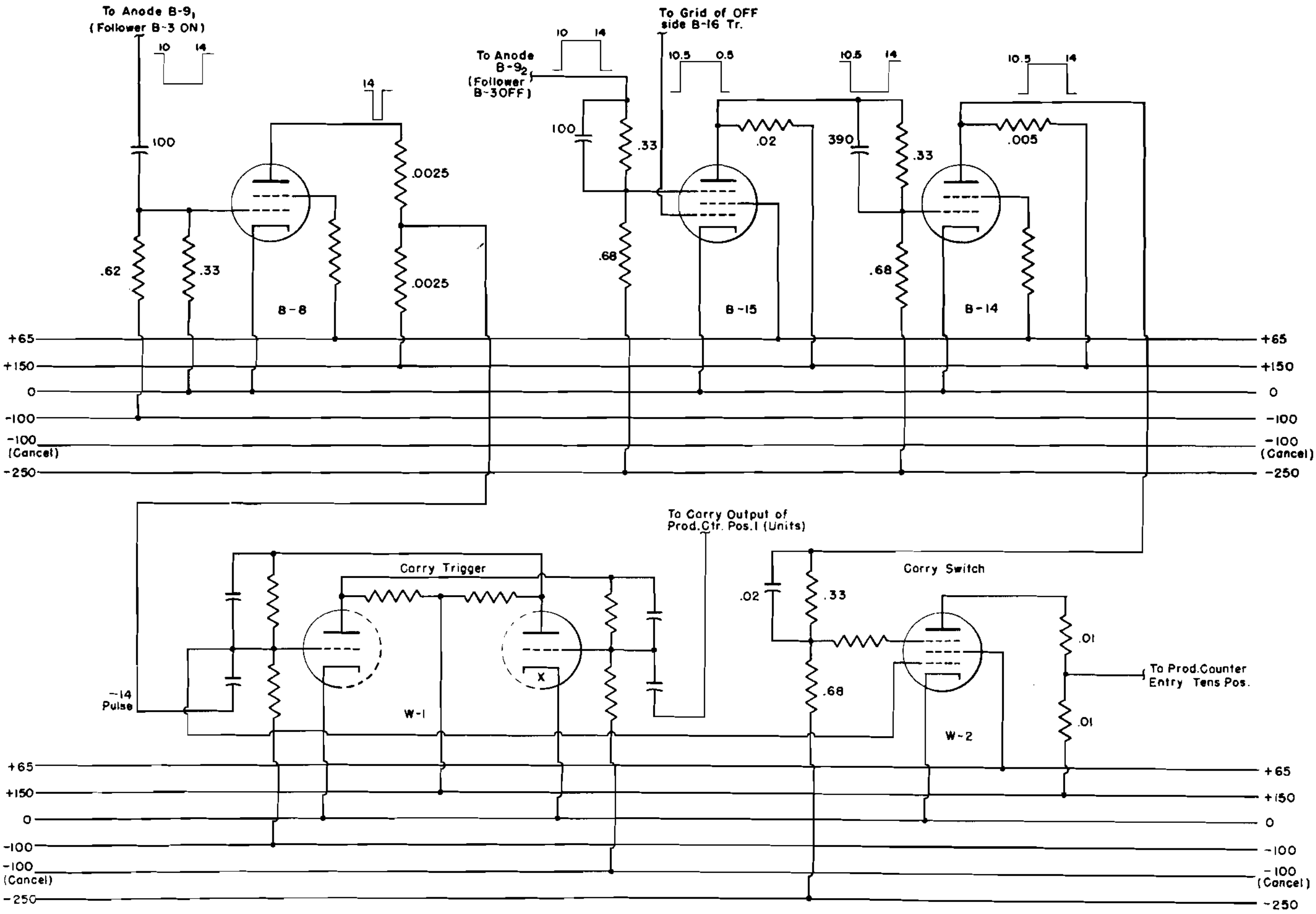

Figure 124. Carry and Carry Control Circuit

The suppressor of B15 is connected to a voltage divider between –250 volts and the anode of $B9_2$. As long as $B9_2$ is conducting, B15 is cut off. B15 can conduct only if $B9_2$ is cut off. Since $B9_2$ follows the OFF side of trigger B3, $B9_2$ conducts as long as B3 is OFF, and is cut off as long as B3 is ON. Consequently $B9_2$ is cut off from 10 through 14. Since both the grid and suppressor of a switch must be above cutoff to conduct, B15 can conduct only from 10.5 through 14, and the anode potential of B15 is low from 10.5 through 14. Therefore B14 power tube is cut off from 10.5 through 14, and its anode potential is high from 10.5 through 14. Since the anode of B14 is connected to the top of a voltage divider controlling the suppressors of all carry switches, the suppressors of all carry switches are above cutoff from 10.5 through 14.

At 14, all carry triggers must be turned OFF in preparation for a new adding cycle. The negative pulse at 14 is produced by B8 power tube. B8 is normally cut off since its grid is at approximately –35 volts. The grid of B8 is capacity coupled through a 100 mmfd capacitor to $B9_1$ triode. $B9_1$ follows the ON side of trigger B3; hence, it produces a positive pulse at its anode whenever the B3 trigger goes OFF. This positive pulse at 14 causes B8 to conduct momentarily, thereby producing a negative pulse at its anode. Since the output from B8 is taken from the midpoint of the load resistor, the pulse produced is a –50 volt pulse. This –50 volt pulse at 14 is fed to all the carry triggers to turn them OFF.

All the carry triggers and carry switches are shown on the circuit diagram for the W and X chassis, while the carry control circuits are shown in the B chassis circuit diagram. The output of B14 is taken from post B51, and the output of B8 is taken from post B50. The inputs to the OFF side of all carry triggers in the W and X chassis are tied together to post W42 and are pulsed at 14 by B8. Similarly, the suppressors of all carry switches in the W and X chassis are tied together and connected to the voltage divider shown beside the W2 switch. The suppressors each have the conventional parasitic suppression resistor in their circuit. The .02 mfd capacitor across the .33 megohm resistor beside W2 compensates for the interelectrode capacitance in all 12 carry switches and permits almost instantaneous response of all carry switches.

It will be observed that the .01 megohm resistor shown in the anode circuit of all carry switches is not tied to +150 volts but connects to the input of a counter. Actually, the input of each product counter position is the midpoint of a load resistor for the inverter following the clipper. The carry switches use the lower half of the inverter load resistors as part of their load resistor.

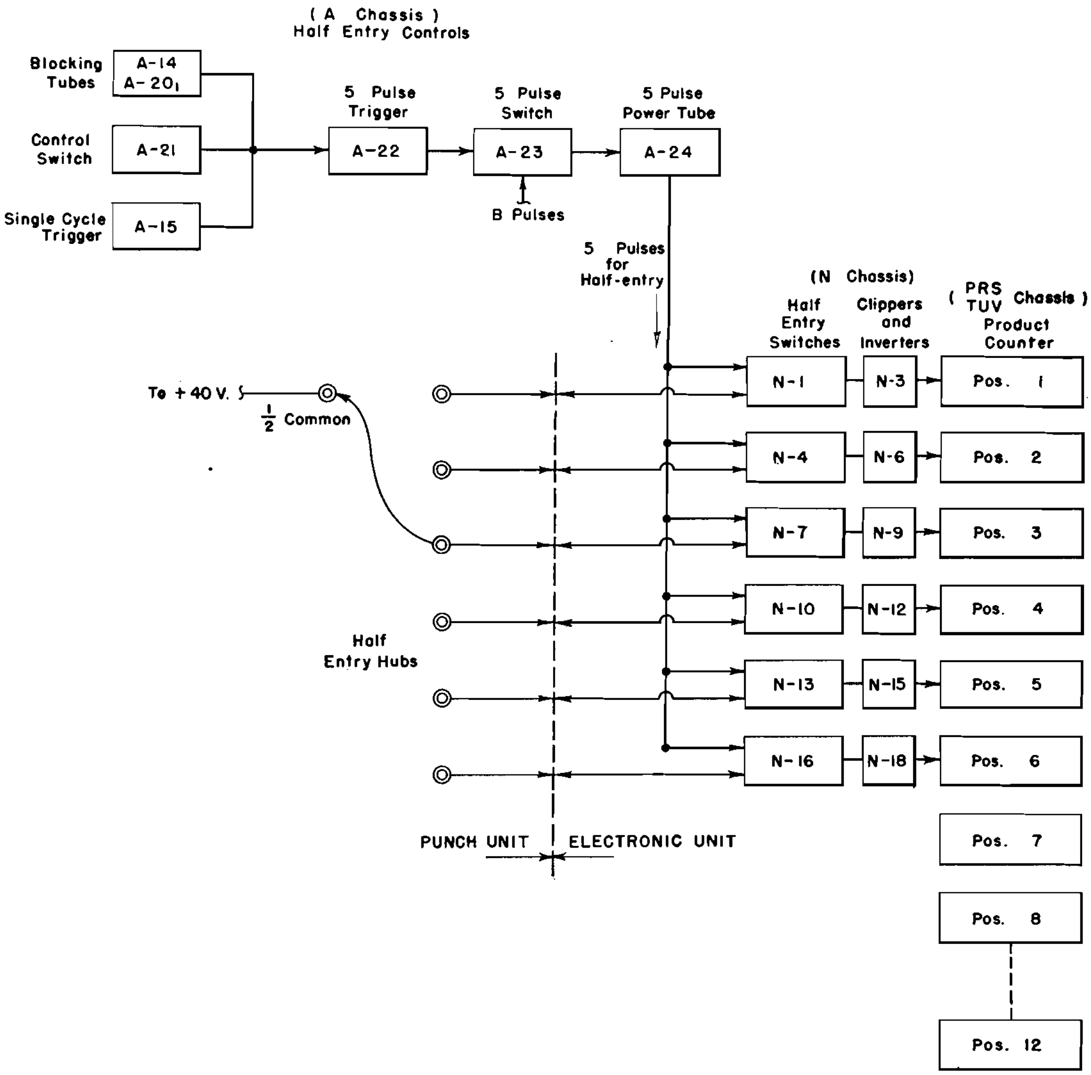

Figure 125. Block Diagram of Half-Entry Circuits

Half-Entry

The half-entry circuit permits correction to the nearest decimal by adding 5 to the position just to the right of the last retained decimal position. This half correction can be entered only in the first six positions of the product counter as indicated by the block diagram in Figure 125.

A half-entry switch is provided for each of the first six positions of the product counter. These switches are in the N chassis, and their suppressors are normally biased well below cutoff. Once during each computation 5 pulses are applied to the grids of all six half-entry switches. Of course, nothing happens unless the suppressor of a switch is brought above cutoff. This is done by wiring on the control panel. When a half-entry hub is wired to the ½ common (+40 volts), the corresponding switch tube is conditioned to conduct by bringing its suppressor above cutoff. Then when the 5 pulses are applied to its grid, these 5 pulses are passed on to the corresponding position of the products counter.

An examination of the circuit diagram for N chassis will show that the suppressors of the half-entry switches (N1, N4, N7, N10, N13, N16) are all tied to −100 volts and are at that potential until wired to +40 volts through the control panel wiring. When a half-entry switch is wired to +40 volts through the ½ common hub, its suppressor rises well above cutoff. The .05 mfd capacitor between the .039 megohm resistors serves to by-pass any transients entering through the cable from the punch. The 5 positive pulses for half correction are applied to post N42 through the .02 mfd coupling capacitor to the grids of all six switches. The grids are normally at about −35 volts as determined by the voltage divider shown under switch N1. When 5 positive pulses are applied to the grids, 5 negative pulses appear at the anodes of the switches. It will be seen that the half-entry switches share the load resistor with the corresponding column shift switches. This arrangement is necessary because pulses from both half-entry switches and the column shift switches enter the clippers and from there pass to the product counter. The carry switches in turn share one of the .01 megohm resistors in the load circuit of the clipper as part of their load resistor.

The 5 half-correction pulses are produced by the half-entry control circuits in the A chassis as indicated in the block diagram of Figure 125. The half-entry is made during the first primary cycle of the last column shift cycle. Remember that no multiplicand rolling can occur during the first primary cycle of each column shift cycle, because the multiplier advancing pulse does not come until 12. Consequently this first primary cycle is reserved for half-entry. However, the half-entry can be made only once during a computation. Therefore, only the first primary cycle of the last column shift cycle is used. From the foregoing it is obvious that provision must be made to:

(1) permit half-entry only during the 6th column shift cycle.
(2) permit half-entry only during the first primary cycle of the 6th column shift cycle.
(3) recognize 5 pulses only during this first primary cycle of the 6th column shift cycle.
(4) produce these 5 pulses with sufficient power to operate the six half-entry switches.

The first of the above requirements is met by blocking tubes $A14_1$ and $A20_1$ as indicated in Figure 125. Trigger A15 together with follower $A14_2$ fulfills the second requirement. The third requirement is met by the 5 pulse trigger A22 under control of switch A21, while the last requirement is met by switch A23 and power tube A24. The actual circuits for the half-entry controls will be found in the circuit diagram for the A chassis (Section 26).

It will be observed that $A14_1$ and $A14_2$ are parallel with the OFF side of the 5 pulse trigger A22. Therefore as long as either $A14_1$ or $A14_2$ is conducting, A22 cannot turn ON. $A14_2$ is normally cut off, but $A14_1$ conducts during the first five column shift cycles under control of $A20_1$ which is cut off during the first five column shift cycles. The wire on post A45 connects to the anode of tube M23, and M23 is cut off only during the 6th column shift cycle. Therefore $A20_1$ can conduct only during the 6th column shift cycle. While $A20_1$ is conducting, $A14_1$ is cut off, therefore A22 can turn ON, beginning with the 6th column shift cycle.

The OFF side of the trigger A22 is controlled by $A34_1$ which follows the OFF side of $A29_1$, the last stage of the primary timer. A29 goes OFF at 0; therefore, at 0 of the first primary cycle of the 6th column shift cycle, trigger A22 goes ON.

The ON side of trigger A22 is controlled by switch A21 which produces negative pulses at 5, 7, 13, and 15. The first pulse at 5 turns A22 OFF and the others are not used. Therefore A22 goes ON at 0 and OFF at 5.

Switch A21 produces its pulses as follows: the suppressor of A21 is tied to the anode of the follower tube A20 for the OFF side of trigger A28, the third stage of the primary timer. Hence the suppressor of A21 is above cutoff when A28 is ON from 4 through 8 and from 12 through 0. The grid of A21 is normally cut off and is pulsed by $A26_1$, the OFF side of the first stage of the primary timer. $A26_1$ provides a positive pulse to A21 each time A26 goes ON at 1, 3, 5, 7, 9, 11, 13, and 15. Since both suppressor and grid must be above cutoff to permit conduction, A21 conducts at 5, 7, 13, and 15 to produce negative pulses at the tap on its load resistor. As previously mentioned, the first negative pulse at 5 turns A22 OFF provided it was ON. It must be remembered that A21 produces its negative pulses every primary cycle, although they are used only during the first primary cycle of the 6th column shift cycle.

It has been shown that A22 goes ON at 0 and OFF at 5 of the first primary cycle of the 6th column shift. When A22 goes OFF at 5, it produces a negative pulse at the OFF side. This negative pulse is passed ON to trigger A15 to turn it ON. Once A15 goes ON, it cannot be turned OFF except by cancelling. When A15 goes ON, follower $A14_2$ conducts and blocks A22, thereby preventing it from turning ON again. In effect, A22 blocks itself from going ON again after just one operation.

The grid of switch A23 is connected to the ON side of A22; therefore, A23 is receptive to pulses applied to its suppressor as long as A22 is ON. In other words, A23 will pass pulses from 0 through 5 of the first primary cycle during the last column shift cycle. The suppressor of A23 receives a constant stream of B pulses, and A23 will conduct on each *positive shift* of the B pulses from 0 through 5 of the first primary cycle during the last column shift cycle. A23 then will conduct at 0.5, 1.5, 2.5, 3.5, and 4.5, and negative pulses will be produced at the anode of A23. A24 power tube is normally conducting; therefore, A24 is cut off at 0.5, 1.5, 2.5, 3.5, and 4.5 of the half-correction cycle, and 5 positive pulses are produced at the anode of A24 to pass on to the half-entry switches in the N chassis.

Compute Stop

At the end of the 6th column shift cycle, computations must be stopped. This is accomplished by turning trigger A31 OFF. Trigger A31 is in Section 23A of the circuit diagram. It will be observed that the ON side of A31 is pulsed from a tap on a voltage divider between +150 volts and post A45, which connects to the anode of tube M23. At the beginning of the 6th column shift cycle M23 is cut off and a positive pulse is produced at the voltage divider controlling A31. However, a positive pulse has no effect since A31 is ON. At the end of the 6th column shift, M23 again conducts, the potential on post A45 drops, a negative pulse is produced at the voltage divider under A31, and A31 is turned OFF. When A31 goes OFF, the start switch A25 is blocked and all computing is terminated.

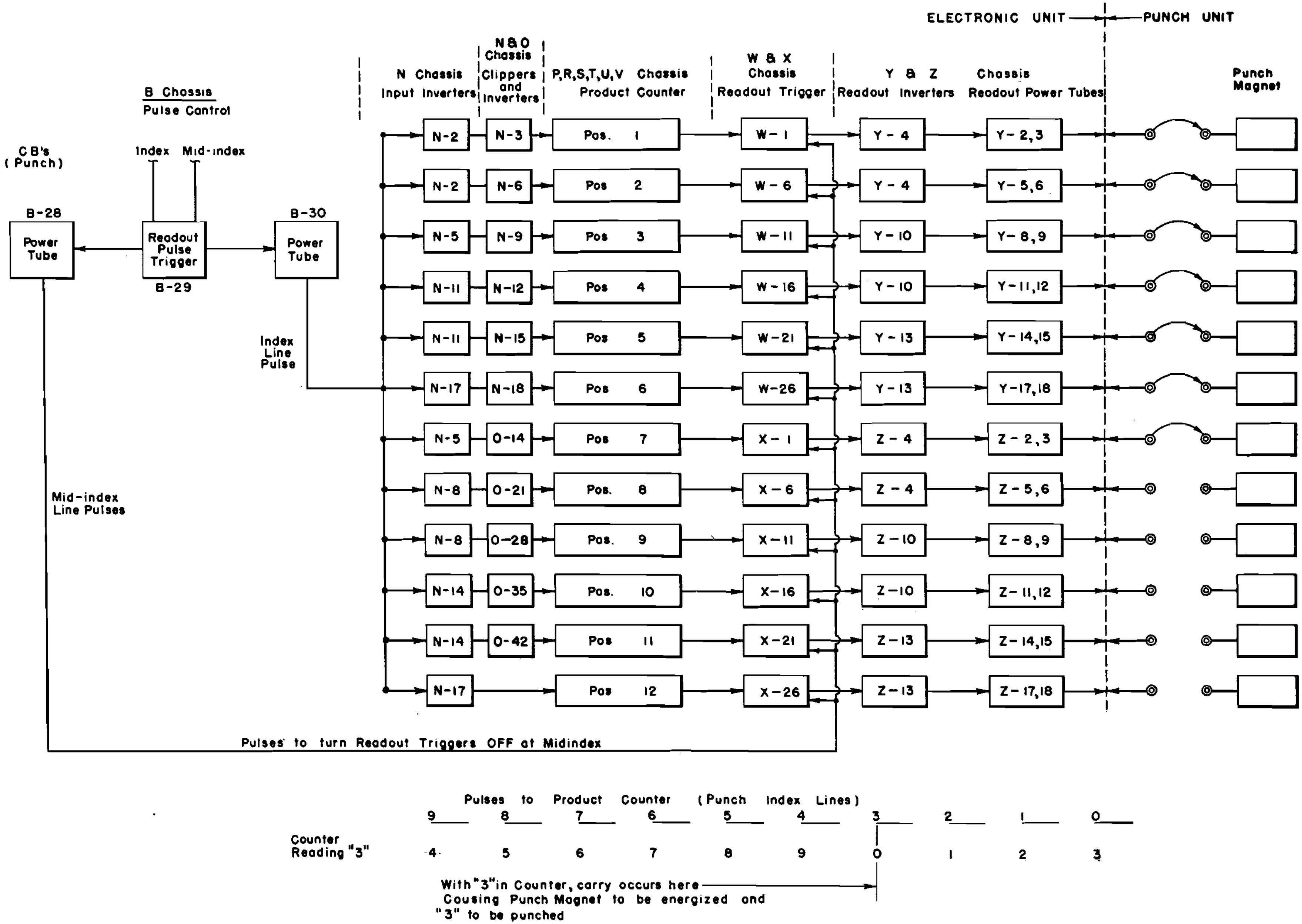

Figure 126. Block Diagram of Read-out Circuits

Read-Out Circuits

After the computation is finished, the electronic unit must wait until the card in which the product is to be punched reaches the die and stripper. During this cycle the product is read out and punched in the card, and the product counter is cancelled shortly after 0 on the punch index.

Read-out is almost exactly the reverse process to read-in. When reading into a counter, pulses are fed to the counter in synchronism with card movement after reading the hole in the card. When reading out, pulses are applied to all product counter positions in synchronism with the card movement, beginning at 9 on the punch index. When a carry occurs, a hole is punched.

Figure 126 shows the read-out circuits in block diagram form. Trigger B29 goes ON and OFF under control of P-cam contacts in the punch unit. B29 goes ON at index lines and OFF at mid-index lines. B30 power tube produces positive pulses in synchronism with card movement through the punch, beginning at 9. These positive pulses are applied to the grids of the 12 inverters in the N chassis which in turn provide negative pulses to feed to the 12 product counter positions. When any product counter position goes from 9 to 0, the corresponding read-out (or carry) trigger goes ON, and the corresponding read-out inverter is cut off, thereby producing a positive pulse to cause the power tubes to conduct and energize a punch magnet. At the mid-index points, power tube B28 turns OFF any read-out triggers which happen to be ON and thereby prevents the possibility of punching two holes in the same column.

The actual circuit for producing the read-out pulses is shown in Figure 127. Trigger B29 is turned ON each time P7 and P8 make on the punch index lines, provided the relay points controlling the read-out circuit are closed. R1 is picked up as long as cards are at the die, and the points of R29 and R19 are closed except when a rate card passes the die when group multiplying, or when accumulating products for punching in a subsequent card on a product summary run.

Trigger B29 is turned OFF at mid-index points each time P5 and P6 make, therefore B29 goes ON at each index line and OFF at mid-index points. Each time B29 goes ON, a negative pulse is passed to B30 power tube through the 50 mmfd coupling capacitor. Since B30 is normally conducting, each time B29 goes ON, B30 momentarily stops conducting and produces a positive pulse at its anode. This positive pulse is passed to post N41 and on to all 12 inverters in the N chassis through the 1000 mmfd capacitor. $N2_1$, inverter for the first position for the product counter, is shown in Figure 127. The inverters produce −50 volt pulses to pass on the product counter. The lower half of the load resistors for inverters in the N chassis are shared with the corresponding column shift switches. Each product counter position receives a rolling pulse each time B29 goes ON. The .0025 megohm resistors shown connected between ground and posts B30 and B31 serve to maintain a continuous current flow through the P-cam contacts.

The read-out circuit for the first position of the product counter is shown in Figure 128. When the first position of the product counter goes from 9 to 0, trigger W1 goes ON, and the potential at the anode of tube $W1_2$ drops. This drop in potential drops the grid of $Y4_1$ below cutoff, and the potential at the anode of $Y4_1$ rises. In turn, the rise in potential at the anode of $Y4_1$ drives the grids of Y2 and Y3 power tubes above cutoff. The 0.1 mfd coupling capacitor provides a sufficient time constant to insure that Y2 and Y3 will conduct long enough to cause a hole to be punched. Two power tubes are used in parallel to furnish the current required by a punch magnet.

It will be observed that the anode potential supply for the read-out power tubes is not in the electronic unit. The +140 volt supply furnished by the half-wave selenium rectifier in the punch unit furnishes power to energize the punch magnets during read-out. The anode potential is applied

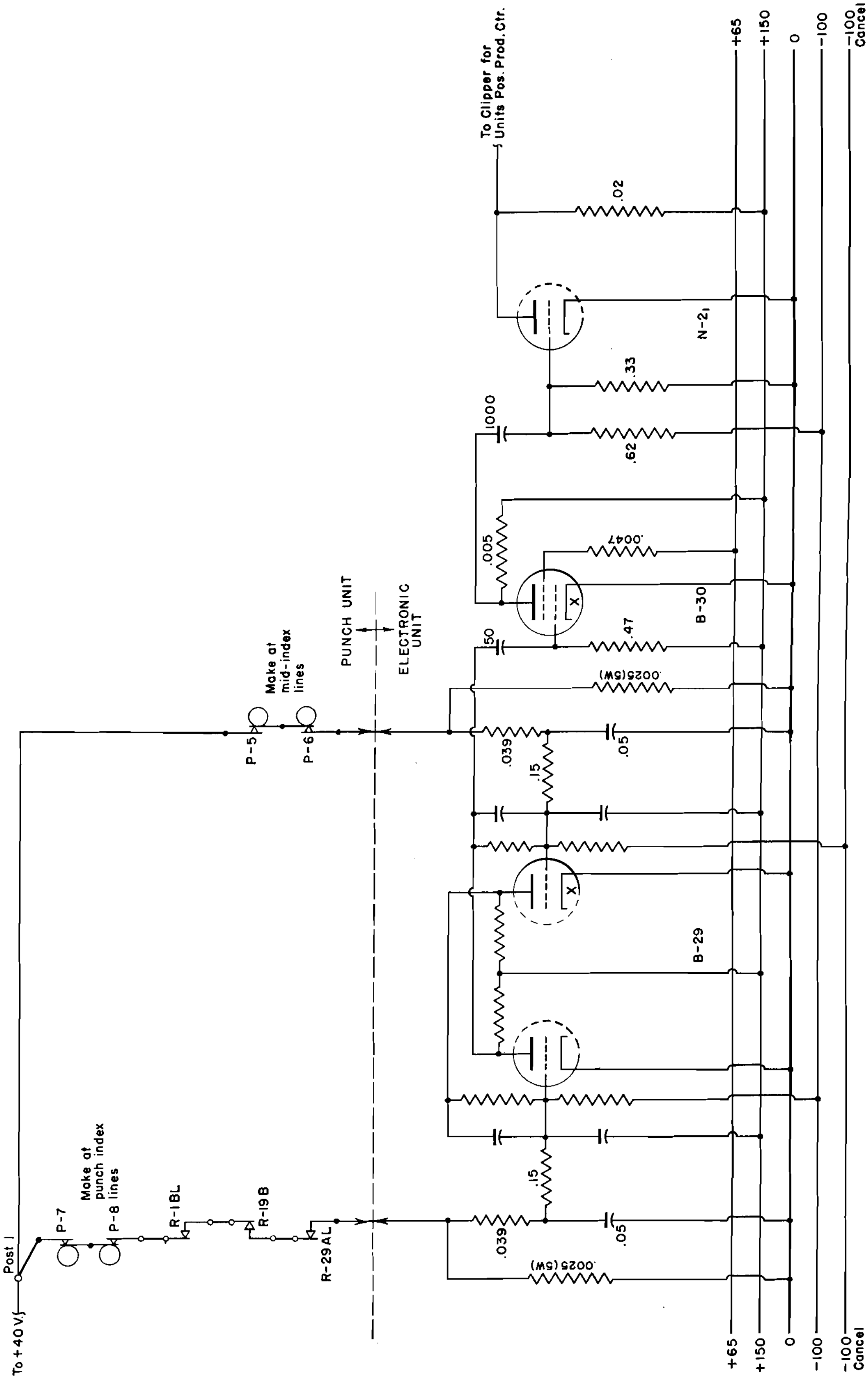

Figure 127. Product Counter Read-out Pulses

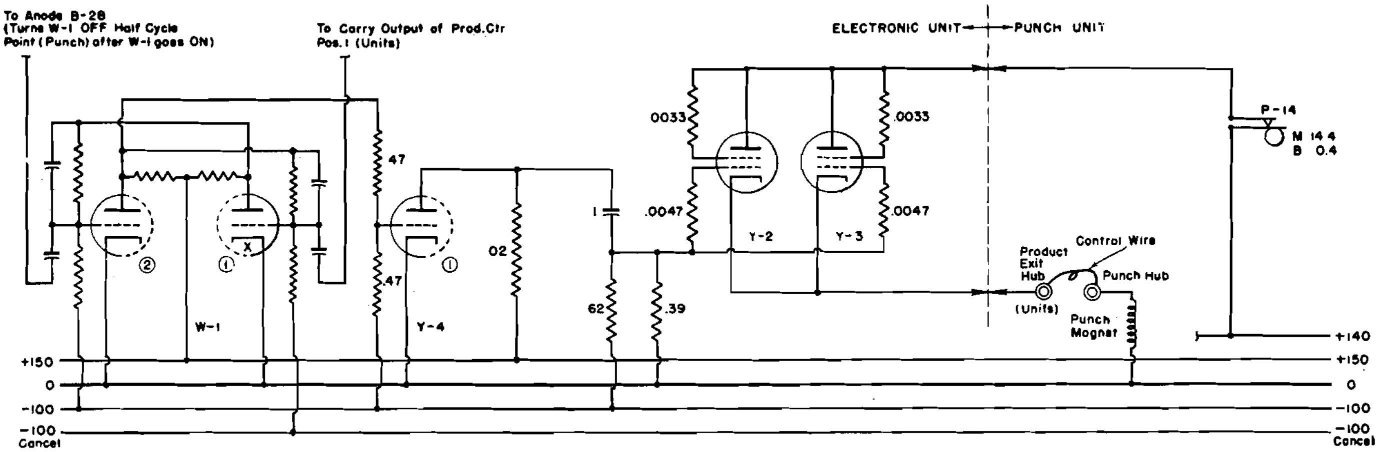

Figure 128. Product Counter Read-out Circuit

only during read-out time by P14 cam contact. The potential drop across the punch magnet is 40 volts and across the power tubes, 100 volts. It will be observed that the cathodes of the power tubes are not at ground potential because the punch magnets are connected to ground.

At the mid-index point following the turning ON of W1 trigger, it is turned OFF by B28 power tube, as shown in Figure 129. Each time B29 goes OFF (at mid-index points) a positive pulse passes to the B28 power tube, which is normally cut off; B28 momentarily conducts and produces a negative pulse at the midpoint of its load resistor. This negative pulse passes to the ON side of all read-out triggers to turn OFF any that happen to be ON. This is illustrated in the block diagram of Figure 126.

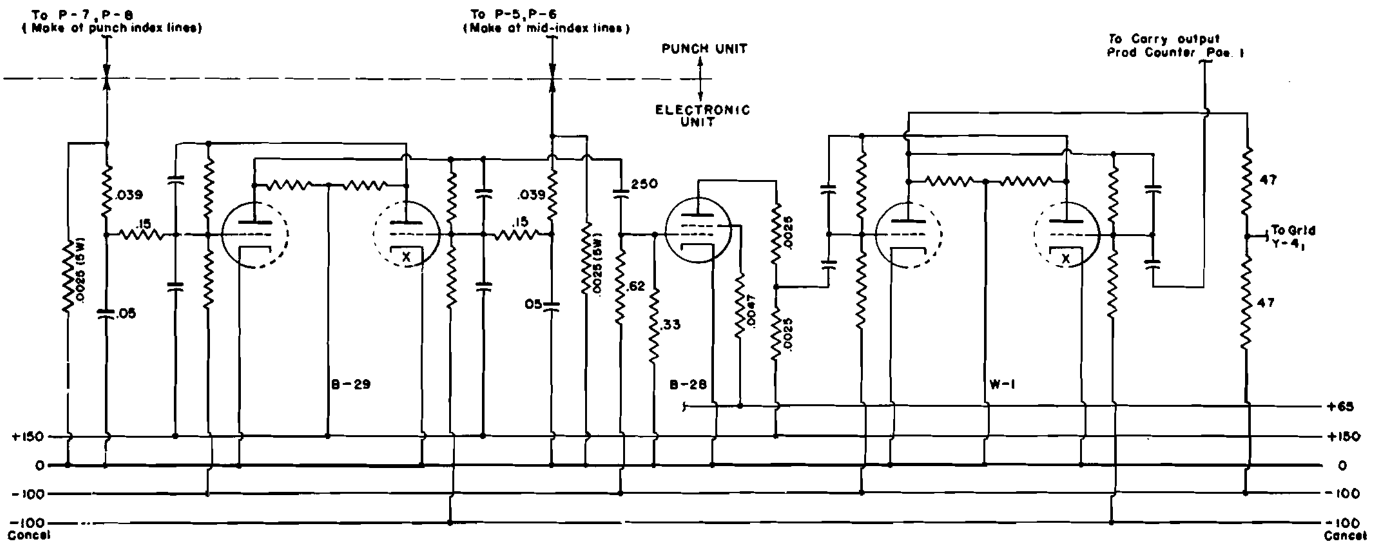

Figure 129. Triggering Off of Read-out Triggers at Mid-Index