IBM

ELECTRIC PUNCHED CARD

ACCOUNTING MACHINES

CUSTOMER ENGINEERING MANUAL OF INSTRUCTION

ELECTRONIC MULTIPLIER

TYPE 603

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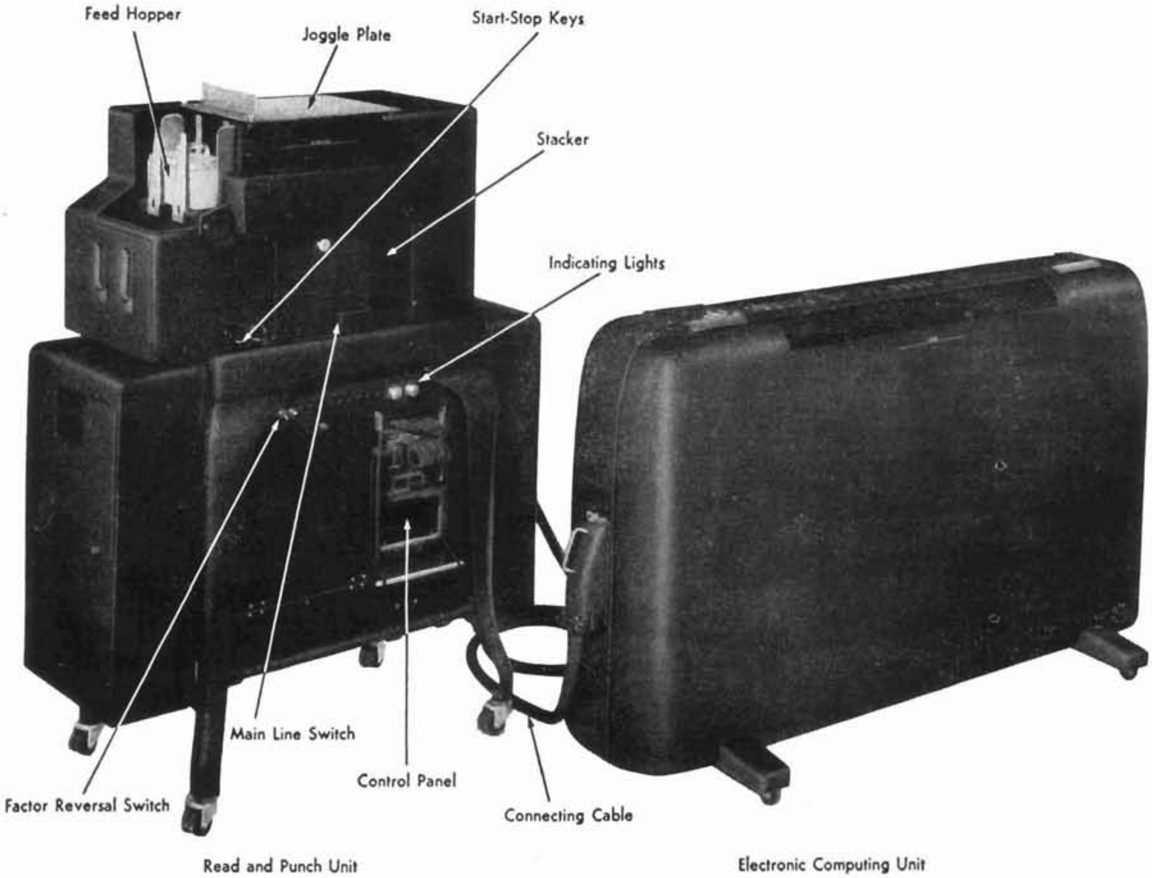

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INTRODUCTION

THE CONVENTIONAL multiplying machine using mechanical counters for the computation of products is considerably limited in its speed of operation because of the inertia of moving parts. By the use of electrical computation circuits, calculating speeds can be increased considerably. The Electronic Multiplier makes use of recently-developed electronic circuits which perform calculations at extremely high speeds. Thus the burdensome and usually slow-speed process of computing products is reduced to an automatic high-speed process in keeping with the other high-speed functions of the IBM Accounting Machine Method. Calculations involving earnings, material costs, discounts, inventories, and many other computations can be effected automatically to speed up the accounting routines which normally require much time and effort.

The Type 603 Electronic Multiplier consists essentially of a unit for reading and punching and an electronic computing unit connected by a cable as shown by the general view of the machine on the frontispiece. The factors punched in an IBM Card are read by the reading unit, computations are automatically made by the electronic computing unit, and the result is then punched in the same card by the punching unit. No time is lost waiting for the completion of the computing operations; all computations are performed between the time a card leaves the reading brushes and the time it reaches the punching position. The machine is equipped with a control panel which makes it entirely flexible as to the reading and punching of information.

The IBM Electronic Multiplier, Type 603, represents the first commercial use of electronics for multiplication. The use of electronic circuits for computing permits operation of this multiplier at maximum punching speed of 6000 cards per hour. The multiplication itself is performed in .027 second, between the reading and punching of each card.

OPERATING FEATURES

THE operating controls and features of this machine, which can be seen in Figure 1, are all located on the punch unit.

Main Line Switch

This switch must be ON for the machine to be operative. It must not be turned OFF while cards are feeding through the machine.

Power Indicating Light (Green)

When this light is ON, the machine is ready for operation. It will not turn on until sufficient time has been allowed for the electronic tubes to warm up.

Start Key

This key is depressed to start the feeding of cards at the beginning of a run. It must be held down through three machine cycles, when first starting, before automatic operation begins.

Stop Key

This key is depressed for manual control of stopping the feeding of cards while the machine is through running.

Error Indicating Light (Red)

This light glows when an error is detected by the Double Punch and Blank Column Detection Device, or when a product exceeds the card field capacity as indicated by the Product Overflow feature.

Error Reset Push Button

This button is depressed to extinguish the error light and restore the machine to normal operation, after the machine has stopped because of an error.

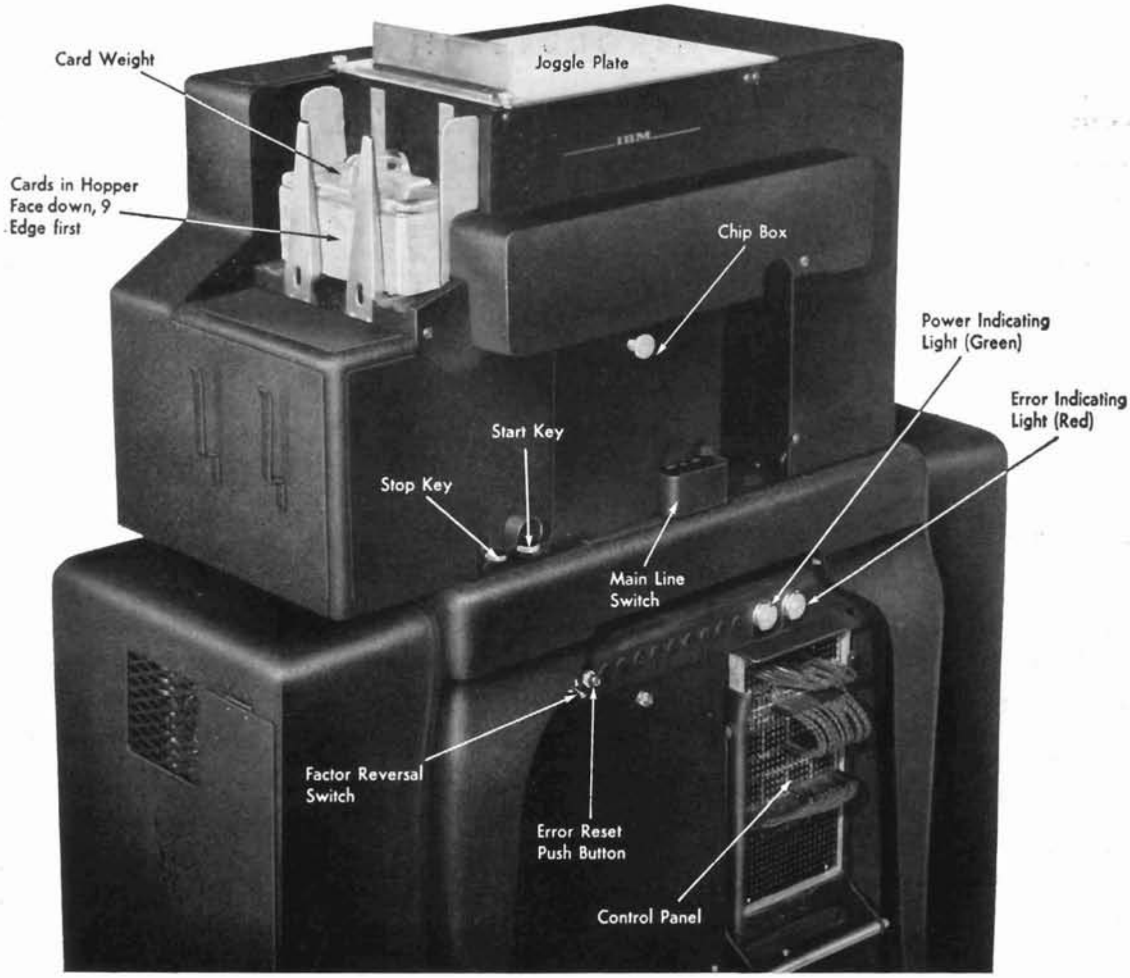


Figure 1. Operating Features

Factor Reversal Switch

When set ON, this switch automatically reverses the multiplier and multiplicand entry hubs. It is used in checking operations.

Card Hopper

Cards are placed in the card hopper face down, 9 edge first. The capacity of the hopper is approximately 800 cards.

Card Stacker

After leaving the last set of brushes, cards enter the stacker which has a capacity of approximately 1000 cards. If the stacker fills to capacity, the machine will be stopped automatically by the stacker stop switch.

Speed

The operating speed of this machine is 100 cards per minute regardless of the number of columns punched and the size of the multiplier or multiplicand fields.

Current

This machine is supplied to operate only on 115 volts or 230 volts A.C., 50 or 60 cycle current.

Control Panel

The automatic control panel provides a means for flexible setup of the machine for all operations. Figure 2 shows a control panel with the function of each hub described.

1—Exit for *1* impulse used for unit multiplier.

PRODUCT SUMMARY

ON—Switch to place feature in operation; permits punching only on summary card.

X—Entry for X impulse identifying summary or detail card; wired to read for Entry brushes.

D—Same as X hub for digit punching.

N—Exit for impulse when No X (or digit) card passes entry brushes; wired to Product Summary Hub.

X—Exit for impulse when X (or digit) punched card passes entry brushes; wired to Product Summary Hub.

Prod. Sum.—Entry for impulse from N or X to cause punching of product and clearing of product counter.

PRODUCT OVERFLOW

Overflow—Entry from Product hub; wired to product counter position next to the highest order wired to punch.

12—Exit for 12 impulse in case product exceeds capacity of card field, i.e., in case any significant digit 1-9 is sensed at the overflow hub.

GROUP MULTIPLYING

On—Switch to place group multiplying feature in operation.

9—Entry for 9 impulse from rate card wired to entry brushes.

PUNCH SUPPRESSION

X—Entry for X impulse identifying card which is to be punched (or non-punched).

D—Same as X but for digits.

N—Exit for impulse when No X (or digit) card passes entry brushes; wired to PCH SUP.

X—Exit for impulse when X (or digit) punched card passes entry brushes; wired to PCH SUP.

Pch. Sup.—Entry for impulse from N or X hub to control punch suppression during following cycle.

COLUMN SPLIT

The 11-12 hubs are internally connected to the corresponding C hubs when the 11 and 12 positions of the card are being read. The 0-9 hubs are connected to the C hubs when the 0-9 card positions are being read.

SELECTOR CONTROL (Optional)

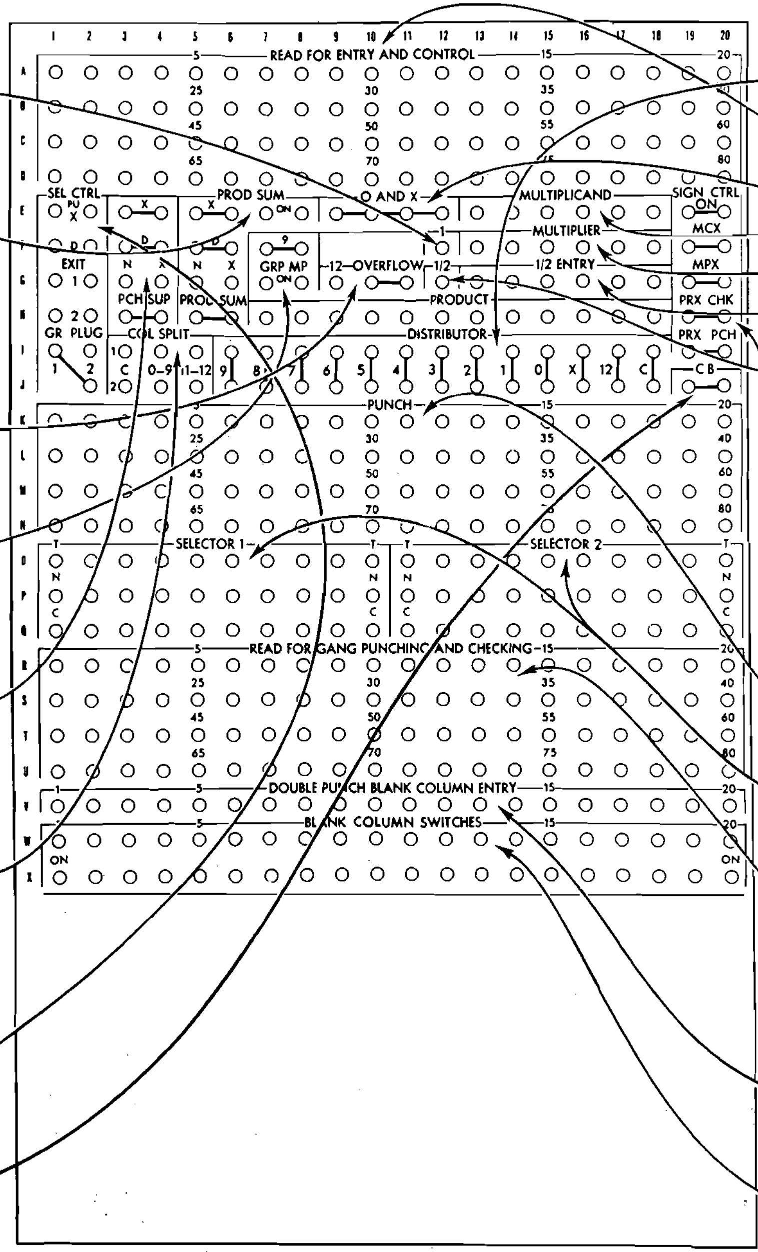
PU; X or D—Entry for X or digit impulses to control operation of Selectors.

Exit 1—Exit for impulse to cause selector to operate on cycle following reading of X or digit, wired to C hub.

Exit 2—Exit for impulse to cause selector to operate on second cycle following reading of X or digit; wired to C hub.

C Plug—Entry for impulses from Exit 1 or 2; causes selector to operate (labelled GR Plug in error).

CB—Exit for impulses at each index point; wired to Distributor common when distributor is used as digit emitter.



DISTRIBUTOR (Optional)

9—12 Exit for impulses at corresponding index point when used as digit emitter or as digit selector.

C—Common brush for distributor; wired to CB when used as digit emitter; wired to brushes when used as digit selector.

Read for Entry and Control—Exit for impulses originating from punched holes in cards passing the first set of brushes; normally used for entering factors in multiplicand and multiplier counters and for control sensing.

O and X—Exit for O and X impulses.

Multiplicand—Entry for multiplicand factor with maximum capacity of six positions.

Multiplier—Entry for multiplier factor with maximum capacity of six positions.

1/2 Entry—Entry to first six positions of product counter for half correction only; a 5 is added to position wired during each computation.

1/2—Common hub for half entry; wired to one of the 1/2 Entry hubs.

SIGN CTRL (Optional)

ON—Switch to place feature in operation.

MCX—Entry for X punching identifying negative multiplicand; wired to Read for Entry brushes.

MPX—Entry for X punching identifying negative multiplier, wired to Read for Entry brushes.

PRX CHK—Entry for X punching identifying negative product; used only during checking run and wired to Read for Entry brushes.

PRX PCH—Exit for X impulse identifying a negative product; wired to Punch hubs.

PUNCH

Entry to punch magnets to cause punching in corresponding card columns.

SELECTORS (Optional)

C,N,T—Common, normal and transferred; represent contact points on relay. In normal position C and N are connected; when selector is transferred, C and T are connected.

READ FOR GANG PUNCHING AND CHECKING

Exit for impulses originating from punched holes in cards passing the second set of brushes; normally wired to punch magnets or to DPBC entry.

DOUBLE PUNCH AND BLANK COLUMN ENTRY

Entry to double punch and blank column check relays for checking; normally wired to Read for Checking brushes.

(Only the first 10 positions are standard; positions 11-20 are optional.)

BLANK COLUMN SWITCHES

Switches to put blank column check circuits in operation; subject to wiring of DPBC hubs.

Figure 2. Control Panel—Explanation of Hubs

Multiplication

The Electronic Multiplier can multiply two 6-digit factors to produce a 12-digit product. Figure 3 shows control panel wiring for an individual multiplication problem. The multiplier and multiplicand are read from the card at the first reading station, represented on the control panel by the 80 exits labelled "Read for Entry and Control." They are wired to the multiplicand and multiplier counter entries. The product is available for punching at Product Exit. The product exit positions from which the product is read must be wired to the Punch Entry hubs representing the columns in which the product is to be punched.

Decimals

When either of the two factors contains decimals, the decimal positions in the product will equal the sum of the decimal positions of the factors. Only those decimal positions which are to be retained in the product are wired from Product Exit to Punch Entry.

One-Half Correction

When some decimal places are dropped from a product, the product can be corrected to the nearest whole number or decimal position by adding 5 to the first position following the retained product. In the Electronic Multiplier, this ½ correction can be made in any of the six right-hand positions of the product counter. On the control panel, ½ entries are located directly above the product exits, and the ½ entry common is adjacent. The 5 for ½ correction will be entered into the product counter during multiplication, once for each card.

Double Punch and Blank Column Detection

The Electronic Multiplier is equipped with 10 double punch and blank column detection positions. Ten additional positions are available on order. These positions are represented on the control panel by the hubs labelled "Double Punch and Blank Column Entry." These hubs are supplemented by 10 control panel switches labelled "Blank Column Switches" which correspond to the 10 DPBC entry hubs. The blank column switches must be set ON for blank column checking.

Multiplication Check

In order that the double punch and blank column feature may be used for checking multiplication, it should be used on each original multiplying run to prove that only one hole has been punched in each product column and that no columns are unpunched. For this purpose, the product field columns in Read for Checking should be wired to Double Punch and Blank Column Entry, as shown in Figure 3.

When the punching has been checked in the original run, the double punch and blank column detection feature may then be used in a separate run to prove the calculation. The cards are re-run through the machine with the wiring of the multiplicand and multiplier counters reversed by placing the factor reversal switch ON. During this second operation the machine again multiplies and punches the result in the product field. With the product field wired from Read for Checking to the DPBC Entry, any product punched in this re-run which differs from the original product will cause a double-punched column and will therefore be sensed by double punch detection. If an error is detected, the machine will stop and turn on the red light at the front of the machine. The reset button must be depressed to turn the light out. The start key must then be depressed for one card cycle, at the end of which time the card in error will be in the top position in the stacker and may be removed for review.

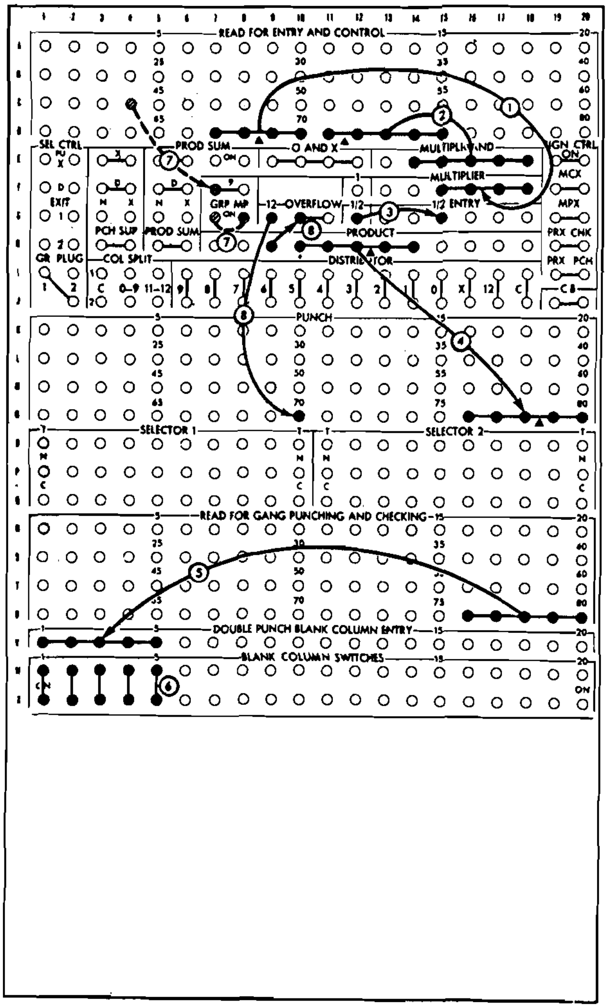


Figure 3. Multiplication

$A \times B = P$

1. *The multiplier field (two decimal places) is entered in the multiplier counter.*
2. *The multiplicand field (four decimal places) is entered in the multiplicand counter.*
3. *Only two decimal positions are retained in the product; 5 is added to the third decimal position to correct the product to the nearest whole cent.*
4. *The product (two decimal places) is punched in columns 76 – 80.*
5. *The punched product field is checked for double punching.*
6. *The punched product field is checked for blank columns.*
7. *For group multiplication, this dotted wiring should be added.*
8. *Only 5 positions are allowed on the card for punching the product. If a product carries to six positions, a 12 is punched in card column 70.*

Wiring for checking is the same as for the original run; the only difference is the reversal of the factors by the factor reversal switch.

Group Multiplication

The Electronic Multiplier can be used for group multiplication, in which one factor remains constant for all cards in a group. The common factor for group multiplication in the Electronic Multiplier must be wired to the multiplier counter. (The multiplicand counter may be used to carry the group multiplier if the factor reversal switch is set ON.) The multiplier must be punched in a card designated by a 9 punch and placed at the front of each group. The multiplier counter will not reset until a group is finished and the special multiplier card for the next group is about to be read.

For group multiplication, the group multiplier control panel switch should be wired ON. The column punched 9 in the group multiplier card must also be wired from Read for Entry and Control to one of the group multiplier pickups labelled "9". The reading of a 9 by the pickup causes the machine to reset the multiplier counter, read in the new multiplier, and eliminate punching and checking of the rate card.

With the group multiplier switch wired ON, the reading of the 9 by the pickup hub causes only the multiplier field to be read from the group multiplier card and only the multiplicand field to be read from the detail cards. The basic wiring for group multiplication is the same as for individual multiplication. The additional wiring required is shown dotted in Figure 3.

Product Overflow

Often the number of columns set aside on a card to punch the product of a multiplication is not large enough to permit punching the largest products. However, if only a very small percentage of the total number of cards exceeds the capacity of the field, it may not be worth increasing the size of the card field, thereby limiting the number of columns available for other punching. To take care of such cases, the product overflow feature is furnished on this machine.

To place the product overflow feature in operation, the product counter position *next to* the highest order wired to punch is wired to the Product Overflow Entry hub. As long as the product counter position wired to Product Overflow contains 0, nothing happens. Any digit from 1 through 9 in this position causes the error light to glow and the machine to stop when the card in error is just ready to enter the stacker.

Since the error light is used for other error signals, it is desirable to distinguish between errors and overflow products. This is accomplished by punching a 12 hole in a card in which the product exceeds the card field capacity. To punch the 12, the Product Overflow 12 hub is wired to any punch magnet, and a 12 hole will be punched in the overflow card.

With this arrangement, a card is examined after an error light, and if a 12 hole is punched, it is apparent that the error was due to an overflow product. This card can then be processed manually.

The necessary control panel wiring is shown by wiring 8 in Figure 3. A 12 is punched in column 70 of the card with an overflow product (Figure 3).

Product Summary

Often it is desired to accumulate several products before punching. This permits special operations, such as crossfooting on two cards, punching the sum of several products, etc. To accomplish this it is necessary to prevent reading out and clearing of the product counter.

The product summary feature is placed in operation by wiring the PROD SUM control panel switch ON. This feature may be either No X or X controlled. Digit control is also provided. If it is desired to punch the product only in X

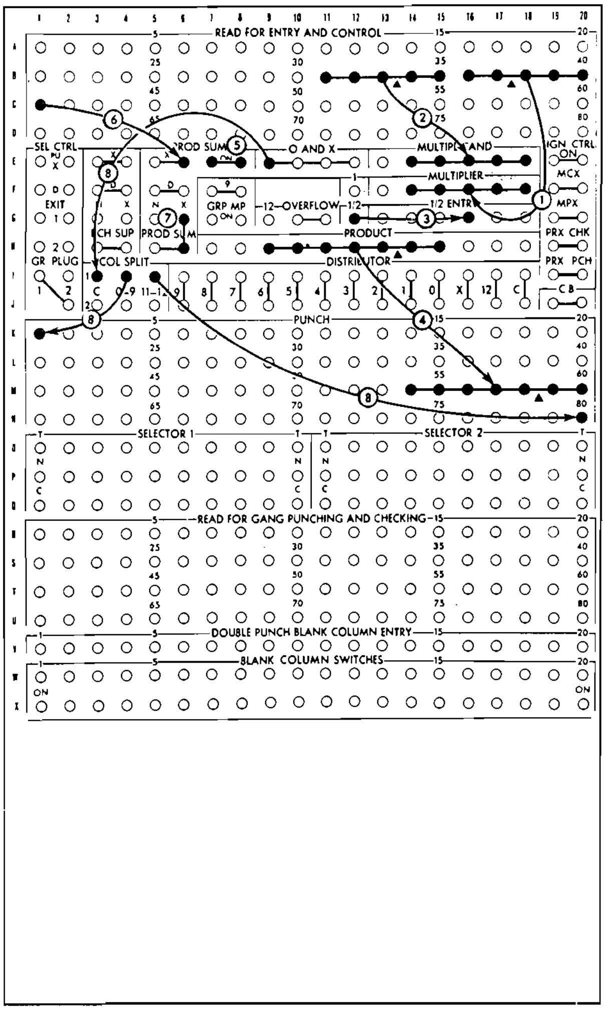


Figure 4. Use of Product Summary and Column Splits

1. *The multiplier field is entered in the multiplier counter.*
2. *The multiplicand field is entered in the multiplicand counter.*
3. *The product is half corrected by adding 5 to the 3rd position.*
4. *The product is punched in card columns 54 – 60 subject to the Product Summary Wiring.*
5. *The Product Summary feature is placed in operation.*
6. *X punchings in the cards to be punched with the products are sensed.*
7. *When an X-punched card passes the die, the product is punched in the card and the counter is cleared.*
8. *An X is punched in column 80 and an O in column 1, in all cards by means of the O and X and Column Split features.*

punched cards, the control panel wiring would be as shown in Figure 4. The standard wiring of the multiplicand, multiplier, half-entry, etc. remains the same as before. Of course, blank column checking cannot be done in this case because many of the cards are blank. However, double punch checking may be used if desired.

If it is desired to punch in No X (or digit) cards, the N hub is wired to the PROD SUM hub, below it. In this case X punched cards will not be punched, and the product will not clear.

A blank card with the proper control punching must precede a product summary run to insure the clearing of the product counter provided a product summary run is made immediately after turning the machine on. This card will insure the clearing of any random figures from the product counter, resulting from turning the power on. On normal runs this is not necessary because the product counter is cleared before starting the first computation.

The 1 hub, which emits a 1 impulse during each card cycle, may be used as a unit multiplier for special crossfooting operations from card to card in connection with the product summary feature.

Column Splits

Two positions of column split are available as standard on this machine. The 0-9 hubs of the column split are connected with the C hubs from 9 through 0 of the card, and the 11-12 hubs are connected with the C hubs from 11-12. This device permits an X or 12 punching over a 0-9 digit to be recognized independently or to be ignored.

Wiring *8* on Figure 4 shows a typical use of the column split device in connection with the 0 and X hubs for automatic punching of X's or 0's.

Punch Suppression

If it is desired to suppress punching in a card, the card is either X punched or punched with a control digit in a specified column. The control punching then causes the suppression of punching on that card with proper wiring of the control panel. No X (or digit) control is also furnished, so that the control punching can appear on the cards to be punched. This feature permits standard group (or interspersed) gang punching operations on this machine.

The use of the punch suppression device in connection with two special features, the distributor and a class selector, is shown in Figure 5. In this example, an offset interspersed gang punching operation is being performed.

If No X (or digit) control is desired, the N hub is wired to the PCH SUP hub below. This setup causes only X (or digit) punched cards to be punched. Master cards would not be punched with a control punching.

Class Selectors (Optional)

Class selectors are optional features on this machine. Two class selectors may be installed on order.

The selectors are arranged for either X or D pickup and for normal or delayed operation. If it is desired to transfer the selector during the cycle following the reading of the X (or digit), the GR PLG is wired to the Exit 1 hub. Wiring the GR PLG to the Exit 2 hub causes the selector to transfer during the second cycle following the reading of the X or D hole.

Figure 5 shows an example of class selector 1 picking up from a 3 punch in column 80 and transferring during the second cycle following the reading of the 3.

Distributor (Optional)

A conventional 12-segment distributor can be installed as an optional feature on this machine. The distributor can be used as a digit emitter by wiring the CB hub to the distributor C hub. The individual hubs of the distributor then emit timed impulses corresponding to the hub label.

The distributor can also be used as a digit selector by wiring from the brushes to the C hub of the

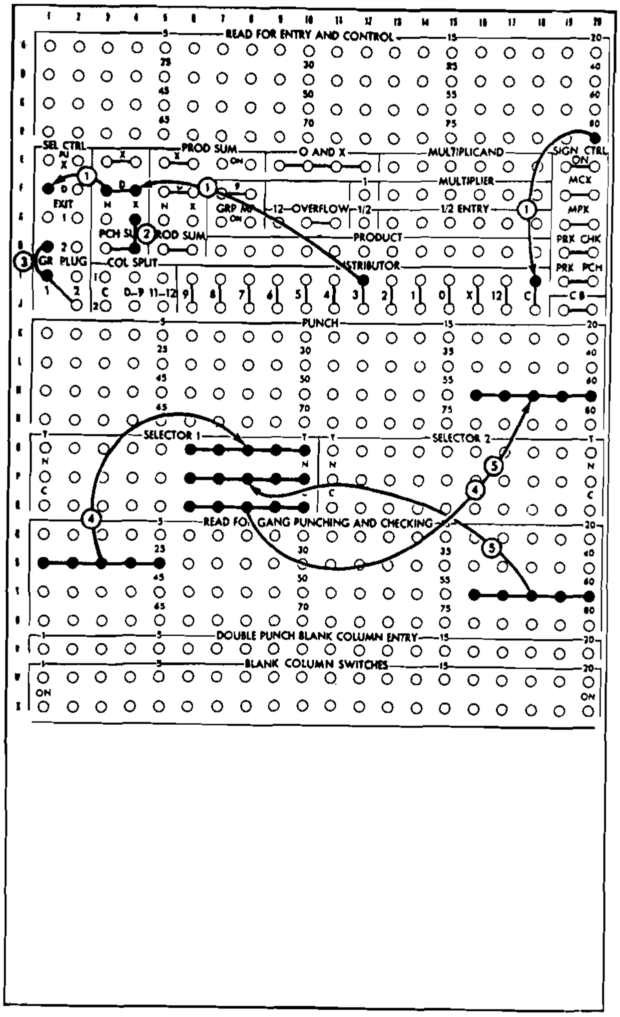


Figure 5. Use of Class Selector for Offset Gang Punching

1. *A 3 in column 80 is sensed for punch suppression control and class selector pickup, using a digit selector.*
2. *Punching is suppressed as the 3-punched card passes the die and stripper.*
3. *The class selector 1 transfers while the 3-punched card passes the second set of brushes.*
4. *The No X card following the 3-punched card is punched in card columns 56 – 60 from columns 21 – 25.*
5. *All No X cards gang punch in columns 56 – 60.*

distributor. Then only the desired digit in any card column can be recognized by proper wiring of the 9-12 hubs of the distributor. Figure 5 shows the distributor used as a digit selector.

Sign Control (Optional)

Sign control permits determination of the sign (plus or minus) of a product by analysis of the sign of its factors. Two factors having the same sign produce a positive product, but if one factor is positive and the other negative, the product will be negative.

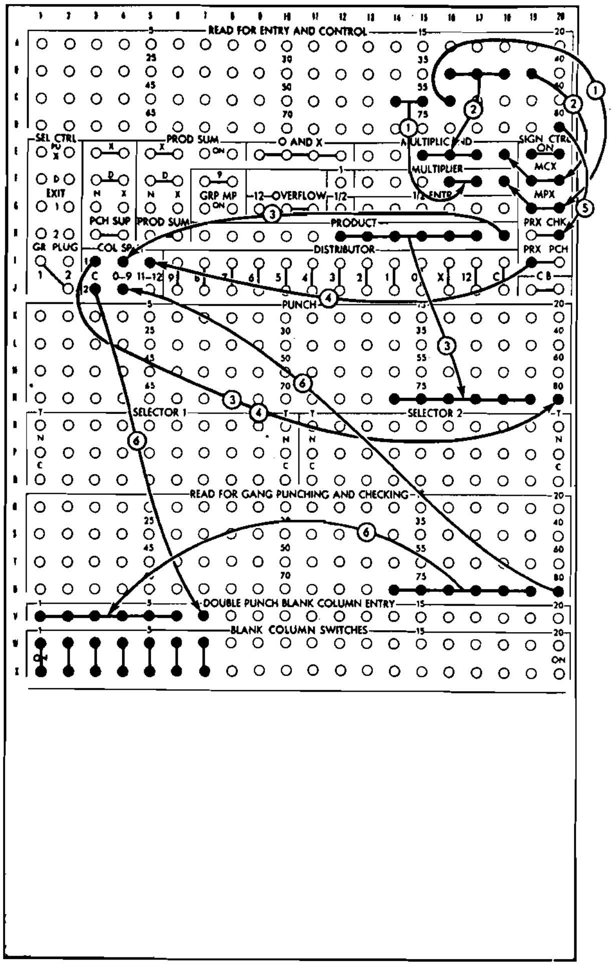
For multiplication, factors should always be punched as true figures whether their sign is plus or minus. In an IBM card the minus sign may be indicated by an X punch. Any column may be used for the X punch, indicating the sign of a factor, but preferably it should be the unit column of the factor field.

Wiring for sign control is shown in Figure 6. To place the sign control feature in operation, the SIGN CTRL control panel switch must be wired ON. There are two sign control pickups on the control panel, labelled MCX (multiplicand X) and MPX (multiplier X). One of the two common hubs, MCX should be wired from the column in Read for Entry and Control containing the minus X for the multiplicand. One of the two common hubs MPX should then be wired similarly for the multiplier minus X.

If only one of the sign control pickups reads an X, the product should be negative. The machine will punch the product in true figures, and to designate the product as negative, will punch an X in the units column of the product field. To punch the minus X in the units column, the units position of the product field must be wired from the PRX PCH hub to the Punch Entry hub (Figure 6). The wiring is taken through the column split to permit X punching over the units digit. If it is desired, the negative product X may be punched in any column of the card.

Sign Control Checking

When sign control is used in the original calculation, with a negative product indicated by an X



(All X's identifying negative amounts punched over units position of corresponding field.)

1. *The multiplier factor is entered in the multiplier counter; the units position is brought through the MPX hubs to recognize negative multipliers.*
2. *The multiplicand factor is entered in the multiplicand counter; the units position is brought through the MCX hubs to recognize negative multiplicands.*
3. *The product is punched in card columns 74 – 80, the units position is taken through the column split to permit both a digit and the sign control X to be punched in the units position.*
4. *An X identifying a negative product is punched in the units position of the product field through the column split.*
5. *An X identifying a negative product is read when sign control checking only.*
6. *The product is checked for double punchings and blank columns; the units position of the product is taken through the column split hub because of the X punched over the units position in negative products.*

Figure 6. Multiplication and Checking with Sign Control

$\underline{+}A \times \underline{+}B = \underline{+}P$

punch, the punching of this minus X for the product may also be checked during the re-run. In the re-run, the wiring of the two sign control pickups, as well as wiring of the entries to multiplicand and multiplier counters, is reversed by the factor reversal switch. To check the minus X punch in the product, the units column of the product field from Read for Entry and Control is wired to one of the two common hubs labelled PRX CHK (Figure 6). These PRX CHK entry hubs should read an X when only one of the two sign control pickups has read an X. If one of these conditions occurs without the other, an error condition will be indicated.

When checking multiplication with sign control for double punching, the X punched for negative products must be eliminated from the double punch check, if it is punched over the product field. This is done by means of the column split device as shown in Figure 6.

A STUDY of the mechanical principles of this machine is limited to the read and punch unit, because the only mechanical units on the electronic unit are the blowers. Only the location of parts on the electronic unit will be given in this section. The read and punch unit is essentially the same as a gang summary punch, and covers are removed in exactly the same manner.

Location of Parts

The five general views of the read and punch unit in Figures 7 through 11 show the location of all parts and units which are visible at a glance. Certain other features not readily visible must be illustrated schematically.

The front view (Figure 7) shows the card lever contacts which are mounted on a plate at the front of the machine. The contacts have been placed outside for convenient access, although the card levers remain in the same relative location as in the gang summary punch. Also visible from the front is the cam contact unit located directly under the hopper and a portion of the tube power supply chassis located on the lower base. The tube power

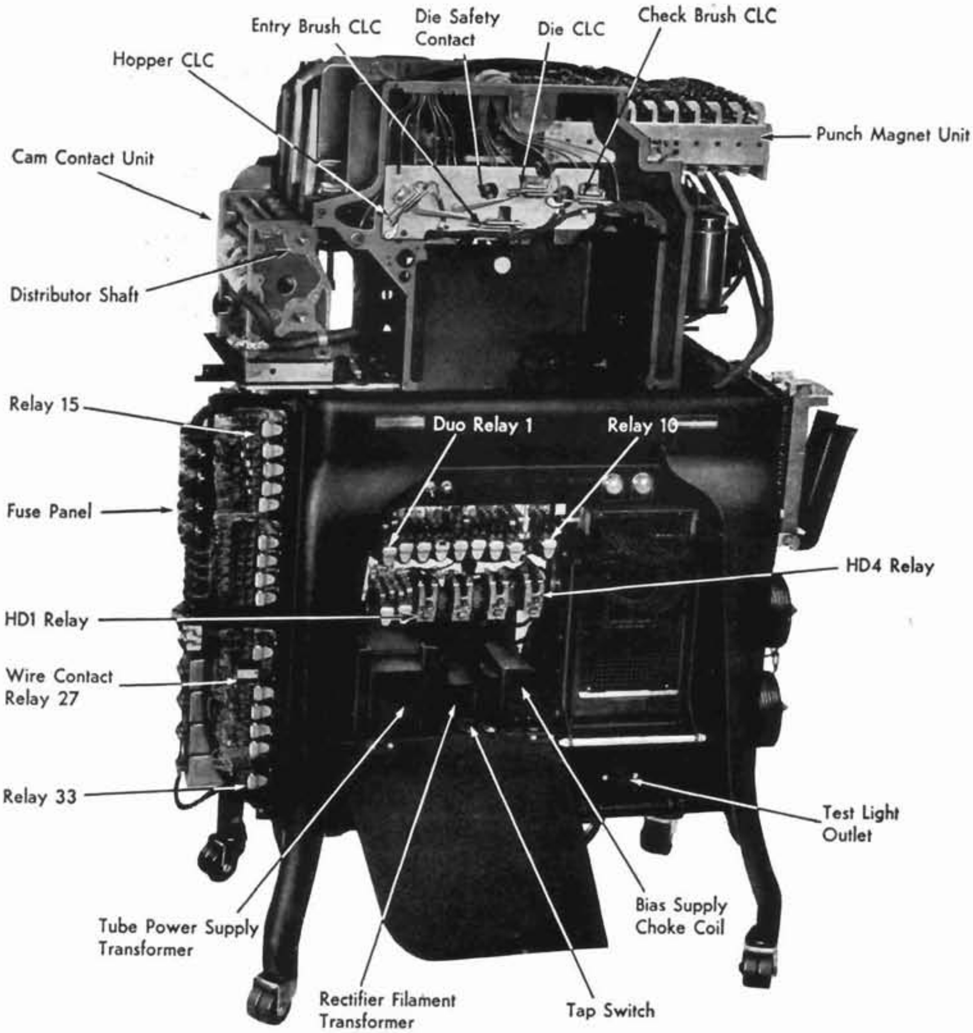


Figure 7. Read and Punch Unit—Front View

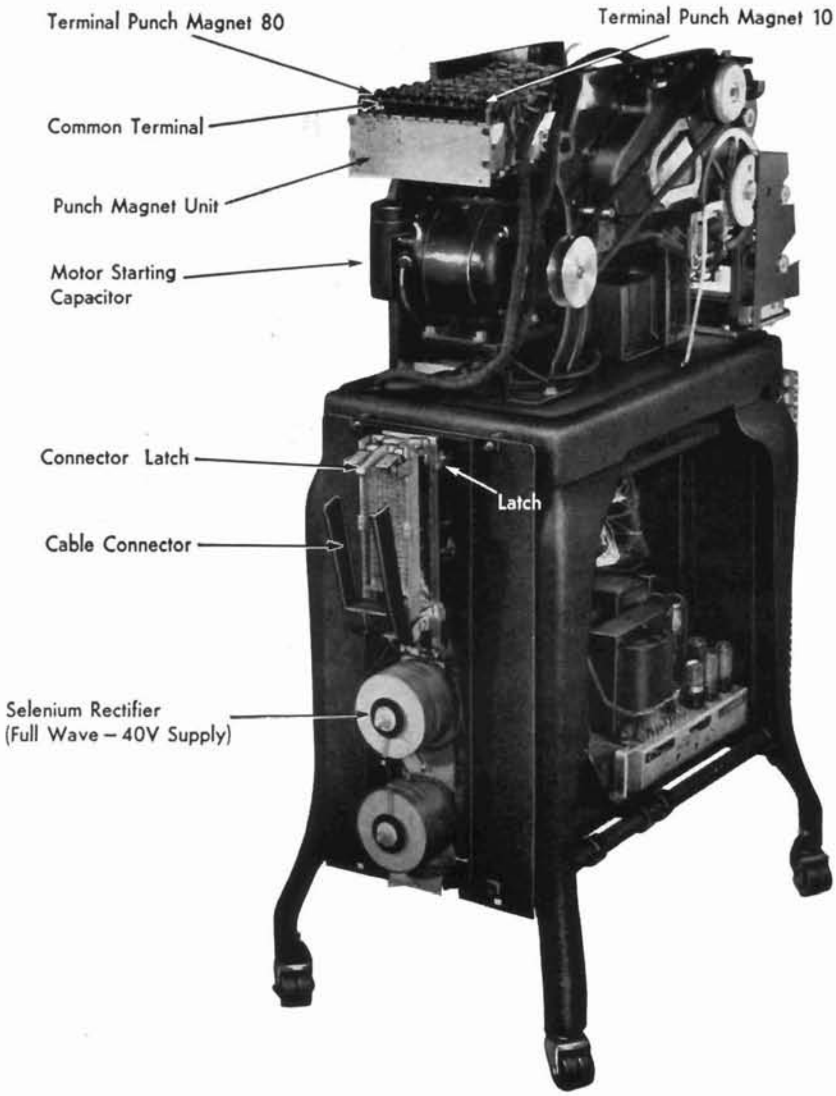


Figure 8. Read and Punch Unit—Right Side View

supply chassis extends across the entire depth of the lower left section of the punch unit. The rest of the power supply chassis can be seen in Figures 10 and 11.

The right side view (Figure 8) shows the punch magnet terminal connections. It will be observed that these connections are the reverse of standard gang punch connections. This is because the cards are fed into this machine face down, 9 edge first. Relays are mounted on the right side only if the class selectors and sign control features are installed. The cable connector which provides a convenient means of electrically connecting the read and punch unit to the electronic unit is a standard connector used on summary punches. To permit access to the rear of the cable connector, the frame on which the cable connector and the selenium rectifier are mounted can be swung down if the latch holding the frame in place is released. The selenium rectifier shown below the cable connector is a full-wave rectifier which supplies 40 volts D. C. in conjunction with the main transformer for the operation of the relays and punch magnets in the punch unit. The filter capacitors for this rectifier are mounted on the left side.

The left side view (Figure 9) shows the cam contact unit which is mounted under the card hopper. There is space for 52 cam contacts in this

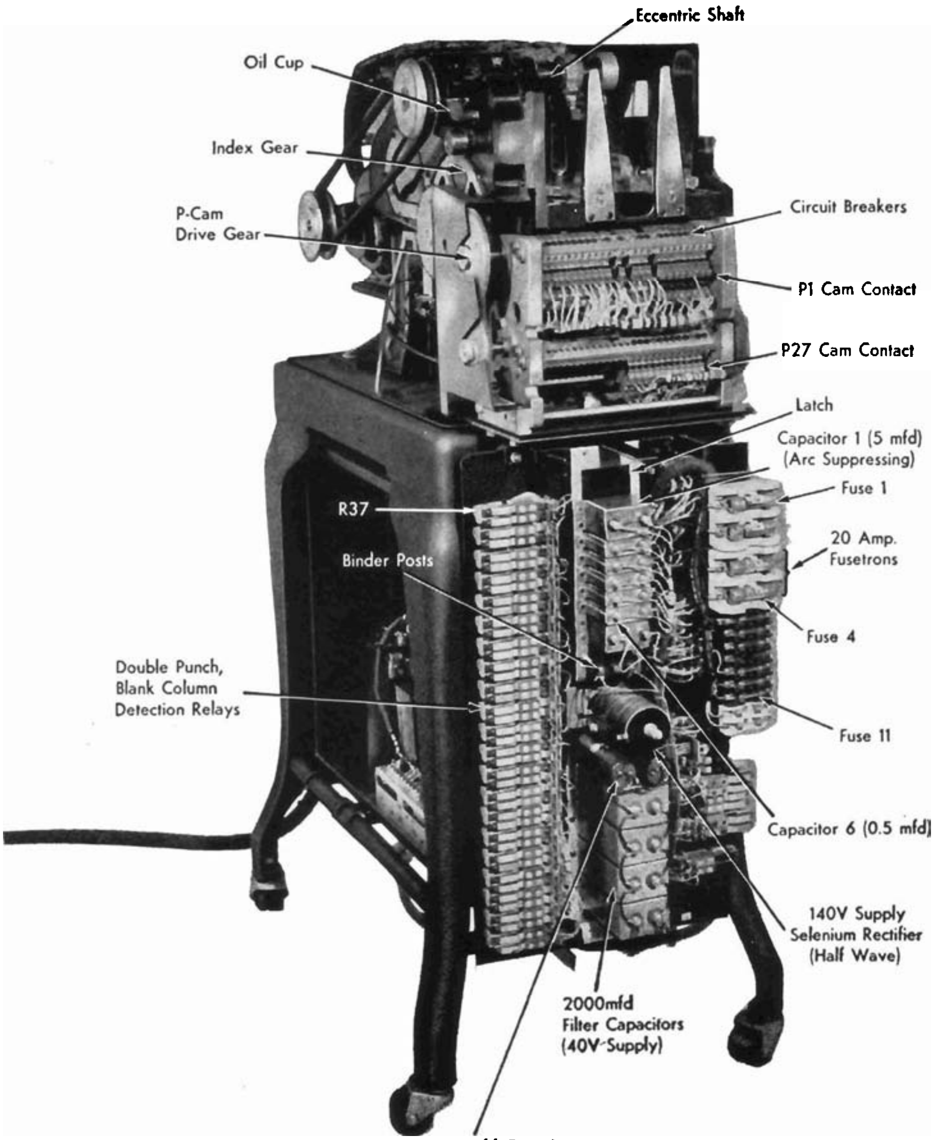


Figure 9. Read and Punch Unit—Left Side View

unit, numbered from front to rear, top to bottom. However, no cams beyond P41 are used, and although cams 9, 13, and 15 are not used, they retain their numbers. The 12 amp fuses and 20 amp fusetrons shown at the top of the fuse panel are in the main transformer circuit. The glass fuses are in the punch circuits and in the tube power supply circuits. The conventional arc-suppressing capacitors are mounted between the relay brackets and above the half-wave selenium rectifier. This selenium rectifier, together with its filter capacitors and bleeder resistor shown below the rectifier, supplies 140 volts D. C. for the read-out power tubes in the electronic unit. The four 2000 mfd. capacitors shown below the 140 volt D. C. selenium rectifier are the filter capacitors for the 40 volt D. C. supply. The double punch and blank column detection relays 37 through 57 are mounted on the left rear gate. If 10 additional positions of DPBC detection are installed, relays 58 through 77 are mounted just to the left of R37-R57.

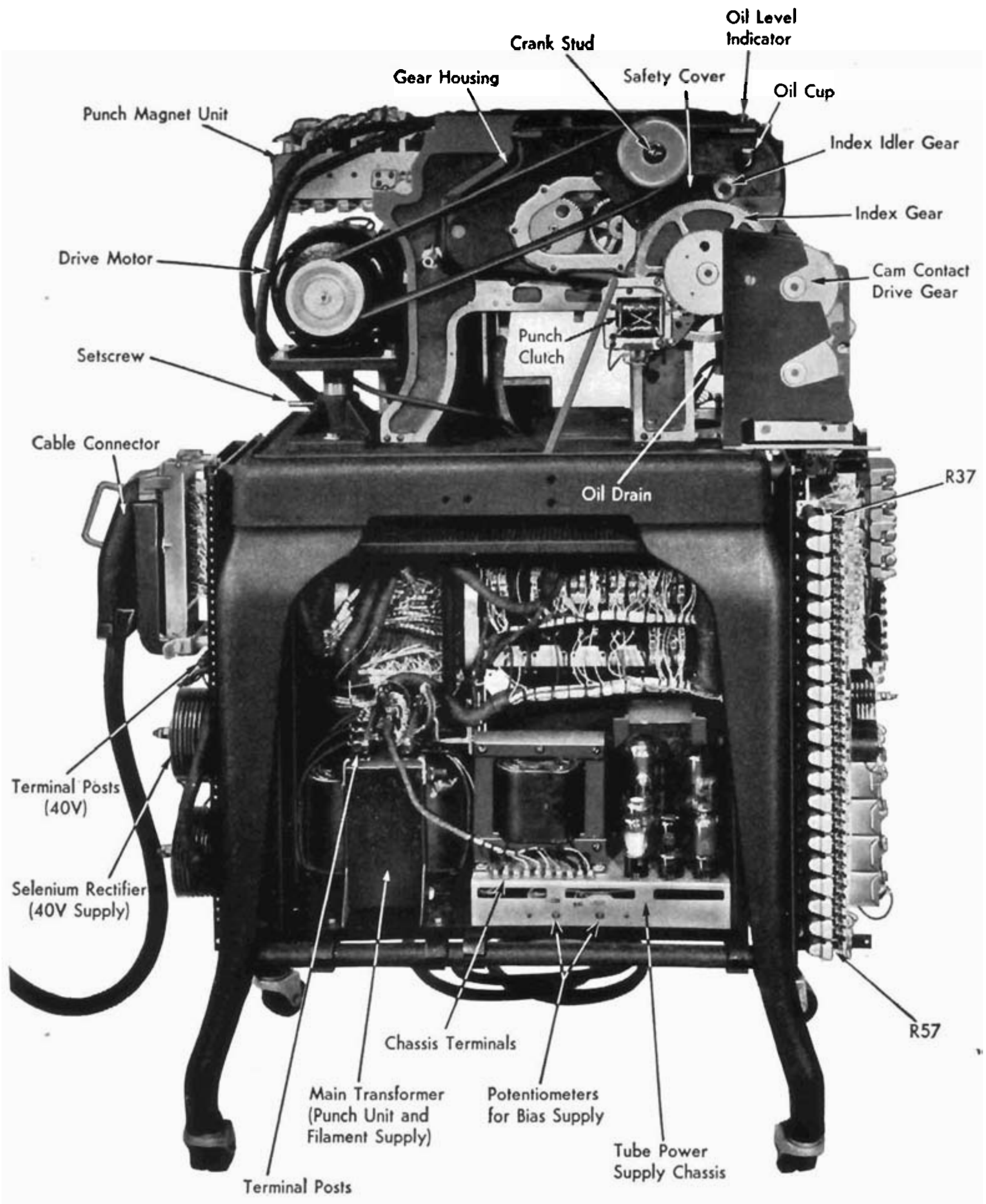


Figure 10. Read and Punch Unit—Rear View

The rear view in Figure 10 shows the mechanical features visible from the rear as well as the main transformer and the tube power supply chassis. The tube power supply furnishes D. C. voltages of 100 volts, 150 volts, and 250 volts for the operation of tubes in the electronic unit. The main transformer supplies A. C. of proper voltage to the 40 volt and 140 volt selenium rectifiers; it also supplies the filaments of all tubes except the gas-filled rectifier tubes.

In the close-up view of Figure 11, a better picture of the main transformer and tube power supply chassis is shown. Note particularly the system for numbering terminals on both the transformer and the power supply chassis. The EL-3C and EL-1C tubes are gas-filled full-wave rectifier tubes,

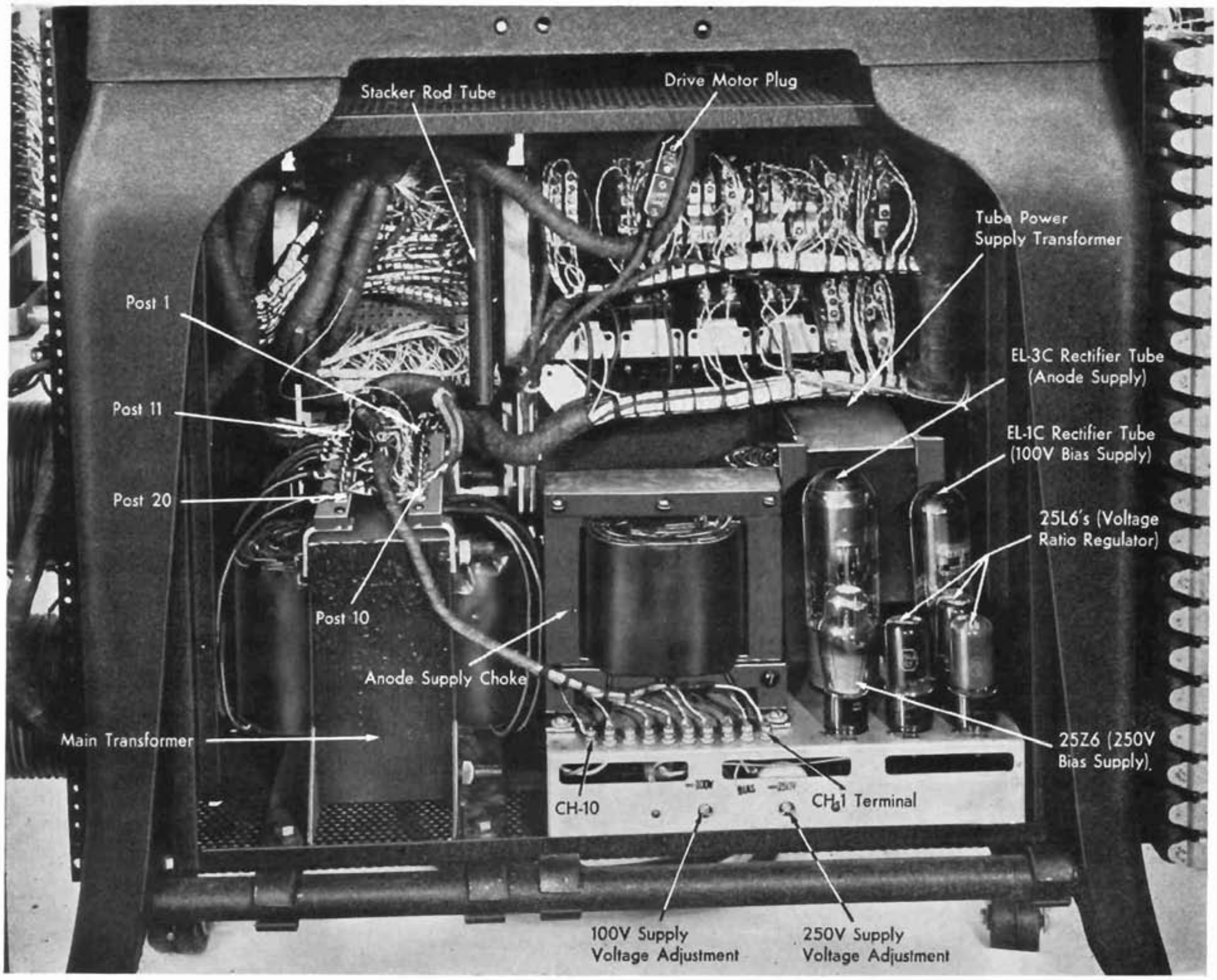


Figure 11. Closeup of Main Transformer and Tube Power Supply Chassis

while all other tubes on the chassis are vacuum tubes of the type indicated. All other components in the power supply circuit are mounted underneath the chassis.

Figure 12 shows schematically the location of the brush assemblies, die and stripper assembly, and the card levers. The hopper card lever is located directly under the hopper. The punch brush 1 and die card levers are mounted on the front side frame. The former is located directly under the punch brush 1 contact roll while the latter is located under the second set of feed rolls. The punch brush 2 card lever is mounted directly above the punch brush 2 contact roll. However, all card lever contacts are mounted on a plate at the front of the machine as shown in Figure 7.

Note from Figures 13, 14 and 15 that there are no relays in the electronic unit. Figure 15 shows the gates open with all connections accessible. The general function of each tube chassis is given, but no effort will be made to discuss these further until the section on *Electrical Principles*. The switch and push buttons shown in Figure 15 are not accessible unless the large gate is open; they are intended solely as an aid in servicing the unit. The blowers shown are provided to cool the tubes. Over 1200 watts of heat from the filaments alone must be dissipated. One blower is provided for each side of the electronic unit.

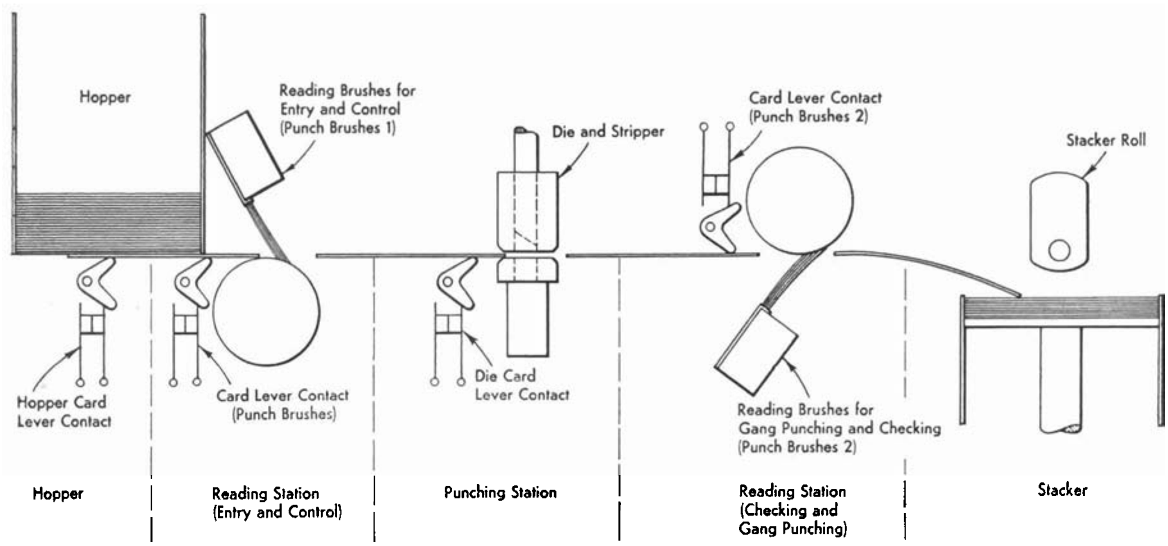


Figure 12. Schematic of Read and Punch Unit

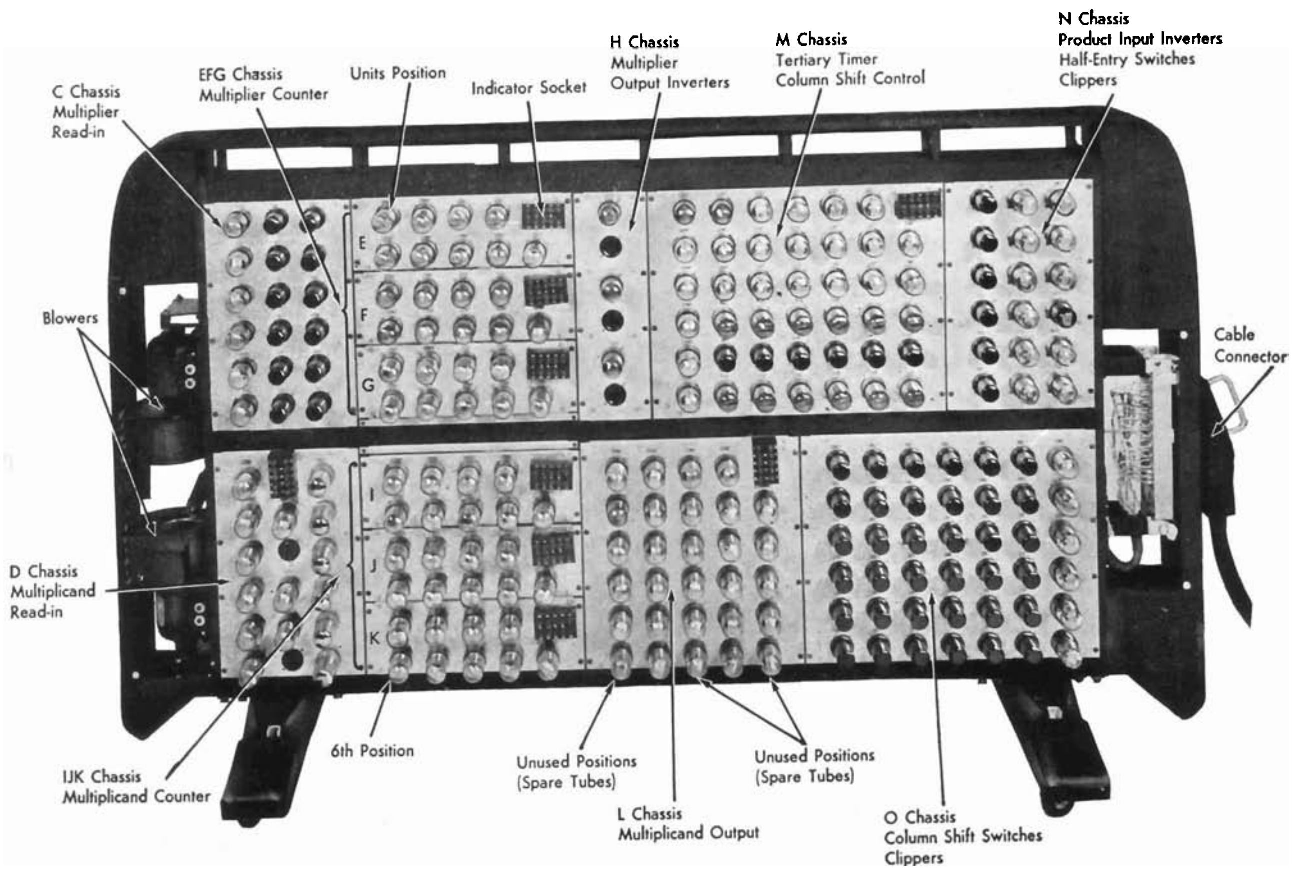


Figure 13. Electronic Computing Unit—Front View

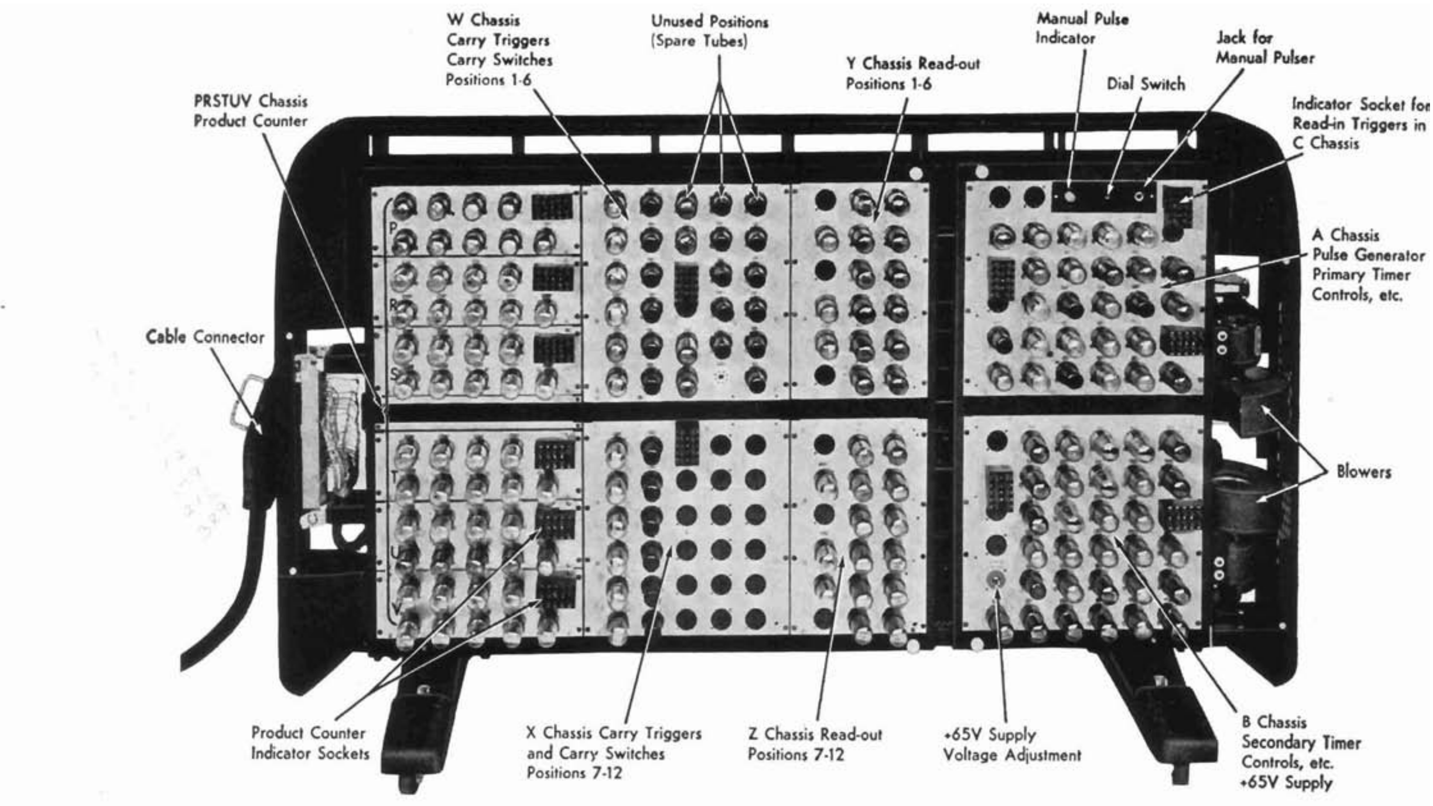


Figure 14. Electronic Computing Unit—Rear View

Drive Mechanism

Power to drive the read and punch unit is furnished by the drive motor which can be seen in Figure 8. The drive motor transmits power to the gear housing through a V belt and pulley. Practically all mechanisms are under control of the punch clutch. All feeding operations are under further control of the intermittent feed clutch (geneva clutch). Figure 16 shows schematically the various units under the control of the two clutches. When only the motor operates (with neither clutch engaged), the drive pulley rotates and drives the drive pulley shaft to which the pulley is keyed. Attached to this shaft inside the gear housing are two gears, the geneva drive gear and the eccentric shaft drive gear. The mechanisms and gear trains inside the gear housing may be seen by removing the top cover from the housing. (Caution: Do not operate the machine under power with this cover off because oil will be thrown out of the housing.) The eccentric shaft drive gear operates the eccentric shaft which in turn transmits motion to the punch bail. (The operation of this bail is discussed in connection with the principle of punching.) The geneva drive gear operates the geneva and geneva pawl and also the punch clutch idler gear and shaft. On the outside of the idler gear shaft is pinned a small gear which drives the index gear (Figure 10). The punch clutch one-tooth ratchet is a part of the index gear assembly and rotates continuously as long as the motor is in operation. The index gear and ratchet rotate on the punch clutch shaft but are not pinned to it.

In order to place the rest of the machine units in operation it is necessary to unlatch the punch clutch pawl from its armature and allow it to engage in the continuously running one-tooth ratchet, which is a part of the index gear assembly.

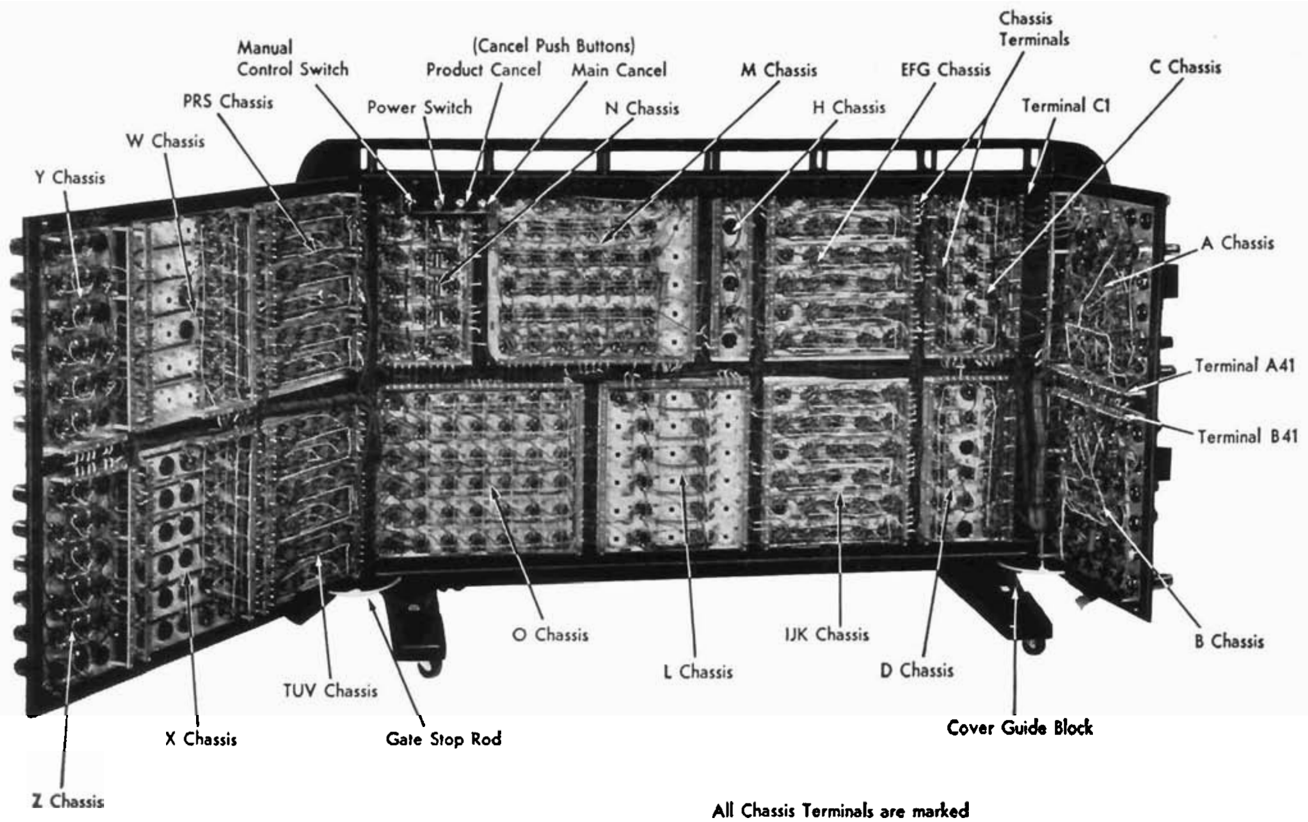


Figure 15. Electronic Computing Unit with Gates Open

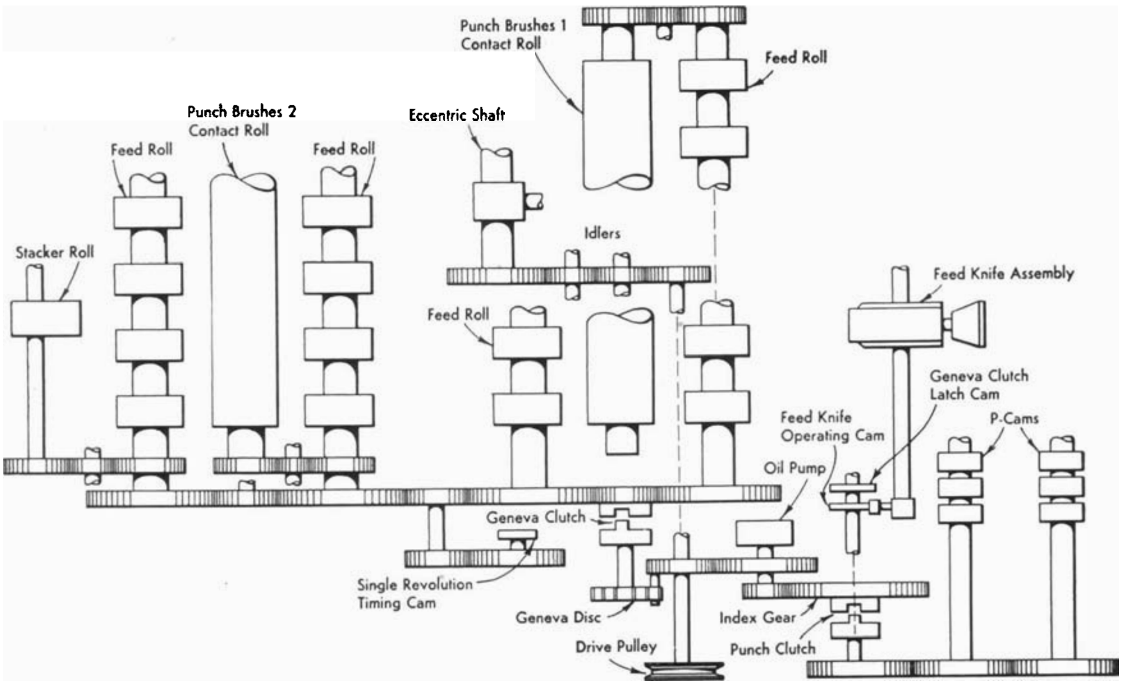


Figure 16. Schematic of Drive Mechanism

When the clutch pawl engages the one-tooth ratchet, the punch clutch shaft turns with the ratchet. The gear mounted on the outside end of the punch clutch shaft in turn drives the P-cam shaft, on which are mounted the P-cams. Within the gear housing there are two sets of complementary cams pinned to the punch clutch shaft. One set of cams operates the feed knives and the other set controls the engaging of the geneva clutch pawl with its ratchet. The geneva ratchet is normally stationary; but when the geneva pawl engages with it, the ratchet is driven by the geneva, which imparts an intermittent motion to this ratchet. Riveted to the geneva ratchet is the ratchet gear which serves as the drive gear for all feed rolls, contact rolls, and the stacker roll. Since all these rolls are driven from the geneva, they all turn intermittently. The intermittent movement is necessary to have the card in a stationary position while punching. (This is discussed in more detail in the section on the *Geneva Mechanism.*) Only the upper feed rolls and the punch brush 2 contact roll are driven from the gear train in the housing. The lower feed rolls are driven by their corresponding upper rolls through gears at the front of the machine. Also, the punch brush 1 contact roll is driven from the first upper feed roll. The stacker roll is driven by a gear train from the last feed roll.

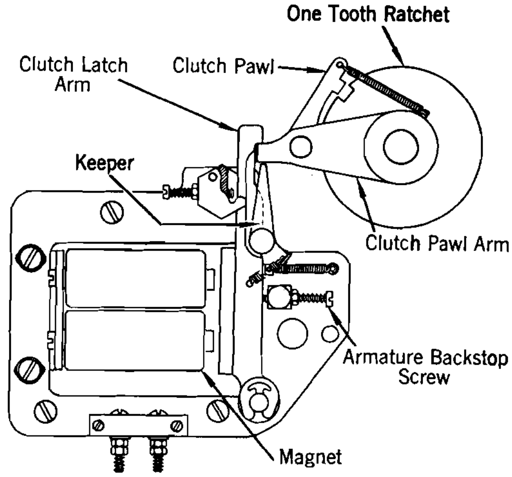


Figure 17. Clutch

Punch Clutch

The punch clutch shown in Figure 17 is of the one-tooth ratchet type commonly used on EAM equipment, and its operation should be thoroughly understood. The principal parts of the clutch are a continuously running one-tooth ratchet, a clutch pawl, a latching mechanism, and a magnet. The magnet provides a means of electrically controlling the operation of the clutch. The clutch magnet armature serves as the latching mechanism to latch the pawl and keep it from engaging in the ratchet.

When the magnet is energized, the armature is attracted and the pawl is released or unlatched. The pawl spring causes the pawl to pivot in a clockwise direction and engage the one-tooth ratchet when the ratchet tooth reaches the pawl. The pawl pivots on a stud riveted to the clutch pawl arm which is pinned to the punch clutch shaft. Thus, when the pawl turns with the ratchet, the shaft must also turn. Once the pawl is unlatched, it must make one complete revolution before it can be relatched since there is but one latching point. For this reason it is necessary to keep the armature attracted only long enough to allow the pawl to engage the ratchet. When the pawl reaches the end of its cycle, the armature has been returned to its normal position by the return spring and the tail of the pawl strikes the armature, causing the pawl to be cammed out of mesh with the one-tooth ratchet. When the pawl has been cammed out of mesh, the keeper drops behind the clutch pawl arm and prevents the clutch shaft from turning backward. Without the keeper, the shaft might turn backward because of the rebound; then the pawl would drop against the ratchet and catch on the tooth once each cycle. This nipping action has a tendency to round off the edge of the one-tooth ratchet. This is objectionable because a rounded edge on the ratchet tooth may cause the pawl to pull out of mesh under load.

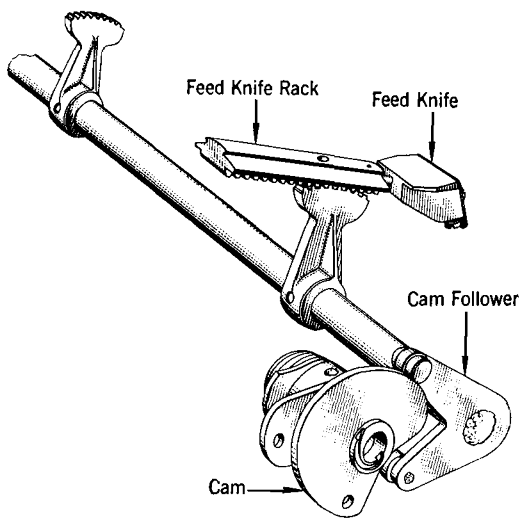


Figure 18. Punch Feed Knife Drive

Feeding Mechanisms

The purpose of the feed knives is to feed one card through the throat into the first set of feed rolls for each revolution of the punch clutch. The feed rolls then carry the card past the brush stations and punching station to the stacker. The knives are driven back and forth by gear sectors which mesh with the feed knife racks. The gear sectors are pinned to a shaft which oscillates under the control of a complementary cam and follower mounted on the punch clutch shaft (Figure 18).

When a card is fed from the magazine, it is fed between the first pair of feed rolls. The feed rolls operate intermittently, hence they will be stationary during a portion of the time a card is being fed between them. The feed knife carries a card up to the first feed rolls while the feed rolls are stationary. To insure that the first feed rolls will pick up the card, the knife buckles the card slightly just before the feed rolls start turning.

As indicated in Figure 16, the card passes through four sets of feed rolls on its way to the stacker. The upper feed rolls are mounted in fixed bearings while the lower feed rolls are provided with pivoted bearings to allow separation of the rolls when a card is fed between them. Feed roll tension is provided by a pressure bracket consisting of four bearing shoes held against the feed roll shaft by compression springs.

The card also passes two sets of brushes and contact rolls. The brush assemblies are identical except for minor constructional differences; each consists of 80 individual brushes mounted in a brush holder so that they are insulated from each other. The contact rolls are made of beryllium copper and are geared to turn at a higher speed than the feed rolls to provide a wiping action by the card.

Index and Cycles

In explaining machine operations it is necessary to make reference to one operation in terms of another. By using an index for a common reference point this becomes possible. The index gear serves as the common reference for all machine operations. One complete revolution of the index gear is called one cycle. If the punch clutch is engaged, a card would move from the first set of brushes to a corresponding position at the die (or from the die to the second set of brushes) during one revolution of the index. For convenience in measurement one cycle is divided into units called *cycle points*. The most logical unit of division is the distance between successive punching positions on the card. Therefore the distance from the *9* punching position to the *8* punching position in one card represents one cycle point, while the distance from the *9* punching position in one card to the *9* punching position in the following card is one cycle.

There are 12 punching positions on the card. Each punching position is $\frac{1}{4}$ inch from the next, therefore, for each cycle point the card moves $\frac{1}{4}$ inch on its path through the machine. Since the card is $3\frac{1}{4}$ inches wide, it requires 13 cycle points to advance a card past any given point. In this machine there is $\frac{1}{4}$ inch between cards, therefore, the cycle consists of 14 cycle points. The teeth on the index gear are used for further subdivisions. Thus a timing given as 14.1 indicates one tooth past the *14* index mark.

Geneva Mechanism

As indicated previously, the feed rolls in this machine operate intermittently to allow punching of the card. The card must not be in motion while the punches are being driven through the card and withdrawn. If the card is moving, the holes will not be clean cut, but ragged and torn. Since the card must be standing still while it is punched, then moved to a new punching position fourteen times each cycle, the motion is necessarily intermittent. This intermittent motion is obtained by means of a geneva mechanism.

The geneva drive gear is located just inside the gear housing and pinned to the pulley shaft. A stud and roller fastened to this gear operate in the slots of the driven member of the geneva gear (Figure 19).

The hub of the geneva drive gear is a cam surface for approximately two-thirds of its periphery. This cam surface holds the feed rolls in a stationary position during punching time by locking the geneva in position.

The geneva disc has seven deep slots and seven shallow cuts in it. The roller of the drive gear operates in the deep cuts in the geneva disc and the cam surface rides in the shallow cuts. As the drive roller leaves the deep cut of the geneva disc,

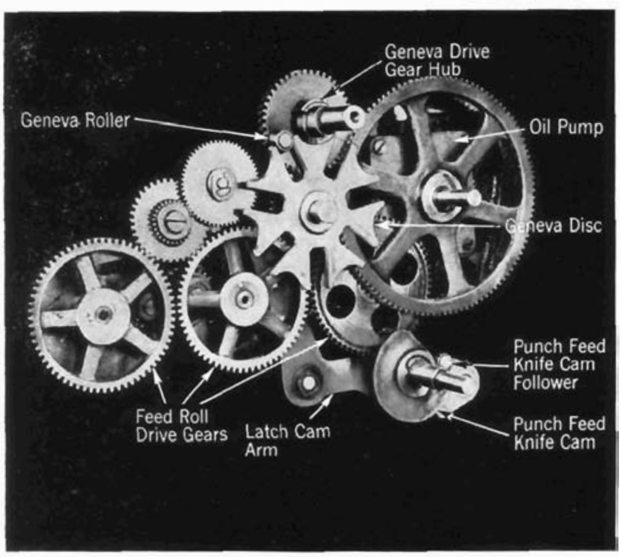


Figure 19. Geneva Mechanism

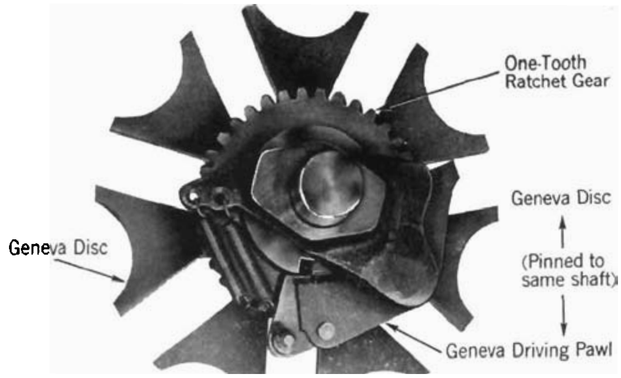


Figure 20. Geneva Pawl and Ratchet

the cam surface turns into the low cut and stops the geneva disc from turning and holding it until the drive gear has rotated to a point where the drive roller enters the next deep slot of the geneva disc and starts driving. Then the cam surface has turned to a point where it releases the disc and allows it to turn freely. The geneva disc turns continuously as long as the drive motor runs. However, no motion is transmitted to the feed rolls until the geneva pawl is engaged with its one-tooth ratchet. The geneva pawl is pinned to the same shaft as the geneva disc. This shaft runs through the hub of the one-tooth ratchet and gear. The one-tooth ratchet is free on the shaft and does not turn unless the geneva pawl is engaged. The one-tooth ratchet gear (Figure 20) is meshed with the feed roll drive gears.

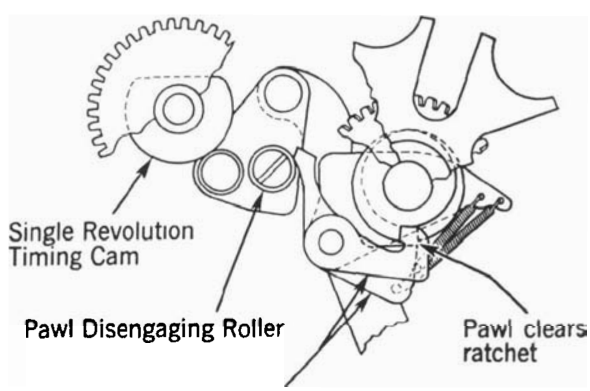


Figure 21. Pawl Disengaging Roller

When the punch clutch is not engaged, the geneva pawl rides on the surface of the one-tooth ratchet during the greater part of the cycle. When the pawl reaches a point opposite the single tooth, the tail of the pawl strikes the pawl disengaging roller (Figure 21) and is cammed away from the ratchet until it has moved past the point where it may engage in the single tooth of the ratchet. By cranking the machine by hand, it can be noted how the pawl disengaging roller prevents the geneva pawl from engaging. From the above, it is evident that the operation of the geneva pawl is controlled by the pawl disengaging roller. The pawl disengaging roller is mounted on a triangular plate (Figure 21) which is free to pivot on the latch cam roller arm. The latch cam roller arm (Figure 22) is operated by the latch cam which turns only when the punch clutch is engaged. When the punch clutch is engaged, the latch cam turns, causing the latch cam arm to rotate in a counterclockwise direction. As the latch cam arm rotates, the upper end moves to the left and down allowing the pawl disengaging roller to move past the single revolution timing cam and the geneva pawl to engage in the one-tooth ratchet. As the cycle is completed, the latch cam causes the latch

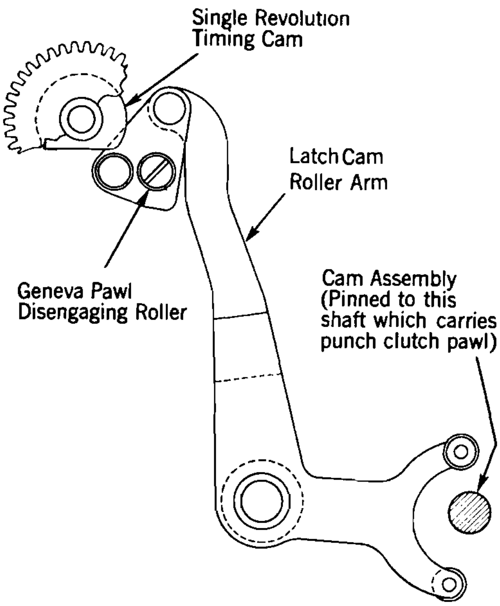


Figure 22. Single Revolution Timing Cam

cam arm to rotate in a clockwise direction carrying the pawl disengaging roller to the right. The roller strikes the tail of the geneva pawl and disengages the pawl from the one-tooth ratchet when the roller is backed by the single revolution timing cam.

Single Revolution Timing Cam

The geneva disc has 7 cuts in it and moves the card one cycle point for each cut. The machine is a fourteen point cycle machine; therefore, the geneva disc must make two revolutions per machine cycle, which means that the geneva pawl will pass the pawl disengaging roller twice during each cycle. The purpose of the single revolution timing cam is to prevent the feed rolls from stopping in a position half way through a cycle. At the end of the first revolution of the geneva pawl and disc, the flat side of the single revolution timing cam should be down (Figure 22). The pawl disengaging roller is free to swing away from the tail of the pawl. Therefore, in case the geneva pawl had become disengaged from the one-tooth ratchet, it would be free to drop into the one-tooth ratchet on the next revolution to complete the cycle. This assures that the pawl will not be disengaged by the pawl disengaging roller until the punch unit mechansim has reached its proper latching position and that the geneva makes two revolutions for each cycle.

Principle of Punching

The mechanism for punching holes consists of 80 individual punches, each controlled by an interposer, 80 punch magnets together with armatures and pull wires to control the 80 interposers, a punch bail to drive the punches through the card, and the eccentric drive shaft and links to operate the punch bail. There is a separate punch for each card column; any one punch may be required to punch any hole from *9* to *12*. The cards feed in *9* edge first, and every *9* to be punched is punched at the same time. The card then moves to the *8* position and every *8* is punched, and so on until

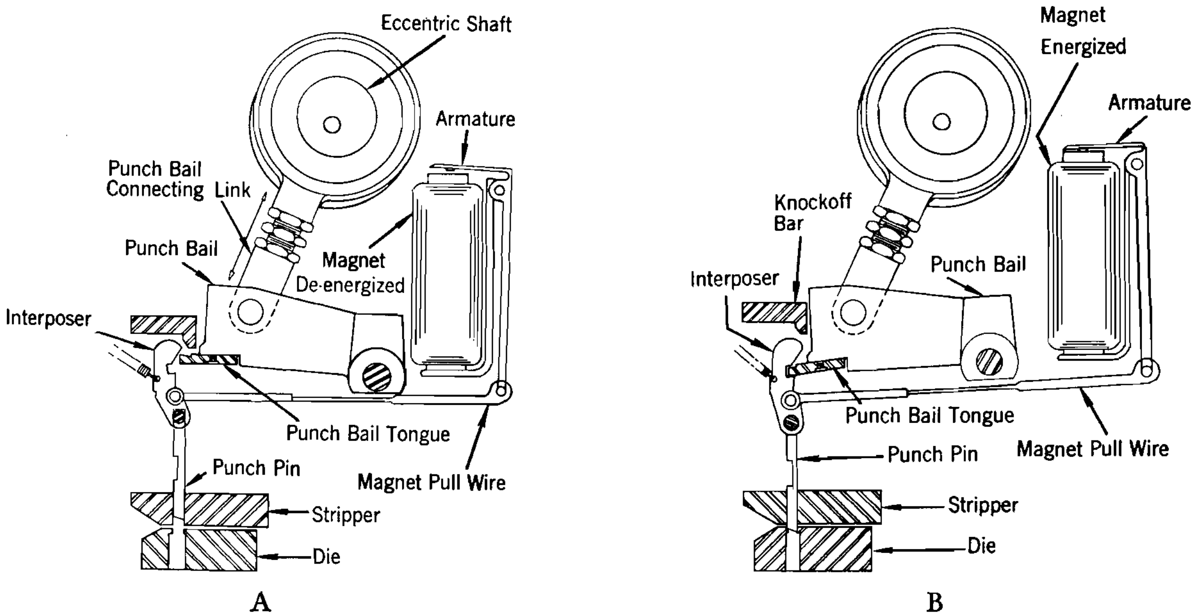


Figure 23. Principle of Punching

all positions have been punched. Thus, all possible punching is done in 12 cycle points.

As previously mentioned, the eccentric shaft operates continuously as long as the drive motor is in operation. The purpose of the eccentric shaft is to convert the rotary motion of the shaft to the reciprocating motion necessary to operate the punch bail. The punch bail operates up and down once for each cycle point. This up and down motion is imparted to the punch bail through the punch bail connecting links (Figure 23A). When the magnet is de-energized, the punch bail may move up and down without contacting the interposer; therefore no punching takes place. When the punch magnet is energized, its armature is attracted, and through the pull wire the corresponding punch interposer is pulled into engagement with the punch bail tongue. Since the punch bail tongue operates up and down, it carries the punch interposer and the punch connected to it down through the cards. On the return stroke, the punch is positively withdrawn from the card by the action of the punch bail. The purpose of the knockoff bar is to disengage the interposer from the punch bail tongue. As the interposer is returned to its normal position, the upper rounded edge strikes the knockoff bar and the interposer is cammed away from the punch bail tongue. The interposer spring then holds the interposer in normal position.

Figure 23A shows the bail in its upward position before the interposer is moved under it, while Figure 23B shows the bail driving the punch down through the die.

Magnet Unit

The punch magnet unit consists of 80 punch magnets along with their armatures and pull wires, 80 interposers and punches, the die and stripper assembly, and the punch bail assembly. Figure 24 shows a magnet unit with the punch bail and interposer knockoff bar removed. The insert shows a closeup of the interposers.

There are three types of interposer and punch assemblies. One type is used in the first column, another type in the 80th column, and yet another is used in all columns from 2 to 79 inclusive. The interposer used in the 1st column is provided with a long stud for the eye of the magnet pull wire to prevent it from slipping off the stud. The inter-

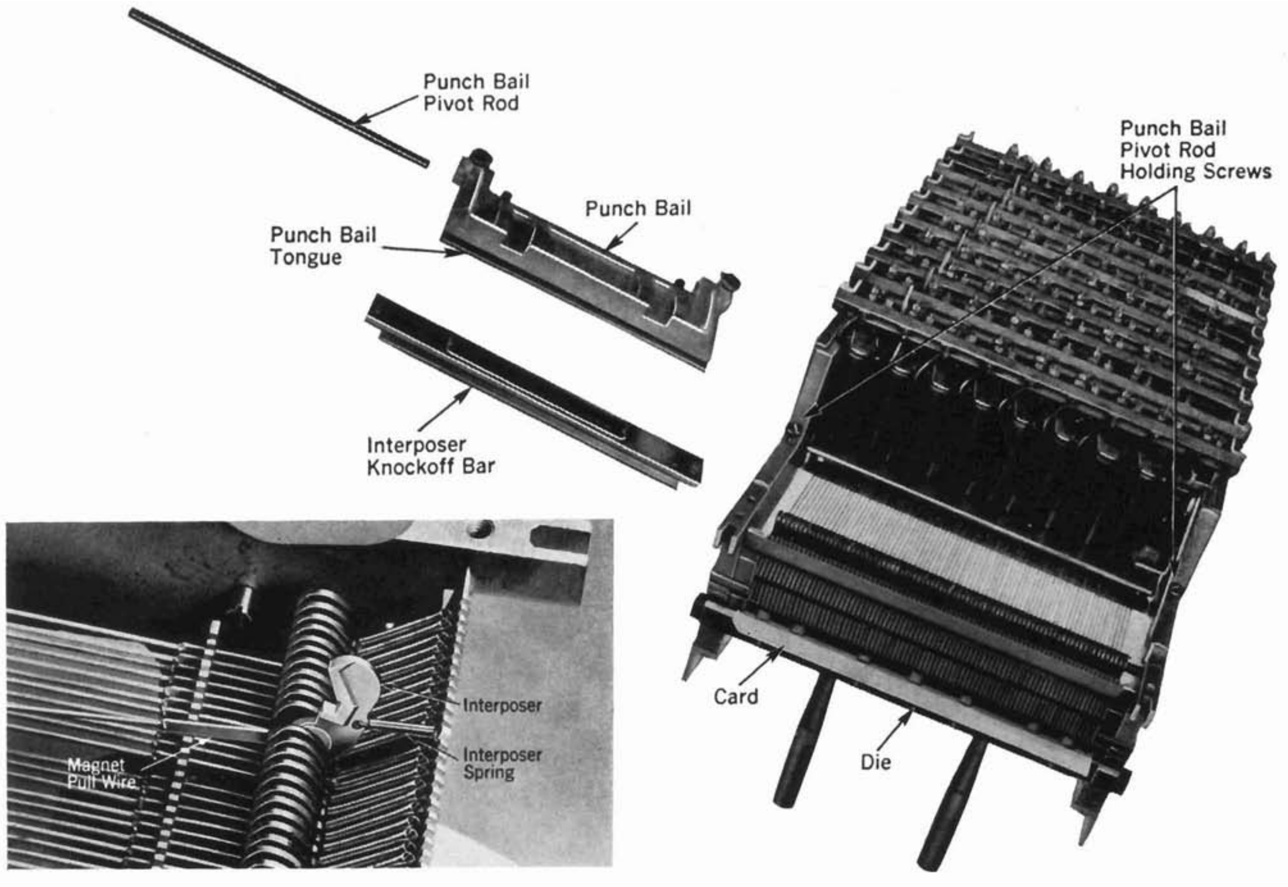


Figure 24. Magnet Unit

poser used in column 80 is attached to the punch to prevent the interposer from slipping off. The other interposers, being protected on both sides by other interposers, do not require any such precautionary design. The three types are shown in Figure 25. The interposers are being referred to as they are located in the Type 603 punch unit and not according to the column of the card as placed in the gang punches. It can be seen that the interposers have been relieved to provide a space between them. This space prevents the interposers from sticking together and causing extra holes to be punched. The interposers should be kept free of foreign particles and gumming oil.

The magnet unit is held in place by four mounting screws and located by two aligning screws (Figure 26). The adjusting screws at the left end locate the unit in a vertical position at the left end to permit proper fit of the die assembly. The

Figure 25. Three Types of Interposers

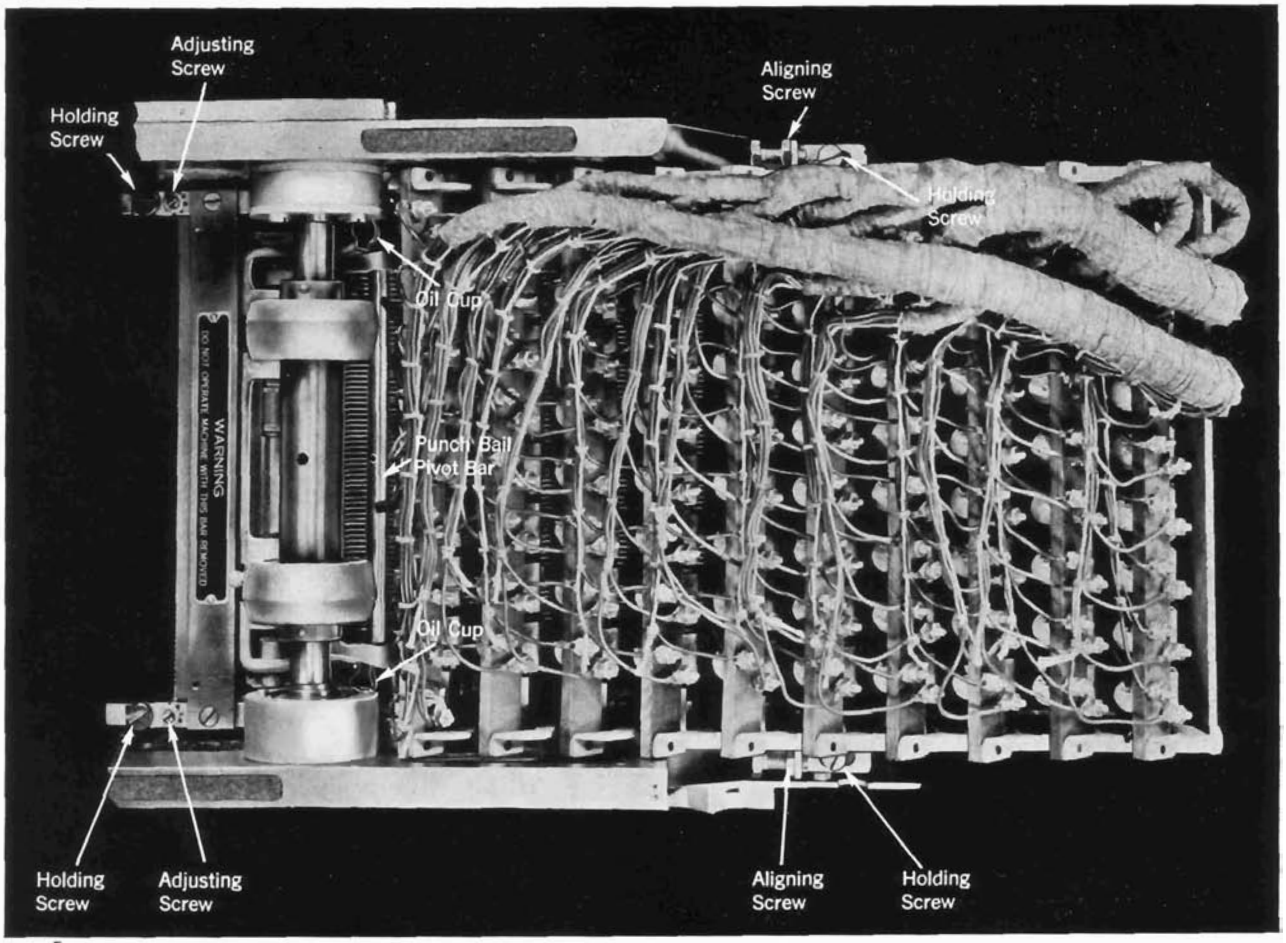


Figure 26. Magnet Unit—Top View

aligning screws locate the magnet unit laterally to permit adjustment of the vertical punching registration.

Oil Pump

The oil pump is a simple rotary-vane type pump. It is located inside the gear housing on the shaft of the small gear which drives the index. It pumps the oil from the bottom of the gear housing to the top where it is free to run down over the geneva and gears.

The rotor is pivoted off-center in the housing as shown in Figure 27. The expansion chamber at the inlet provides a vacuum and causes the oil to enter the pump from the well below. The compression chamber at the outlet causes oil to be forced out at the top.

Cam Contacts

The cam contact used on this machine makes it possible to obtain any desired duration of contact ranging from a fraction of a cycle point to a complete cycle.

This contact is available in two styles, latching and non-latching. The latching style (Figure 28) is used for all contacts that operate but once during a cycle; the non-latching style is used for contacts which must make more than once during a cycle, such as the circuit breakers which feed impulses to the brushes for reading the card.

All contacts are closed by a lobe on a bronze cam which operates against the contact plunger and carries it beyond the latching point so that the contact latch lever may support the contact

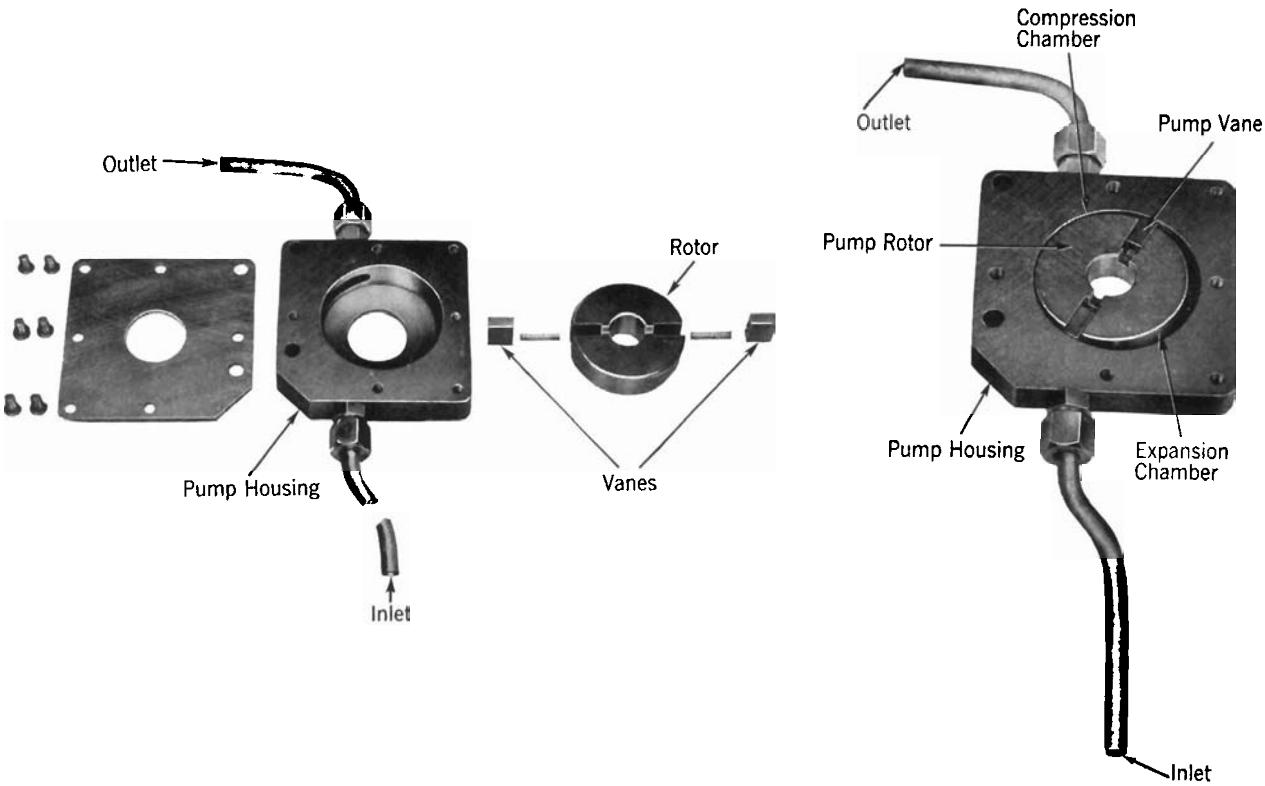


Figure 27. Oil Pump Dismantled

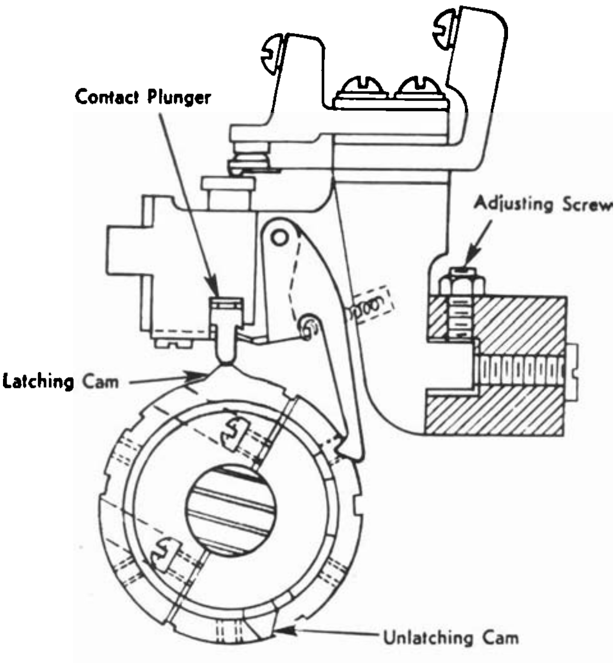


Figure 28. Contact Cam

plunger. The unlatching cam may be adjusted to any position with respect to the periphery of the bronze cam. This cam strikes the contact latch lever and unlatches the contact plunger. In this manner the contact duration may be adjusted.

There is a maximum of 41 cams and contacts mounted in the P-cam unit numbered from front to rear, top to bottom. Cams 9, 13, and 15 are not used but they retain their number. The P-cam unit is arranged so that it can be swung to the left to permit access to the underside of the cams and contacts. Care must be exercised when remeshing the unit to see that the unit is installed in time with the index.

PUNCH CLUTCH

1. Mount clutch assembly with the three mounting screws.

2. Set clutch latch stop screw for .015″ clearance between the latch point and the tail of the clutch pawl when the latch is against the latch stop screw. Move magnets if necessary (Figure 29).

3. Set the clutch latch backstop screw for $\frac{1}{16}$″ overlap of the latch over the tail of the pawl (Figure 30).

4. Move the magnet coil mounting plate in elongated holes to provide for .008″ to .010″ clearance between the armature and cores when the latch is against the stop screw (Figure 31).

5. There should be .003″ clearance between the keeper and the clutch pawl arm when the pawl is latched. This is obtained by stoning or peening the keeper (Figure 32). If the clutch is removed and replaced, the clutch plate should be mounted with the mounting screws in the center of the oversize holes. The other adjustments should then be checked.

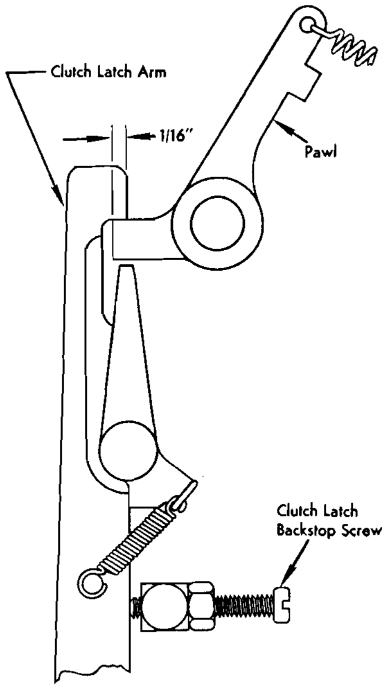


Figure 30. Clutch Adjustment

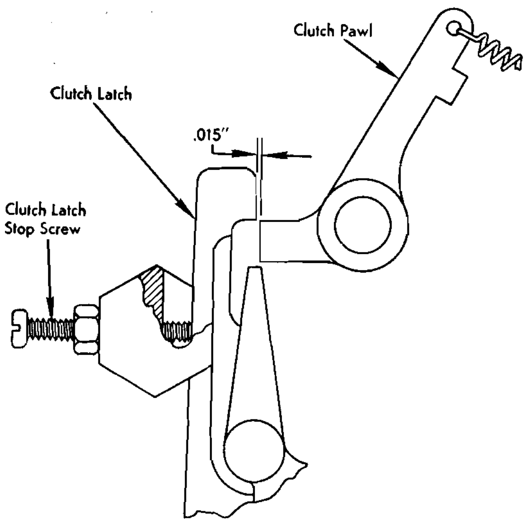


Figure 29. Clutch Adjustment

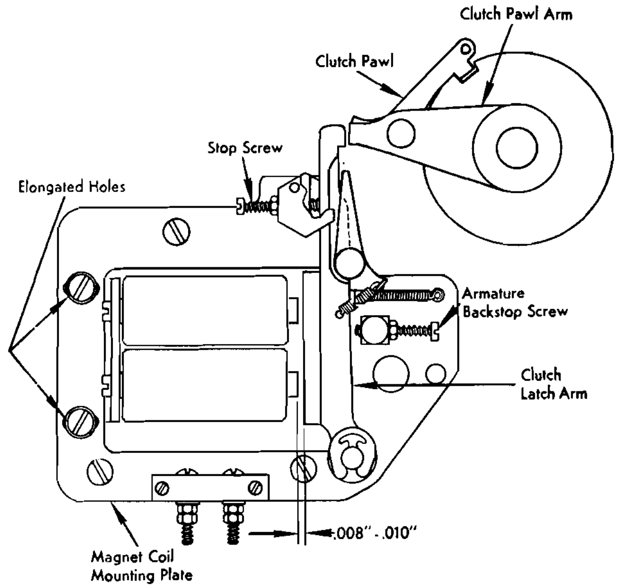


Figure 31. Clutch Adjustment

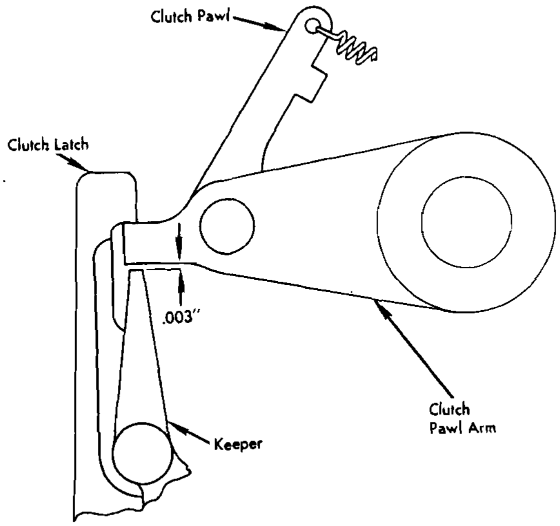


Figure 32. Clutch Adjustment

GENEVA MECHANISM

Single Revolution Timing Cam

This cam should be timed so that the flat side of the cam is up and in a horizontal position at one tooth past 14 on the index. Move the cam and gear out on the shaft far enough to unmesh the teeth and remesh for above condition (Figure 33).

The geneva pawl should be engaged when checking this adjustment.

Single Revolution Timing Cam Bracket

Loosen the holding screw. Move the bracket up or down until the cam holds the geneva pawl

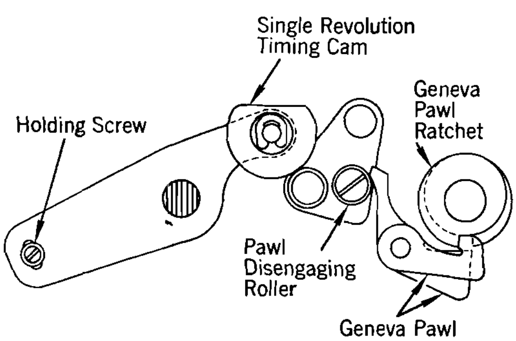


Figure 33. Single Revolution Timing Cam and Bracket Adjustment

disengaging roller in position to hold the geneva pawl away from the one-tooth ratchet on the geneva gear when the punch clutch is latched up at D and the machine is operated by hand. Only the raised portion of the tail of the pawl should operate against the roller.

Set bracket so that geneva clutch pawl just nips the one-tooth ratchet. Then move the left end of the bracket up until the pawl just clears the one-tooth ratchet.

An approximate adjustment may be obtained by setting the bracket so that the locking screw is about one-third of the way up from the bottom of the elongated hole (Figure 33).

Geneva Clutch

A two-pawl geneva clutch is used with the 603 punch unit. This assembly is more positive in its action than the single-pawl type, and is interchangeable with the geneva clutch assembly on all high-speed punches.

Two pawls, one a driving pawl and the other a detenting pawl, are used to eliminate the critical knockout timing of the clutch. The pawl disengaging roller is not adjustable because it is pinned to the bracket.

PUNCH UNIT

Belt Tension

The belt tension is adjustable by moving the motor up or down on its pedestal. The belt should be adjusted for enough tension to prevent slippage; excessive tension, however, will cause the motor bearings to overheat and should be avoided.

Feed Roll Tension

Feed roll tension is determined by compression springs in the feed roll pressure bracket. If for any reason any pressure spring in any one bracket is replaced, all springs in the bracket should be replaced to provide for even tension. The pressure bracket is equipped with holes tapped for 5-40 screws which may be used to lock the pressure shoe under spring tension before removing the bracket.

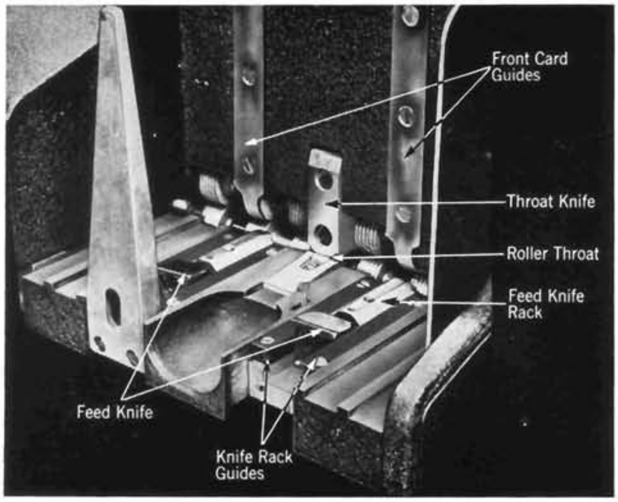


Figure 34. Feed Hopper

Feed Knife Guides

The adjustable guides for the feed knife racks should be positioned for a minimum of play of the racks between the guides without causing any binds. Check this over the entire length of the stroke (Figure 34).

Feed Knife Projection

The card feed knives are adjustable and should be set evenly on each side for a projection of .004″ to .0045″. To adjust a feed knife, remove the feed knife block from the feed knife rack. This may be done without changing the left-to-right position of the knife block if the knife holder adjusting screw is held with a ¼″ open end wrench while the knife block holding screw is removed.

A Go-No Go gauge is provided with two accurately ground surfaces at opposite ends. The surface marked "Go" is cut .0045″ deep and the opposite surface marked "No Go" is cut .004″ deep. When the feed knives are adjusted, the locking screws should be loosened until they are just snug enough to prevent the knives from moving with a slight pressure. Turn either in or out on the adjusting screws, as required, to raise or lower the feed knife. If the knife is properly adjusted, the "Go" end of the gauge will pass over the feed knife on either side and the "No Go" end will not pass over the projection.

The knife must project evenly all the way across, and both knives must be adjusted for the same condition.

After a period of use, the knife blocks may wear, particularly at a point near the feed knife, in which case accurate adjustment is not obtainable. If such a condition exists, it should be remedied in the following manner before the above adjustment is performed.

Set feed knife for the slightest possible projection above the knife block. Stone knife and block assembly until the top surface of the knife and block are even. Then proceed as above.

Feed Knife Block

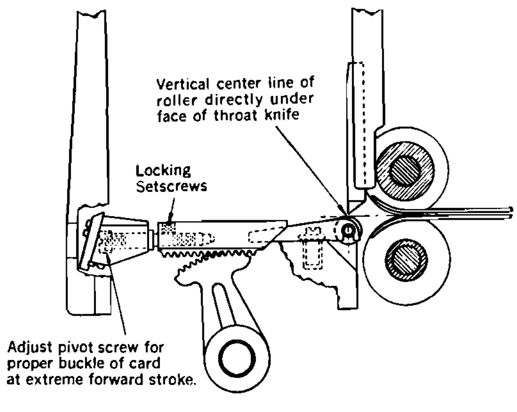
The knife block pivot screws should be adjusted so that at the extreme forward stroke (2½ teeth before 1) the feed knife edge travels .015″ past the edge of the card with the card against the first feed rolls. This provides the proper buckle of the card to insure good feeding (Figure 35A).

Hopper Guide Posts

The hopper guide posts are positioned by means of shims so that there is at least .010″ clearance over the width of the card. Also check to see that at their extreme left position, the feed knives travel at least .030″ beyond the edge of a card held against the guide posts.

Throat

With the throat knife and block only snug under their holding screws, place a .010″ feeler gauge into the throat opening. This gauge must be separated from all other gauges. Adjust the throat block and throat knife until the .010″ gauge between the knife and the roller is parallel with the card feed knife slides. This can be determined



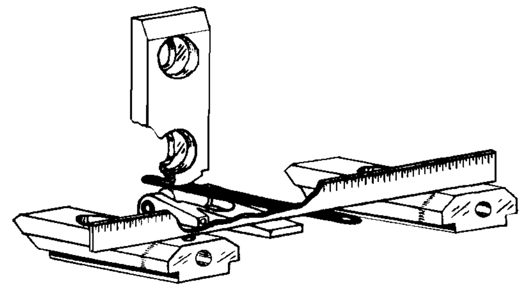


Figure 35. Feed Adjustments

by laying a straight edge across the feed knife slides. The .010″ gauge should just touch the under edge of the straight edge, which can be a IBM card on edge or a scale (Figure 35B).

This will insure that the face of the throat knife is in the correct relationship with the roller, which is important if the throat adjustment is to be realized. Secure the throat block in this position, keeping it to one side in its locating channel. This will keep the axis of the roller parallel with the face of the throat knife. Adjust the throat knife so that the .010″ gauge enters the throat opening freely when held parallel to the card line. Tighten the throat knife and check to see that a .010″ gauge will not enter the throat from any angle other than the horizontal card line. Under no condition should the .011″ gauge enter the throat.

Die

The stop studs in the stripper must be maintained snugly against the die. These studs provide minimum clearance between the die and the stripper. Adjust this by positioning the left end of the magnet unit assembly up or down by means of the adjusting screws, one beside each of the two clamping screws at the left end of the unit. Remove and replace the die several times to be sure that the latching bars have a slight drag as they enter and leave the castings.

The two angle guides, one on each end of the die assembly used on high-speed punches, are for the purpose of keeping the die level when placing it in position in the machine. The following method should be used to adjust these guides correctly. If these guides are properly adjusted, it will be easier to remove and replace the die in the machine.

Install the die assembly in the machine with the angle guide loose, and lock the die in place. Each angle should then be pressed lightly toward the side frame and tightened in this position. An excessive amount of pressure must not be placed on these guides, or they will bind and make it difficult to remove the die.

Punch Bail Tongue

The punch bail tongue should be adjusted so that it is 2-17/32″ from the front edge of the tongue to the back of the punch bail pivot shaft (Figure 36). Loosen the four holding screws. Then position the tongue in relation to the bail by means of the two adjusting screws. This should not require adjustment unless a punch bail or punch bail tongue is replaced.

Interposer Pawl Lock Bar and Spring Bail

The interposer pawl lock bar is positioned and pinned at the factory so there is a minimum clearance between the interposers and the punch bail tongue when the interposers are engaged with the

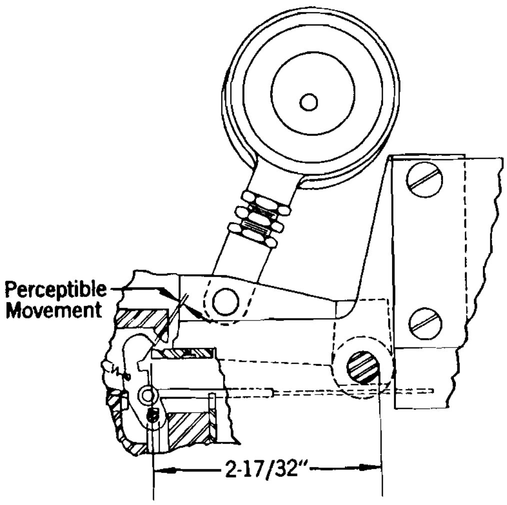


Figure 36. Punch Bail Tongue Adjustment

punch bail tongue and are driven to their extreme downward limit by the punch bail.

The interposer spring bail should be positioned so that it does not touch the interposers when the interposers are engaged with the punch bail tongue and are driven to their extreme downward limit. Check several interposers at each end.

Punch Magnet Armatures

The magnet armatures should be adjusted so that the interposers will move 1/8″ toward the magnets when the armatures are attracted. The 1/8″ travel is obtained by increasing or decreasing the armature air gap by bending the armature just above the point where the pull rod connects (Figure 37). The interposers should line up when in a normal position and should move freely.

Punch Bail Connecting Links

There must be a perceptible movement between the punch bail tongue and the interposers when the bail is in its uppermost position. This condition prevents binds and also provides for a minimum travel of the punches into the die. Proceed as follows:

1. Remove the front punch bail connecting link pin.
2. Turn the machine until the punch bail is in the extreme upward position (eccentric up).

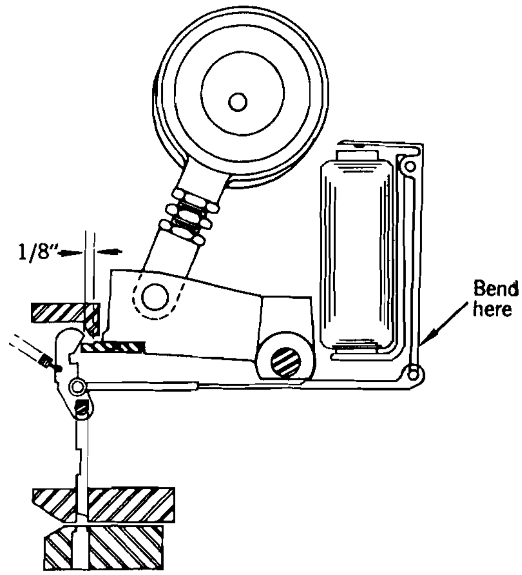


Figure 37. Punch Magnet Armature Adjustment

3. Adjust the rear punch bail connecting link adjusting screw for a slight clearance (.003″) between the punch bail tongue and the interposers. (Figure 36). If there is any variation in the clearance from one end to the other, the .003″ clearance should apply to the closest end. This may be checked with a leaf gauge or by moving the interposers.
4. Adjust the front connecting link adjusting screw so that the front punch bail connecting pin will slide freely into position in the punch bail and punch bail connecting link. This assures an even adjustment on both connecting links and eliminates strain on the punch bail.

After adjusting the connecting link adjusting screws, check to see that the punches are not jammed down against the punch stop bar. Check in the following manner:

1. Engage the interposer at each end of the punch bail and turn the machine until the punch bail is at its extreme downward limit of travel.
2. Press on the top of the interposer with a screwdriver and check for a slight movement.

The punch stop bar should be set as near the punch as possible without interfering with the movement of the punch.

Punch Hopper Side Plates

The punch hopper front and rear side plates are adjustable forward or backward so that cards are punched in proper horizontal alignment on the card registration gauge. Adjustment is provided by means of an elongation of the holes provided for the mounting screws. Shifting the side plates should result in the punched holes lining up with the grooves in the first upper feed roll. The hopper side plates should then be located for a minimum clearance over the length of the cards.

Punch Brush Lateral Alignment

The punch brushes should be positioned so that the brush strands will track through the center of the holes in the card. This may be visually checked if a deposit of some soft substance, such as wax crayon or carpenter's chalk, is placed across the 0 and 9 edges of the printed surface of a card punched 9, 0, 9, 0, etc., and the card is run through the machine. The brush tracks will be plainly visible on the chalked surface of the card. The brush holders and separators can be moved to the front or back if the three locking screws in the slide assembly are loosened (Figure 38).

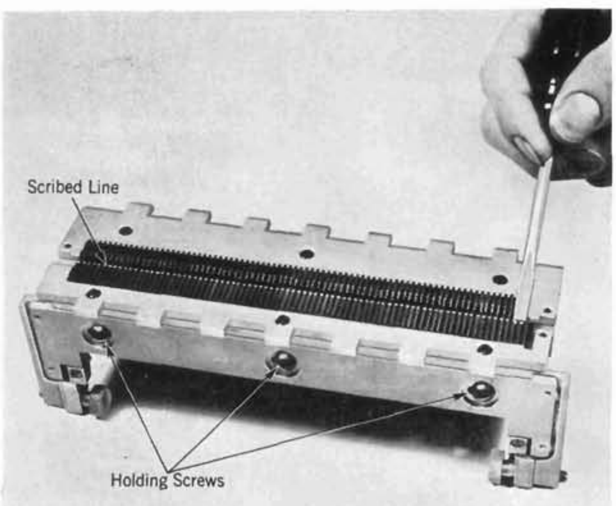


Figure 38. Brush Slide Assembly

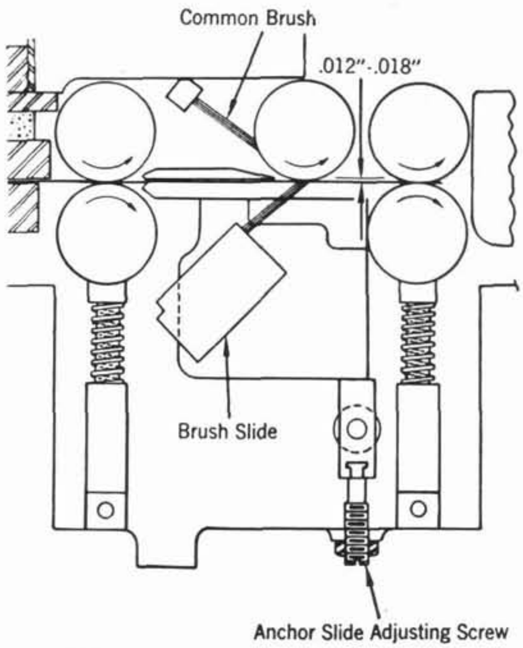


Figure 39. Anchor Slide Adjustment

Anchor Slide Adjustment

The clearance between the contact roll and the brush separators must be .012" to .018". Adjust the brush slide unit up or down by means of the anchor slide adjusting screws in the front and rear support castings (Figure 39) for gang punch and check brushes.

The entry and control brushes are not provided with an anchor slide adjustment. In order to obtain the proper clearance between contact roll and brush separators of the first set of brushes, it is necessary to shim the card guide plate or to grind away the card guide support. Because of the design of the original punch, the location of the read for entry and control brushes require a special brush block assembly.

Brush Timing

Both sets of brushes are set in their holder so that the heels of the brushes are aligned with the scribed line (Figure 38). The brush projection should be $\frac{1}{8}''$ above the separators (Figure 40) which requires a measurement of $\frac{27}{32}''$ from the brush block

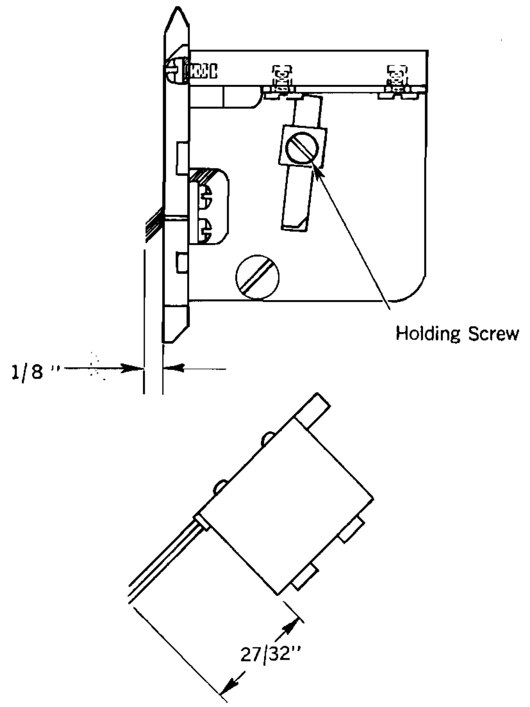


Figure 40. Brush Projection

to the toe of the brush. Adjust the brush holders in their assembly by loosening the holding screws shown in Figure 40 so that the brushes make through the holes in the card ¾ to ½ tooth before the line of index (check with a test light).

Vertical Registration

Cards must be punched in proper vertical alignment. Registration should be checked with a card gauge. To change the registration, loosen the 4 magnet unit mounting screws and adjust the 2 magnet unit aligning screws to position the magnet unit assembly toward the right or left, for proper vertical registration of the holes punched in the card. (Move the vertical registration aligning screws evenly and only when the magnet unit holding screws are loosened; otherwise, the unit may be strained and incorrect horizontal registration may result.) Be sure the aligning screws and holding screws are tight after making this adjustment.

After repositioning the magnet unit for the proper vertical alignment as in the above adjustment, recheck for the slight clearance between the punch bail tongue and the interposers when the punch bail is at the top of its stroke, because repositioning the magnet unit will affect that adjustment.

Stacker Plate

If the stacker has a flat plate (no indentations under rubber rollers), adjust the stop nut on the rod in the bottom of the stacker tube so that there is .006″ to .010″ clearance from the stacker plate to the face of the rubber rollers when the rubber rollers are in the extreme downward position. The felt washer serves as a brake to prevent the stacker from returning to its upper position too fast when cards are removed. The braking action is adjusted by compressing the felt washer by means of an adjusting nut.

Stacker Timing

To time the stacker roll:

1. Remove the blue steel clip from the stud of the idler gear.
2. Disengage the idler gear.
3. Engage the punch clutch and turn the machine to 3 on the index.
4. Turn the stacker roll so that the high side is down and remesh the idler gear. This timing should cause the card to be carried to within $\frac{1}{32}$″ of the right side of the stacker.

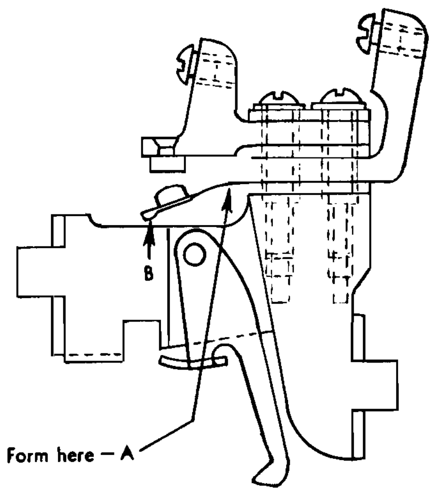


Figure 41. Circuit Breaker Adjustment

CONTACTS

Adjustment of Cam Contacts

1. The lower contact strap should be formed at point *A* (Figure 41) to provide proper tension. At the factory these straps are adjusted so that a force of 160 plus or minus 10 grams (approximately 6 oz.) applied at the tip of the lower strap, point *B*, will just close the points. This tension must be maintained accurately to avoid a bouncing condition.

2. Place shims beneath the plunger stop plate as required to obtain .040″ to .050″ travel of the plunger before latching up occurs. If the contact plunger is overlapped by the latch by an amount equal to the thickness of the latch metal, this should provide the .040″ to .050″ travel (Figure 42).

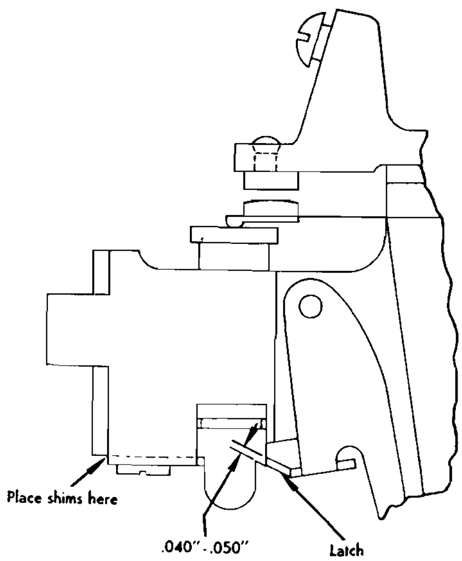


Figure 42. Circuit Breaker Adjustment

3. Place shims between the lower contact terminal block and the contact strap to provide .015″ to .018″ air gap between the contact points (Figure 43).

4. Check to be sure that the plunger does not bind. The design of the split bushing is such that the coil spring spreads the bushing to create a drag between the bushing and frame which increases the pressure required to close the contact from 160

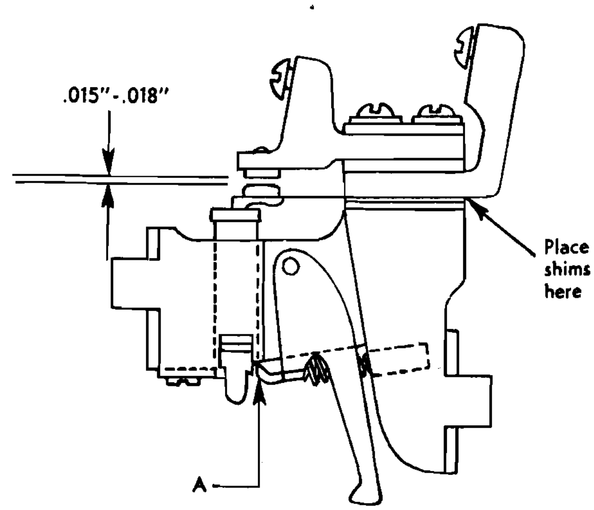


Figure 43. Circuit Breaker Adjustment

grams (pressure required to compress the spring) to 225 grams (approximately 8 oz.). This friction is used to dampen the rebound when the contact closes. Check to be sure that a maximum of 240 grams applied to the plunger will close the contact (Figure 44).

5. A pressure of 600 plus or minus 20 grams (approximately 21 oz.) on the contact plunger should be required to compress the plunger spring to the latching point (Figure 45). These values have been tested and found to provide a good operating condition.

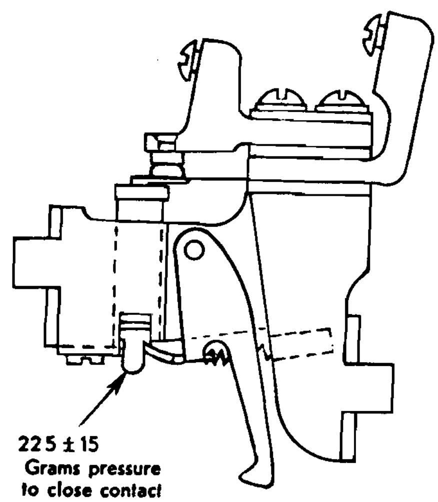


Figure 44. Circuit Breaker Adjustment

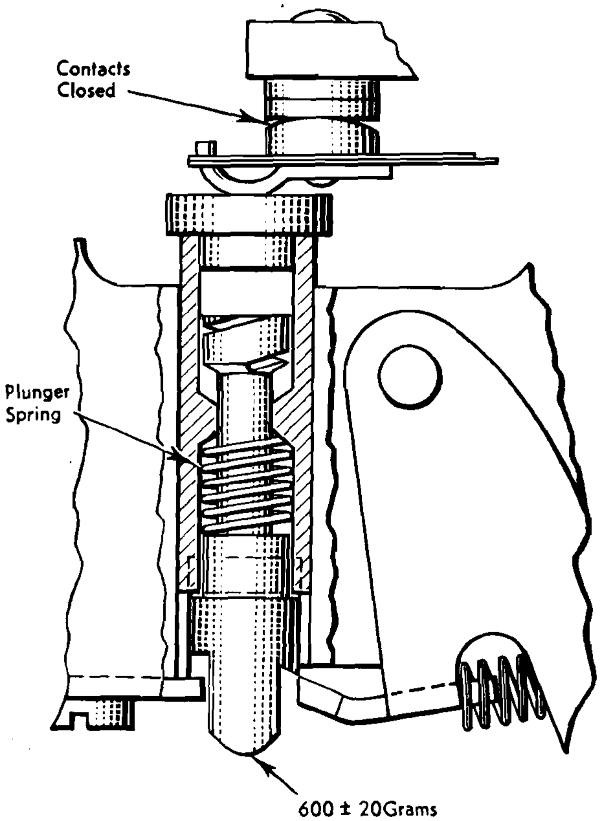


Figure 45. Circuit Breaker Adjustment

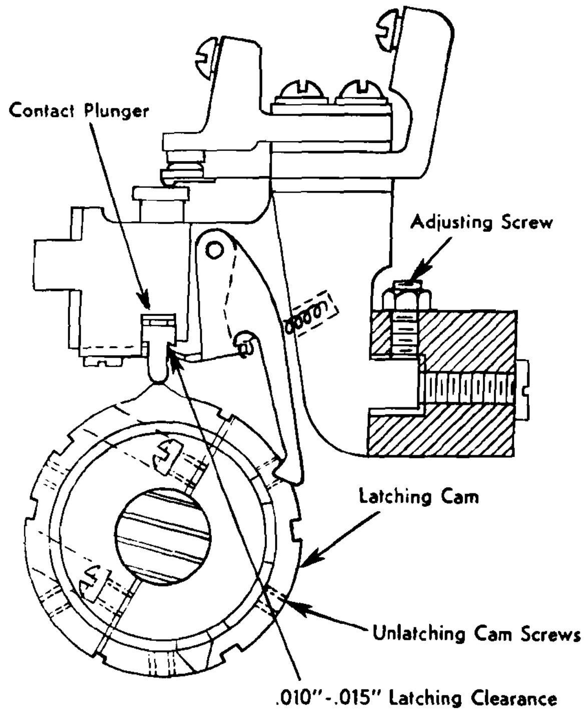


Figure 46. Circuit Breaker Adjustment

6. Locate the cam contact unit on the mounting bar at its extreme limit of travel away from the cam, and with the plunger on the highest point of the cam lobe, advance the adjusting screw until the plunger latches; then advance the screw one-half turn additional to obtain .010″ to .015″ movement of the plunger beyond the latch point (Figure 46). This will provide clearance between the low dwell of the cam and the plunger. On the non-latch type there should be a .003″ minimum clearance between the low dwell of the cam and the contact plunger when the plunger is against its stop (Figure 47). If a latching cam contact does not latch, it may be recognized by the fact that the contact points will close for 11°, or approximately 4 teeth on the index.

7. To adjust the make time of the contact, loosen the screws holding the cam to the shaft until the cam is just snug on the shaft. Turn the machine to the index point corresponding with the

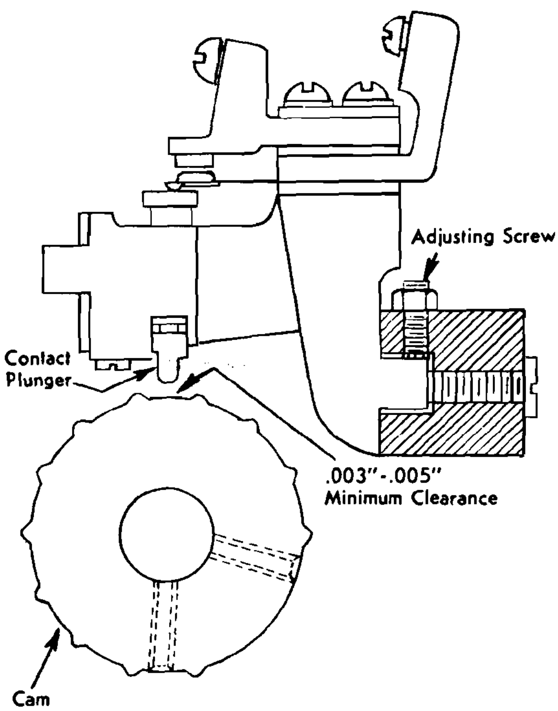


Figure 47. Circuit Breaker Adjustment

make time of the cam. Move the cam on the shaft in the direction of rotation until the contact just closes. The machine may now be turned to a point where the cam holding screws can be tightened. An accurate adjustment may be obtained by inserting a screwdriver in the slots provided on the periphery of the cam for moving it on the shaft.

8. To adjust the break time of the contact, loosen the contact unlatching cam screws (Figure 46). Turn the machine to the proper index point and move the unlatching cam in its slot until the contact opens. Tighten the holding screws. There are six possible positions for holding screws, only two of which will be used at any one time.

Adjustment of Card Lever Contacts

All card lever contacts should have at least $\frac{1}{32}''$ air gap when open, and at least $\frac{1}{32}''$ rise off the support strap when closed. Adjust by bending the brass support, or by shifting the entire contact assembly. The operating lever must be positioned on the shaft so that the lever is just against the operating strap when the contact is open.

THE circuits for this machine will be studied in three sections; namely, punch unit circuits, D. C. power supply circuits, and electronic computing unit circuits. In all circuit explanations, the location of the various circuit components both on the machine and on the wiring diagram will be stressed. Owing to the newness of electronic computing circuits to most Customer Engineers, the electronic circuits will be analyzed in as much detail as possible.

PUNCH UNIT CIRCUITS

WIRING diagram 213639A shows the power supply, punch unit circuits and the electronic circuits. The timing chart for the punch unit is a part of this wiring diagram. An electronic timing chart will be found on the last page of the manual. The diagram is indexed to facilitate location of circuit components. Before proceeding with the discussion of these circuits, the various terminals used on this diagram will be listed together with an indication of their location on the machine. All terminals are counted from left to right, top to bottom, front to rear, facing the machine.

On machines equipped for 115 volt A.C. operation only, there are twenty terminals for the 115 volt A.C. and 40 volt D.C. connections in the punch unit. These terminals are located on top of the main transformer. Post 1 and post 3 are the 40 volt D.C. supply terminals while posts 7 to 20 are 115 volt A.C. and transformer terminals. Post 2 and 4 are not used. The terminals on the tube power supply chassis are designated by a number preceded by CH. There are ten of these terminals located at the rear of the power supply chassis. Post CH3 represents power supply chassis terminal 3.

On machines equipped for 115-230 volt A.C. operation, all transformers have two primary coils and more terminals are necessary. In these machines there are 24 terminals on the main transformer and 15 on the tube power supply chassis.

The terminals designated as CN, for example CN9, represent the connections on the cable connector. CN9 is the 9 connection on the cable connector on the punch unit, counted as indicated on the wiring diagram, Section 22B. The cable is detachable at both ends, hence, a sub-letter is used to indicate which connector is meant. Every other terminal is used to lessen the possibility of a short across terminals.

Relays and cam contacts can be located on the circuit diagram by means of the location chart shown in Section 17-18 of the wiring diagram. In tracing circuits, normally closed points will be abbreviated by N/C, normally open points by N/O, and the operating strap O/P.

All power is furnished by the commercial supply through the attachment cord which is connected across terminals 7 and 8 on top of the main transformer. The main line sentinel switch turns power to the machine ON or OFF. Most machines made require a 115 volt A.C. supply. However, transformers are available which permit either 115 volts or 230 volts A.C. operation. The power supply circuits for 115-230 volts A.C. operation appear in Section 3 of the wiring diagram, while Section 4 shows the circuits for 115 volts A.C. operation only.

HD3 and HD4 relays are A.C. relays wired directly across the A.C. line from post 9 to post 10. When the main line switch is ON, HD4 is picked up and its points complete a circuit to the primary of the main transformer. The main transformer is protected by two 20 ampere fusetrons. The reason for this arrangement is that no sentinel switch was available to handle the total current demand when this circuit was designed. With this arrangement, HD4 relay points act as a switch, and the sentinel switch protects only the punch drive motor and the tube power supply transformers;

the main transformer is protected by fusetrons. HD3 points open the ground connection when the switch is OFF.

The tube power supply transformer primary connections are made across posts 9 and 10. The drive motor is directly across the main line switch and hence operates on the commercial A.C. supply under the control of HD1 relay. It is protected by the 10.9 ampere element in the sentinel switch. A split plug allows the motor to be disconnected from the machine.

Note that the test lamp outlet is "hot" as long as the attachment cord is plugged in, regardless of the setting of the sentinel switch. The test lamp outlet is protected by 3 ampere glass fuses 12 and 13.

As soon as the main line switch is turned ON, 40 volt D.C. supplied by the selenium rectifier is available across posts 1 and 3. Post 1 is the positive side of the line and post 3 is the negative side. For sake of consistency, wherever possible, *all circuits will be traced from negative terminals to positive.*

Time Delay Circuit

Owing to the necessity of heating the cathodes of the rectifier tubes and the vacuum tubes to operating temperature before putting them in operation, it is necessary to allow an interval of time before starting the machine. To insure full operating temperature, approximately 50 seconds is allowed for heating the tube cathodes. The rectifier tubes in the power supply chassis are gas-filled tubes and will be damaged if the load is applied before their filaments have reached operating temperature. If vacuum tubes are placed in operation before they have been fully heated, the tubes will not be damaged, but erratic operations will result.

The time delay is effected by a thermal delay relay (R5 in machine). One contact strap of this relay is a bi-metal strip, i.e., it consists of two strips of different metal placed one on top of the other and bonded together. These two metals expand at a different ratio when heated and hence the strap will bend. A coil of high resistance wire is wound around this strap to serve as the heating element. The lower strip of metal has the greater expansion rate; therefore, the strap will bend upward when heated, and the contact points will touch to close a circuit to the coil and complete circuits for the operation of the machine. The upper contact point is in the form of a screw tipped with contact metal. This screw provides a means of varying the time interval required for the relay points to close by varying the distance between the contact points. The adjusting screw is normally set to provide 50 seconds delay. An air gap of approximately $\frac{3}{32}''$ will provide a good starting point in setting this adjustment. This time is applicable when starting with a cold machine. Naturally, the time delay will vary if the machine is turned ON and OFF several times in a few minutes because the heating unit will not have time to cool.

The time delay relay operates on the regular 40 volt supply of the punch unit furnished by the selenium rectifier. With the main line switch ON, a circuit is complete to the time delay heating element as follows: post 3, terminal CNp5, through ground cable in the electronic unit and back to CNp13, through heater element, N/C points of R5BL, to R2A N/C, P16, P1, post 1. Also, as soon as the main line switch is closed, R2 coil will be energized in parallel with the heating element. The purpose of R2 and the cable jumper will be explained shortly.

When the heating element has sufficiently heated the bimetal contact strap, which is one strap of R5A points, the R5A points will close, and a circuit will be completed to the coil of R5 as follows: post 3, terminal CNp5, through ground cable to CNp13, through R5 coil, R5A contact, and out to post 1.

Relay 5 will then pick up and its BL and BU points will transfer. When R5BL transfers, the circuit to the heating element is opened and a holding circuit for R5 is completed.

When R5BU points close, the HD2 relay will be energized since R2 is already energized and the R2A contacts transferred. The circuit is as follows: post 3, terminal CNp5, through ground cable, power switch in electronic unit (Section 22A), back through cable to post CNp15, through HD2 coil, R5BU, R2A N/O to P16, P1, and post 1. The HD2 contacts are in the primary of the tube power supply transformer and are shown on the power supply circuit diagram. Power for the tubes in the electronic unit becomes available as soon as HD2 is energized.

Start Circuit and Bias Interlock

In order to insure that the tube power supply is functioning properly, the starting of the machine is under the control of start circuit interlock relay R6 and bias interlock relay R4. R4 must pick up to complete the anode power supply circuit and also to pick up R6. The bias interlock is necessary to insure that the grid bias voltage is applied before the anode voltage is applied; otherwise, excessive anode current will flow through the tubes and overload them before the control grid comes into operation. Eventually this will damage the tubes. When R4 is picked up, the R4 contacts complete a circuit to R6, which is connected across the grid and anode voltage supplies; hence R6 cannot pick up unless the anode voltage is applied to the vacuum tubes.

The voltage output terminal CH3 (Section 4A) on the power supply chassis is the ground terminal, or point of reference for all voltages, and is considered the zero point for all voltage references. Note that CH3 is connected to post 3 which means that post 3 may be considered as a zero voltage reference point. Terminal CH4 supplies plus 150 volts, i.e., 150 volts *above ground*, while CH2 supplies minus 100 volts, or 100 volts *below ground*, making the voltage between CH2 and CH4, 250 volts. Terminal CH1 supplies minus 250 volts.

Each of the power lines is protected by a 2 amp glass fuse. Fuse 9 protects the −250 volt line, fuse 10, the −100 volt line, and fuse 11 the +150 volt line.

Note that the coil of R4 is connected directly across the −100 volt supply (bias supply), between fuse 10 and the ground connection at the relay common. The circuit for picking up R4 is as follows: post 3, fuse 6, to R1, R3, R7, through R4 coil, to fuse 10. This relay will then remain energized as long as the bias voltage is applied. Bias voltage is furnished to the electronic unit through the cable connector CNp3.

When the R4A points close, a circuit is completed to supply +150 volts to the electronic unit through 2 amp fuse 11, R4A, and the cable connector CNp7. The R4A contacts also complete the following circuit: fuse 11, R4A, R6 coil, three 25,000 ohm resistors in parallel, to fuse 10. Thus, R6 remains energized as long as R4 is picked up and as long as the +150 volt supply is available.

The purpose of the three 25,000 ohm resistors (net resistance approximately 8000 ohms) is to create a sufficient voltage drop across the 250 volts between fuses 11 and 10 so that the proper voltage is applied to the coil of R6. The purpose of the capacitor across the R4A contacts is to absorb the arc across R4A in case a fuse blows, etc.

Once R6 is picked up and the R6A contacts close, the machine is ready to start. The green pilot light indicates that the punch is ready to start. The circuit to light the pilot light is as follows: post 3, through pilot light, post 5, die contact, post 6, knockoff bar contact, R6A contacts, to center strap of R2A, P16, P1 and post 1. The knockoff bar contact and die contact are both safety contacts. The die contact is closed only if the die is properly in place with its latching bars in position in the grooves in the side frame. The knockoff bar contact is closed only if the knockoff bar in the magnet unit is properly in place.

Start Interlock Circuits (Gang Punching Only)

In case it is desired to use the punch unit for gang punching only, it is desirable to disable the start interlock circuits and open the tube power supply circuit, although it is not necessary. This can be done by disconnecting the cable at either end.

If the cable is to be disconnected at either end, it is recommended that the main line switch first be turned OFF. With the cable disconnected, the circuit to R2 and R5 coils is opened. If R2 and R5 fail to pick up, the HD2 relay cannot pick up, and no power will be furnished by the power supply chassis to pick up R6. Note, however, that the N/C side of the R2A contacts provides a path around R6A to post 1.

Start and Running Circuits (No Cards in Machine)

It is most important to bear in mind, when tracing any circuit or set of circuits, the objective of the circuit. The objective of the start and running circuits is to control the feeding of cards through the punch. This is done by starting the motor, causing the punch clutch to engage, and then keeping the machine running once cards have reached the second set of brushes. The motor is under the control of HD1 relay which in turn is controlled by R10. The punch clutch is also under the control of R10; hence it is obvious that R10 must be energized to cause the motor to run and to cause the punch clutch to engage. Depressing the start key and closing the contact will cause R10 to pick up (assuming R6 is picked up). R10 will remain energized as long as the start key is held depressed through the following circuit: post 3, through fuse 6 to R1P, R1H, HD1, through R10 coil, through start key contact, stop key contact, R57B contact, post 5, die contact, post 6, KO bar contact, R6A contact, to center strap R2A, to P16, P1, post 1.

The closing of the R10 contacts simultaneously completes a circuit to the P-clutch and HD1 motor relay. Circuit for the P-clutch is as follows: post 3, fuse 5, punch clutch coils, R10BU, P16 cam contact, to P1 and post 1. This circuit energizes the P-clutch magnets, which in turn unlatch the clutch pawl so that it may engage the ratchet at D on the index.

The circuit to the motor relay is as follows: post 3, through fuse 6, 40 volt HD1 coil, R10BL contacts, and on to post 1 as in the start key circuit. The HD1 contacts complete a circuit to the drive motor and keep the drive motor in operation as long as R10 remains energized. The 2mfd capacitor across the HD1 contacts suppresses arcs which might cause trouble in the electronic circuits. This capacitor is not shown on the wiring diagram, 213639A.

The motor drives the continuously running mechanisms; at D, the P-clutch engages, and all units go into operation. Shortly after the P-clutch engages, the circuit to the P-clutch magnet is broken by P16 at 14 on the index. Remember, from the mechanical operation of the clutch, that once the clutch engages it must make a complete revolution before relatching. If the start key is held closed for more than one cycle, P16 makes again at 12.3 on the index to energize the P-clutch magnet and prevent relatching of the pawl.

In order to prevent the machine stopping part way through a cycle when the start key is released, a P-cam provides a hold circuit for R10 to insure the completion of any cycle during which the start key may be released (or when the machine stops owing to any other reason). The start relay hold circuit is completed through P19 as follows: post 3, through fuse 6, R10 coil, R10AL, P19, die contact, and on to post 1 as in the start key circuit.

Start and Running Circuits (Cards in Machine)

The running circuits are designed to keep the machine running automatically once cards have reached the second set of brushes and to stop the machine for any of the following reasons (1) when the last card runs out of the magazine, (2) when the stacker is filled to capacity, (3) when an error is made in checking, or (4) when any card fails to advance to the die or to the punch brushes 2 (read for gang punching and checking).

Card lever contacts are provided to signal the presence of cards in the magazine or at any of the stations through the machine. A stacker stop switch signals a full hopper, while a relay is provided to signal an error when checking.

As soon as cards are placed in the hopper, R3 will pick up as follows: post 3, through fuse 6, through R3 coil, hopper card lever contact, to post 1. The R3A contacts are in the R10 running hold circuit.

The other card lever contact relays R1, R7, and R8 are energized through their corresponding card lever contacts when the contacts are closed by the cards.

After the cards are placed in the hopper, it is necessary to hold the start key depressed through three complete cycles before the machine runs continuously.

After the third cycle, the machine runs automatically. The card levers are designed so that their contacts do not open between cards; therefore all card lever contacts remain closed once cards start through the machine. As a safety precaution, R1 is held by P33 between cards, and R8 is held by P16 between cards. This insures the card lever relays remaining energized even if the card lever contacts open for an instant when corner cut cards are used.

All that is necessary to keep the machine running continuously is to keep R10 energized. This is done through the following circuits once cards reach the second set of punch brushes: post 3, through R10 coil, R10AU, R7BL, R3A, R1AL, stacker stop switch, stop key contact, R57B, die contact, KO bar contact, R6A, to R2A o/p and post 1. This circuit is complete until any one of the contacts is opened.

Reading Brush Circuits

R8B contact is used in the read for entry and control brush reading circuit, while R7A contacts are similarly used in read for gang punching and checking brush reading circuit. The purpose of these contacts is to prevent readings from the brushes when no cards are in position at the brushes.

P1 through P4 (Section 7A) serve as circuit breakers for both sets of brushes. P1 and P2 control the making time at the line of index while P3 and P4 control the breaking time at three teeth past the line and provide CB pulses of 3-tooth duration.

The purpose of the first set of brushes is to read the card for entering the factors in the various counters and for X control, group multiplier control, sign control, while the purpose of the second set of brushes is to read the card for checking or for gang punching operations. The complete circuit for reading into a counter will be deferred until the electronic circuits are discussed but the portion shown on the punch unit diagram will be traced. To simplify the tracing of this circuit it will be necessary to depart from the rule established and start at the positive terminal. The circuit for reading into any one position of the multiplier counter is as follows: post 1, through P1, P2, P3, P4, R8B, common brush, contact roll, through hole in card, individual brush, brush hub, entry hub for multiplier counter (Section 15A), through factor reversal relays, cable connector and cable to electronic counter.

In gang punching, the punch hubs are connected to the second set of brushes, and a punch magnet is energized when a hole is read in the column to which the punch magnet is wired. The circuit is as follows: post 3, through R12B (Section 15B), punch magnet common connection, punch magnet coil, punch hub, wire to hub, read for gang punching brushes (Section 7A), individual brush, through hole in card, contact roll, common brush, R7A contacts, P3, P4, P1, P2, to post 1.

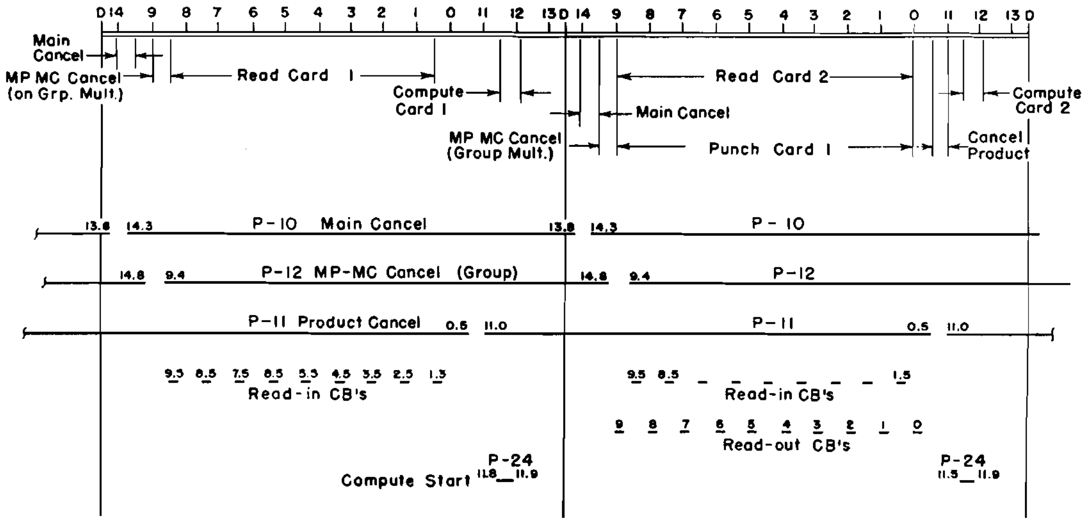


Figure 48. Timing Chart for Computing Operations

Electronic Computing Control Circuits

The circuits in the punch unit for controlling the electronic computing unit are primarily timing circuits to time the computing operations to the movement of the cards through the punch unit. No attempt will be made to trace complete circuits for these controls; only the general function of each timing cam will be given. Figure 48 is a timing chart showing the relationship between the computing functions and the card movement through the punch unit.

Electronic counters are restored to zero by opening the −100 volt grid bias circuit by means of a P-cam contact. Other circuits are similarly restored to normal by opening a contact. P10 (Section 5A) is the main cancel contact and controls the restoration of all circuits except the product counter to normal. This restoration occurs at the very beginning of a cycle before any figures are read from a card. When group multiplying, R26 is picked up, R26A points transfer, and either the multiplier or the multiplicand counter, depending upon the setting of the factor reversal switch, is cleared by P12 under further control of R27-3 points. P12, which opens slightly after P10 closes, is effective only during cycles that R27 is picked up.

The product counter cannot be cleared until after punching is complete, consequently the clearing is separately controlled by the product cancel cam contact P11, which is under further control of R19A. P11 opens at 0.5, and the product counter is cancelled or cleared, provided R19, the product summary relay, is not picked. When it is desired to store and accumulate products, R19 is picked up and P11 is no longer effective.

The reading of factors into the electronic counters occurs at mid-index points under control of P5 through P8 (Section 8A); P5 and P6 provide read-in pulses of three-teeth duration at mid-index points. P17 permits only 9 of these pulses to be used. P7 and P8 provide pulses of three-teeth duration at index points to control the electronic read-out circuits. P18 allows 10 of these pulses to be used. The reason for the two sets of CB's will be apparent in the discussion of the electronic read-in and read-out circuits.

Once factors are read into the counters from a card, it is necessary to start the computing section. This is timed by P24 cam contact which provides a pulse to start computing at 5 teeth past 11 on the index if R1BU points are closed. R1BU prevents computing operations in case the punch is running without cards.

Read-out is also under the control of P5 through P8 except that read-out pulses are index line pulses. Also, read-out is under further control if R1BL (die card lever relay), R19B (product summary relay), and R29AL(group multiplier relay). If any of these three relay points are open, the product cannot be read from the electronic unit to the punch.

Read-out is further controlled by the P14 cam contact (Section 4B), which applies anode potential to the read-out power tubes only during the 9 through 0 punching time of the cycle. The electronic portion of the read-out circuit is reserved for the section on the electronic computing circuits; only the portion on the punch unit will be covered. Read-out pulses from the electronic unit come to the punch under the control of P7 and P8 through the cable and to the hubs labelled PRODUCT (Section 15B). Normal wiring for punching the result is from the PRODUCT hubs to the PUNCH hubs. The circuit for energizing a punch magnet from the product counter is as follows: post 3 (Section 5B), through R12B (Section 15B), punch magnet common, through punch magnet, hub, wire, to hub marked PRODUCT, to cable connector, through cable to electronic unit, back through cable to CNp28 (Section 4A), P14, to +140 volt terminal.

Punch Suppression

If it is desired to suppress punching in a card, the card is either X-punched or punched with a control digit in a specified column. The control punching then causes the pickup of R12 to suppress punching on the cycle following.

R15 (Section 9B) is the X relay which picks up from 0.3 through 11.3 of each cycle under control of P37. Points of R15 are used in the X pickup circuits of various relays. For example, R15AU is in the X pickup circuit of R11 (Section 8B), so that R11 can pickup only on X's if the X pickup is wired from the first set of brushes (read for entry and control). If it is desired to pick R11 on other digits, the D pickup hub is wired from the first set of brushes.

The sequence of operations for punch suppression is shown in Figure 49. When R11 picks, the R11A points close to hold R11 energized through P21 until 14.5 of the next cycle. The R11B points establish a circuit to pick R12 under control of P22. If the punch suppression device is wired to suppress on X's, R12 will pick up at 13.6, provided R11 is already energized. R12A points close to hold R12 through the R12H coil until P23 breaks at 13.4 of the same cycle. R12B is in the punch magnet common circuit so that no punching can occur as long as R12 is energized.

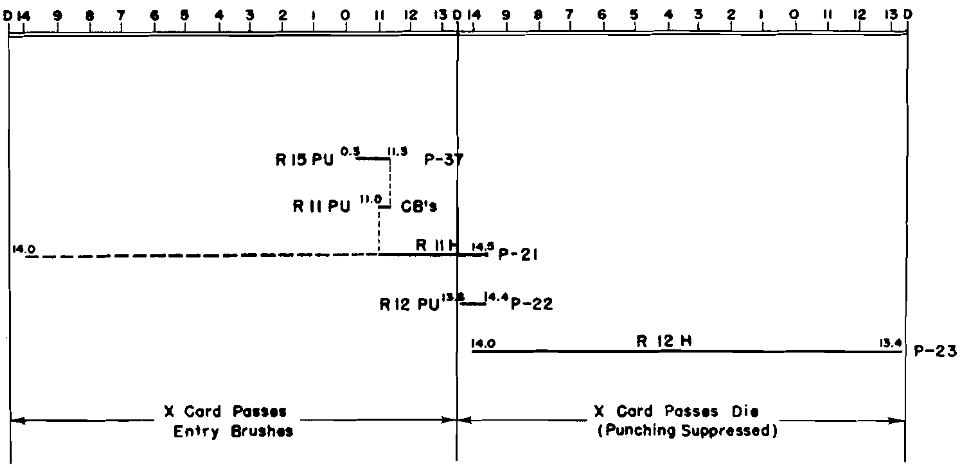


Figure 49. Sequence of Operations on Punch Suppression

It is obvious from the circuit that if the punch suppression feature is wired for N suppression, R12 will pick up every cycle that R11 is *not* picked up. Therefore, punching will be suppressed when there is no X (or digit) punched in a card.

The punch suppression feature can be used to perform group gang punching operations, that is, information in interspersed master cards can be punched into the detail cards following the master. Either the master cards or the detail cards can be X (or digit) punched.

Product Summary

Often it is desired to accumulate several products before punching. This permits special operations, such as crossfooting on two cards, punching the sum of several products, etc. To accomplish this, it is necessary to prevent reading out and clearing of the product counter. The product summary feature has the same type of controls as punch suppression, i.e., X or digit pickup and X or N control. To place the product summary in operation, a jack must be placed in the ON position of this switch. This causes R19 to be picked up as long as R18B points are closed. R18 picks under the control of R17, which in turn picks under control of an X or digit punching. The X or D hubs of the product summary device are wired to the first set of brushes (read for entry and control). The X hub is under control of R15BL points so that only X's can energize R17.

Once R17 is picked, it is held by the R17H coil through R17A and P21 until 14.5 of the next cycle. Then with R17B transferred, R18 picks when P22 makes, provided X control is being used. R18 holds through R18H coil, R18A, and P23 until 13.4 of the cycle following the reading of the X (or digit). During the cycle that R18 is energized and R18B points are open, R19 cannot be energized. When R19 is in a normal position, R19B points (Section 8A) are closed to permit read-out from the product counter, and R19A points (Section 5A) are open to permit cancelling the product counter when P11 opens. Thus, an X or digit punching will cause normal operation when set for X control.

If the product summary is set for N control, R18 picks every cycle that no X or digit punching appears and normal operation continues until an X or digit punching appears. An X or digit will cause progressive addition of products and suppression of punching when set for N control.

A blank card with the proper control punching must precede a product summary run if the machine has just been turned ON. Otherwise, the first group may be over because of the random figures which might set up in the product counter when the switch is turned ON. Remember that on normal multiplication the product counter is cleared before the first computation, whereas on a product summary run, it is not.

Product Overflow

Often the number of columns set aside on a card for punching the product of a multiplication is not large enough to permit punching the largest products. However, if only a very small percentage of the total number of cards exceeds the capacity of the field, it may not be worth increasing the size of the card field and thereby limiting the number of columns available for other punching. To take care of such cases the product overflow feature is furnished on this machine.

To place the product overflow feature in operation, the product counter position *next to* the highest order wired to punch is wired to the product overflow entry hub. Observe that P38 cam contact (Section 9B) is in this circuit and that P38 will permit any impulse from *9* through *1* to pass and pick up R16. As long as the product counter position wired to product overflow contains *0*'s, nothing happens. Any digit from *1* through *9* in this position causes R16 to pick. R16 then holds through its R16H coil, R16AL, and P21 cam contact. R16AU points complete a circuit to the error light and error relay R57 (Section 11B), so that the machine will stop and indicate with a red light that the product just computed and punched exceeds the capacity of the card field.

Since the error light is used for other error signals, it is desirable to distinguish between errors and overflow products. This is accomplished by punching a 12 in a card in which the product exceeded the card field capacity. To punch the 12 the product overflow 12 hub is wired to any punch magnet, and a 12 hole will punch under control of P36 (Section 9A) provided R16B points are closed. With this arrangement, a card is examined after an error light and if a 12 hole is punched, it is apparent that the error was due to an overflow product. This card can then be handled manually.

Factor Reversal and Check Circuits

Multiplication is checked by re-multiplying with the multiplier and multiplicand factors reversed, then checking for double punchings or blank columns by means of the double punch and blank column detection circuit. This checks the multiplication, because if a different answer is obtained on a check run than was obtained on a multiplying run, the card will be double punched in some column. The check circuit also checks for failure to punch during the first multiplication run and again checks for blank columns during the check run. An error will cause the machine to stop and the error light to glow. Before restarting the machine, the double punch reset push button must be depressed to extinguish the error light.

Factor reversal is accomplished by switch control to permit rapid change-over from one setup to another. When the factor reversal switch is ON, relays R21 through R25 are picked up and remain energized as long as the switch is ON. R21, R22, and R23 are used to reverse the entry to multiplier and multiplicand counters so that the factors normally entering the multiplier enter the multiplicand and vice versa. R24 reverses the multiplier and multiplicand read-in control and cancel circuits on a group multiplying setup, while R25 is used in connection with sign control.

One control panel switch is provided for each position of blank column checking. Double punch checking may be used alone or in combination with blank column checking. Blank column checking cannot be done alone, but must be used in combination with double punch checking. The product field in the card is wired from the second set of brushes (read for gang punching and checking) to the double punch entry hubs for double punch detection. If blank column checking is also desired, the corresponding blank column switches are set ON. When checking multiplication, it is necessary to use both double punch and blank column checking.

As the card passes the first set of brushes, the factors are read in to re-multiply. The result is again punched, and the card is checked as it passes the second set of brushes. As the card passes the second set of brushes, a circuit will be completed through the hole in the corresponding column of the card to pick up R37. Only the first position will be considered in tracing circuits. The R37B points indicate the presence of a hole in the column being checked. R38 then picks up and sets up a circuit through its R38A points to the error relay, R57. If another hole is present in the same column after R38 is picked up, the error relay will be energized and the machine will be stopped.

The circuit for energizing R37 is as follows: post 3, through fuse 7, relay common, through R37 coil, R38A N/C, DPBC entry hub, wire, read for gang punch and check brushes, hole in card, contact roll, common brush, R7A, P3, P4, P2, P1 to post 1.

This circuit picks up R37, closes the R37A points, and opens the R37B points. The opening of the R37B points prevents the energization of R57H coil when P35 makes.

R37 is held through R37A and P34 until 13.3 of the same cycle. R38 will not pick up as soon as R37A points close, because there is a shunt circuit around the R38 coil through the hole in the card and the CB's. When the CB's open, R38 will be energized through the R37 hold circuit.

R38A points then transfer and open the pickup circuit to R37 and set up a circuit to the R57P coil. If no other hole is punched in the same column, nothing further happens and no error is indicated. However, if another hole is sensed in the same column, after the foregoing circuits have been established, R57P will be energized as follows: post 3, fuse 7, R57P coil, R31BL, R38A N/O, hub, wire to read for gang punching and checking brushes, and out through hole in card to post 1.

R57 will then be held by its holding coil and R57A points until the reset push button is depressed. As the error light is in parallel with the R57H coil, it will light when the hold circuit is completed and remain lighted until the push button is depressed.

When R57 picks up, its R57B points open, and as soon as P19 opens, R10 will drop. This will open the circuit to the P-clutch magnets and to the HD1 motor relay, thus stopping the machine. The error light will also glow, indicating an error.

In case of a blank column in the units position, R37 will not pick up and the following circuit will be completed to pick up R57 when P35 makes at 12.2: post 3, through fuse 7, R57H coil (and error light in parallel), R37B, hub, jackplug, R31AL, R7BU, P35, to post 1.

R57 and the error light then remain energized through the R57A points until the reset push button is depressed.

The circuits are the same for any position other than the first. The circuits are designed so that an error in any one column will stop the machine.

As an optional feature, ten additional positions of double punch and blank column checking are available. When the additional ten positions are installed, relays 58 through 77 are used.

Group Multiplying

Group multiplying signifies multiplication of a group of cards by the same multiplier. The multiplier factor is punched in the first card of each group and is known as the *rate card* or *master card*. The rate card is identified by a 9 punching in any column. As the rate cards are interspersed in front of each group, the machine senses the approach of a new rate card by the 9 punching and clears the multiplier counter to allow a new rate to enter. Also the machine suppresses punching of the rate card during the cycle the rate card is passing the die. When checking, the machine must also suppress the checking operations when the rate card passes through the machine.

Relays 26 through 31 are the group multiplying relays. Relay 27 is a wire contact relay. This relay is used in this circuit because of its fast pickup. This relay must pick up between 9 time, when a hole is read, and 5 teeth past 9. To allow a sufficient safety factor the wire contact relay is used. The contacts on the wire contact relays are in line, and therefore the identification of the contacts is by contact number. Thus R27-3 indicates the number 3 contact on wire contact relay 27.

When it is desired to group multiply, the control panel switch labelled GRP MP is wired ON. This causes R26 to pick up and remain energized as long as the GRP MP switch is wired ON (Section 10B).

The R26BU points set up the circuit to the 9 pickup hub to control the pickup of R27. R26BL points transfer to place the screens of the multiplier or multiplicand read-in switch tubes (depending on the setting of the factor reversal switch) under the control of R27-2 points. R26A points transfer the control of the multiplier or multiplicand cancelling circuit (depending on setting of factor reversal switch) from P10 to P12 and the R27-3 points. A pentode can be blocked by opening the screen potential circuit. Use is made of this fact in controlling read-in to the counter containing the rate. When it is desired to block all entries to a counter, the screen potential circuit for the read-in switch tubes of that counter is opened.

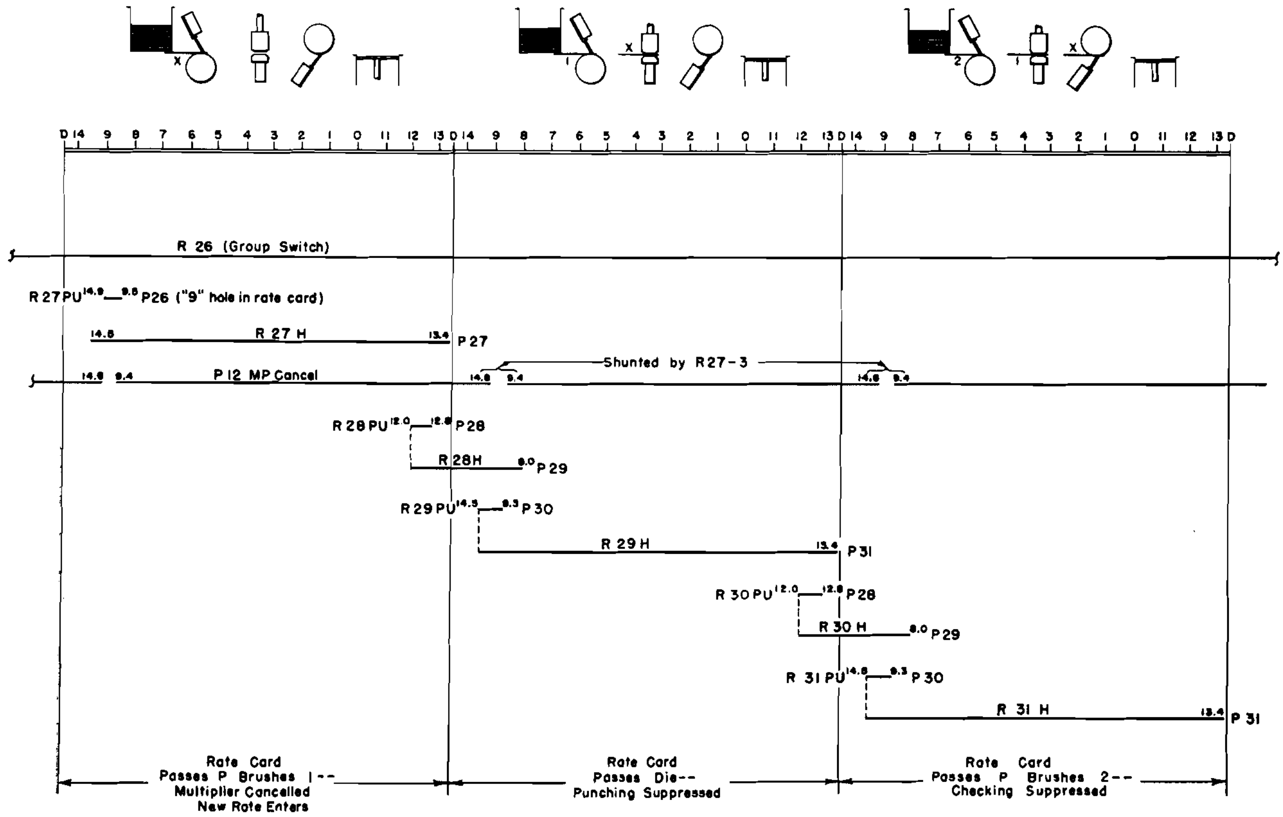


Figure 50. Sequence of Operation for Group Multiplication

To signal a rate card, a 9 is punched in a predetermined column and this card column is wired to the 9 pickup hub. Then when a 9 is read as the rate card enters the first set of brushes, a circuit is completed to pick R27 as follows: post 3, through fuse 7, relay common, R27P coil, R26BU, P26, 9 hub, control wire, brush hub, individual brush in first set of brushes, 9 hole in card, contact roll, common brush, R8B, CB's, to post 1. P26 allows only 9 holes to be recognized. R27 is then held through its R27H coil, R27-1 points, and P27 until 13.4 of the same cycle. The sequence of operations of the above and succeeding circuits for group multiplying is shown in Figure 50. This sequence chart should be studied carefully in connection with the group multiplying circuits.

In the following circuits it is assumed that the factor reversal switch is OFF and that the multiplier counter contains the rate (or group multiplier).

When R27 picks up, R27-3 points open and permit P12 to cancel the previous multiplier as P12 is open at this time. P12 is required in addition to P10 because the cancelling of the multiplier counter must be delayed until it has been determined whether or not the card entering the first punch brushes contains a 9. R27-2 points close to complete a circuit which provides screen potential to the tubes controlling multiplier read-in, and thus permit reading of a new factor into the multiplier counter. R27-4 sets up the circuit to R28P coil so that when P28 makes at 12, R28 is picked, and it holds through its R28H coil, R28A, and P29 until 8 of the next cycle. The R28B points set up a circuit to cause R29P coil to be energized when P30 makes at 14.5 of the cycle following the pickup of R28. R29 is held through its R29H coil, R29AU points, and P31 until 13.4 of the same cycle.

While R29 is energized, the R29AL points (Section 8B) are open to suppress the product read-out circuits so that no punching of the rate card from the product counter can take place.

R29BU points set up a circuit to pick R30 when P28 makes at 12. R30 then holds through its R30H coil, R30A points, and P29 until 8 of the following cycle. R30B points set up a circuit to R31 so that R31P is energized when P30 makes at 14.5 at the beginning of the cycle during which the rate card passes the second set of brushes. R31 then remains energized through this entire cycle through its R31H coil, R31AU points, and P31.

R31AL points open to suppress the blank column check circuits as the rate card passes the second set of punch brushes. R31B points open the circuit to R57P coil, thereby suppressing the double punch detection circuit.

As previously stated, the sequence of operations from the reading of the 9 hole in the rate card through the holding of R31 is shown in Figure 50. A careful study of this chart should provide a complete picture of the group multiplying operations.

Column Split, 0 and X, Hot 1

Two positions of column split are available as standard on this machine. R33 picks up each cycle when P33 makes from 0.2 through 12.2. Thus the 0-9 hubs of the column split are connected with the C hubs from 9 through 0, and the 11-12 hubs are connected with the C hubs for 11 and 12. This device permits an X or 12 punching over a 0-9 digit to be recognized independently or to be ignored.

The 0 and X hub provides a source for impulses at 11 and 0 time to punch *X's* or *0's* under the control of P32 cam contact (Section 7A). If only an *X* or *0* is desired, the 0 and X impulse is wired through a column split to separate the 0 from the X.

The Hot 1 hub provides a source for a 1 impulse under control of P20 cam contact (Section 7A). This may be used to punch 1's or to enter a 1 into the electronic counters for unit multiplication.

The hub labelled CB is a source for impulses at all index points. It is used primarily in connection with the distributor which is an optional feature.

Sign Control (Optional Feature)

As an optional feature, this machine is designed to handle either positive or negative factors. Negative factors are identified by an X punch. The X may be punched in any column to identify a negative factor. If *either* factor is negative, the result is negative. If *neither* factor, or *both* factors are negative, then the result is positive. Hence, it is obvious that an X must be punched in the card if either the multiplier or the multiplicand is negative.

The MCX and MPX hubs are wired to the first set of brushes. The MCX hub is wired to the brush in the column containing the X to identify a negative multiplicand, while the MPX hub is wired to the brush in the column containing the X to identify a negative multiplier. The PR X PCH hub is wired to the punch magnet corresponding to the card column in which the product X is to be punched. To make the sign control wiring effective the SIGN CTRL switch must be wired ON (Section 13B).

The objective of the sign control circuit is to sense a negative result and punch an X over the proper column to identify a negative product.

The general sequence of events for punching an X to identify a negative product is as follows:

1. R100 picks up at X time.
2. An X is sensed in either the MC or the MP field, and the corresponding sign control relay picks up.
3. The sign control relay is held until after X time and the sign delay relay picks up and is held through the next cycle when the card is in punching position.
4. At X time of the second cycle an X is punched to identify a negative product.

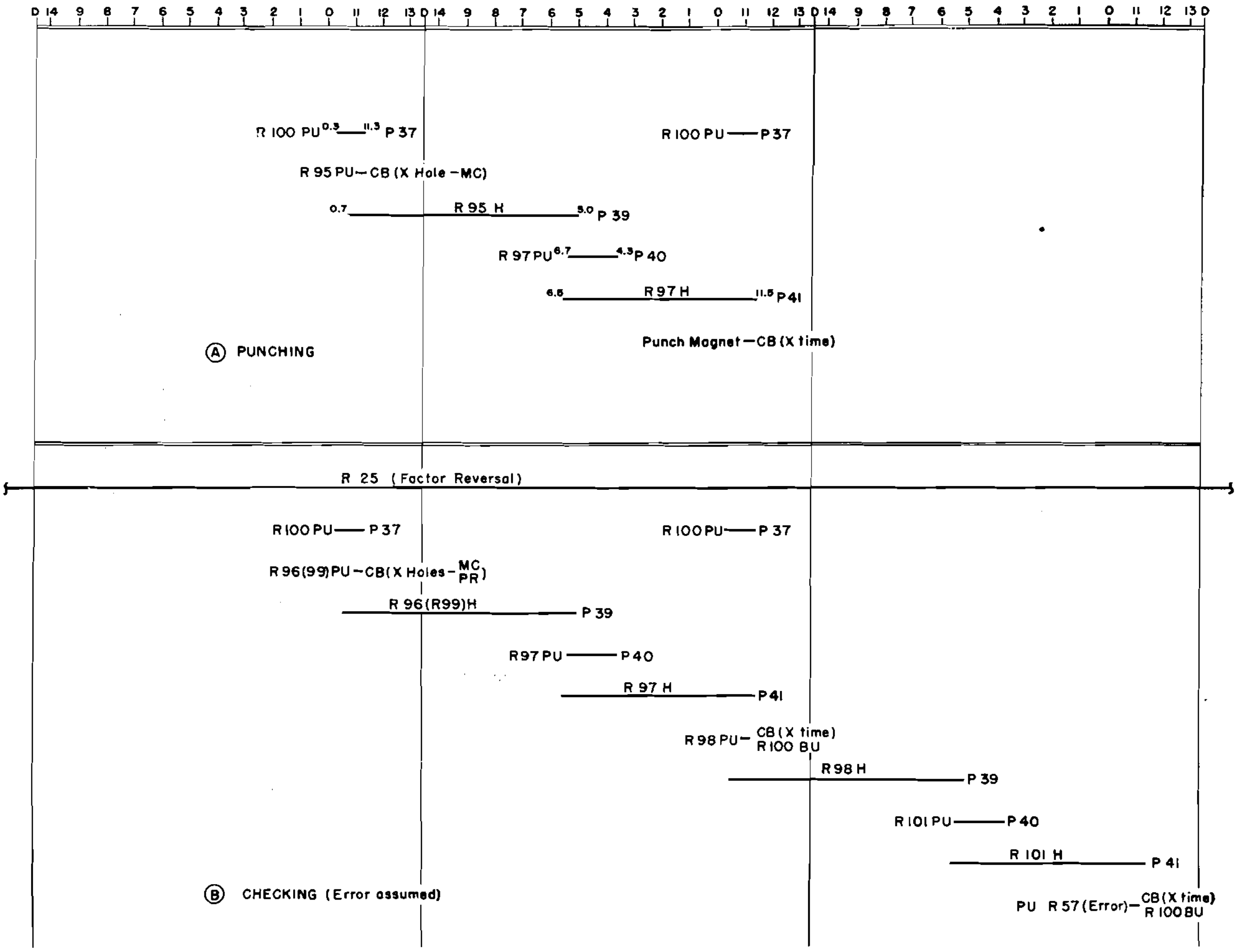


Figure 51. Sequence of Operations for Sign Control

The actual contacts and relays involved in this operation together with the timings are shown in sequence chart in Figure 51A.

The circuits traced in the order in which they operate are given below. R100 picks up at X time every cycle when P37 makes provided the SIGN CTRL switch is wired ON. The points of R100 control the pickup of all other sign control circuits.

Assuming an X in the multiplicand field, R95 will then pick up when the card passes the first set of brushes and the X hole is read. R96 would be energized if there were an X identifying a negative multiplier. R95 holds through its holding coil R95AU, and P39 until 5 of the following cycle, and R95B points set up a circuit to pick R97 when P40 makes.

The sign delay relay R97 is energized when P40 makes at 6.7 of the cycle following the reading of the X. Note that if *neither* or *both* R95 and R96 are energized, R97 cannot pick up. R97 is then held through its R97H coil, R97A points, and P41 until 11.5 of the same cycle. At X time of this cycle the punch magnet wired to PR X PCH is energized as follows: post 3, through R12B, punch magnet common, punch magnet coil, PUNCH hub, control panel wire, PR X PCH hub, R25AL N/C, R97B, R100BU, through CB's, to post 1.

For standardization it is recommended that the X identifying negative amounts always be punched in the units column of the field. In this manner a negative amount can always be spotted at a glance.

Sign control checking is accomplished by comparing X-punchings in the multiplier and multiplicand fields against X's in the product field. If the factors indicate a negative product and the product is not so identified (or vice versa), the machine will stop and indicate an error.

The only additional control panel wiring necessary for a checking operation is the wiring of the card column containing the product X to the PR X CHK hub from the first set of brushes. The X's for the multiplier or multiplicand are sensed through the MPX or MCX hubs. However, when checking, the factor reversal switch is ON and R25 is picked up; consequently the MPX and MCX hubs are reversed so that a multiplier X picks R95 and a multiplicand X picks R96.

In order to set up a given problem, assume an X punch in the multiplicand field only. The single X means that the product is negative and that an X should be punched. If for some reason the product X is not punched, the machine must detect this as an error.

The sequence of events involved in a sign check are shown on the chart in Figure 51B. Note that when an error is sensed, the machine is not stopped until the end of the cycle during which the card in error passes the second set of brushes.

The circuits are completed in the sequence in which they are traced below. Remember that R25 is energized during a check run and that R100 picks up at X time of each cycle under control of P37.

When the card passes the first set of brushes, the multiplicand X is read and R96 picks as follows: post 3, through fuse 8, R96P coil, R100AL, R25BL N/O MCX hub, control wire to hub of read for entry and control brushes, individual brush, X hole, contact roll, common brush, R8B, CB's, to post 1. R99 would be energized if the product X were punched. Since the assumption is that no product X is punched, R99 is not picked up. R96 holds through its R96H coil, R96AU points, and P39 until 5 of the next cycle. R96B points set up the circuit to R97P, which picks as follows when P40 makes: post 3, through fuse 8, R97P coil, R96B N/O, R95B N/C, R99B N/C, P40, to post 1. R97 holds through its R97H coil, R97A, and P41 until 11.5 of the same cycle. R97B sets up a circuit to R98P, so that at X time of this cycle, R98 is energized as follows: post 3, through fuse 8, R98P coil, R25AL N/O, R97B, R100BU, through CB's, to post 1. R98 holds through its R98H coil, R98AL, and P39; R98AU points set up a circuit to R101P so that R101 picks when P40 makes. R101 then holds until 11.5 through its R101H coil, R101A, and P41. R101B points set up a circuit to energize the error relay at X time as follows: post 3, through fuse 7, R57P coil, R31B, to R38A N/O, through R101B (Section 14B), R-100BU, CB's to post 1.

When R57 picks, its R57B points open, causing the machine to stop as previously explained. Also, the error light will glow to indicate an error.

Observe that if the X to identify a negative product had been punched, R99 would have picked and held through its R99H coil, R99A, and P39; then when P40 made, R99B would be transferred along with R96AL, and R97 could not pick up. If R97 does not pick up, nothing further happens in the checking operation. The R99B points in combination with the R95 and R96 points provide a means of completing a circuit to R97 for proper X punch and X-check control.

Since it is recommended that X's be punched over the units column of a field, it is necessary to suppress the X check when using the double punch check. This may be done by wiring the units column through the column split, so that only the 0-9 positions of the card column are checked for double punch.

Class Selectors (Optional)

Class selectors are optional features on this machine. If one class selector is installed, relays 80 through 86 are used. The second class selector

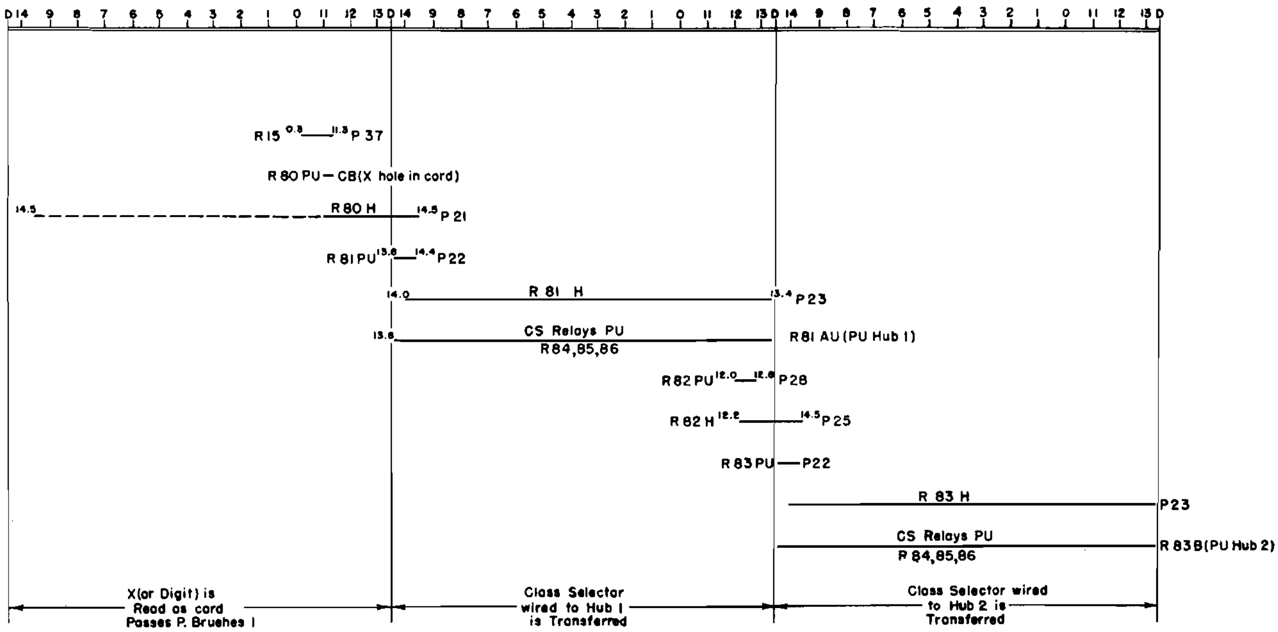


Figure 52. Sequence of Operation of Class Selectors

uses relays 87 through 93. The circuits will be traced for number 1 class selector.

The sequence of operation of the selector circuits is shown in Figure 52. This sequence should be carefully studied in connection with the circuits to enable a clear understanding of the circuits.

The selectors are arranged for either X or D pickup and for normal or delayed operation. If it is desired to transfer the selector during the cycle following the reading of the X, the C PLG hub is wired to the 1 hub. Wiring the C PLG hub to the 2 hub causes the selector to transfer during the second cycle following the reading of the X hole.

When an X is sensed at the first set of brushes, a circuit is completed to R80P through the X pickup hub and R15AL. R15AL allows only X's to be recognized by the X hub. If digit control is desired, the D hub is used to pick R80. R80 holds through its R80H coil, R80A, and P21 until 14 of the cycle following its pickup. At 13.6 of this same cycle, R81P is energized through R80B and P22. R81 holds through its R81H coil, R81AL, and P23 until near the end of the cycle. Then if the selector is wired to operate on this cycle, R84, R85, and R86 are energized through the R81AU points during this entire cycle. The points of R84 through R86 are the actual selector points, as indicated by the chart on the wiring diagram.

If the selector is wired to operate during the second cycle following the X, R83 must be energized before R84, R85 and R86 can pick up. At 12.2 of the first cycle following the X, R82 is energized through R81B and P28, and a holding circuit is completed through R82H coil, R82A, and P25 until 14.5 of the second cycle. At 13.6 of the second cycle, R83 is energized through R82B and P22. R83 holds through the entire second cycle through its R83H coil, R83A points, and P23. R83B points complete a circuit during this cycle to energize the class selector relays R84 through R86.

Distributor (Optional)

A conventional 12-segment distributor can be installed as an optional feature on this machine. The distributor can be used as a digit emitter by wiring the CB hub to the C hub of the distributor.

Any timed impulse from 9 through 12 is available at the distributor hubs labelled accordingly. The distributor can also be used as a digit selector by wiring from the brushes to the C hub of the distributor. Only the desired digit in any card column can be recognized by proper wiring of the 9-12 hubs of the distributor.

POWER SUPPLY CIRCUITS

Main Transformer and Selenium Rectifiers

Power is supplied to this machine by two transformers, the main transformer and the tube power supply transformer, which can be seen in the power supply circuit diagram (Section 3 for 115-230 volt A.C. operation and Section 4 for 115 volt A.C. operation). The main transformer is mounted directly behind the control panel. The only difference between the 115 volt A.C. transformer and the 115-230 volt A.C. transformer is that the latter has two primary coils. All following discussion will assume a 115 volt A.C. transformer. Three taps are provided in the primary to permit constant secondary output voltages at 105, 115, or 125 volt primary voltages. The secondary is provided with six taps to supply 115 volts A.C. for the tube filaments and to supply the selenium rectifiers which provide D.C. outputs of 40 volts and 140 volts. The 140 volt supply is the anode voltage supply for the 25L6 read-out power tubes in the electronic computing unit. The 40 volt supply furnishes the power for all relays and magnets in the punch unit which are usually supplied by a generator.

From the punch running circuits it will be remembered that when the main line switch is ON, the A.C. from the main line appears across posts 9 and 10 to pick up HD3 and HD4. The HD4 points in turn complete a circuit to the main transformer primary across the two 20 amp fusetrons. The circuit through the primary of the main line transformer is from post 8, through 20 amp fusetron 3, HD4 points, primary terminal 17, primary coil, terminal 19 (for 115 volt supply), fusetron 4, to post 7. The RMS or effective voltage produced at *full load* by transformer action between each of the secondary taps is shown in Figure 53. (RMS is the abbreviation for the root mean square value of alternating current or voltage, also called "effective value." It is the square root of the mean values of the squares of the instantaneous values taken over a complete cycle.) All tube filaments in the electronic computing unit are heated by the 115 volt A.C. between terminals 13 and 14. The filament supply uses cable connectors CNp18 through CNp20 and CNp38 through CNp40. Three connectors are used on each side to distribute the load. It is advisable to adjust the primary tap so that the filament supply is approximately 110-115 volts. Although the tubes will require slightly longer to heat, their life will be considerably longer. A 15% increase in voltage will reduce the life of the tubes 30%.

40 volt D.C. is supplied by the full-wave selenium rectifier across terminals 11 and 12. This rectifier is mounted on the right end gate. The center connection of the selenium rectifier is the positive connection while the transformer center tap between terminals 11 and 12 (terminal 15) is the negative connection. Terminal 15 serves as the reference point for *all* voltages, i.e., it is the point of zero reference and is the ground connection. Four 2000 mfd, 40 volt electrolytic capacitors connected in parallel act as the filter for the 40 volt supply. These capacitors are mounted on the lower section of the left end gate. Post 1 and post 3, which are the 40 volt terminals, are connected across the 2000 mfd capacitors.

The actual D.C. voltage produced at the output terminals is greater than the A.C. voltage at the transformer secondary because the capacitors charge to peak voltages. The actual D.C. voltage is equal to the peak voltage of the A.C. ($\sqrt{2}$ times the RMS voltage) minus the voltage drop across the selenium rectifier stack, which is approximately 6-10 volts at full load.

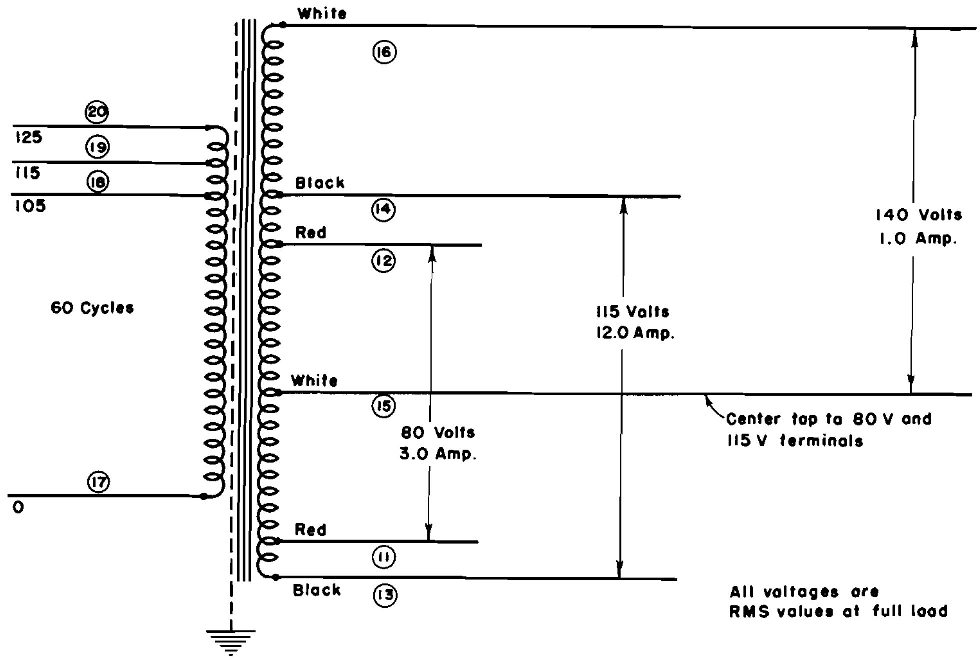


Figure 53. Main Transformer

140 volt D.C. is supplied by the half-wave selenium rectifier connected to transformer terminal 16 through R4B contacts. The purpose of R4 was discussed in connection with the start and bias interlock circuits. A half-wave rectifier is sufficient for this supply because of the very light load. The two 200 mfd 200 volt electrolytic filter capacitors in parallel are able to maintain a fairly constant supply with the light load on this line. A 5000 ohm bleeder resistor is connected across the capacitors to maintain a minimum current flow and thus prevent the high peak voltages which would exist at very light or no load. With this bleeder resistor, better voltage regulation results. All the components for the plus 140 volt supply are mounted on the left end gate.

Tube Power Supply Chassis

The tube power supply chassis contains all components enclosed in the dash-dotted section in Section 4 of the main wiring diagram. The tube power supply transformer for 115 volt A.C. operation is provided with taps on the primary in 5-volt steps to permit constant secondary output voltages at primary voltages of from 100 volts to 125 volts. The taps are connected through a tap switch to post CH10 and to post 10. The extreme right-hand setting is the 100 volt tap. When the tap switch is set to the extreme left-hand setting, the transformer primary is disconnected. The tap switch is mounted on the power supply chassis and is accessible from the front of the machine by lowering the left front cover.

Note that the circuit to the transformer primary passes through the HD2 contacts. The operation and purpose of this relay was discussed in connection with the time delay circuits. The circuit through the primary is from post 9, through HD2 contacts, post CH7, primary coil, tap switch, post CH10, to post 10. The secondary of the transformer is in two equal sections, one delivering 388 volts RMS approximately, and the other approximately 364 volts RMS. These values vary with the setting of the tap switch. Each section is centered-tapped to allow full-wave rectification. The upper section shown on the circuit supplies

$+150$ volts for the anode voltage and -250 volts for bias voltage, while the lower section supplies -100 volts for bias voltage. A voltage regulating circuit is provided between the $+150$ volt and the -100 volt lines to maintain a constant ratio between anode and grid voltages. This circuit will be discussed shortly.

The tube power supply transformers along with the rectifiers and chokes are shown in Figure 54. Note that all transformers are supplied with grounded electrostatic shields, indicated as dotted lines between the primary and secondary windings in Figure 54. The purpose of these electrostatic shields is to prevent any high frequency transients in the A.C. line from being passed to the secondary through the capacity coupling between windings. With these shields any transients are by-passed to ground.

Full-wave rectification to obtain $+150$ volts and -100 volts is accomplished by directly heated, gas filled, twin diodes. Heater current is supplied to both rectifier tubes by a separate filament transformer as shown in Figure 54. The chokes are connected to the center taps of the corresponding filament transformer secondaries to provide a more nearly constant output.

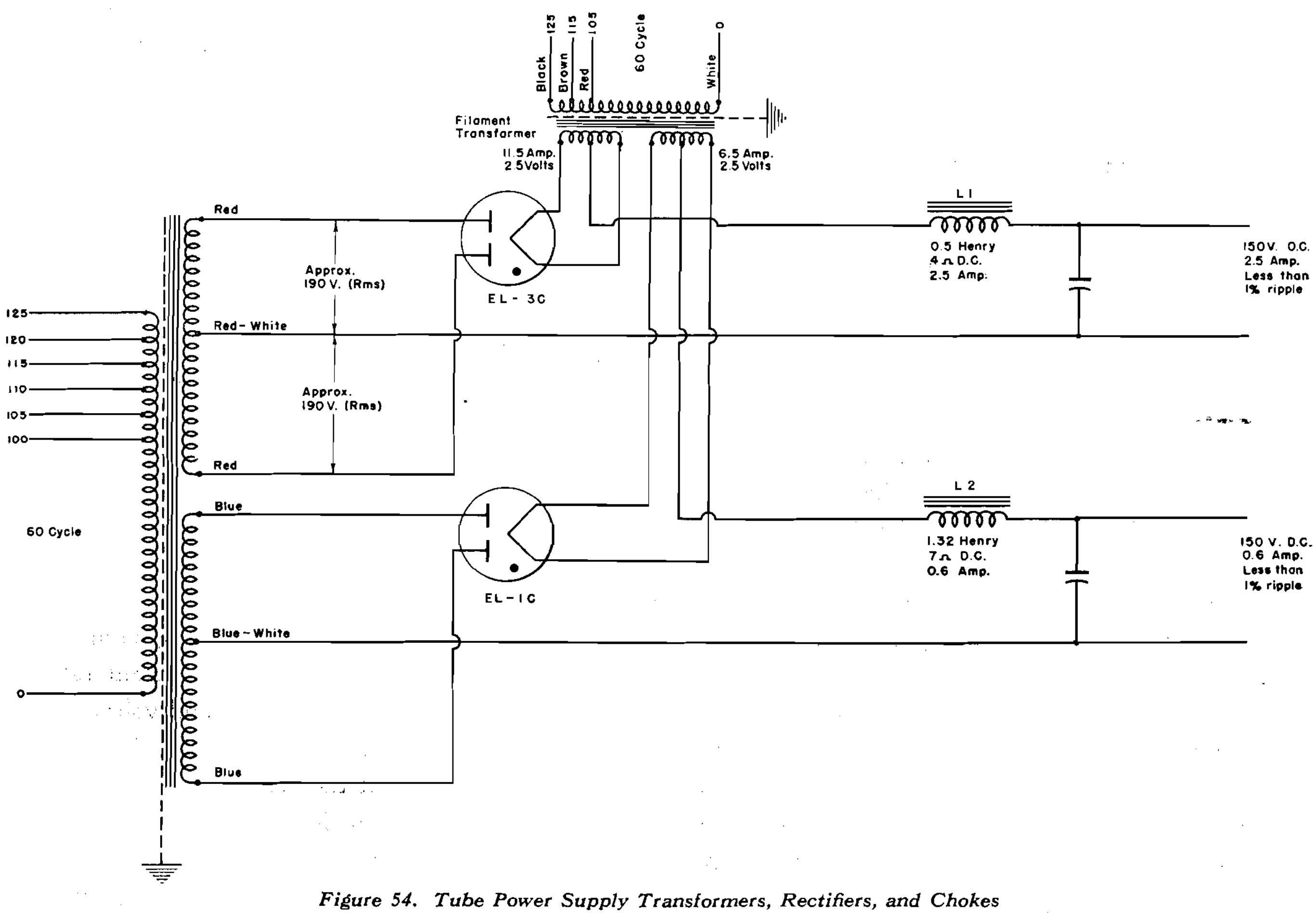


Figure 54. Tube Power Supply Transformers, Rectifiers, and Chokes

The anode supply rectifier is a type EL-3C directly heated twin diode manufactured by Electrons, Inc., of Newark, N. J. The –100 volts bias supply rectifier is a type EL-1C. Both are xenon filled and have an internal drop of approximately 12 volts when conducting. Characteristics of these tubes are shown below:

	Type EL-1C	Type EL-3C
DC Current (Maximum Rated Output)		
Continuous	1.0 ampere	2.5 amperes
Surges (3 seconds or less)	1.5 amperes	3.7 amperes
Oscillograph peaks (continually recurring)	4.0 amperes	10.0 amperes
Peak Inverse Voltage (maximum instantaneous)	725 volts	725 volts
A.C. Volts per Anode	12-250 volts	12-250 volts
Tube Drop	12 volts	12 volts
Filament Voltage	2.5 volts	2.5 volts
Filament Current	6.5 $\pm$0.5 amperes	11.5 $\pm$1.0 amperes

To provide the best voltage regulation, choke input filters are used in the +150 volt and –100 volt lines. The ratings of the chokes and capacitors are shown on the circuit diagram and on Figure 54. The chokes L1 and L2 are mounted beside the power supply transformer. Choke L3 and all capacitors are mounted under the chassis and are accessible only when the chassis is removed.

The purpose of the 0.1 mfd capacitor across the electrolytic capacitors is to protect the electrolytics by by-passing high frequency transients. Electrolytic capacitors by their nature do not readily pass high frequencies.

Note that the output across the filter capacitors of both the +150 volt line and the –100 volt line is 150 volts D.C. This is arrived at by subtracting the voltage drop across the rectifier tube and across the choke from the RMS voltage across one-half the secondary and converting the resulting RMS voltage to *average* voltage, since the filter capacitors charge to the *average* voltage when a choke input filter is used. (RMS voltage = 0.707 peak voltage, and average voltage = 0.636 peak voltage.) To obtain 100 volts for the –100 volt line, the voltage ratio regulator circuit provides a regulated 50 volt drop.

Before discussing the voltage regulator, the rectifier circuit for the –250 volt bias supply will be discussed. The load on this line is very light and consequently a vacuum tube is used. The tube used is a type 25Z6 twin diode. Note in Figure 55 that the cathodes of the 25Z6 are connected across the upper section of the transformer secondary. It is necessary to reverse the connections in this case because the output from this rectifier must be negative with respect to ground, and the same common ground as the +150 line is used. Since the load is very light on this line (approximately 10 ma), satisfactory voltage regulation can be obtained with a capacitor input filter. In this manner a higher output voltage can be obtained since the capacitors charge to peak voltage. This is necessary in this case because only about 190 volts RMS are available at the transformer yet 250 volts D.C. are needed at the output. The 50,000 ohm resistor across the 16 mfd electrolytic capacitors serves the usual function of a bleeder resistor, i.e., to maintain a minimum current and thus prevent excessively high peak voltages across the capacitors. All the components for this rectifier are mounted under the chassis and are accessible only by removing the chassis.

In order to provide an adjustment of the –250 volt supply, a rheostat is mounted between the anodes of the 25Z6 and the choke L3. By adjusting the amount of voltage drop across the rheostat, the output can be maintained at –250 volts. The rheostat adjusting knob is accessible through a hole at the rear of the power supply chassis.

Constant Ratio Voltage Regulator

The purpose of the voltage regulating circuit in the –100 volt line is to maintain a constant ratio between the anode voltage and the grid voltage. It is very important in the operation of the electronic computing section that the same relation be maintained between the anode voltage and the grid voltage. If the anode voltage drops sharply owing to a suddenly applied load, the bias voltage must

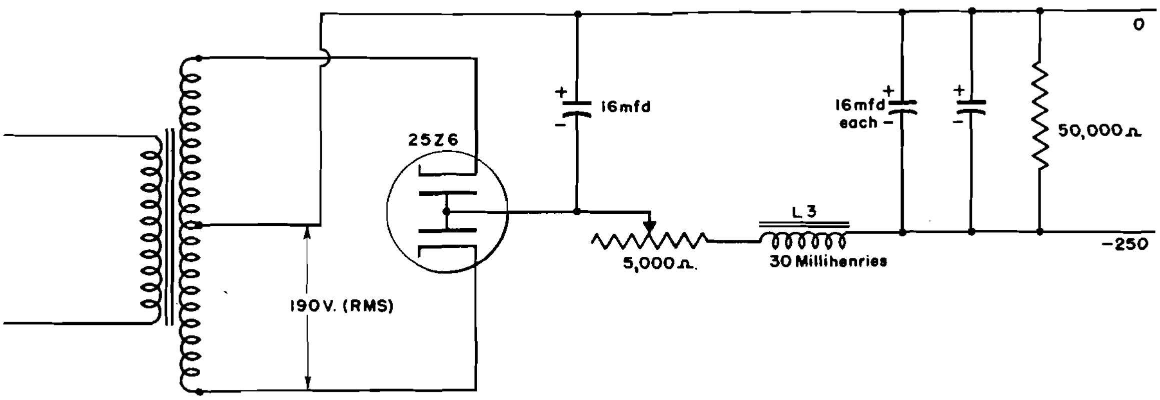


Figure 55. Schematic of -250 Volt Rectifier Circuit

be made less negative to compensate for this. Any increase in anode voltage requires a more negative bias voltage. If the A.C. supply voltage changes, both anode and grid bias voltages change, and the regulation circuit merely adjusts for the proper ratio between the two.

Note that a resistor network consisting of a 36,000 ohm resistor, a 10,000 ohm potentiometer, and a 20,000 ohm resistor is connected between the +150 volt and the -100 volt line. Also note that a 10,000 ohm resistor by-passed by a 0.1 mfd capacitor is connected across the -100 volt terminals. The 10,000 ohm resistor serves as a bleeder for the -100 volt line, and the 0.1 mfd capacitor serves as a by-pass across the -100 volt line for high frequency transients. The regulator tubes consist of three type 25L6 beam power tubes connected in parallel between the filter output and the ground line.

The bias voltage is originally adjusted at -100 volts by the potentiometer. The adjusting knob of the potentiometer is accessible from the rear of the machine through a hole in the rear of the chassis. The 3,300 ohm screen grid resistors and the 10,000 ohm control grid resistors are both current limiting resistors and do not enter into the operation of the regular circuit other than to stabilize the tube operation. Observe that the screen grid resistors are tied to the +150 volt line. This arrangement provides increased current through the 25L6's. Note that the heater filaments of all 25L6's along with the heater for the 25Z6 rectifier are connected in series across post 12 and post 13. 100 volts A.C. is available across these terminals of the main transformer. All components of this regulator circuit except the tubes are mounted under the chassis and are accessible only if the chassis is removed.

In order to simplify the explanation of the regulator circuit, a schematic drawing showing only the essential elements is illustrated in Figure 56. The output from the filters is represented by batteries of the corresponding polarity, and the three 25L6's have been replaced by a single triode. In this circuit the tube acts as a variable resistance controlled by the grid voltage. The value of tube resistance is varied so as to maintain the proper voltage across the -100 volt line at all times. The voltages existing, together with polarities, are shown in Figure 56 when all conditions are normal. The voltage drops across R_1, P, and R_2 can be computed by determining the current flow through the resistors, then calculating the IR drop across each. Or the voltage drops may be computed by the ratio of resistors as follows:

$$E_{R1} = 250 \times \frac{R_1}{R_1 + P + R_2}, \text{ etc.}$$

For sake of illustration, it is assumed that the tap on the potentiometer is set so that there is a 95 volt drop from the -100 volt line to the grid.

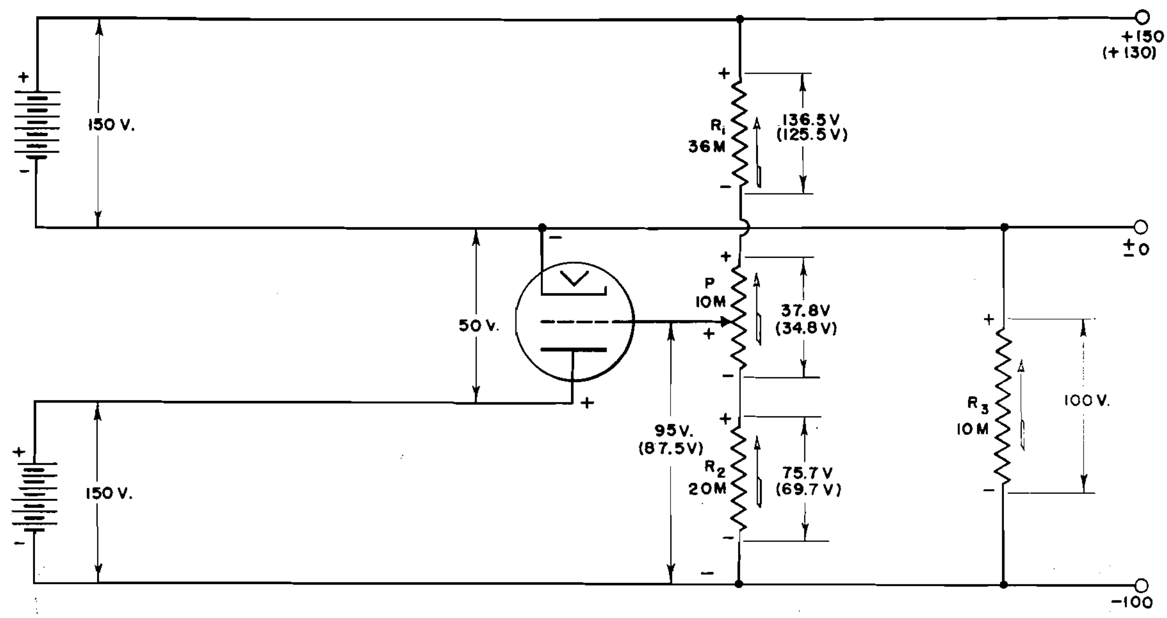


Figure 56. Schematic of Voltage Ratio Regulator Circuit

Because of the polarity of the IR drop across the resistors, this 95 volts can be subtracted from −100 volts to obtain the grid potential (cathode is at ground potential, or at zero potential). This means that the grid is at −5 volts, and sufficient current flows through the tube to provide a 50 volt drop in the line. This 50 volts subtracts from the battery voltage of 150 volts and leaves 100 volts across the −100 volt line. As long as conditions remain normal, nothing further happens.

Assume now that a heavy load is suddenly applied across the +150 volt line. The tendency will be to drop the voltage across this line. The job of the regulator is then to make the −100 volt line less negative to compensate for the drop in anode voltage. For sake of analysis assume the anode voltage drops to +130 volts as indicated in parenthesis. Then the new voltage drops across the resistors on the basis of 230 volts across the network are shown in parenthesis. This change will produce a voltage of −12.5 volts at the grid (100 − 87.5), and the current through the tube will be considerably decreased. The decrease in current means an increased voltage drop across the tube. An increased tube drop leaves less voltage across the −100 volt line, thus producing the desired result. Another way of looking at this is that the decreased tube current results in a decreased IR drop across R_3 which is across the −100 volt line.

Of course the operation will be reversed if the anode voltage increases. If both anode and grid voltages change owing to variations in the A.C. supply, the regulator again adjusts for the proper ratio between the two. An analysis in this case is more difficult, but the end result is the same.

The circuits shown outside the chassis on the main wiring diagram have already been discussed in connection with the punch unit circuits.

Screen Grid Supply

Although it is not included in the power supply chassis and not shown in the punch circuit diagram, there is a separate +65 volt supply for the screen grids of all tetrodes and pentodes in the electronic computing unit. This power supply is located on the B chassis (Section 30B), and the circuit is shown in Figure 57. It was necessary to place this power supply on the B chassis because the original design did not call for a +65 volt supply. When it was decided that this supply was

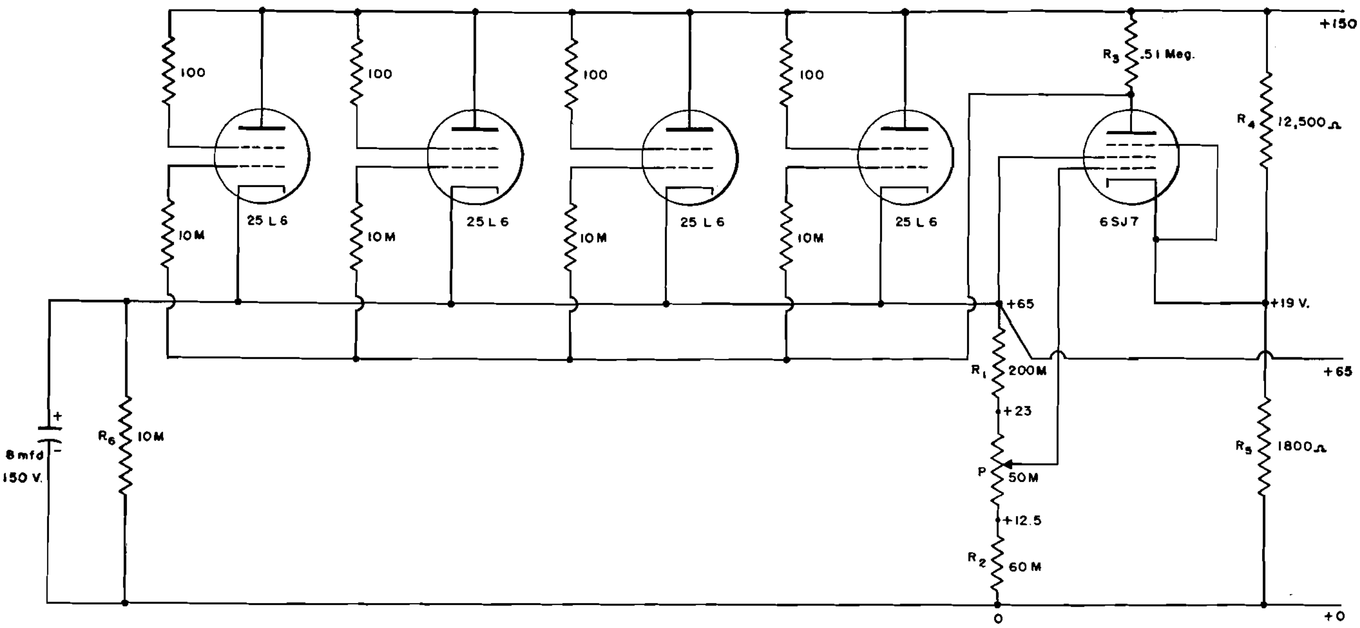


Figure 57. +65 Volt Supply

necessary, there was no room on the power supply chassis for the additional tubes and components.

The +65 volt supply is in reality a voltage regulator circuit. Since +150 volts were already available in the machine when this supply was added, the easiest method of obtaining +65 volts was by means of a voltage regulator circuit which provided an 85 volt drop across the 150 volt line. This provided a 65 volt supply between the ground line and the cathodes of the regulator tubes. In order to provide a constant voltage, a voltage regulating circuit under the control of a 6SJ7 pentode is provided. The operation of this circuit follows:

A study of the circuit in Figure 57 will reveal that four type 25L6 beam power tubes are connected in parallel between the +150 volt line and the +65 volt line. Four tubes are necessary to handle the current requirements of this supply. Obviously, there must be an 85 volt drop across these tubes. Since the D.C. voltage drop across a vacuum tube varies with the amount of current passing through it, it is necessary to regulate the amount of current so that the proper anode current flows at all times to maintain this 85 volt drop. This is done by adjusting the grid potential of the 25L6's. Note that all the grids are connected together to the anode of the 6SJ7 pentode. Any change in anode current through the 6SJ7 will produce a change in potential at its anode owing to the change in IR drop through the anode resistor. Any change in potential at the anode of the 6SJ7 will be felt at the grids of the 25L6's. Consequently, by adjusting the current flow through the 6SJ7, the current flow through the 25L6's can be adjusted. This provides a means of obtaining very close control, since the 6SJ7 has an extremely high amplification factor. A very slight change in grid potential on the 6SJ7 will produce an appreciable change in grid potential at the 25L6's.

The grid of the 6SJ7 is normally biased at approximately −1 volt by means of the potentiometer. This setting provides the proper potential on the 25L6 grids to provide +65 volts between ground and the 25L6 cathodes. This 65 volt potential is maintained at a constant value as follows:

The voltage divider R_4 and R_5 provides a voltage drop of 19 volts across R_5, thus placing the cathode of the 6SJ7 at +19 volts. Between the ground line and the +65 line there is a resistor network consisting of resistors R_1 and R_2 and potentiometer P. The voltage at the top of each component is shown in Figure 57. As previously shown, these values are easily computed by the ratio of resistances. The voltage at the top of R_2 is +12.5 volts and at the top of P is +23 volts; hence by adjusting the potentiometer tap, the grid can be set anywhere from +12.5 volts (–6.5 volts with respect to cathode which is at +19 volts) to +23 volts (+4 volts with respect to cathode). This adjustment is made only once when the 65 volt supply is being adjusted to the line voltage. Thereafter adjustment is automatic. Assume, for example, that the +150 volt line tends to drop in voltage. This will in turn reduce the voltage across the 65 volt supply, meaning a lower voltage drop between ground and the tap on potentiometer P. Less voltage at this tap means a more negative grid on the 6SJ7, since the cathode remains at essentially +19 volts at all times. The more negative grid means a decreased anode current with a consequent reduction in IR drop across R_3, the anode resistor of the 6SJ7. A lower IR drop across R_3 means a less negative voltage at the anode of the 6SJ7. This is the voltage of the 25L6 grids; hence the 25L6 grids will be less negative than before and more anode current will flow with the consequent reduction in drop across the 25L6's and increase the 65 volt line. In this manner the 65 volt supply is restored to its proper value.

Any change in the opposite direction will make the 6SJ7 grid more positive which, in turn, will make the 25L6 grid more negative. This will increase the drop across the 25L6's and again 65 volts will be maintained across this supply.

The 100 ohm screen grid resistors in the 25L6 circuits are current limiting resistors. Low values were selected to allow maximum current without damage to the screen grids. The 10,000 ohm control grid resistors are also current limiting resistors. These resistors also provide more stable tube operation. The 8 mfd capacitor across the 65 volt line serves as a filter with the 10,000 ohm resistor R_6 as its bleeder. R_6 serves the purpose of a dummy load in case the operating load is removed. An extremely high resistance is used at R_3 in the anode circuit of the 6SJ7 to provide very close control. A very slight change in anode current produces a large change in voltage drop across R_3. For example, a *1 micro-ampere* increase in anode current increases the IR drop across R_3 by 5 volts.

NOTE: The 6SJ7 may be replaced by a 6SK7 in an emergency. A slight readjustment of the potentiometer may be necessary.

On some early models the 12,500 ohm resistor, which is part of the voltage divider which establishes the cathode potential of the 6SJ7 tube B-26 (Section 30B on wiring diagram) is a 0.5 watt carbon resistor. The load across this resistor is considerably more than 0.5 watt, consequently this resistor overheats and changes in value, thereby causing fluctuations in the +65 volt supply. This carbon resistor should be replaced by a 12,500 ohm, 5 watt, wire-wound resistor as indicated on the wiring diagram.

Voltage Adjustments

When it is desired to adjust the voltage supplies, a definite procedure should be used to insure that one change does not affect the other. First, the filament voltage should be checked for 110-115 volts. If a change is necessary, the voltage tap on the main transformer primary can be moved to either post 18, 19, or 20. The series filament strings are designed for approximately 113 volts, but a slightly lower voltage will considerably increase the life of the tubes. However, a slightly longer time must be allowed for the tubes to heat. Changing the primary tap on the main transformer will change the voltage output from the selenium rectifiers slightly, but these voltages are not critical and are usually higher than necessary.

The first adjustment in the tube power supplies is the +150 volt supply. This output is adjusted by varying the position of the tap switch in the primary of the power supply transformer. By varying the position of the tap switch, the voltage across the secondary is changed. Since the voltage drop across the tube and the choke does not vary to any extent, any change in the secondary voltage will result in a change in the +150 volt line. 147 to 152 volts are acceptable.

After the +150 volt line is adjusted, the bias voltages may be adjusted in any order. The −100 volt line and the −250 volt line are both adjusted by means of potentiometers. Both potentiometers are accessible from the rear of the power supply chassis. The +65 volt supply is also adjusted by means of a potentiometer in the B chassis.

PRINCIPLE OF MULTIPLYING

Multiplication is performed in this machine by over-and-over addition of the multiplicand factor. The value of the multiplier digit determines the number of times that the multiplicand is to be added into the product counter. The order of the digit (i.e., units, tens, etc.) determines which positions of the product counter will receive the multiplicand factor and also during which column shift cycle the adding will take place. An example of multiplication by over-and-over addition is shown in Figure 58. Observe that no adding occurs in the 12th position of the product counter; this position is reserved for carry-overs. This method of multiplication is the simplest possible since only three counters are required. This method is not feasible for mechanical machines, because the time required to complete a problem is too great. However, electronic addition is so rapid that it permits use of this simple method. The time required by the electronic unit to complete a problem by this method corresponds to slightly over one-half a cycle point of mechanical movement of the card through the punch unit.

Observe that the column shifting is performed in the reverse order to that customarily done when multiplying by hand. The order of column shifting is immaterial, as the final result will be the same regardless of the order in which the multiplier factors are taken. In the 603 multiplier, column shifting is from the 6th multiplier position to the first simply because the earliest engineering model required it. When changes were made which no longer required reverse column shifting, it was felt that it was not feasible to make the necessary circuit changes to establish normal column shifting.

Note from Figure 58 that no addition occurs during column shift cycles in which the multiplier is 0. Mechanical machines usually have some arrangement to test for 0's so that all multiplier positions containing 0 may be skipped. This complicates the machine but saves time. Where time is not a factor, this unnecessary complication may be eliminated by completing all the column shift cycles regardless of the value of the multiplier digit. This is done in the 603 electronic computing unit; six column shift cycles are taken for every multiplication regardless of the value of the multiplier.

Also observe from Figure 58 that the multiplicand is added into the product counter as many times as the value of the multiplier digit by which multiplication is taking place. This means that during any given column shift cycle, the multiplicand may have to be added as many as 9 times. Again, to avoid unnecessary complications a fixed number of adding cycles are taken each column shift cycle regardless of the value of the multiplier digit. In the 603 computing circuits ten adding cycles are taken during each column shift cycle rather than nine for reasons explained later. This means that each multiplication consists of six groups of ten adding cycles, or a total of 60 adding cycles.

The computing section of the 603 multiplier is arranged so that a definite number of voltage pulses represent an adding cycle. For an analogy to a mechanical machine, one pulse may be considered as one cycle point of the basic adding cycle. The basic adding cycle consists of 16 pulses; 10 are reserved for adding, 4 for carrying, and the other

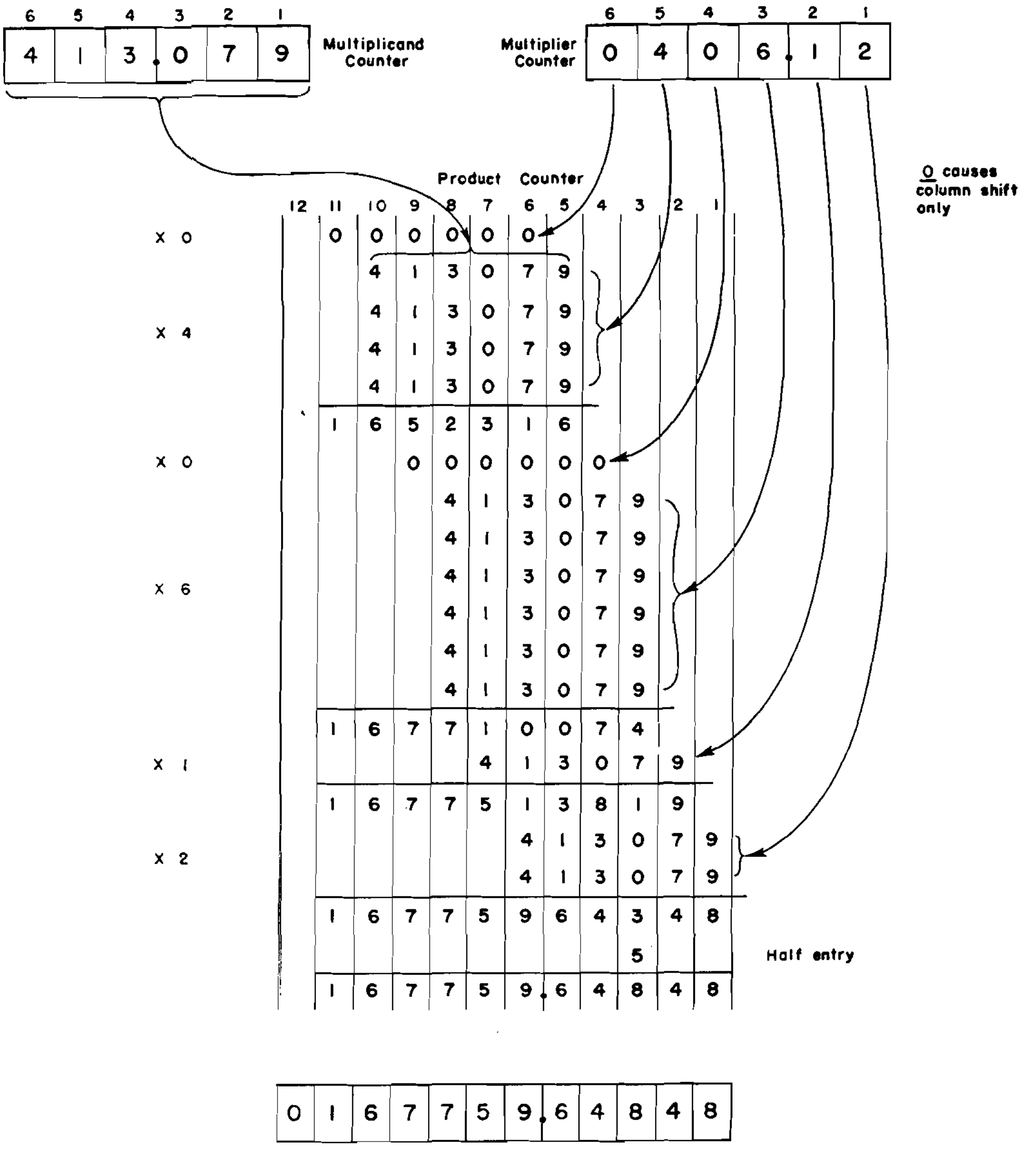


Figure 58. Principle of Multiplication

2 for setting up certain circuits. It is obvious then that one multiplication will require a total of 960 pulses, since there are 60 adding cycles of 16 pulses each. In order to establish these cycles electronically it is necessary to provide pulse counters. Three of these pulse counters are provided—one to count pulses and establish the basic adding cycle; one to count adding cycles and determine when to column shift; and one to count column shift cycles. These three pulse counters are called the primary timer, secondary timer, and tertiary timer. Figure 59 is a block diagram showing the operation of the three timers in schematic form. A careful study of Figure 59 is essential for proper understanding of the electronic cycle. All pulses for the electronic computing operation are generated by a multivibrator which is an oscillator generating essentially square waves of 35,000 cycles per second frequency. The multivibrator generates pulses continually as long as the power is ON,

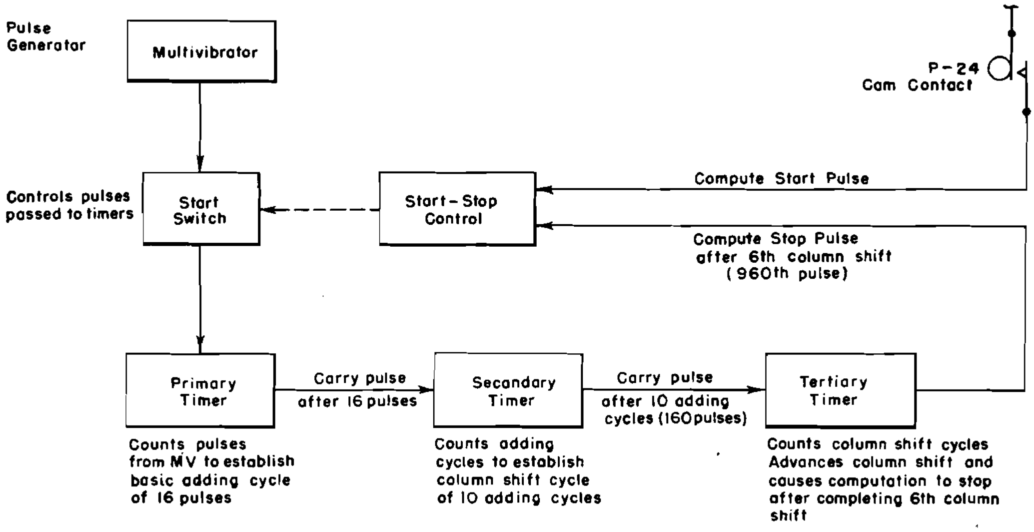


Figure 59. Block Diagram of Timers

but these pulses cannot pass to the timers until permitted by the electronic start switch. The start switch is controlled by an electronic start and stop control which opens the switch and closes it. For an analogy, the electronic switch may be visualized as a valve. An open switch permits pulses to pass while a closed switch prevents passage of pulses. After the factors are read into the counters from a card passing the entry brushes, the compute start contact P24 makes (at 11.5 on the punch index) to start computing. This is done by opening the start switch and permitting pulses to pass to the electronic timers (or pulse counters). On every 16th pulse entering the primary timer, a carry pulse is passed to the secondary timer which advances 1 to indicate that one adding cycle has been completed. When 10 adding cycles are completed, the secondary timer carries, and a pulse is passed to the tertiary timer to signal a column shift. When 6 column shift cycles have been completed, a pulse from the tertiary timer passes to the compute stop control, and the start switch is again closed, thus stopping the pulses from passing to the timers after 960 pulses have been counted and indicating the completion of the problem. This entire operation requires only 27 milliseconds during which time the punch index moves 6 teeth.

As an example of the multiplication operation, 4 x 8 may be used as a problem. The multiplier 4 indicates that the multiplicand 8 is to add into the product counter 4 times. The 8 in the multiplicand counter indicates that the product counter is to receive 8 impulses during each of four adding cycles for a total of 32 pulses.

Figure 60 indicates the machine operation in schematic form. Since the only digit in the multiplier is in the units position, not until the sixth column shift cycle will there be signals to cause addition in the product counter. Then during the sixth column shift, 8 pulses are added into the product counter during each of the last four adding cycles. Observe that the machine goes through all adding cycles and all column shift cycles even though addition occurs only during the last four adding cycles of the last column shift cycle.

For a more complete illustration, the same problem shown in Figure 58 is worked out in detail in Figure 61, showing all the adding cycles through which the machine goes to complete one multiplication. Notice that during the entire first column shift cycle consisting of ten adding cycles no adding takes place because there is a 0 in 6th position of the multiplier. During the second column shift cycle the multiplicand is added into the product

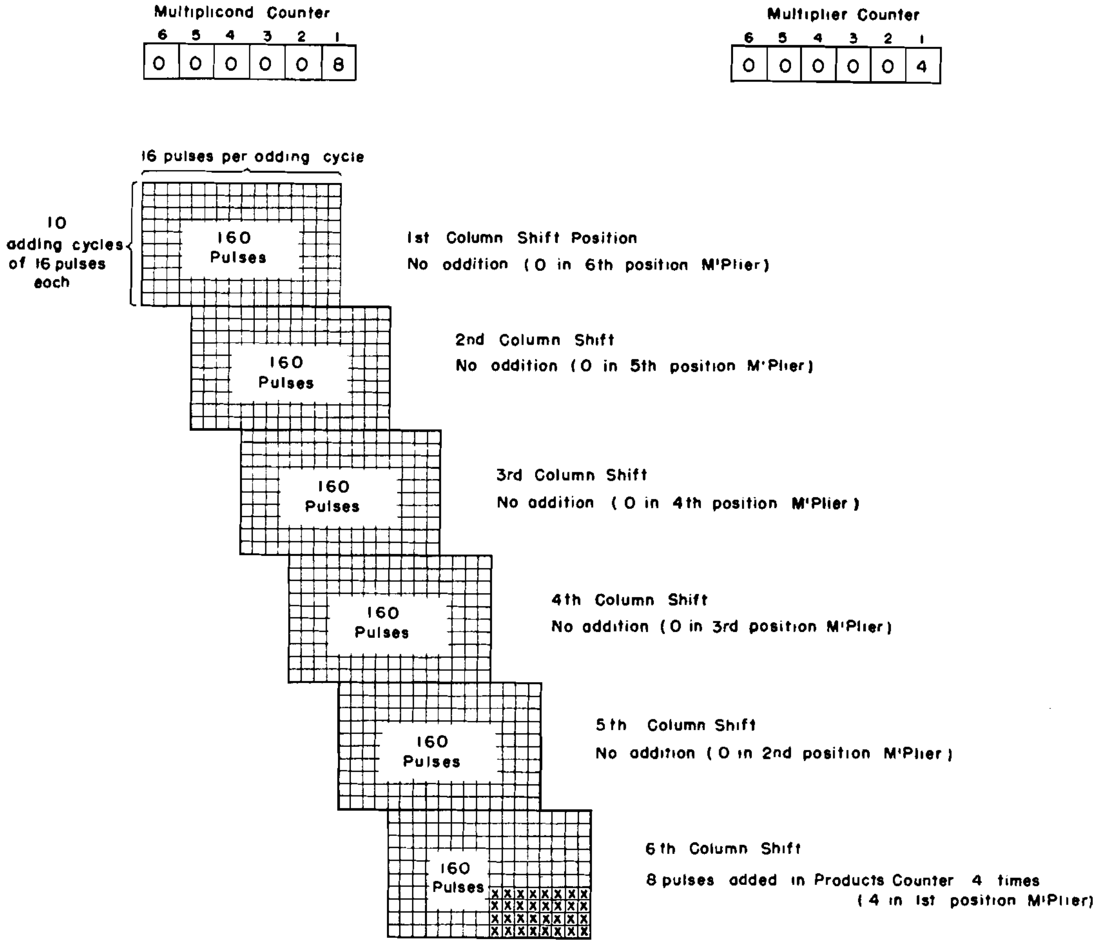


Figure 60. Block Diagram of Multiplication by Over-and-Over Addition

counter only during the last four of the ten adding cycles, because the multiplier digit in the 5th position is a 4, etc.

If half-entry is being used, a 5 is added into the proper position of the product counter during the first adding cycle of the last column shift cycle. Observe that except for half-entry, no adding takes place in the products counter during the first adding cycle of each column shift. One reason for having ten adding cycles in each column shift cycle is to permit half-entry during a cycle when no other addition is taking place.

Figure 61 indicates how the machine determines the number of times to add the multiplicand amount in the product counter during any given column shift. One position of the multiplier is advanced 1 during each adding cycle. Since there are ten adding cycles in each column shift, each position will advance through 0 and back to where it started. When the counter position goes from 9 to 0, a signal is provided to start adding the multiplicand on the next adding cycle and to continue through the tenth adding cycle. Figure 61 shows this operation for all six column shift cycles. There are no carry circuits in the multiplier counter; hence adding ten pulses to each position will return the counter to its original reading. The chief reason for having ten adding cycles in each column shift instead of nine is to permit restoration of the counter to its original reading at the completion of a multiplication. This is necessary when group

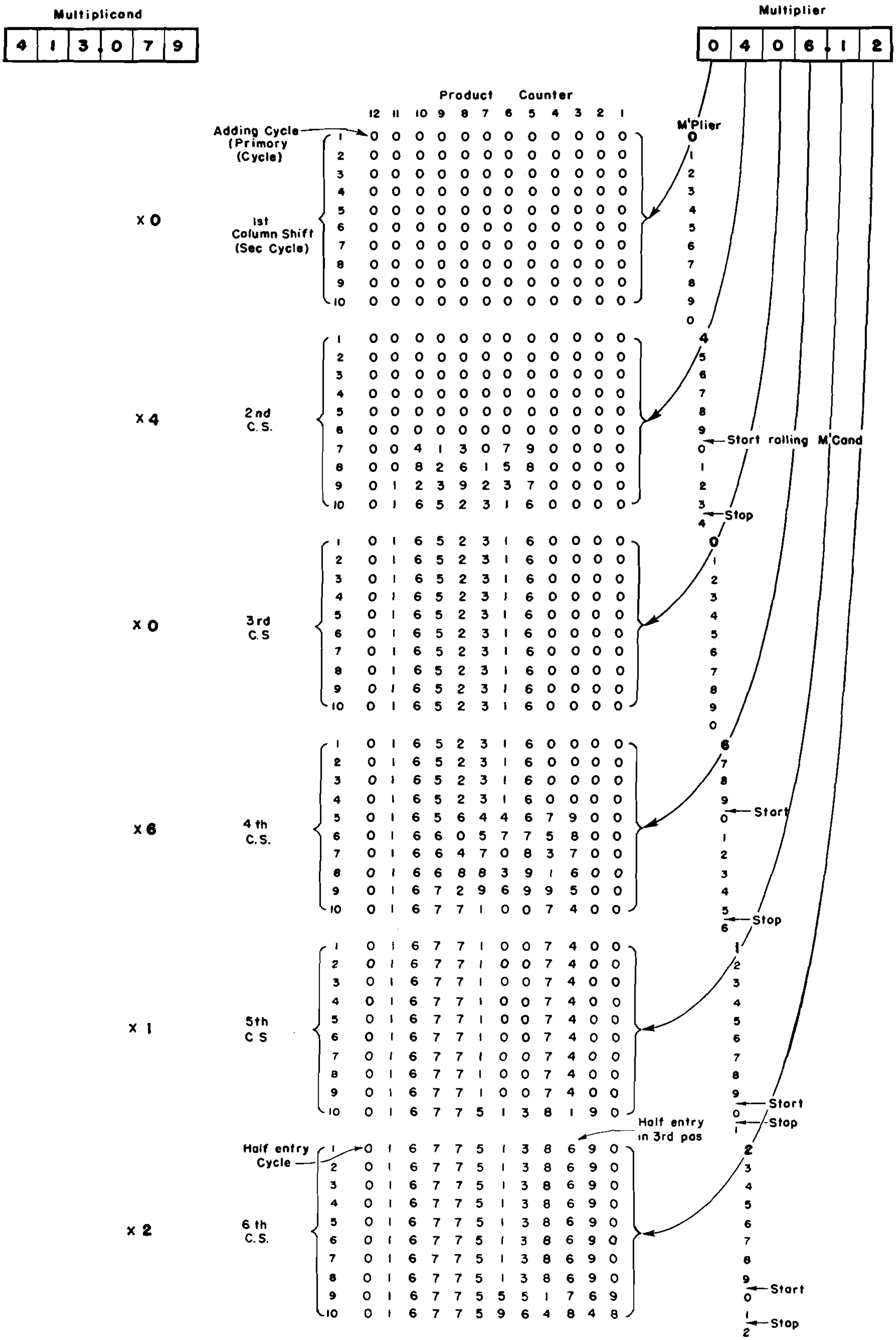


Figure 61. Principle of Multiplication Showing Detailed Operation

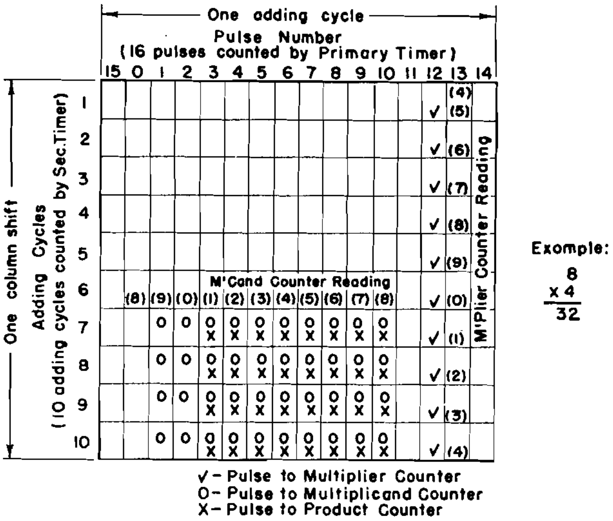


Figure 62. Schematic Showing Details of Operation of One Position

multiplying, because the same multiplier is used for a large number of multiplications.

For a more complete understanding of the multiplying operation, the last column shift cycle in the illustration in Figure 60 is analyzed in detail in Figure 62. This schematic shows all that takes place in one position of the multiplicand and product counters during one column shift cycle. All column shift cycles are alike except for the digit in the multiplier; consequently, a careful study of Figure 62 should illustrate the principles employed by the 603.

Observe that Figure 62 illustrates 10 adding cycles (laid out horizontally) divided into 16 pulses each (vertical divisions). Also observe that the pulses are not numbered from zero; the first pulse is number 15. This method of counting the pulses is used for the same reason that the first division on the punch index after unlatching is 14 instead of 9. A short time is necessary for setup before addition starts, and it is desired to have the pulse number correspond to the actual number of pulses added into the multiplicand counter.

As indicated in Figure 62, near the end of each adding cycle one pulse is added to the multiplier position corresponding to the column shift cycle. This pulse is the number 12 pulse of each cycle (14th pulse from the start of the cycle). Since there are ten adding cycles, the multiplier position will return to its original reading in the tenth adding cycle. During the 6th adding cycle the multiplier position advances from 9 to 0. This provides a signal to the multiplicand to add into the product once during each of the 4 remaining adding cycles.

The method of transferring the multiplicand to the product counter is also shown in Figure 62. When the signal is received from the multiplier counter, each position of the multiplicand counter receives 10 pulses during *each of the remaining adding cycles* of the column shift cycle. This means that each position of the multiplicand is "rolled" once each adding cycle and returned to its original reading. Since there are no carry circuits for the multiplicand counter, the counter may be rolled as many times as desired without changing the reading of the counter. When a position of the multiplicand counter is rolled, it passes from 9 to 0 sometime during the adding cycle, as determined by the value of the digit in that position. When this occurs, it is a signal for the product counter to receive all the remaining pulses of the group of 10. This effectively transfers the multiplicand digit to the product counter; this transfer will occur once each time the multiplicand counter is rolled. An examination of Figure 62 will reveal that in the illustrated problem the multiplicand is rolled 4 times, and the product counter receives 8 of the 10 rolling pulses during each adding cycle that the multiplicand rolls. Since it requires 2 pulses to bring the multiplicand to 0, it means that the 8 remaining pulses pass to the product counter.

Figure 62 illustrates only one position of the multiplicand counter. Remember that all six positions will be rolling simultaneously during an actual multiplication. From Figure 61 it will be remembered that the multiplicand is transferred to the product counter many times during the multiplication. However, each transfer is identical to

	Multiplicand Counter Position					
Pulse Number	6	5	4	3	2	1
15	4	1	3	0	7	9
0	4	1	3	0	7	9
1	5	2	4	1	8	0
2	6	3	5	2	9	1
3	7	4	6	3	0	2
4	8	5	7	4	1	3
5	9	6	8	5	2	4
6	0	7	9	6	3	5
7	1	8	0	7	4	6
8	2	9	1	8	5	7
9	3	0	2	9	6	8
10	4	1	3	0	7	9
11	4	1	3	0	7	9
12	4	1	3	0	7	9
13	4	1	3	0	7	9
14	4	1	3	0	7	9

Pulses to M'Cond start here

Pulses to Product Counter start after M'Cond passes from 9 to 0, as indicated by double lines.
(No carry in M'Cond counter)

Pulses stop here

Transferring 413079 from M'Cond to Product Counter

Figure 63. Operation of Multiplicand Card Counter During Transfer to Product Counter

the other except for the positions of the product counter which receive the multiplicand. Figure 63 illustrates in detail one adding cycle during which the multiplicand is transferred to the product counter once. Observe that each position of the multiplicand is rolled through 0 and back to its original reading. In each position a double line is drawn at the pulse number where that position passes from 9 to 0. The corresponding position of the product counter will receive all the pulses remaining of the 10 rolling pulses. In this way six positions of the product counter, as determined by the column shift position, will receive the proper number of pulses to add the multiplicand amount in the product counter.

A block diagram showing all the operations taking place when multiplying in the computing section is shown in Figure 64. All slow-speed pulses, which travel through the cable either to or from the punch unit in synchronism with the card movement through the punch, are shown in heavy lines to distinguish from the high-speed computing pulses in the electronic unit. Dotted lines indicate locking circuits, and light solid lines indicate pulsing circuits.

The master timer for the computing section is the multivibrator, which is a square wave oscillator generating essentially square waves of 35,000 cycles per second frequency. The clipper clips the multivibrator output to square the top of the wave, and its output is fed to the "A" and "B" pulse tubes which produce almost perfect square waves 180° out of phase with each other. In other words, "A" pulses are going positive at the same time "B" pulses are going negative, and vice versa. These pulses are used throughout the computing section for high-speed computing. "A" and "B" pulses are being produced continuously as long as power is on the tubes, but nothing happens until the start switch is opened to allow the pulses to start a computation. The reason for two pulse sources will become apparent when the actual circuits are discussed.

The multiplier and multiplicand factors are read into their corresponding counters from the card as it passes the entry brushes. The principle used in reading into electronic counters will be discussed later in the circuit description.

After the factors are read into the counter, P24 cam contact makes to start the computation. P24 trips the start trigger and opens the start switch to start the primary timer by feeding a stream of "A" pulses to it. As previously explained, the primary timer is an electrical timer which counts 16 pulses to establish the basic adding cycle. The operation of all computing circuits is based on this timer. The primary timer counts 16 pulses and then returns to zero to produce a 16-point cycle effectively. Thus the reading of the primary timer is equivalent to the index used in the punch unit.

The primary timer in turn operates the secondary timer which in turn operates the tertiary timer. For every primary cycle (or adding cycle) the secondary timer receives one pulse and advances one. After 10 pulses the secondary timer returns to zero and starts over, at the same time advancing

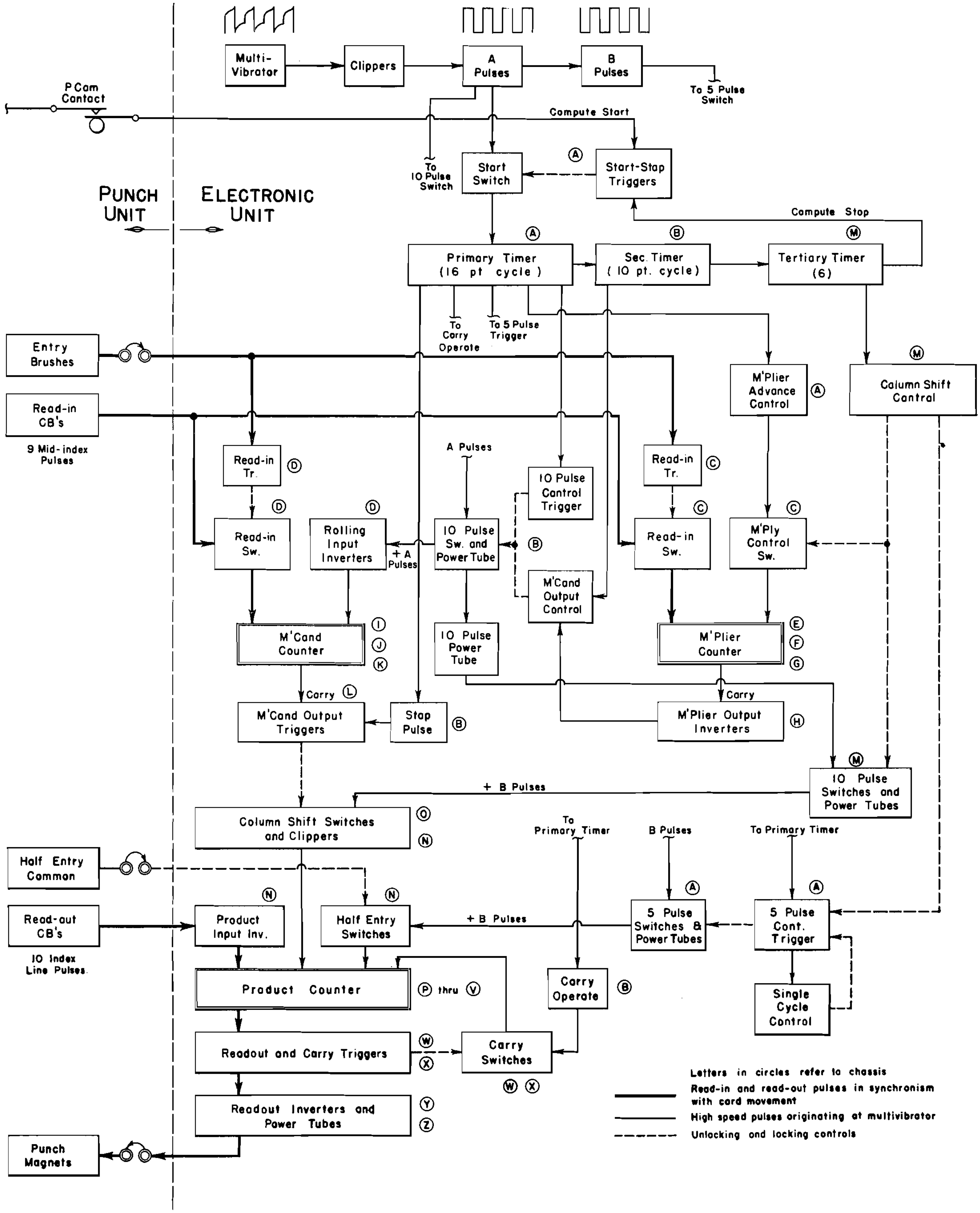


Figure 64. Block Diagram of Type 603 Circuits

the tertiary timer one; hence, it is obvious that the tertiary timer advances once for each 10 primary cycles. The secondary timer provides 10 adding cycles in each column shift position while the tertiary timer controls the column shift.

During each primary cycle, a pulse is passed to the multiplier counter by the multiplier advancing control through the multiplying control switch, thus advancing the proper position of the multiplier 1. The multiplier counter position receiving the pulse depends upon the column shift position as indicated in Figure 64 by the dotted line from the column shift control to the multiplying control switch. Thus, at the beginning of a computation the pulse is passed to the 6th position of the multiplier counter, since column shifting is from left to right. During the adding cycle that the 6th position passes from 9 to 0, a carryover pulse through the multiplier output inverters opens the 10-pulse switch through the multiplicand output control to start rolling the multiplicand counter. For example, if the 6th position of the multiplier contains a 3, this counter position would pass from 9 to 0 during the cycle in which it received its seventh pulse from the multiplier advancing control. This means that there are 3 adding cycles left in the first position of column shift, and the multiplicand counter will be rolled three times in this column shift position.

Rolling the multiplicand counter is accomplished by adding 10 pulses to *all* positions of the multiplicand counter. Since there are no carry circuits for the multiplicand (or multiplier) counter, after ten pulses, each position will return to the same reading from which it started; a signal carry pulse will be provided from each position through the multiplicand output control when that position advances from 9 to 0. This carry pulse opens the column shift switches which have been conditioned for the first column shift position, and "B" pulses start adding into the product counter. The 10th rolling pulse then closes the column shift switches through the stop pulse control, and the product counter will have received as many pulses as the reading of the corresponding position of the multiplicand counter. In this same manner the figures in the multiplicand are rolled into the products counter three times during the first column shift cycle if there is a 3 in the 6th position of the multiplier. All carry pulses in the products counter are stored in the carry control section, and carry takes place at the end of each adding cycle (primary cycle).

When 10 primary (or adding) cycles have been completed, the tertiary timer is signalled to advance. The column shift control then feeds pulses to a new set of column shift switches to shift the output of the multiplicand over one column to the right in the product counter, and the 5th position of the multiplier counter starts receiving advancing pulses. Again when a carryover occurs, the multiplicand starts receiving rolling pulses. After this operation has been performed six times, the computation is complete and the primary timer is stopped.

Five pulses are added into the products counter during the first adding cycle of the 6th column shift cycle, if half-correction is wired on the control panel. An explanation of this operation is reserved for the section on circuit description.

After the end of the sixth column shift cycle, the product is retained until the card in the punch unit moves to punching position. To read out the answer from the product counter, CB's in the punch unit start pulsing the product counter at 9 on the index, and one is added to all positions of the product counter for each index point at the line of index. When a position in the products counter carries over, the carry pulse trips a power tube which energizes the corresponding punch magnet to cause punching of the proper digit in the card. A more complete description of this operation will be found in the circuit explanation.

Computing Circuits — General

The circuits for electronic computing are shown in Sections 21 through 80 of wiring diagram

213639A. The diagram is laid out by chassis to permit a close tie-in with the machine. None of the cable wiring is shown, but each cable wire or jumper is indicated at each chassis terminal on the wiring diagram.

The terminals on the chassis are numbered from 1 through 20 on the right side (facing the *rear* or wired side of the chassis). On the left side terminal strip the terminals are numbered 21 through 40. Across the top or bottom the terminals are numbered 41 through 60. Since no chassis has both a top and a bottom terminal strip, the same numbering is used for either top or bottom. Unused terminals retain their number and must be counted to locate the proper terminal. To prevent possible trouble from capacity coupling in the cables in the electronic unit, all cables carrying high-speed pulses traveling from one chassis to another are shielded.

A color code is used to identify all power lines *within* a chassis. This code does not hold for the cable wires. The wiring diagram indicates the color coding used. For reference it is repeated below.

Ground—Black
+65 volts—Slate
+150 volts—Red
−100 volts—Green
−100 volts—White
(Cancel)
−250 volts—Red-White
115 volts A.C.—Blue
(Filaments)

NOTE: On some chassis on early models the −250 volt lines were purple instead of red-white.

The +65 volt supply was added after the original circuit layout was made, hence the +65 volt line is placed above the +150 volt line on the circuit diagram.

In addition to the color coding used on all the power lines, all controlled grid and suppressor circuits are indicated by yellow wires. In some cases a slight departure from this rule is necessary, but usually a yellow wire indicates a grid or suppressor circuit. The cathodes of all tubes in the computing circuits (except the multivibrator) are connected to the ground line (zero potential), which is shown as a heavy line throughout all the electronic circuits.

There are only three types of tubes used in the computing circuits, namely, types 12SN7, 6SK7, and 25L6. The 12SN7 is a twin triode, used as a trigger, as a blocking tube, and as an inverter switch; the 6SK7 is a pentode used as an electronic switch; and the 25L6 is a beam power tetrode used as a power tube in circuits requiring power. Figure 65A shows the symbols for the tubes used, along with the pin connections on the tube, while Figure 65B shows the socket connections. The tube symbols are also shown in Section 22B of the wiring diagram. Observe that the 25L6 symbol is shown on the wiring diagram as a pentode with the suppressor internally tied to the cathode, whereas Figure 65A shows a symbol for beam-forming plates. The beam-forming plates act as a suppressor and for that reason the symbol often shows a suppressor tied to the cathode internally. In practical circuits, however, neither is shown in order to simplify the symbols. All circuits show the 25L6 with only two grids.

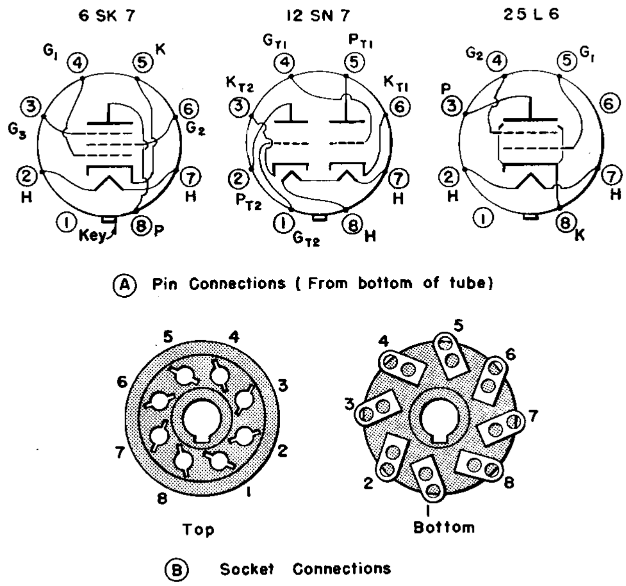


Figure 65. Tube and Socket Connections

Since the three tube types mentioned are the only types used in the computing circuits, they are not labelled by tube type. Merely remember that all triodes are 12SN7's; all tetrodes are 25L6's; and all pentodes are 6SK7's. As an aid to servicing, it is recommended that the pin connections of these three tube types be drawn on a card and the card kept in the bottom of the electronic unit for ready reference.

Spare tubes for replacement purposes are mounted in unused positions on the L, M, and W chassis. These spare tubes are readily identified by white tube sockets. The spares in the L and M chassis are 12SN7's, while the W chassis carries spare 25L6's, 6SK7's, one 6SJ7, and one 25Z6.

All the tubes used in the computing circuits draw the same filament current of 0.3 amperes, consequently the tube filaments can be wired in series in any arrangement. In order to allow connection to a common source, the filaments are connected in series strings providing a total potential drop of approximately 113 volts. In some cases a string of filaments may include tubes from two different chassis. The exact arrangement will be found on the circuit diagrams for the individual chassis. The filaments do not directly affect the circuit operation and for this reason no further reference will be made to the filament circuit. In several instances dummy tubes are used to fill out a filament string. These can be readily identified because the tube socket is painted red.

In describing the circuits, the control grids of all tubes will simply be referred to as *grids*, while the suppressor grids of the pentodes will be called *suppressors*. The screen grids of all the 25L6's and 6SK7's are connected to a +65 volt supply line which is shown above the +150 volt line on the circuit diagrams. The screens of 25L6's require a resistor in the circuit to limit the screen current. Resistors are used in the screen circuits of 6SK7's only to prevent parasitic oscillations when several screens are wired in parallel. The screen grids may be ignored in the description of the circuits unless they serve a functional purpose.

The anodes of all the tubes are connected to the +150 volt line through load resistors ranging from 5000 ohms for the 25L6's to 20,000 ohms for the 12SN7's and 6SK7's. The +150 volt line is shown parallel to and directly above the ground line. The 5000 ohm anode load resistors for the 25L6's are 5 watt wire-wound resistors to dissipate the energy in the anode circuit of the 25L6 power tubes, while the 20,000 ohm resistors are 0.5 watt carbon resistors of the BTS type.

The circuits are designed and the tubes are controlled in a manner to assure positive operation and to overcome chance or unavoidable differences between tubes of the same type. For this purpose, a tube is held non-conductive, when so required, by a potential on one of its grids which is considerably below cutoff. To drive a tube to a conducting state, its grid potential is given a tendency to rise considerably above cutoff. The grid resistor has a high value, so that grid current flow will bring the potential of the grid to the cathode potential.

The potential necessary to cut off the various tubes with +150 volts on the anode is as follows:

12SN7	− 9 volts
25L6	−25 volts
6SK7	−17 volts (grid)
	−40 volts (suppressor)

To insure safe operation, the following potentials are maintained at the grids of the various tubes when they are cut off:

12SN7	−25 volts
25L6	−35 volts
6SK7	−35 volts (grid)
	−50 volts (suppressor)

These potentials are maintained through resistor networks. The exact values of resistance in the voltage divider networks can be found in the circuit diagrams for the individual chassis. It must be remembered that exact voltage values are not always attainable because standard available resistors must be used. The values given above are approximate.

If a tube is to be maintained in a conductive state, its grid is connected to a high positive potential through a high value resistor. The grid current flowing through the grid resistor will reduce the grid potential to the cathode potential. Any tendency of the tube current to drop will be accompanied by a reduction in grid current, hence the grid potential will rise and overcome the tendency of the tube current to drop. This method of connecting the grid in normally conducting tubes overcomes any difficulty which is due to variations in individual tubes. All normally conducting tubes are indicated on the wiring diagram by placing an X under the cathode symbol.

In many parallel arrangements, grid resistors are used to prevent *parasitic oscillations.* A parasitic oscillation is any undesirable oscillation in a circuit which interferes with its normal operation, or lowers its efficiency. Parasitics may result from a momentary fluctuation of current through a tube which causes grid potentials on other tubes to change. This would cause current through these other tubes to change, which in turn changes the potential on the grids of the first tube, and creates a continuous interaction or oscillation. By placing resistors in the grid circuits, the effect of potential variations in one tube on the grid of another is decreased to a point where interaction is eliminated. An example of parasitic suppressing resistors is shown on the circuits for the C and D chassis. On the C chassis (Section 31) the suppressors of six 6SK7's are in parallel, while the D chassis (Section 34) shows six grids in parallel.

By-pass capacitors are also used in many cases throughout the computing section to prevent undesirable effects by *transient voltages.* Transient voltages are very rapid voltage changes resulting from load changes, fluctuation in supply voltage arcs resulting from breaking inductive circuits, etc.

Transients can cause parasitic oscillations if proper precautions are not taken. Also transients can cause improper operation of triggers. To eliminate possible transients caused by arcs, extreme care must be exercised to eliminate all arcs in the punch unit.

The trouble resulting from arcing at HD1 relay points may be used as an example. Although these points in the motor circuit are on the shielded side of the transformer, a heavy arc across its points will cause the product counter read-out trigger to operate and add 1's in the product counter. Of course this will happen only when the motor is being started. This trouble was eliminated by suppressing the arc with a 2 mfd capacitor across the HD1 points.

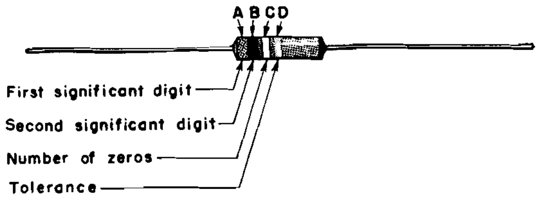
Transient voltage pulses may be transferred from one circuit to another by capacity coupling between wires in a cable. To minimize this possibility, all high-speed pulses traveling from one chassis to another not adjacent to it are carried by shielded cable.

An example of by-pass capacitors used to eliminate trouble from transients can be found in the circuit for the C chassis (Section 31). The .05 mfd capacitors at the input to the read-in triggers are by-passes for transients.

All resistor values are shown on the circuit in *megohms.* All capacitor values, shown as *whole numbers,* are in micro-microfarads, while capacitor values shown as *decimals* are in microfarads.

All tubular capacitors and wire-wound resistors are stamped with their value. However, the value of molded mica capacitors and carbon resistors is indicated by color code only. The code used is shown in Figure 66.

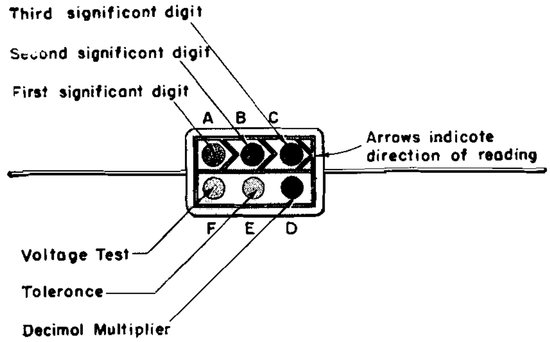
As an example, a resistor with a yellow stripe on the end, followed by a violet stripe, another yellow stripe, and a gold stripe will have a resistance of 470,000 ohms, and the value will be within ±5%. For another example, assume a molded mica capacitor with a yellow dot at the upper left, followed by two black dots. The lower left has a green dot followed by a red dot and a gold dot. This code



Ⓐ Resistor Color Coding (Values in ohms)

Values in Ohms

Color A	1st Significant Figure	Color B	2nd Significant Figure	Color C	Decimal Multiplier	Color D	Resistive Tolerance
Black	0	Black	0	Black	—	None	± 20%
Brown	1	Brown	1	Brown	10	Silver	± 10%
Red	2	Red	2	Red	100	Gold	± 5%
Orange	3	Orange	3	Orange	1,000		
Yellow	4	Yellow	4	Yellow	10,000		
Green	5	Green	5	Green	100,000		
Blue	6	Blue	6	Blue	1,000,000		
Violet	7	Violet	7	Violet	10,000,000		
Gray	8	Gray	8	Gray	—		
White	9	White	9	White	—		



Ⓑ Capacitor Color Coding (Values in micro-microfarads)

Capacitance in micromicrofarads *(μμf.)*

Dot Color	Significant Figures A	Significant Figures B	Significant Figures C	Decimal Multiplier D	Capacitive Tolerance E	DC Test Voltage F	Dot Color
Black	0	0	0	—	—	—	Black
Brown	1	1	1	10	± 1%	100	Brown
Red	2	2	2	100	± 2%	200	Red
Orange	3	3	3	1,000	± 3%	300	Orange
Yellow	4	4	4	10,000	± 4%	400	Yellow
Green	5	5	5	100,000	± 5%	500	Green
Blue	6	6	6	1,000,000	± 6%	600	Blue
Violet	7	7	7	10,000,000	± 7%	700	Violet
Gray	8	8	8	100,000,000	± 8%	800	Gray
White	9	9	9	1,00,000,000	± 9%	900	White
Gold	—	—	—	0.1	± 5%	1,000	Gold
Silver	—	—	—	0.01	± 10%	2,000	Silver
No Color	—	—	—	—	± 20%	500	No Color

Figure 66. Color Coding Used on Carbon Resistors and Mica Capacitors

will signify a 40 mmfd capacity accurate within ±2% and tested for operation up to 500 volts.

BASIC CIRCUITS

Before proceeding with the actual electronic circuits, several elementary principles will be reviewed and several basic circuits which will facilitate later explanations will be discussed.

In all the electronic circuits, voltages are referred to the cathode. The cathode will thus be at zero voltage and all voltages positive with respect to the cathode will be considered *above* the cathode and will be indicated with a plus sign (+). All voltages negative with respect to the cathode will be considered *below* the zero voltage of the cathode and will be indicated with a minus sign (–). For example, in the simple triode circuit of Figure 67A, the grid is at –25 volts and the anode is at +150 volts.

In Figure 67A it is assumed that the triode will cut off at –15 volts; therefore, no current flows in the anode circuit since the grid is at –25 volts. With no current flowing through the load resistor R there will be no potential drop across it, and point A will be at the same potential as the battery + terminal, i.e., +150 volts. In Figure 67B the switch S has been transferred over to the cathode, thus placing the grid at cathode potential. Conduction will take place through the tube and through the load resistor R. Assume that 10 milliamperes of current pass through the tube. With the given value of 10,000 ohms for the load resistor, the potential drop across R will be 100 volts. The direction indicated is the direction of electron flow in conformity with the direction of flow through the tube. The potential drop across the tube will be $E = Ea - IR = 150 - 100 = 50V$, since the sum of the potential drops across the series components of a circuit must equal the potential of the source. The potential at the midpoint tap M in Figure 67A is +150 volts before conduction starts. However, when the tube is conducting, the potential at point M is +100 volts.

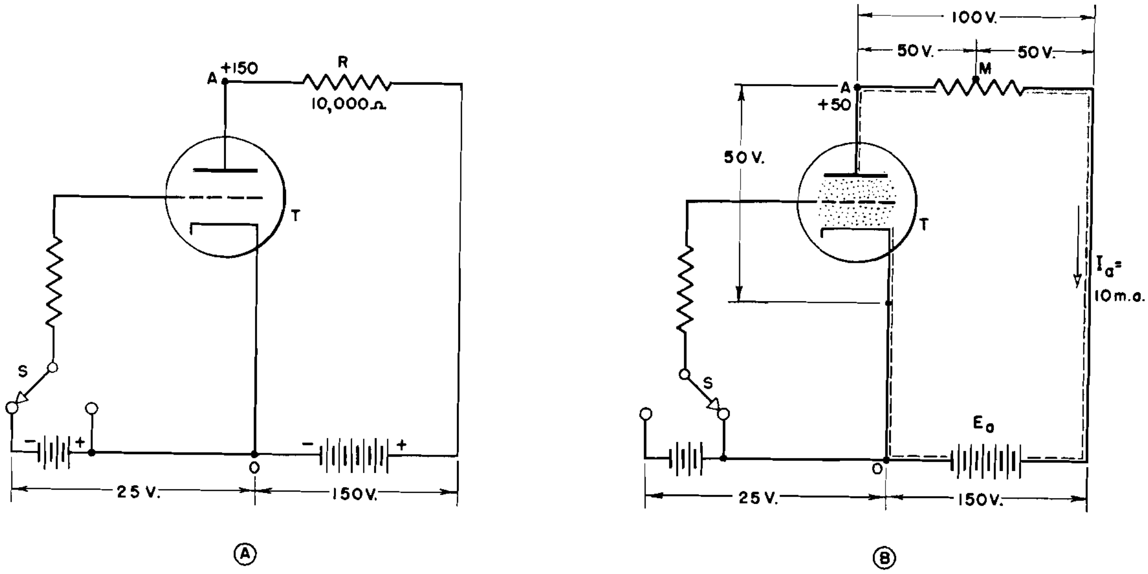


Figure 67. Basic Notation

This is evident from the fact that the two halves of resistor R can be considered as two equal resistors with a 50 volt drop across each.

This change in potential at the anode of a tube, when conduction takes place, can be utilized to control another tube by connecting the grid of the second tube to the anode of the first as shown in Figure 68. The grid battery Eg2 is necessary to reduce the potential on the grid of T2 to the desired negative potential when the tube is cut off. The potential of this battery must be the potential at point A when T1 is conducting plus the desired negative bias for T2. Assuming the same tube as shown in Figure 67, the potential at point A when T1 is conducting is +50 volts. It is desired to bias T2 at –25 volts; hence Eg2 must be a 75 volt battery. As long as T1 is conducting, the grid of T2 is at –25 volts and T2 cannot conduct. However, when the switch S is transferred to the –25 volt tap, T1 is cut off, and no current flows

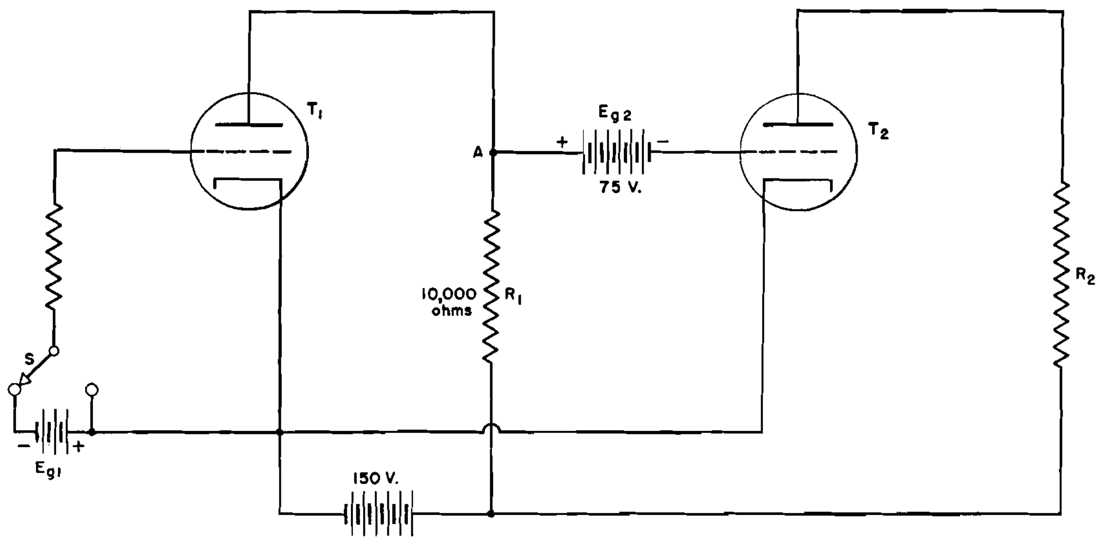


Figure 68. Control of One Triode by Another

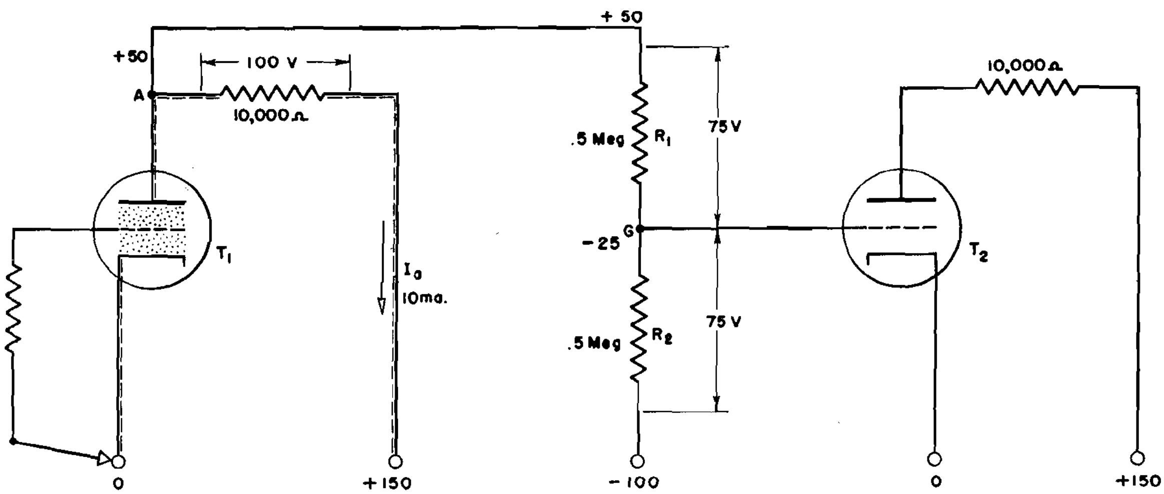


Figure 69. Direct-Coupled Triodes

through R1. With no IR drop across R1, the potential at point A is the same as the 150 volt battery potential at the plus terminal, i.e., +150 volts. This means that the grid of T2 will now be at +75 volts (150 volts – 75 volts) and conduction will take place through T2. Therefore, *T2 can conduct only if T1 is not conducting.* In this manner T2 can be controlled by controlling T1.

The circuit of Figure 68 is not a practical one. A more practical circuit using a resistor network to obtain the grid bias of T2 is shown in Figure 69. In this circuit a voltage divider consisting of R1 and R2 is connected between the anode of T1 and the –100 volt line. When T1 is conducting, point A is at +50 volts as shown in previous illustrations. Under these conditions, there are 150 volts across R1 and R2 (from +50 volts to –100 volts is 150 volts). Since R1 and R2 are equal, there is a 75 volt drop across each. The IR drop across R1 and R2 is of a polarity opposite to the –100 volt supply; therefore, the potential at point G (grid of T2) is –100 + 75 or –25 volts. Assuming T2 cuts off at –15 volts, it is evident that T2 is cut off, *providing T1 is conducting.* When T1 is not conducting, point A is at +150 volts, and the total potential across R1 and R2 is 250 volts (+150 to –100). This means a 125 volt drop across each resistor and a potential of +25 volts at the grid of T2 so that T2 conducts. Actually, the grid of T2 will not go very much positive; it will only *tend* to rise to +25 volts. As soon as the grid reaches cathode potential, some grid current starts to flow through R1 from cathode to grid, through R1, to point A, through the 10,000 resistor to +150 volts. The resulting IR drop across R1 due to the grid current is of a polarity opposite to the positive potential at the grid, and the grid potential is thus reduced. The grid potential will stabilize at approximately cathode potential (zero).

The values of R1 and R2 must be very large compared with the load resistor R otherwise the potential at points A and G will not be of proper value. In the preceding calculations involving Figure 69 it was assumed that R1 and R2 were so large compared with R, that R could be ignored in calculating the grid potential of T2. This is not strictly true, because there is always a current flowing from the –100 volt line through R2, R1, R and back to the +150 volt line, even though tube T1 is out of its socket. A rigid analysis would show that there is a 2.48 volt drop across R at all times. However, compared with the total potential of 250 volts across the resistor network, the potential drop across R due to this current is so small that it can be ignored for practical calculations.

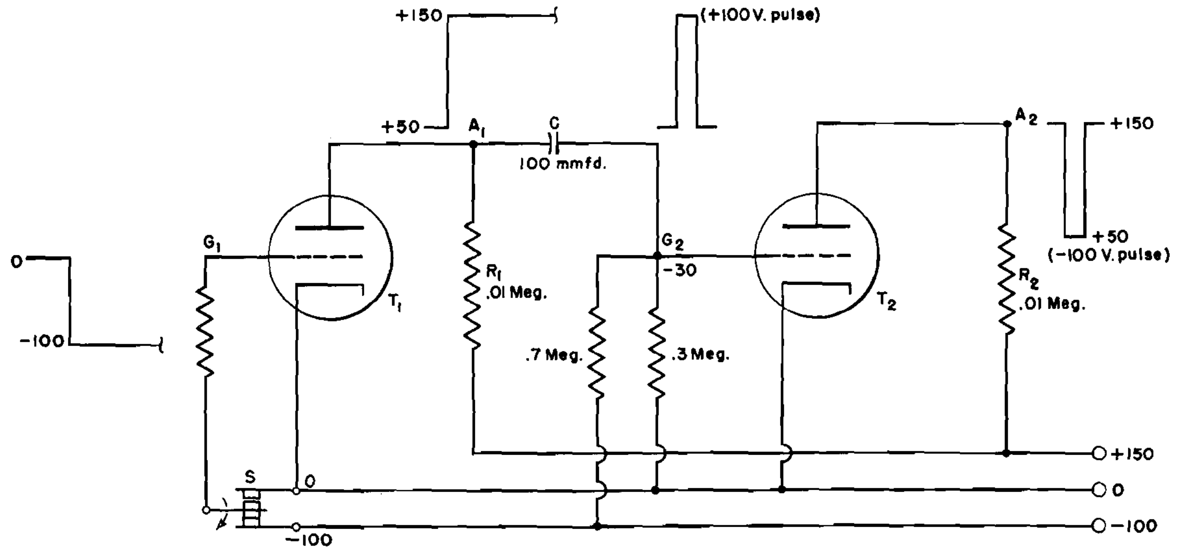


Figure 70. Capacity-Coupled Triodes Showing Phase Inversion

Often it is not desirable to couple one circuit directly to another. In these cases capacity coupling is used to pass a pulse from the anode of one tube to the grid of the next. In studying capacity-coupled circuits it is important to remember that *the reactance of a capacitor decreases as the frequency of the applied potential increases.* Direct current cannot pass through a capacitor, since direct current has a frequency of zero and results in an infinite reactance. Conversely, an infinite frequency will pass through a capacitor with zero reactance. Infinite frequency implies an *instantaneous* change of voltage. Obviously, this is impossible in practice; but very rapid changes can be obtained. Very rapid changes in voltage are equivalent to very high frequencies; consequently, very rapid changes in voltage can easily be transmitted through a capacitor, even an extremely small one.

Figure 70 shows a capacity-coupled circuit wherein changes in the anode potential of T1 control T2. The anode of T1 is coupled to the grid of T2 through capacitor C. Only *changes in potential* will be transmitted through C. Once point A1 reaches a steady value of potential, no further effect is felt at point G2.

With T1 conducting, the steady state potential at A1 is +50 volts (assume the same circuit constants as previous illustrations). Point G2 (grid of T2) is connected to the cathode through a 300,000 ohm resistor and to the −100 volt line through a 700,000 ohm resistor. This voltage divider places point G2 at −30 volts normally, thus cutting off T2 (assume −15 volt cutoff).

Assume now that contact S is suddenly transferred to the −100 volt line as shown in Figure 70. If it is assumed that the transfer takes place instantaneously, then there will be an instantaneous shift of potential on the grid of T1 from 0 to −100 volts. This shift in potential can be represented by the square wave shown at the grid of T1. This shift in potential is toward a more negative point and is thus a negative pulse. This shift of potential causes T1 to be cut off with the resultant increase in potential at point A1 from +50 volts to +150 volts as shown by the square wave at point A1. This voltage shift passes through C as a positive pulse to point G2, thus tending to drive point G2 to +70 volts. Only the *change in voltage,* i.e., 100 volts will be felt through the capacitor. Since the grid of T2 is at −30 volts, it will tend to approach +70 volts. Actually, grid current will

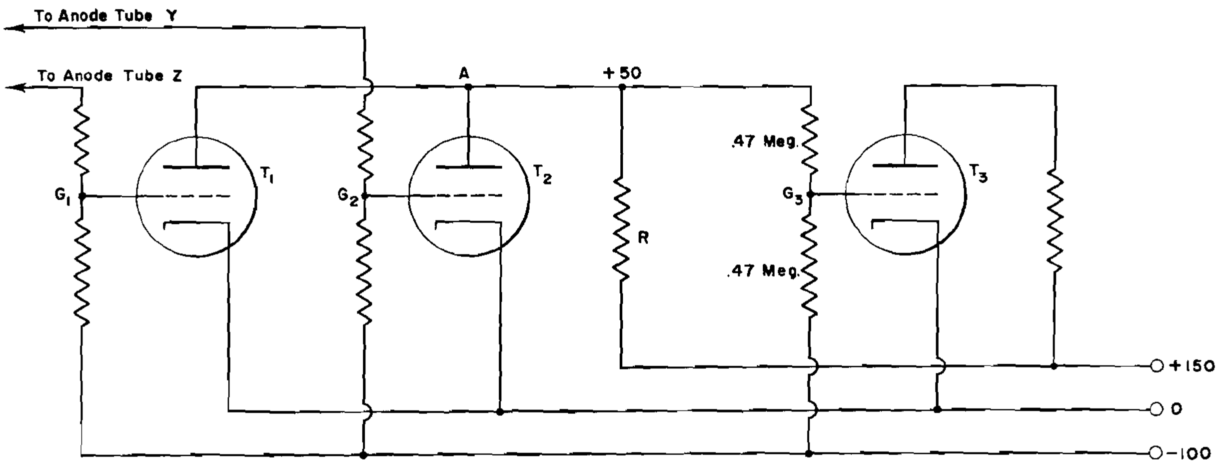


Figure 71. Use of Blocking Tubes

start to flow through the grid resistors as soon as the grid tries to go positive, the resultant IR drop opposes the tendency for the grid to go positive, and the grid potential will not go much above cathode potential. It is important to note here that although the potential at point A1 rises to +150 volts and remains there, the pulse through capacitor C is of short duration. The actual duration of the pulse is determined by the capacitance of C. This means that although point A1 *remains* at high potential, point G2 will be at high potential for only a short instant, i.e., for the time required to charge the coupling capacitor C.

Tube T2 will then conduct as long as point G2 is at cathode potential or above, with a resultant IR drop across load resistor R2. Thus the potential at point A2 drops from +150 to +50 volts. This illustrates the inversion of pulses by a tube. A negative shift in potential applied to the grid of T1 causes a positive shift in potential at the anode of T1. In turn, the positive pulse at point G2 produces a negative pulse at point A2. This is a most important fact to remember in the study of electronic circuits.

On the circuits illustrated so far one tube has been controlled by another. Sometimes it is desirable to block the action of the controlling tube under certain conditions. This can be done by connecting two controlling tubes in parallel with a common load resistor and providing separate grid controls, as shown in Figure 71. The value of the load resistor R is chosen so that the tubes are operated on the portion of their characteristic curve where most of the potential drop is across the load resistor and where changes in potential at the anode are very slight with a change in anode current. This means that the potential at point A in Figure 71, is essentially the same whether one tube is conducting or both are conducting. Hence with *either* T1 or T2 conducting, point A is essentially at +50 volts and point G3 at -25 volts, since the grid resistors between +50 volts and -100 volts are equal. This means that as long as T1, T2, or both are conducting, T3 is cut off. Only when *neither T1 nor T2 is conducting* does point G3 go positive and allow T3 to conduct. When neither T1 nor T2 is conducting, point A rises to +150 volts, and the grid of T3 tends to rise to +25 volts. Thus, T1 can nullify the action of T2, or vice versa. As indicated in Figure 71, T1 and T2 have separate grid controls in the form of other tubes which are indicated as tube Y and tube Z, which are not shown in this figure.

Another method of obtaining dual control is to use a pentode and provide grid control on both the control grid and the suppressor grid as shown in Figure 72. Since the suppressor is spaced much farther from the cathode than the control grid, a

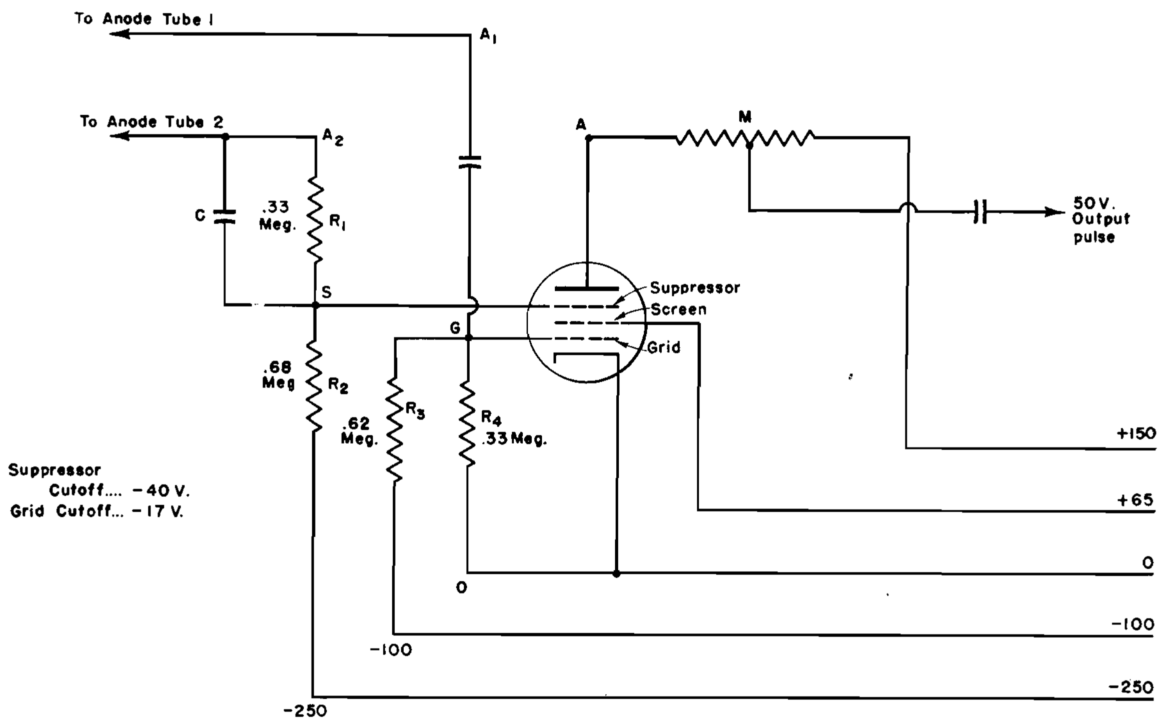


Figure 72. Two-Circuit Control of a Pentode

greater negative potential is required to cut off the tube by means of the suppressor than is required for cutoff by means of the control grid. In this case, assume the tube can be cut off by –17 volts on the control grid or by –40 volts on the suppressor. Either the control grid or the suppressor grid can stop conduction. In order for conduction to take place *both grids must be above cutoff potential.*

In Figure 72 it is assumed that the grids of the pentode are controlled by the anode potential of preceding tubes. Assuming that both tubes controlling the pentode are conducting and that they are of the same type illustrated in previous examples, the potential at their anodes will be +50 volts. This will place the suppressor at –50 volts, which is determined as follows:

Total potential across R1 and R2 is 300 volts (from +50 volts to –250 volts).

Suppressor is at point S and the potential at S is determined by the ratio of the resistors R1 and R2 as follows:

$$\frac{300 \times R2}{R1 + R2} = \frac{300 \times 680{,}000}{1{,}010{,}000} = 200\text{V (approximately)}$$

Hence point S is 200 volts above the –250 line, or at –50 volts.

The control grid is normally at approximately –35 volts as determined by the voltage divider R3 and R4 between the cathode and the –100 volt line. With both grids negative no conduction can take place.

Now assume that the tube controlling the suppressor stops conducting. Point A2 will rise to +150 volts potential and point S will tend to rise to approximately +17 volts. Thus the suppressor has been conditioned to allow conduction through the pentode; but the control grid is still blocking conduction, since it is below cutoff. When point A1 rises in potential, a positive pulse will be passed to point G and the tube will conduct for an instant, providing the suppressor is still conditioned to conduct.

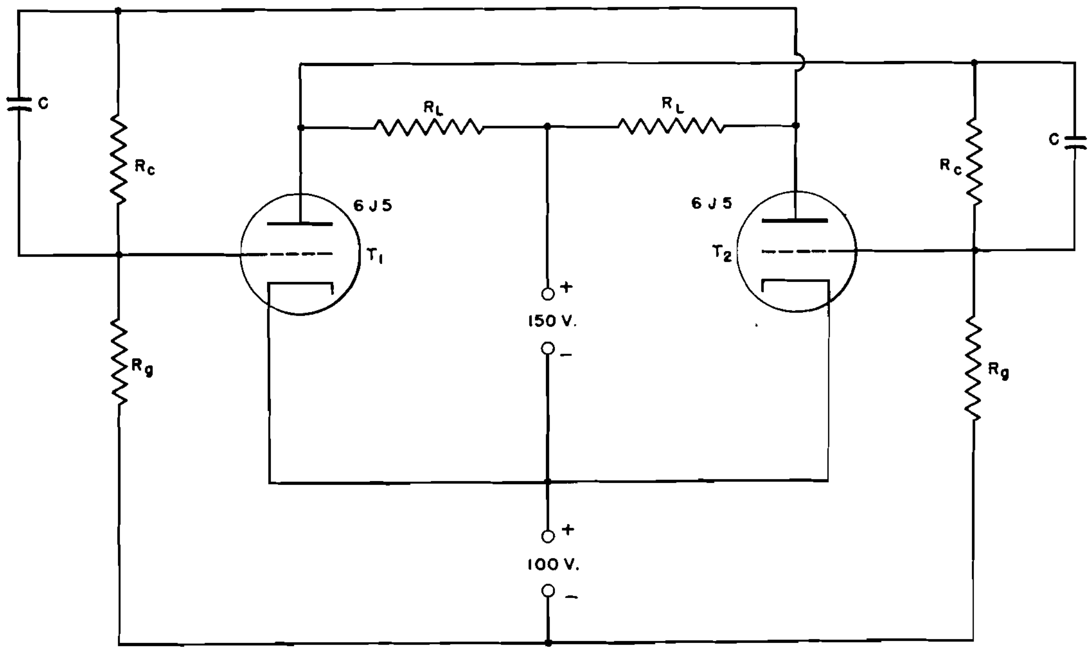


Figure 73. Basic Eccles-Jordan Trigger Circuit

When the tube conducts, the potential at point A drops because of the IR drop across the load resistor of the pentode. In this case the output is taken from a midpoint tap M on the load resistor. This would be done if the voltage shift desired is only half the voltage shift at point A. Assume the potential at point A changes from +150 volts to +50 volts. When conduction starts, a 100 volt negative pulse is produced at A. However, at point M the potential only changes from +150 volts to +100 volts, producing a 50 volt negative pulse at M.

The screen grid in Figure 72 is shown at a fixed potential of +65 volts supplied by a 65 volt screen voltage supply. The capacitor C across R1 is necessary to balance the interelectrode tube capacity so that the grid of the tube can follow the applied potential without any time delay.

TRIGGER CIRCUIT

Theory of Operation

The most important and basic circuit used in the electronic computing section is the trigger circuit. For this reason a detailed analysis of the operation of a trigger circuit will be presented. Although a detailed knowledge of the theory of operation of a trigger is not necessary to repair the machine, a thorough knowledge of the theory will assist in analyzing trigger troubles. A trigger circuit is one which has two states of equilibrium for fixed values of supply potential and circuit components. The trigger circuit derives its name from the fact that it can be made to "trigger" abruptly from one state of equilibrium to the other by means of small controlling potentials. The trigger circuit used in this machine is basically the Eccles-Jordan trigger circuit shown in Figure 73. The use of this circuit is based on the fact that current can flow through only one tube at a time. A change in grid potentials or anode potentials can be made to transfer conduction abruptly from one tube to the other.

As mentioned above, the trigger circuit is a device using two triode tubes so interconnected that one tube is conducting while the other is non-conducting. As shown in Figure 73 the grid of T2 is coupled to the anode of T1 through the coupling resistor Rc and capacitor C. The grid of T1 is

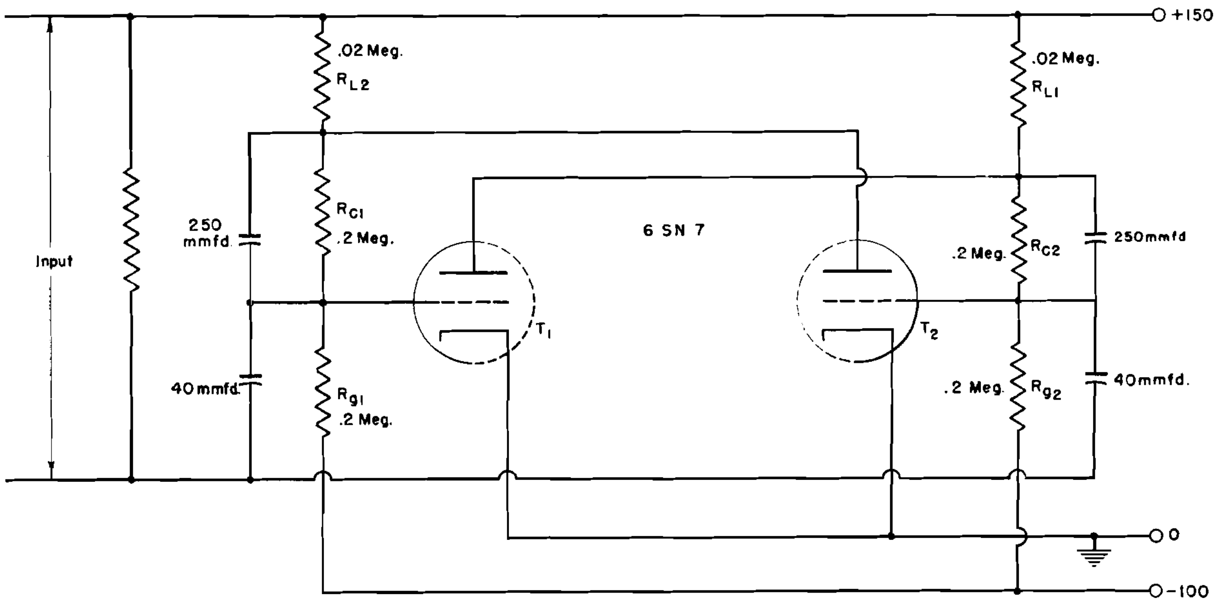


Figure 74. Practical Eccles-Jordan Trigger Circuit

similarly coupled to the anode of T2. The resistors RL are the anode load resistors while the grid bias is normally furnished through the grid resistors Rg. The values of RL, Rc, and Rg are not critical as to their exact value but *it is essential that the circuit be symmetrical.* Rc and Rg must be matched within 2% and they should be approximately ten times as large as RL. The value of C determines to a great extent the speed of response of the trigger circuit to an applied pulse.

A suitable voltage pulse applied at the proper points causes the conducting tube to stop conducting and the non-conductive tube to start conducting. A second pulse restores the original condition. This cycle may be repeated at will at any speed from zero up to speeds in the low radio-frequency range, depending upon the circuit constants used.

The tubes used in the circuits illustrated in Figure 73 are 6J5's or the equivalent. The two triodes can just as well be the two halves of a twin triode.

Figure 74 shows the Eccles-Jordan trigger circuit in a form more suitable for analysis. A close study of Figure 74 will reveal that it is the same circuit as Figure 73 with only the input circuit added. The resistance and capacitance values shown in this figure are the values used in the actual triggers in the electronic computing circuits: In this illustration the two triodes are the two halves of a twin triode, Type 6SN7.

Figure 75 shows how T2 can control T1. Assuming that both tubes are non-conducting, the potential at the grid of T1 can be determined by the ratio of the resistors between the +150 volt line and the −100 volt line, or by determining the current flow and computing the IR drop across each resistor. In this manner the potential at G1 is found to be +19 volts; or 19 volts positive with

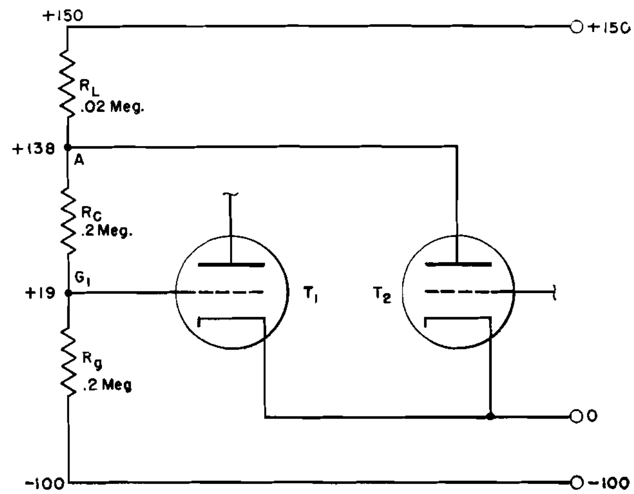


Figure 75. Anode of T_2 Controls Grid of T

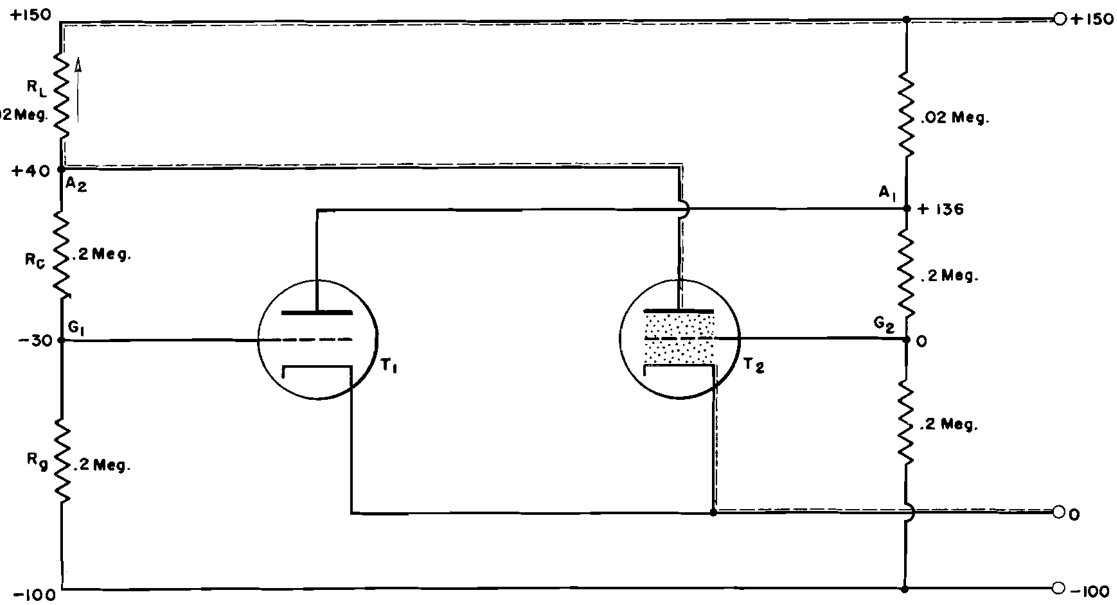


Figure 76. Retroactive Coupling

respect to the cathode since the cathode is at zero potential. Actually, point G1 will only tend to reach +19 volts, since this positive potential will cause T1 to conduct, and sufficient grid current will flow through Rc to hold the grid down to approximately cathode potential.

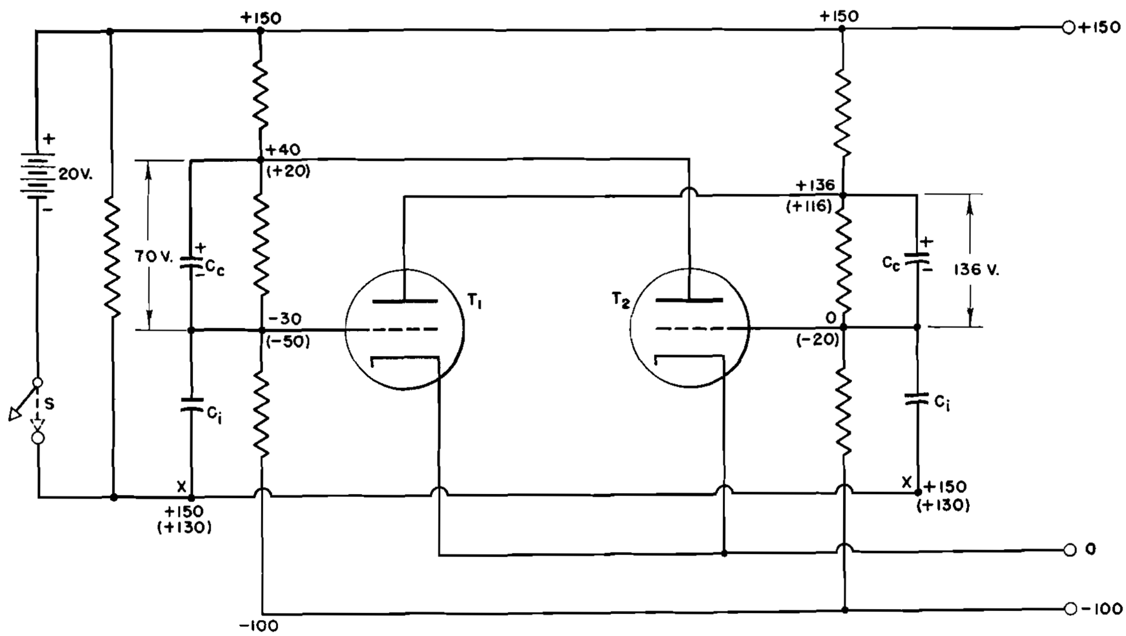
Now suppose that T2 is made to conduct by some means as shown in Figure 76. Assuming the potential drop across T2 when conducting is 40 volts, point A1 will have to be at +40 volts. Another method of looking at this is as follows: when T2 conducts, approximately 5 milliamperes of current flow as determined by the anode potential and the load resistor. This current flow through RL causes an IR drop of .005 × 20,000 or 100 volts. Naturally, this is in the same direction as and *in addition* to the drop resulting from the bleeder current always flowing from the –100 volt line to the +150 volt line. Therefore, the potential drop across RL is increased by 100 volts, making point A1 100 volts more negative than it was previously. In practice, this potential at point A1 is +40 volts instead of +38 volts with T2 conducting, since the current is not *exactly* 5 milliamperes.

A new analysis of the potential at point G1 will show that the grid of T1 is at –30 volts when T2 conducts, thus cutting off T1. Since Rg and Rc are equal, G1 is halfway between +40 volts and –100 volts.

From +40 to –100 volts is 140 volts, and the drop across Rg is 70 volts. Therefore, G1 is 70 volts above the –100 volt line or at –30 volts. From this analysis it is obvious that if T2 is conducting, it prevents T1 from conducting.

If the grid of T2 is connected to the anode of T1 by means of a similar network (Figure 76), T1 can control T2 in the same manner described above, and the desired condition in which only one tube can be conducting at a time is obtained. In Figure 76 point A2 is shown at +136 volts instead of +138 volts. This is because the grid current reduces the potential at point G2 to zero. On analyzing the potential between point G2 and the +150 volt line, it is found that point A2 is at +136 volts.

In order to provide a means of applying a triggering pulse, both grids must be coupled to a source providing the pulse as shown in Figure 77.



Instantaneous Potentials in Parenthesis

Figure 77. Use of Capacitors in Trigger Circuit

The potential values shown outside parenthesis are those existing when T2 is conducting and before a pulse is applied. This circuit is designed to trigger on the application of a 20 volt negative pulse to both grids. In order to operate properly, the triggering pulse must have a very steep wave front. For this reason a square wave is used as a source of pulses.

When a negative pulse of 20 volts with a steep wave front is impressed across the input, there is a sudden drop of 20 volts at point X. Since a steep wave front is equivalent to an extremely high

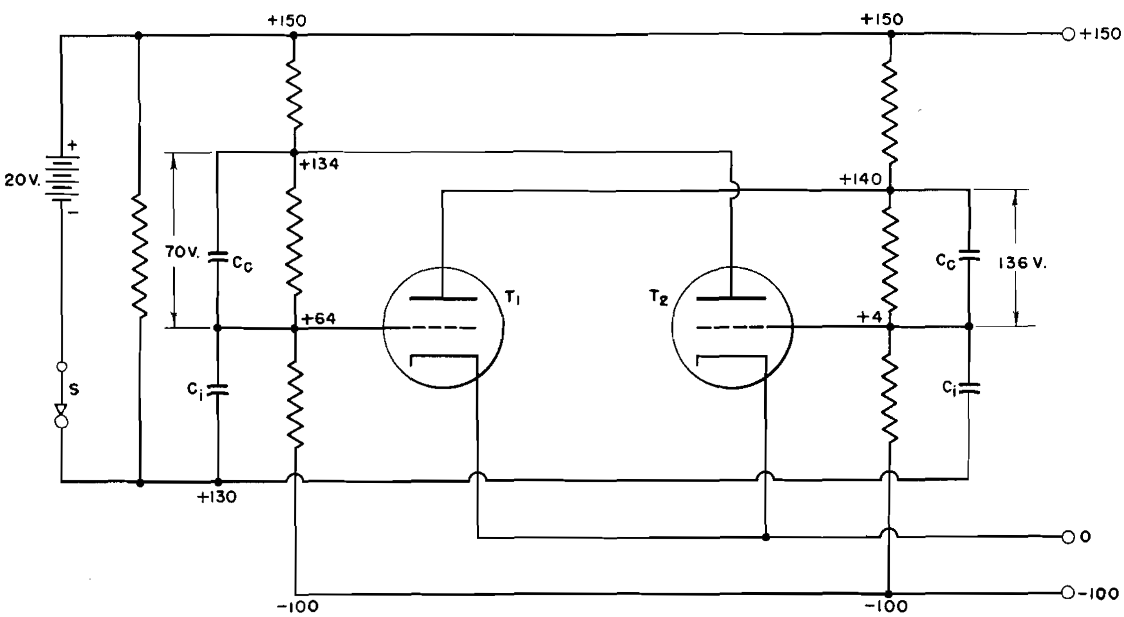


Figure 78. Voltages Existing after Ci Discharges but before Cc Discharges with Neither Tube Conducting

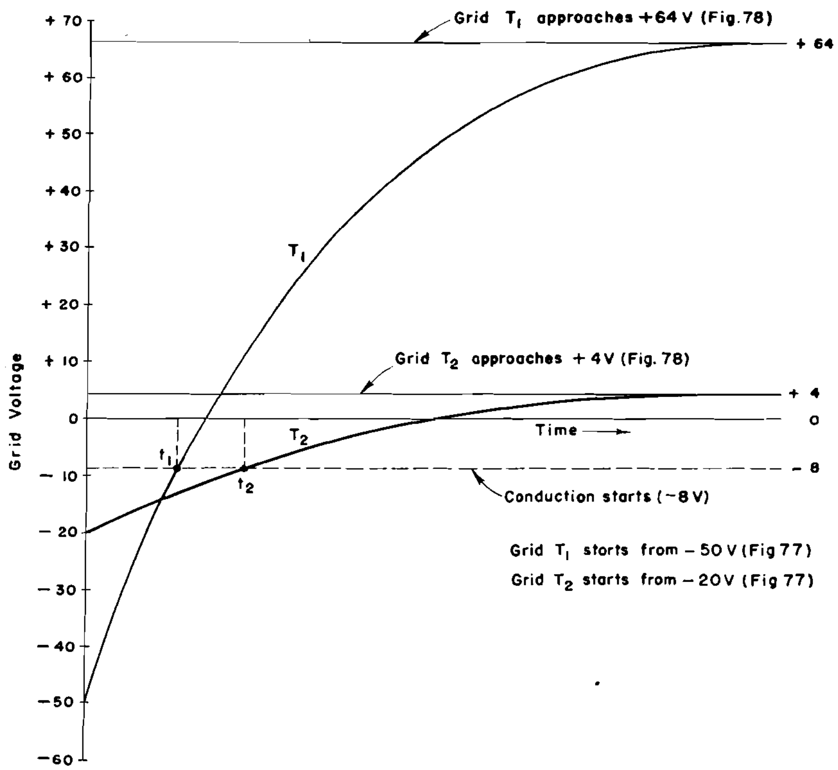


Figure 79. Calculated Rise of Grid Voltage as Circuit Voltages Change from Those in Figure 77 to Those in Figure 78.

frequency, the input coupling capacitors Ci will offer practically no reactance to the pulse and the sudden drop of 20 volts will be felt at points G1 and G2. The potential values shown in parenthesis are the instantaneous values obtained when the −20 volt pulse is applied. This pulse will render both tubes non-conducting for an instant.

In order for the trigger to operate, the Cc capacitors must be considerably larger than the Ci capacitors so that there will be very little change in the potential across the Cc capacitors in the time required for the smaller input coupling capacitors to reach a steady state condition. To simplify the explanation, assume that there is no change in potential across the Cc capacitors in the time required for the Ci capacitors to reach steady state values. As shown in Figure 77, both tubes are rendered non-conducting by the instantaneous potentials resulting from the −20 volt pulse, since these tubes cut off at −8 volts. If both tubes could be held non-conducting by some external means, the potentials shown in Figure 77 in parenthesis would soon change to those shown in Figure 78. The potentials shown in Figure 78 exist with the input coupling capacitors Ci in equilibrium, with capacitors Cc not yet discharged, and with neither tube conducting. If it is assumed that the Cc capacitors are not discharged, they will maintain the potential across them, and they can be considered as batteries with a potential equal to the charge on them at the time the pulse was applied. The potentials at the various points can then be analyzed on this basis.

Since the tubes are not held non-conducting, the potentials shown in Figure 78 will never be reached. The grids will only *tend* to reach the values shown. However, on the basis of the tendency of the grids to approach the limiting values shown in Figure 78, the actual rise of potential on

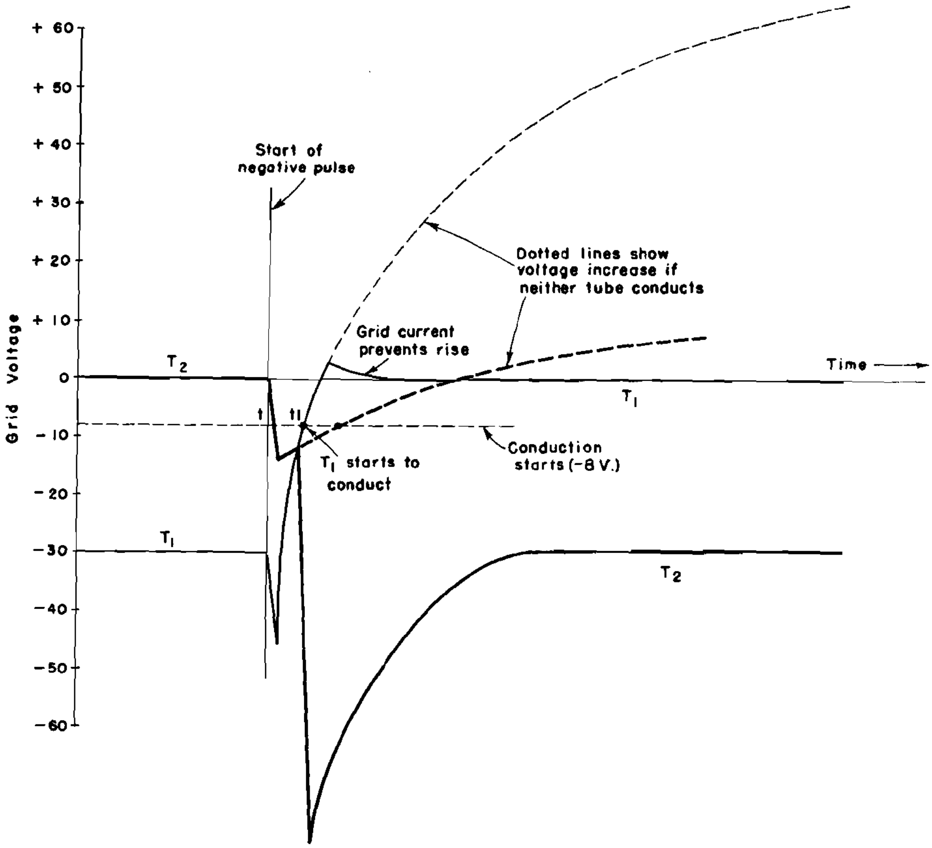


Figure 80. Oscillogram of Actual Grid Voltages During Triggering

the grids can be determined as shown graphically in Figure 79.

While these curves could be accurately calculated, they were actually obtained by plotting an e^x curve between the known limits of grid potential. This gives a theoretical capacitor discharging or charging curve. Because of the much greater swing in potential on the grid of T1, caused by the relatively low potential existing on the capacitor Cc between the grid of T1 and the anode of T2, it is obvious that the rate of potential rise will be much greater than the rate of rise in the potential on the grid of T2. It is evident that the grid of T1, which has been non-conducting, is the first to rise above the conducting point of −8 volts. These tubes cut off at −8 volts, therefore conduction will start as soon as a grid goes above this potential. Hence T1 starts conducting and blocks T2 from conducting, as previously explained, and the trigger is reversed. The action of the capacitors Cc produce the desired trigger action, and the trigger will now reverse itself every time the grids are given a negative pulse of 20 volts or more.

In Figure 78 it was assumed that the capacitors Cc were much larger than the grid capacitors Ci. As evidence that this assumption does not alter the general shape of the curves of grid potential rise, Figure 80 shows a sketch of the grid potential rise in an actual trigger circuit. This sketch is adapted from an actual oscilloscope pattern and shows exactly what happens to the grids of T1 and T2.

Originally T2 was conducting and T1 was held non-conducting by the −30 volt potential on its grid as shown previously. At time t (Figure 80) a 20 volt negative pulse is applied to both grids through the input capacitors Ci. Owing to the fact that the square wave input is not perfectly square, the negative pulse as it appears at the grids is not

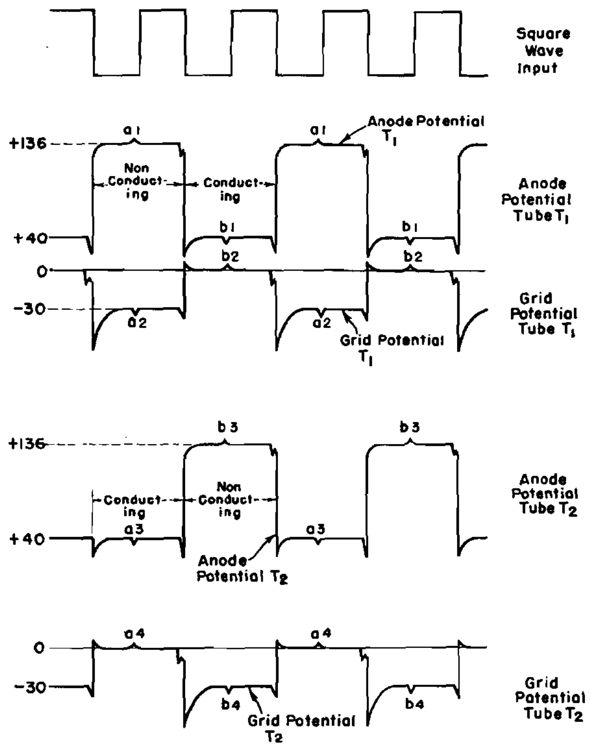


Figure 81. Oscillogram of Overall Trigger Operation

quite square, and at the grids the peak negative dip is only −15 volts. As soon as the maximum negative potential is reached, both grids start to rise in potential. As previously shown in Figure 79, the grid of T1 rises much faster than that of T2 and reaches the conducting point of −8 volts first. As soon as T1 starts to conduct, the potential at its anode starts to drop, forcing the grid of T2 down and holding T2 non-conductive. With the circuit constants shown in Figure 74, after a time interval of approximately 3 to 5 microseconds, the charges on all capacitors will have been equalized and the circuit will be as before except that T1 is now conducting instead of T2. The dotted lines indicate what the rise in the grid potentials might look like if the tubes could be held non-conducting by some external means. It is important to note that, although the triggering action is very fast, a definite time interval is required, hence a peaked pulse of extremely short duration (say 1 microsecond) may not trigger the circuit.

Figure 81 shows a sketch of both grid and anode potentials adapted from patterns taken directly from an oscilloscope. The potential graphs represent the potentials when the trigger is triggered or reversed continually by a square wave input. Note that the shape of the grid potential is the same as shown in Figure 80.

So far nothing has been said about the ability of this trigger circuit to distinguish between positive and negative pulses. The constants of this trigger are such that it is considerably more sensitive to negative pulses than it is to positive pulses. Therefore, if the input pulse is kept within reasonable limits, the trigger will respond only to the negative pulses of a square wave (Figure 81). For example, a −20 volt shift in potential will cut off the conducting tube, enabling the trigger to transfer; but a +20 volt shift will not bring the grid of the non-conducting tube up to the conducting point and thus cannot make the tube start to conduct. The only action of a +20 volt pulse on the conducting tube is to drive the grid slightly positive. Therefore, the trigger will transfer only on a negative pulse (or shift in potential), and the trigger can be made to distinguish between negative and positive pulses. The limits within which the trigger will respond only to negative pulses for the circuit constants given is approximately 20 to 80 volts. That is, at least −20 volts are required to trigger, but around 80 volts the trigger responds to positive pulses as well as negative. For this reason the triggers in this unit are operated by 50 volt pulses, or roughly at the middle of the range.

Figure 81 shows why the trigger is not reversed on a positive pulse which is theoretically large enough to bring the grid of the non-conducting tube up to the conducting point. Notice that at point a2 the grid of the non-conducting tube T1 actually appears to go negative although the square wave input is shifting in a positive direction. This is because the positive pulse acting on the grid of the conducting tube T2 drives the anode potential of T2 down almost 20 volts as shown at point a3.

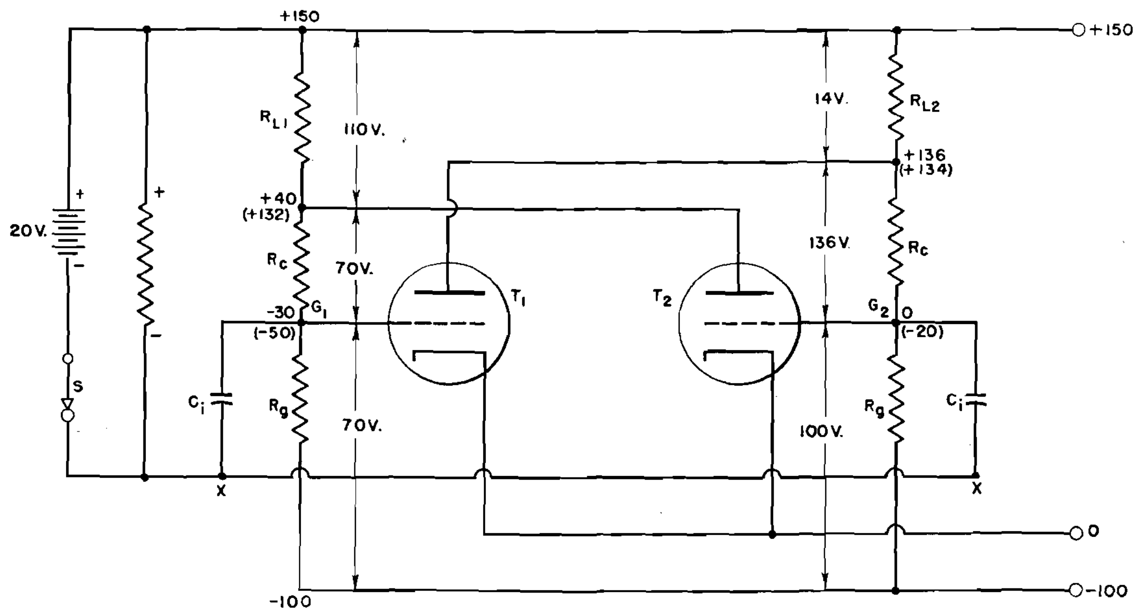


Figure 82. Application of Pulse to Trigger Circuit Without Cc Capacitors

Through this anode to grid coupling capacitor Cc, this dip in anode potential of the conducting tube over-rides the positive pulse on the grid of the non-conducting tube, producing a negative dip as shown at a2 (Figure 81). The dip in the anode potential of the conducting tube shown at a3 is in this case caused by the same positive pulse acting on its own grid.

For a positive pulse to trigger the circuit, the pulse must be sufficiently positive to overcome the initial bias plus the negative swing produced at the grid of the non-conducting tube by the dip in anode potential of the conducting tube.

If properly designed, triggers such as those described above are very stable, dependable, and independent of reasonable variations in supply potentials. A 20% variation in either bias or anode potential supply, or more if both vary together, can be tolerated.

In order to illustrate the importance of the Cc

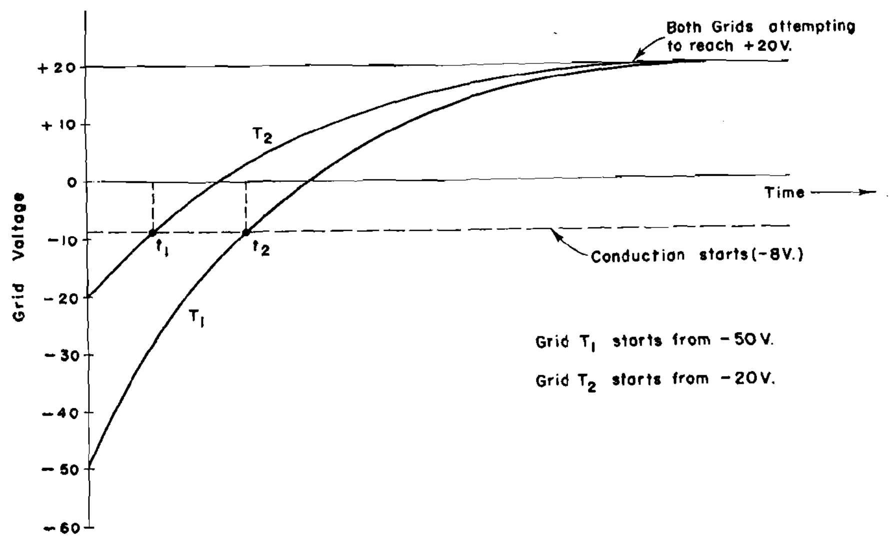


Figure 83. Rise in Grid Voltage as Capacitors Discharge

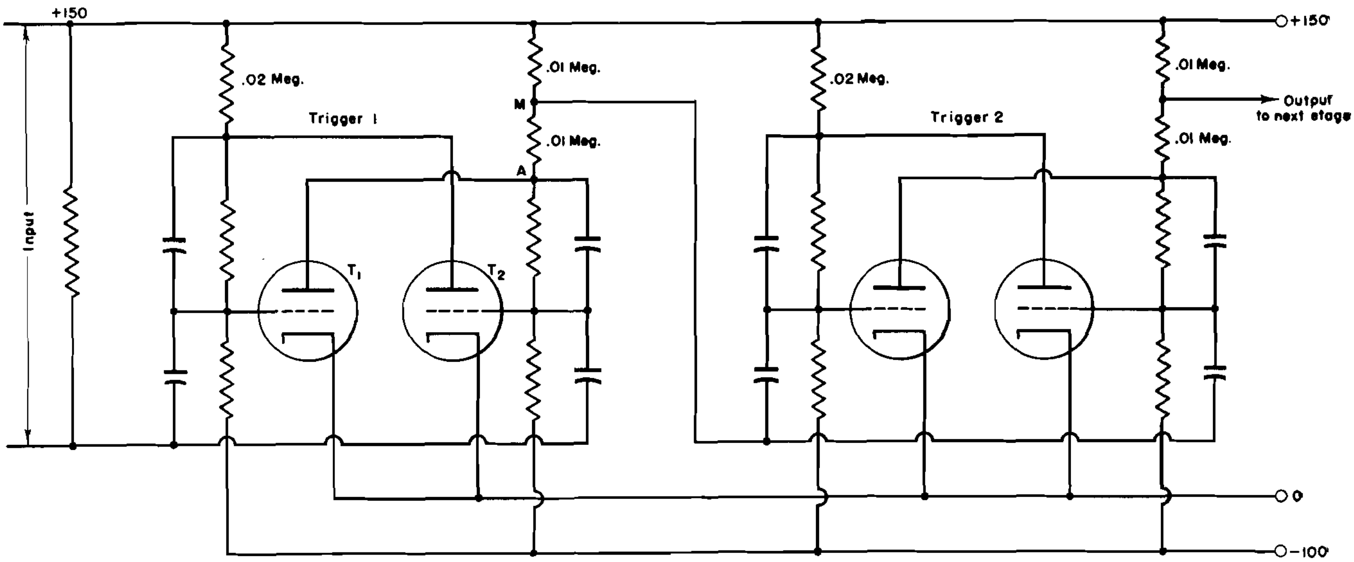


Figure 84. Coupling Trigger Circuits

capacitors, an analysis will be made without the Cc capacitors in the circuit. Figure 82 shows a trigger circuit without the Cc capacitors; it will be shown that this circuit is fundamentally incapable of reversing on application of a pulse to both grids.

The potential values shown outside parenthesis are those existing when T2 is conducting and before a pulse is applied. When a negative pulse of 20 volts is impressed across the input, there is a sudden drop of 20 volts at point X. The potential values shown in parenthesis are the instantaneous values obtained when the −20 volt pulse is applied. This pulse will render both tubes nonconducting for an instant.

The new potential values at the anodes are determined by an analysis of the IR drops across Rc and Rg using the new instantaneous values of grid potential and assuming both tubes are cut off. However, both grids will immediately start to rise to the resistor network limited value of +19 volts. The rate of rise is determined by the time constant of the resistor-coupling capacitor network. Since these are the same for each tube, the time constant will be the same for both grids.

The exponential rise of potential on both grids will be as shown graphically in Figure 83. These tubes cut off at −8 volts; hence, conduction will start as soon as a grid goes above this potential. Obviously, the grid of T2 will be the first to reach the −8 volt line, which means that T2 will start conducting first and prevent T1 from conducting as before. In other words, the trigger has not been reversed. Likewise, a positive pulse will not reverse the trigger, since the only effect it might have on the non-conducting tube will be offset by a stronger effect on the conducting tube.

Coupling of Trigger Circuits

To couple two triggers together, it is only necessary to tap one anode resistor of the first trigger at approximately mid-point and couple it to the input capacitors of the second trigger (Figure 84). This provides a means of tripping the second trigger under control of the first trigger. Tapping the anode resistor at one-half of its value serves to furnish a voltage pulse of one-half the voltage shift in the anode resistor. Point A in Figure 84 changes from +136 when T1 is not conducting to +40 when T1 is conducting, thus providing a negative shift of approximately 100 volts; whereas point M changes from +143 when T1 is not conducting to +95 when T1 is conducting, thus providing a negative shift of approximately 50

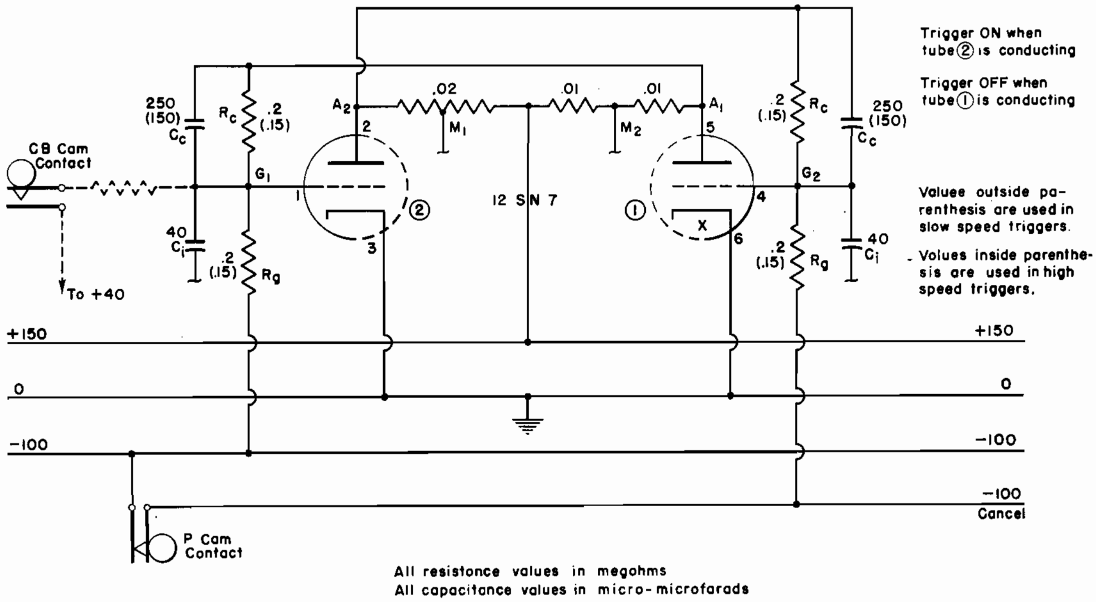


Figure 85. Actual Trigger Circuit Used in Type 603

volts. Since a –50 volt pulse is within the limits wherein the trigger will distinguish between negative and positive pulses, the first trigger can operate the second by passing this –50 volt pulse to the second trigger. Note that the second trigger will change its status only when conduction in the first trigger transfers from T2 to T1. When conduction in the first trigger transfers from T1 to T2, a 50 volt positive voltage shift occurs at point M, but as previously explained, a positive pulse will not operate the second trigger. As many triggers as desired may be coupled together by the method shown in Figure 84 to obtain any desired frequency reduction, the frequency being reduced by a factor of two for each trigger. Such a device may be used for high-speed counting, for providing timed pulses, as an electronic storage device, etc.

Trigger Circuits Used in Electronic Computing

The computing section of this machine uses a large number of triggers of the type just described. The only difference found is in the method of pulsing the trigger. All triggers are pulsed between ground and the input coupling capacitors.

Figure 85 shows a trigger as it is actually connected in the circuits. This arrangement of components is used to simplify the circuit diagram. All power lines are shown parallel at the bottom of the diagram. The ground line (zero potential) is shown heavy throughout the circuit. The tubes 1 and 2 are the two halves of the twin triode of the 12SN7 type. The circuit component values are as shown. The values of Rc and Rg must be matched within 2% for proper operation, although the exact value of the resistors may be within 5% of the nominal value. The capacitors should be within 5% of the nominal value.

As explained in the section on trigger theory, the size of the Cc coupling capacitors primarily determines the speed of response of the trigger. Also, the size of Cc should be as large as possible compared with Ci, the input capacitor. In practice then, a compromise must be reached between desired speed of response and stable operation. If Cc is made too large with respect to Ci, the trigger may respond too slowly to operate at 35,000 cycles per second. On the other hand, if a trigger never receives high-speed pulses, it is permissible to make Cc larger and thereby more nearly approach the theoretical ideal. Of course, the speed of response is determined to some extent by the size of the resistors Rc and Rg. Therefore, the speed of response can be raised both by using smaller values of Rc and Rg and by using smaller values of Cc. For the above reasons two types of triggers are used in the Type 603 computing circuits, as indicated in Figure 85. All triggers receiving pulses at relatively slow rates are known as slow-speed triggers, whereas triggers receiving computing pulses at high speed are known as high-speed triggers.

The earlier models of this machine employed a standard trigger throughout. This trigger had the same values as the slow-speed trigger except that the Cc capacitors were 100 mmfd. The first ten machines were shipped with these old type triggers in all chassis except the A, B, and M. In cases where trouble is experienced on these machines because of the old triggers, they may be replaced and the old chassis returned to Endicott.

For convenience in reference, the trigger is said to be ON or OFF depending upon which tube section is conducting. When tube 2 is conducting, the trigger is said to be ON: and when tube 1 is conducting, the trigger is said to be OFF. The tube notation is in conformity with the number of the tube sections used in tube manuals.

In the discussion of the trigger circuit theory the only method of pulsing mentioned was by means of simultaneous pulses to both grids through the input coupling capacitors. Often it is desirable to turn a trigger ON from one source and turn it OFF from another source. In this case the input capacitors Ci are not tied together. Each input capacitor is connected to its pulsing source. When the grids of the trigger are separately pulsed, the exact action of the trigger differs somewhat from the theory as presented, but the end result will be the same.

Tripping may be effected only by applying a *negative* pulse to the grid of the tube conducting. For instance, with the trigger OFF (tube 1 conducting), a negative pulse received by the grid of tube 1 turns the trigger ON (tube 2 conducting) even though tube 2 receives no pulse whatsoever. Such negative pulses decrease current flow in tube 1 and the attendant positive pulse on its anode is transferred by capacitor Cc to the grid of tube 2 with the same result described before. If the trigger is ON, any further negative pulses at the grid of tube 1 will have no effect, but a negative pulse at the grid of tube 2 will turn the trigger back OFF in the same manner explained before. As explained in the theory, the circuit is much more sensitive to negative pulses than to positive. Thus, a positive pulse applied to the grid of tube 2 through Ci, when the trigger is OFF (tube 1 conducting), must be considerably greater than the negative pulse in order to trip the trigger. Therefore, within the operating range, positive pulses have no effect.

Often it is desired to trip triggers with a positive potential. In these cases, the grids of one or both of the tubes in the trigger are *directly coupled* to a positive potential sufficiently high to raise the grid potential above its critical value. The direct coupling instead of capacity coupling is necessary to hold the positive potential at the grid of the non-conducting tube long enough to insure triggering. This may be done as shown by the dotted circuit in Figure 85. Here a cam contact directly connects the grid of tube 2 to +40 volts. If the trigger is OFF, it will be turned ON since tube 2 is forced to start conducting, and by the retroactive coupling of its anode to the grid of tube 1, tube 1 is cut off. Once the trigger is ON, it will stay ON even after the CB contact opens. To turn the trigger OFF a negative pulse must be applied to the grid of tube 2 or a positive potential must be impressed on the grid of tube 1. When a positive potential is impressed on the grids for tripping the triggers, the input capacitors Ci are connected to the +150 volt line, and they serve only as stabilizing capacitors.

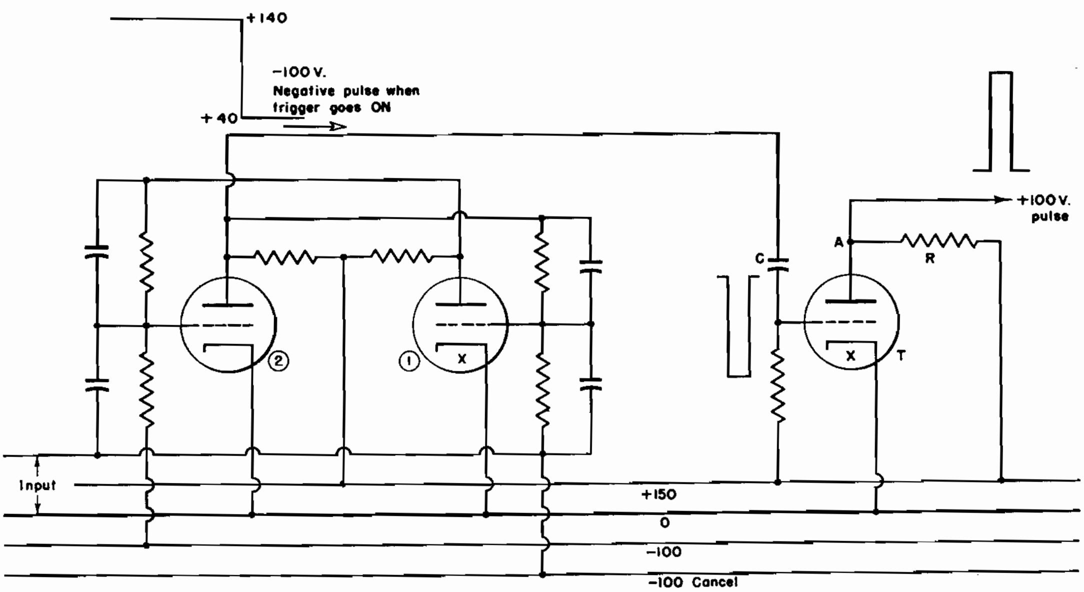


Figure 86. Use of Trigger to Control Triode

It will be noted that the grid resistor for tube 1 is connected to a line marked *-100 cancel.* The only difference between the -100 volt line and the cancel line is that the cancel line can be opened by means of a P-cam contact. When the contact is opened, potential is removed from the cancel line, and negative bias potential is removed from the grid of tube 1. This leaves the grid of tube 1 connected to the +150 volt line through the coupling resistor Rc and the load resistor of tube 2. Tube 1 will thus start conducting if it had not been previously conducting (trigger goes OFF.) This arrangement provides a means of resetting the triggers to the desired stand-by state. When power is first applied to a trigger, there is nothing but chance to determine which tube will start conducting. Hence, before starting a computing operation, all triggers are cancelled to their proper stand-by state.

Some of the triggers have the grid resistor of tube 2 connected to the cancel line instead of the grid resistor of tube 1. Such triggers are ON in their stand-by state. When the cancel line is opened these triggers will go ON if they were previously OFF.

The proper stand-by state of any trigger can always be determined from the circuit diagram by observing which grid resistor is connected to the cancel line. However, for simplification the normal state of a trigger is noted on the circuit diagram by placing a small "x" under the cathode of the normally conducting tube (Figure 85).

When the trigger shown in Figure 85 is OFF, tube 1 is conducting; its anode and the points of its load resistor and grid resistors Rc and Rg are at their low potentials. On the other hand, tube 2 is non-conductive and the corresponding points on this branch of the circuit are at their high potentials. Upon reversal of the trigger, positive and negative shifts in potential (potential pulses) are produced at different points of the circuit. For instance, upon reversal of the trigger from ON to OFF, a drop in potential (negative pulse) is produced on the anode of tube 1. As mentioned in the theory, a 100 volt shift is produced at points A1 and A2, whereas a 50 volt shift is produced at the mid-point taps on the load resistors M1 and M2. Points G1 and G2 are at cathode potential when their corresponding tube is conducting and at -30 volts when their corresponding tube is non-conducting.

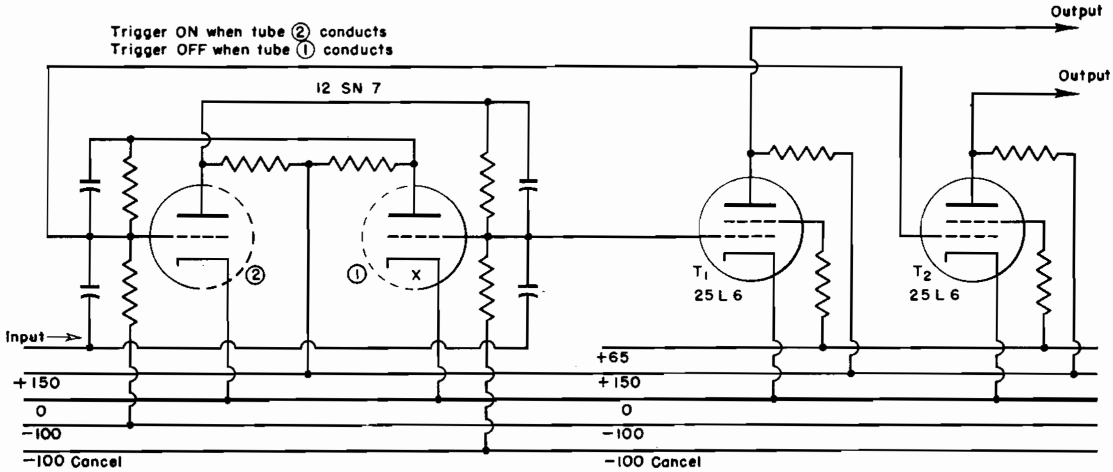


Figure 87. Control of Power Tubes by Trigger with Grid-to-Grid Connections

Control of Other Tubes by Triggers

The shift in potential at the various points on a trigger can be utilized to control other triggers, or to control electronic switch tubes and power tubes. As mentioned before, the triggers used in this unit will trigger on negative pulses, from 20 to 80 volts (approximately), when both grids are pulsed simultaneously. At 80 volts and above, a positive pulse will trip the trigger as well as a negative. For this reason the triggers are operated by 50 volt pulses, or roughly at the middle of the range. This means that when one trigger is controlled by another, potential pulses are taken from the midpoint of the load resistor. However, when a switch or power tube is controlled by a trigger, a +100 volt shift is required and the pulses are taken from the anodes of the trigger. A switch or power tube may also be controlled by connecting the grid of the controlled tube to the proper grid of the trigger. The controlled tube then acts as a follower. In controlling other circuits with a trigger precautions must be taken not to load the trigger. *The trigger cannot be loaded and still operate properly.*

Figure 86 shows a method commonly used in these circuits for providing a +100 volt pulse when a trigger goes ON. The grid of tube T is connected to the +150 volt line, therefore T is normally conductive. There is approximately a 50 volt drop across T when it is conducting; therefore, point A is normally at +50 volts potential. The grid of T will of course be at approximately cathode potential owing to grid current. When the trigger is turned ON by an input pulse, tube 2 conducts, and its anode drops approximately 100 volts in potential. Since the grid of T is normally at cathode potential, the negative shift in potential at the anode of tube 2 will be transmitted through coupling capacitor C and momentarily drive the grid of T negative, thus stopping conduction through T momentarily. Point A will momentarily rise in potential from about +50 volts to +150 volts and provide a +100 volt pulse to operate some other tube. Note that tube 1 is shown normally conductive. This is determined by the fact that the grid of tube 1 is connected to the cancel line. Thus, this trigger is cancelled OFF.

Figure 87 shows a method of controlling power tubes by a grid-to-grid connection with a trigger. In this case the trigger itself could be used without the power tubes if it were not for the fact that the trigger cannot be loaded. The circuits being controlled require appreciable power; therefore, power tubes T1 and T2 controlled by the trigger are used to provide high and low potentials according to the status of the trigger. When the trigger is OFF

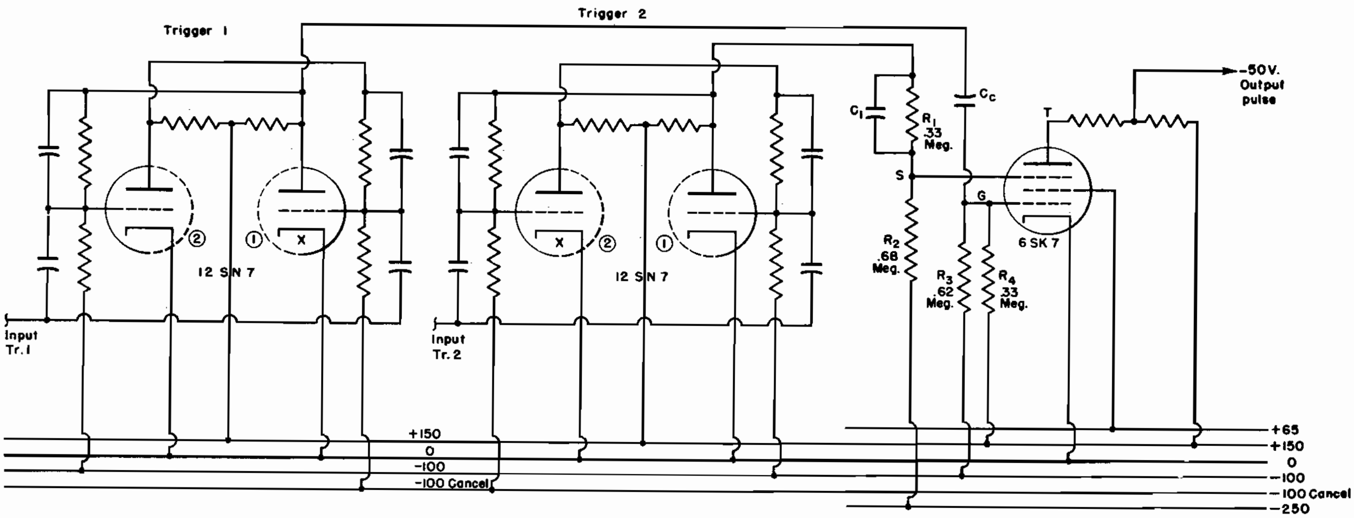


Figure 88. Control of Pentode Switch with Two Triggers

(stand-by state), tube 1 is conductive and its grid is at cathode potential, whereas the grid of tube 2 is below cutoff. Since the grid of T1 power tube is directly connected to the grid of tube 1, T1 will conduct whenever the trigger is OFF, and the anode of T1 will be at low potential. On the other hand, the grid of T2 is connected to the grid of tube 2, which is cut off when the trigger is OFF, thus holding T2 non-conductive and its anode at high potential. Conversely, when the trigger is ON, T2 conducts and T1 does not, thus placing line A1 at high potential and line A2 at low potential.

Figure 88 shows two triggers working in combination to control a pentode switch tube. Pentode tube T is connected so that either its grid or suppressor can stop conduction independently of the other. The grid is normally at approximately −35 volts as determined by the resistor network R3 and R4 between the ground line and the −100 volt line. The suppressor is at approximately −50 volts when the top of R1 resistor is at low potential, as determined by the network R1 and R2 between the anode of tube 1 of trigger 2 and the −250 volt line. Before conduction can occur through the pentode, *both grids must be driven positive.*

Note that trigger 1 is normally OFF and that the anode of its tube 1 is connected to the control grid of T through coupling capacitor Cc. Also note that trigger 2 is cancelled ON, and thus is normally ON with tube 2 conducting. The anode of tube 1 in trigger 2 is directly coupled to the suppressor of T via resistor R1. The shunting capacitor C1 is a compensating capacitor to compensate for the interelectrode capacity of the tube and thus permit more instantaneous response of tube T. When trigger 2 is ON, the anode of tube 1 is at high potential and the suppressor of T will be conditioned to conduct. However, no conduction can take place until the control grid is driven positive. This occurs when trigger 1 goes ON and the anode of its tube 1 rises in potential. Since the coupling from the anode of tube 1 of trigger 1 to the grid of T is through a capacitor, the grid of T will be driven positive only momentarily, and conduction will occur through tube T momentarily. When T conducts, there is a drop in potential at its anode and at any point on its load resistor. Thus when T conducts, a −50 volt pulse is produced at the midpoint of its load resistor. Note that tube T can conduct *only when trigger 1 goes* ON, *providing trigger 2 is* ON *at this time.*

Practically all the tubes controlled by triggers are controlled by one of the foregoing means. These methods will be recognized throughout the circuits for the computing section, and hence they should be carefully studied before proceeding with the actual computing circuits.

ELECTRONIC COUNTER

We are accustomed to using the decimal system when dealing with numbers, that is, to think in terms of tens, hundreds, thousands, etc. Our machine computation methods and number storage devices for the most part employ the decimal systems, perhaps because of our thought habits rather than because of machine parts, economy, or operating speed. Figuring mentally will very likely remain in the decimal system but machine methods are slowly evolving to a special system where results warrant the use. For example, to store a number in relays (or tubes), *using the decimal system,* it is necessary to use one relay (or tube) to represent each digit, or 10 relays (or tubes) per position. For this reason it is expedient to make use of a number system other than the decimal system, which will mean a definite saving in relays or tubes for storage. By using a number system with the base *2,* known as the *binary* system, it is possible to store a digit value in only 4 relays instead of 10. This is done by assigning to 4 relays the values *1, 2, 4,* and *8.* Any digit in the decimal system can then be expressed by means of one or more of the relays as indicated below.

Digit	Relays Energized
0	None
1	1
2	2
3	1, 2
4	4
5	1, 4
6	2, 4
7	1, 2, 4
8	8
9	1, 8

Once a reading is sensed, it must be maintained in order to store the number. Also, a means must be provided to read out the number. When using relays, this is accomplished by using one contact point on the relay for holding and other points for reading out. The relays can just as well be tubes; but when using tubes, this cannot be done by means of one tube. It can be accomplished by using *one trigger* for each position, because a trigger remains ON, once it is turned ON by an input pulse, until another pulse turns it OFF. Therefore, by using four triggers in a tandem connection and designating them as *1, 2, 4,* and *8,* a digit may be stored as indicated by the chart below.

Digit	Triggers ON
0	None
1	1
2	2
3	1, 2
4	4
5	1, 4
6	2, 4
7	1, 2, 4
8	8
9	1, 8

The problem then resolves itself to providing a means of turning the proper triggers ON for a given number. Remember that if triggers are coupled as shown in Figure 84, *when the first trigger goes* OFF, *the second trigger goes* ON. If four triggers are coupled in the manner shown in Figure 84 and designated as shown in Figure 89, the following results are obtained:

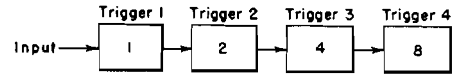
Trigger 1 will turn ON every 2 impulses.

Trigger 2 will turn ON every time trigger 1 turns OFF, or every 4 impulses.

Trigger 3 will turn ON every time trigger 2 turns OFF, or every 8 impulses.

Trigger 4 will turn ON every time trigger 3 turns OFF, or every 16 impulses.

Obviously the system illustrated in Figure 89 cannot be used in storing numbers in the decimal system, since the counter does not restore to zero on the tenth pulse as it should in the decimal system. The device in this case counts on the binary system, that is by 2's, and 16 pulses are required to restore the counter to starting position at *0.*



Pulse No.	Trigger 1	Trigger 2	Trigger 3	Trigger 4	Code
0	OFF	OFF	OFF	OFF	0
1	ON	OFF	OFF	OFF	1
2	OFF	ON	OFF	OFF	2
3	ON	ON	OFF	OFF	1,2
4	OFF	OFF	ON	OFF	4
5	ON	OFF	ON	OFF	1,4
6	OFF	ON	ON	OFF	2,4
7	ON	ON	ON	OFF	1,2,4
8	OFF	OFF	OFF	ON	8
9	ON	OFF	OFF	ON	1,8
10	OFF	ON	OFF	ON	2,8
11	ON	ON	OFF	ON	1,2,8
12	OFF	OFF	ON	ON	4,8
13	ON	OFF	ON	ON	1,4,8
14	OFF	ON	ON	ON	2,4,8
15	ON	ON	ON	ON	1,2,4,8
16	OFF	OFF	OFF	OFF	0

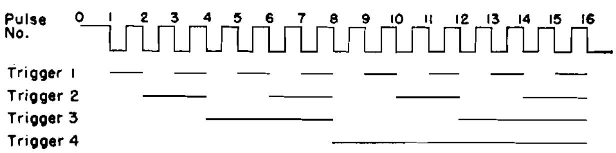


Figure 89. Binary Counter Operation

Note from Figure 89 that the counter follows the decimal system up through 9. Now if some means can be provided to restore the counter to 0 on the tenth pulse, the counter can be used to store and add numbers on the decimal system. This is done in the electronic counter by means of special coupling between triggers and by the use of a special blocking tube, as illustrated by the circuits for one position of an electronic counter shown in Figure 90. The triggers are designated by their digital value and the blocking tube is designated as B.

Note that triggers 1, 2, and 4 are coupled in tandem in conventional manner. However, trigger 8 has special connections to the input capacitors, and tube B is connected in parallel with tube 1 of trigger 2 to serve as a blocking tube. Tube B is normally non-conductive and conducts only when trigger 8 is ON. This arrangement operates exactly as shown in Figure 89 up through the ninth pulse. Then, on the tenth pulse trigger 8 must be turned OFF and trigger 2 must be blocked from turning ON as it normally would on the tenth pulse. The special coupling from trigger 1 to the left side of trigger 8 turns trigger 8 OFF on the tenth pulse, while tube B blocks trigger 2 on the tenth pulse. Thus all triggers are OFF on the tenth pulse, and a negative pulse is available at the output for carry. Figure 91 shows the operation of one position of an electronic counter in chart form, indicating the special coupling from trigger 1 to trigger 8 and the blocking of trigger 2 on the tenth pulse.

Addition in an electronic counter is accomplished by successive impulses, the number depending on the value of the digit to be entered. A

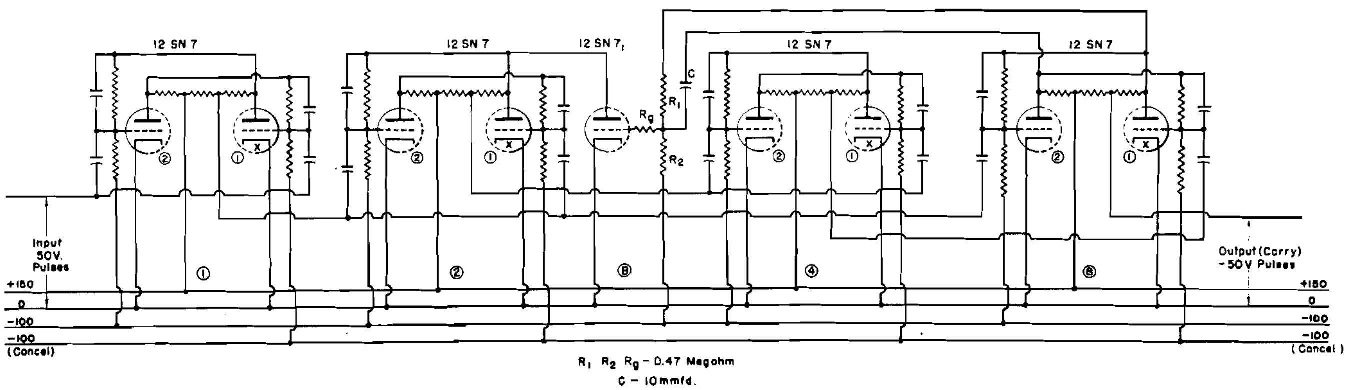


Figure 90. One Position of an Electronic Counter

Number in Counter	0	1	2	3	4	5	6	7	8	9	0	
1st. Trigger ①	O	X	O	X	O	X	O	X	O	X	O	
2nd. Trigger ②	O	O	X	X	O	O	X	X	O	O	O	BLOCK
3rd. Trigger ④	O	O	O	O	X	X	X	X	O	O	O	
4th. Trigger ⑧	O	O	O	O	O	O	O	O	X	X	O	
Code	0	1	2	1 2	4	1 4	2 4	1 2 4	8	1 8	0	Carry

Note—X Indicates Trigger ON
O Indicates Trigger OFF

Figure 91. Electronic Counter Chart

carry to the left is effected each time a position of the counter changes from 9 to 0. Two tubes are required for carrying from each counter position except the last. A trigger is turned ON when the counter advances from 9 to 0. The trigger conditions a switch tube to permit a carry impulse to be fed to the next higher order counter position. If the position receiving the carry impulse stands at *9* and advances to *0*, its carry trigger is turned ON to condition the switch and continue the carry to the next higher counter position. The carry is not instantaneous to two or more positions, but the carry impulse is of sufficient duration to complete the carry to all counter positions if necessary. The carry impulse is made available after the adding portion of the cycle, and the carry triggers that have been turned ON are restored to the OFF position at the completion of carry. The carry operation is shown in block diagram form in Figure 92. The details of the carry circuit are described in a later section after the computing circuits have been described.

Pulses may be delivered to a counter at the comparatively slow rate of card cycle point timing, or at the 35,000 cycle per second rate as in the case of counter transfers. Counters have been successfully operated at impulse rates up to 150,000 cycles per second. The impulse admittance is controlled by tube switches, to be described later.

A detailed explanation of the operation of one position of an electronic counter circuit is presented below (Figure 90).

Triode B has its grid connected between the anode of tube 1 of trigger 8 and the −100 volt line by means of a voltage divider R_1R_2. The anode of tube 1 of trigger 8 is at +40 volts as long as trigger 8 is OFF. (See discussion of *Trigger Circuits.*)

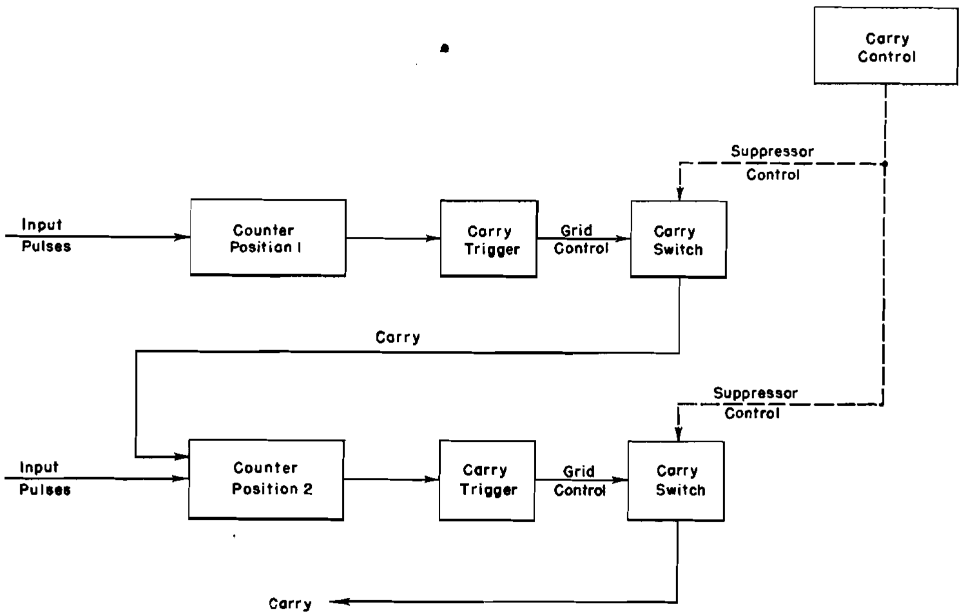


Figure 92. Block Diagram of Carry Controls

This means that the grid of B is midway between +40 volts and −100 volts, that is, −30 volts as long as trigger 8 is OFF. This is considerably below the cutoff potential of tube B, therefore B is non-conductive as long as trigger 8 is OFF.

When trigger 8 goes ON, the potential at the anode of its tube 1 rises to +136 volts. The grid of tube B is then midway between +136 volts and −100 volts, or +18 volts. Of course, the grid does not actually go to +18 volts, because grid current starts flowing through Rg as soon as the grid tries to go positive. This current flow through Rg and R1 is the reverse of the normal current flow through R1 resulting from the +136 volt and −100 volt potentials; consequently the potential at the grid is kept from rising above zero and remains substantially at zero, or cathode potential. With tube B conducting, the potential at its anode is +40 volts. Since the anode of B is directly connected to the anode of tube 1 of trigger 2, the anode of tube 1 of trigger 2 will be maintained at +40 volts regardless of what trigger 2 attempts to do. From the theory of operation of a trigger it will be remembered that the rise in potential at the anode of one tube is necessary to cause the other tube to conduct. If trigger 2 is OFF when tube B is conducting then *trigger 2 cannot be turned* ON regardless of the pulses applied, because the anode of tube 1 of trigger 2 cannot rise above +40 volts, and as a result, the grid of tube 2 of trigger 2 cannot go above cutoff potential.

The input pulses to the counter are 50 volts square wave pulses. From the theory of operation of a trigger it will be remembered that the trigger will recognize only negative pulses provided the voltage amplitude of the pulses is kept within certain limits. Hence, only the negative shifts in voltage are recognized by the triggers. The entry pulses are fed to both input capacitors of trigger 1 to turn it ON and OFF on successive pulses. Each time trigger 1 goes ON, a 50 volt positive pulse is produced at the anode resistor tap of tube 1 of trigger 1. However, this positive pulse is not recognized and consequently can be ignored. Each time trigger 1 goes OFF, a 50 volt negative pulse is produced at the anode resistor tap of tube 2 of trigger 1, and this negative pulse is fed to both input capacitors of trigger 2.

Assuming the counter position is at zero, all four triggers are OFF and tube B is non-conductive. One entry pulse turns trigger 1 ON, and the counter position stands at 1. The resulting positive pulse to triggers 2 and 8 has no effect. A second entry pulse turns trigger 1 OFF which in turn trips trigger 2 ON, and the counter stands at 2.

Note that the negative pulse which turned trigger 2 ON also is fed to the left side of trigger 8. Trigger 8 is OFF at this time, and the grid of tube 8_2 is already negative; consequently this negative pulse has no effect. Also, the positive pulse from the anode resistor tap of tube 2_1 has no effect on trigger 4.

A third entry pulse turns trigger 1 ON again, and a positive pulse is fed to trigger 2. This positive pulse has no effect; consequently, trigger 2 remains in the ON status, and the counter stands at 3 (triggers 1 and 2 ON). A fourth entry pulse switches trigger 1 OFF, which in turn switches trigger 2 OFF. When trigger 2 goes OFF, a negative pulse is produced at the anode resistor tap of tube 2_1, and this pulse is fed to both input capacitors of trigger 4, turning it ON. This leaves only trigger 4 ON, and the counter stands at 4.

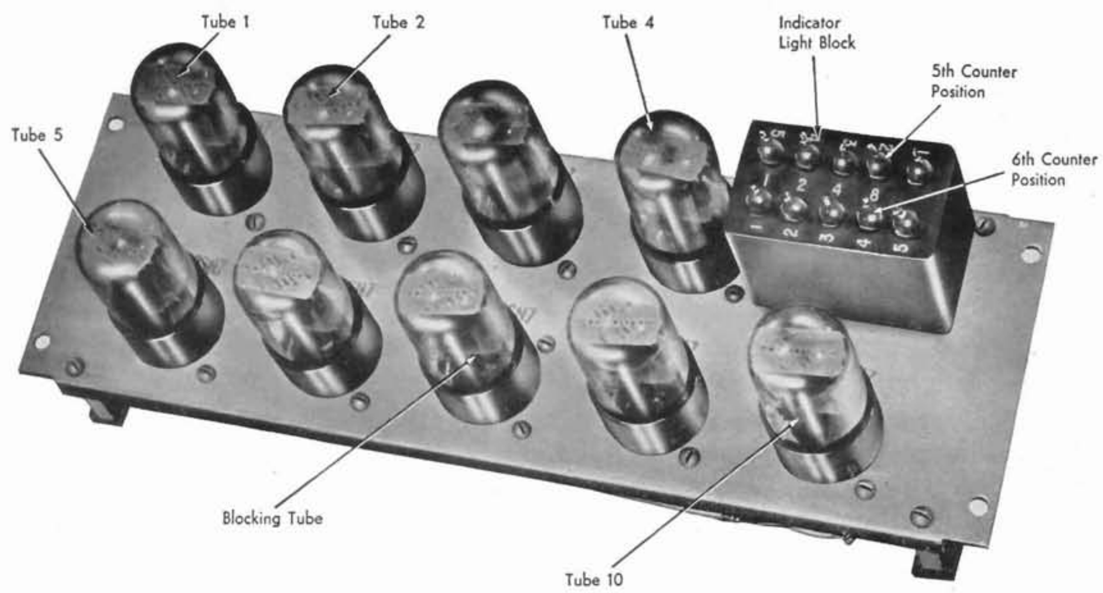
A fifth entry pulse again turns trigger 1 ON, and the counter stands at 5 (triggers 1 and 4 ON). A sixth entry pulse turns trigger 1 OFF, causing trigger 2 to go ON, and the resulting positive pulse has no effect on trigger 4; therefore, the counter stands at 6 (triggers 2 and 4 ON). A seventh entry pulse again turns trigger 1 ON, but has no effect on trigger 2, thus leaving triggers 1, 2, and 4 ON, and the counter stands at 7. An eighth entry pulse turns trigger 1 OFF, causing trigger 2 to go OFF; as trigger 2 goes OFF, it turns trigger 4 OFF. When trigger 4 turns OFF, it produces a negative pulse which is impressed on the grid of tube 1 in trigger 8. This negative pulse stops conduction in tube 8_1 and causes trigger 8 to go ON and the counter stands at 8.

When trigger 8 goes ON, the anode of tube 8_1 is at high potential (+136 volts). Since this potential is applied to the grid of tube B through the voltage divider R_1R_2, it means that the potential at the grid of tube B will rise above cutoff and tube B becomes conductive. This tube is used on the tenth pulse. A ninth entry pulse will again turn trigger 1 ON and have no effect on other triggers, thus leaving the counter at 9 (triggers 1 and 8 ON). A tenth entry pulse turns trigger 1 OFF which in turn passes a negative pulse to trigger 2 and to the left side of trigger 8. This negative pulse tends to trip trigger 2 ON, but such action in trigger 2 demands a rise in potential at the anode of tube 2_1. Since tube B is now conductive, it holds the potential at the anode of tube 2_1 to +40 volts and overcomes the attempted rise in potential at the anode of tube 2_1 and at the grid of tube 2_2. Thus, with tube B conductive, trigger 2 is blocked from turning ON. The negative pulse produced by stage 1 is also applied to the grid of tube 8_2. This causes tube 8_2 to stop conducting; consequently, trigger 8 goes OFF, and the counter has restored to zero (no triggers ON). When trigger 8 goes OFF, the potential at the anode of tube 8_1 drops abruptly from +136 to +40 volts, while the potential at the anode of tube 8_2 rises abruptly from +40 volts to +136 volts. A tap on the anode resistor of tube 8_1 furnishes a −50 volt pulse to operate the carry trigger. If a positive pulse is desired to operate a switch when a carryover occurs, a tap on the anode of tube 8_2 can be used.

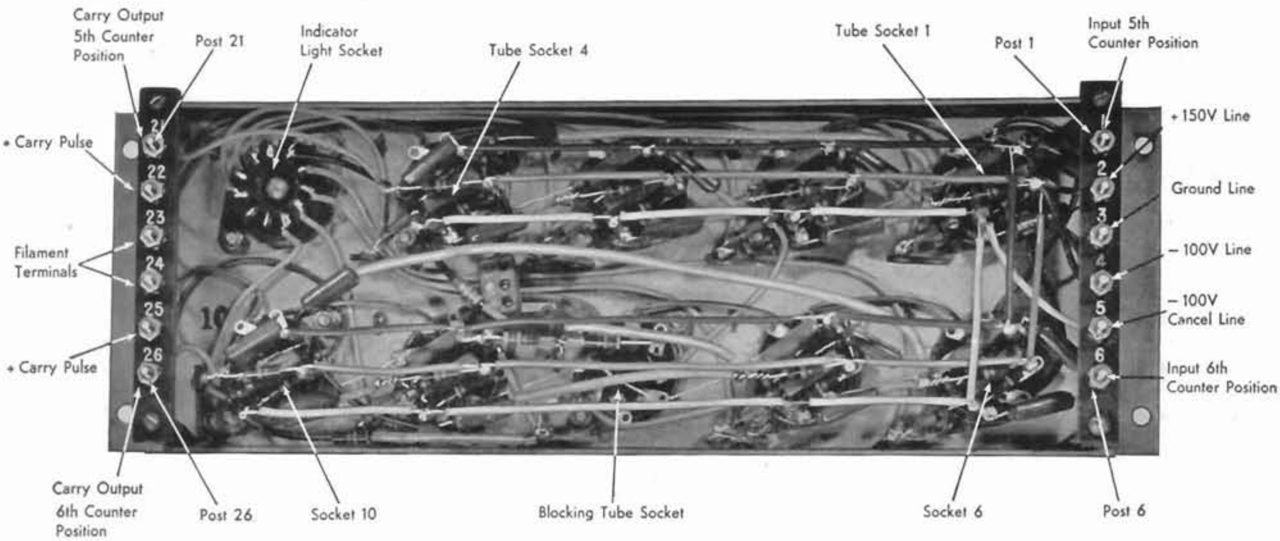
Any digit can then be added into this counter by applying the proper number of negative pulses. If 6 pulses are applied, the counter will stand at 6, since triggers 2 and 4 will be ON. A counter will retain a reading as long as power is applied. When a counter is to be cleared, it is merely a matter of opening the −100 volt cancel line. This applies +150 volts to the right side of all the triggers and they are all turned OFF, thus restoring the counter to 0. Cancelling is always necessary before reading into a counter, because when power is first turned ON, the triggers may assume any status, depending entirely upon chance or upon variations in individual tubes.

Observe that on the tenth pulse when trigger 8 goes OFF and the potential drops at the anode of tube 8_1, triode B is rendered non-conductive, and its anode potential immediately rises, thus releasing trigger 2 from the blocking action. If this occurred too soon, the tripping pulse produced by trigger 1 on the tenth pulse might still be effective to turn trigger 2 ON. To insure against this, the blocking action of tube B is maintained for a short time after trigger 8 goes OFF by maintaining conduction through tube B for a short period after trigger 8 goes OFF. This insures that trigger 2 is not unblocked until the tripping pulse from trigger 1 is spent. It is for this reason that the grid of tube B is coupled to the anode of tube 8_2 through capacitor C. During the reversal of trigger 8 to the OFF status, the potential at the anode of tube 8_2 is rising rapidly while that at the anode of tube 8_1 is dropping rapidly. The rising potential is transmitted by way of the capacitor C to grid resistor Rg of tube B. This rising potential counteracts the effect of the dropping potential on the grid of tube B and maintains the grid of tube B above cutoff until capacitor C is fully charged. Thus, the grid of triode B does not follow the anode of tube 8_1 immediately, but is held above cutoff potential for a definite delay period determined by the charging time of capacitor C. Thereafter, the low potential at the anode of tube 8_1 is effective to hold tube B cut off as long as trigger 8 is OFF.

In practice the blocking tube is one-half of a 12SN7 twin triode. The other half is used as the blocking tube for another counter position. For this reason and to facilitate the handling of the tube chassis, counter chassis are built with two counter positions per chassis as shown in Figure 93. Each chassis also contains an indicator light block



A. Front View – Showing Indicator Block



B. Rear View – Showing Terminals

Figure 93. Two-Position Electronic Counter (K Chassis)

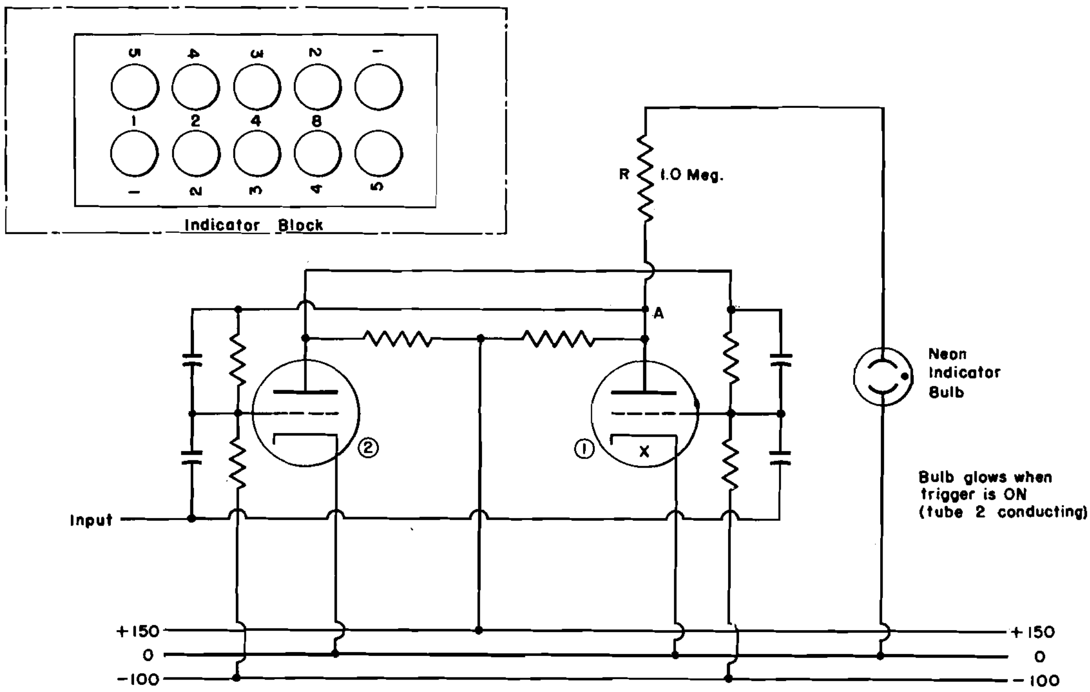


Figure 94. Indicator Lights

used to indicate the counter reading at any time by indicating which triggers are ON. One row of lights applies to each counter position. The bottom view of the chassis indicates the terminal connections.

As an example of the circuits for a complete counter chassis, see the circuit diagram for chassis K, the 5th and 6th counter positions of the multiplicand counter (Sections 47 and 48 on wiring diagram). Note that the nine filaments are in series across the 115 volt A.C. line, placing 12.8 volts across each filament. All counter chassis are the same regardless of where they are used. If carry circuits are necessary, the tubes controlling carry are mounted in separate chassis. No carry circuits are used in the multiplier or multiplicand counters; only the product counter requires carry circuits.

Observe that all counters use high-speed triggers. Since counter read-in may be at either high or low speed, it is necessary to employ high-speed triggers throughout.

Indicator Blocks

Neon indicator lights are used throughout the electronic unit to indicate the status of various triggers. The light is wired to glow when the corresponding trigger is in the ON status. Figure 94 shows how the indicator light is connected to a trigger. As long as the trigger is OFF (tube 1 conducting), the anode of tube 1 (point A) is at +40 volts, and there are 40 volts impressed across the neon bulb since the bulb is connected between ground and the anode of tube 1 through resistor R. This bulb will not glow, however, until at least 90 volts are impressed across it. When the trigger goes ON, the potential at the anode of tube 1 rises to +136 volts, and the neon bulb will glow, indicating that the trigger is ON.

The 1 megohm resistor R limits the current through the neon bulb, isolates the anode of tube 1 from other circuits, and thus prevents capacity coupling in the cables.

As a word of caution, it should be pointed out that the neon bulb will glow when the potential at point A is over +90 volts regardless of the trigger status. For example, if the filament of a trigger tube is burned out, neither tube can conduct. However, the indicator light glows, indicating that the trigger is ON. Sometimes this can be used to detect a faulty trigger tube.

The indicator bulbs are mounted in a block which can be plugged into a socket. An extension cable is provided to permit viewing indicator lights from the rear of the chassis. The layout of the bulbs in a block is shown by the insert in Figure 94. Note that there are ten bulbs in the block. The numbering is designed to permit use of a standard block in all applications. The horizontal numbers between the bulbs (1, 2, 4, 8) refer to the digital value of triggers used in counters while the numbers along the edges of the block merely represent the bulb number. When the socket is used in locations other than counters, it is ordinarily mounted vertically so that the numbers on the outer edges can be read. In these cases the left side is counted first, and number 6 is the first bulb in the row to the right.

To avoid confusion, it is recommended that on the indicator blocks used in counters the outer numbers be blacked out with masking tape or crayon.

Counter Read-In from Card

Reading into an electronic counter from a card requires that the electronic counter receive a number of negative pulses equal to the value of the digit punched in the card. The method of doing this is illustrated by the block diagram in Figure 95. A set of CB's provides 9 positive pulses which are fed to a switch tube. The pulses from the CB's have no effect, however, until the switch is "unlocked" by the trigger, and consequently no negative pulses can pass through from the switch tube to the counter until the read-in trigger is turned ON. (A tube inverts a pulse so that the positive pulses from the CB's pass to the counter as negative pulses.)

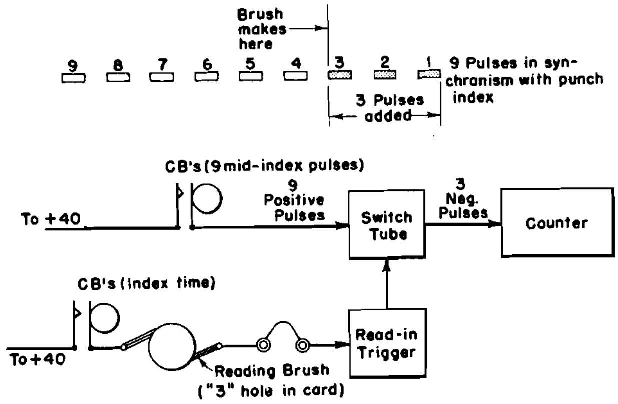
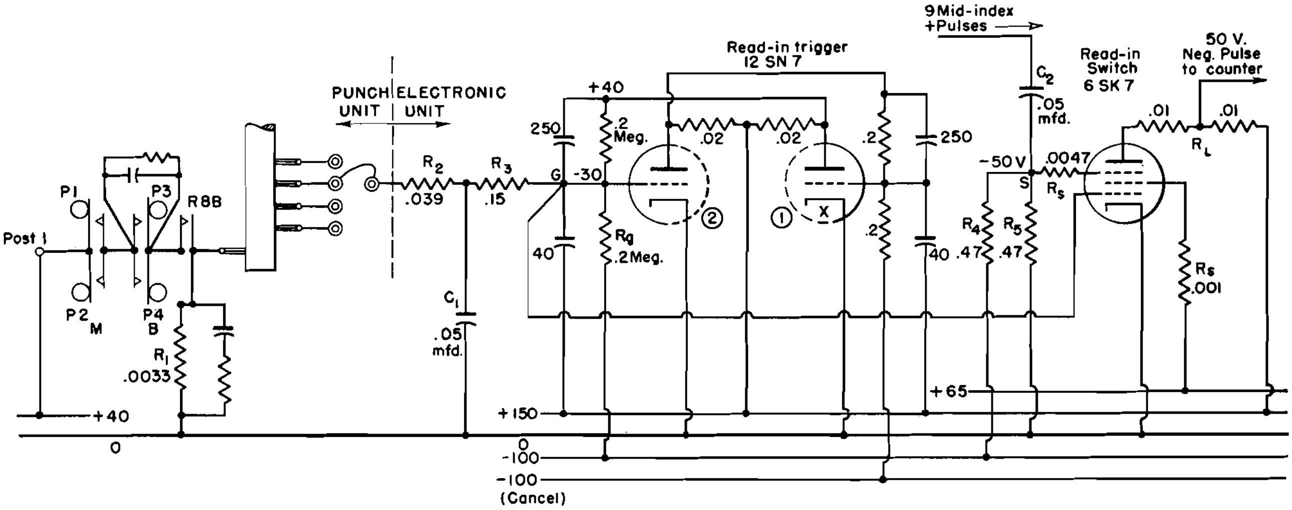


Figure 95. Block Diagram of Counter Read-in Circuits

When a brush drops through a hole in the card, the read-in trigger is turned ON, and the switch tube is "unlocked" so that it can start passing pulses. If, for example, the brush drops through a 3 hole, the CB's will make only 3 more times in that cycle and only 3 pulses will be passed to the counter. The trigger is necessary to provide a means of maintaining the switch tube in a conductive state until the end of the cycle, because the impulse from the hole in the card has a duration of only 0.3 of a cycle point on the index. Before a new cycle is started, the read-in trigger is cancelled OFF to prepare it to accept a new reading. The block diagram does not indicate the actual connections, but these can be found in the complete circuit for read-in control of one counter position shown in Figure 96.

Observe that the control grid of the pentode switch tube is tied directly to the grid of tube 2 of the trigger, so that the grid of the pentode follows the grid of tube 2 of the read-in trigger in potential. As long as the trigger is OFF, as indicated in Figure 96, the potential at point G is –30 volts and the pentode switch is cut off. When the trigger goes ON, point G rises to cathode potential and so does the control grid of the pentode, thereby conditioning the pentode to conduct. The positive pulses on the suppressor of the 6SK7 can then be inverted to negative entry pulses for the counter input. The voltage shift at the anode of



All resistance values shown in megohms
All capacitance values shown in micro-microfarads unless otherwise indicated

Figure 96. Counter Read-in Control Circuit

the 6SK7 is 100 volts when conduction starts. Since the counter requires only a 50 volt pulse, a center tap is used on the pentode load resistor R_L.

The suppressor of the 6SK7 is connected to point S between resistors R4 and R5 which are tied to the −100 volt line and the ground line respectively. Since R4 and R5 are equal, this places point S at −50 volts normally and the tube is cut off regardless of the potential at the grid. However, once the grid is conditioned to conduct, then any time the suppressor rises above cutoff potential, the pentode will conduct and a negative pulse is produced at the anode of the 6SK7. The suppressor rises above cutoff whenever a positive pulse is applied to point S through the coupling capacitor C2. The number of these pulses accepted by the 6SK7 depends upon the point in the punch cycle when the trigger is turned ON from a hole in the card.

The turning ON of the trigger is accomplished as follows: When the card brush makes contact through a hole in the card and the CB's make, a circuit is established from the +40 volt line, through post 1, CB's R8B, common brush, contact roll, hole in card, individual brush, brush hub, control panel wire, counter entry hub, through resistors R_2, R_3, and Rg to the −100 volt line. This circuit will cause current flow through R_2, R_3, and Rg. The increased current through Rg, in addition to the normal bleeder current, causes an increased IR drop across Rg and point G rises above cutoff for tube 2 of the trigger so that tube 2 of the trigger starts conducting. Immediately the dropping potential at the anode of tube 2 cuts off tube 1 by means of the retroactive coupling from the anode of tube 2 to the grid of tube 1. This means that the trigger is turned ON. Observe that the input capacitors of this trigger are tied to the +150 volt line and that the tripping pulse from the brush is applied to the left side only.

Once the trigger goes ON it remains ON until it is cancelled OFF, and the 6SK7 is conditioned to accept the pulses applied to the suppressor. The use of this arrangement provides a safeguard against "bouncing" brushes or CB contacts. Once the trigger is turned ON, any opening of the circuit due to a "bouncing" brush will not turn it OFF. Also, if the circuit is completed again, the trigger is already ON and no effect is produced. Only a short making time is required to turn the trigger ON, and after that it does not matter what happens to the brush.

The purpose of the capacitor C_1 tied between R_2 and R_3 to ground is to by-pass any stray pulses on the line to ground and thus prevent them from turning the trigger ON. Before the effect of a pulse can be felt at G, the capacitor C_1 must be charged, because during the charging time of C_1 it is effectively a shunt to ground. This means that any short duration transients will be dissipated in charging C_1. The exact time constant is determined by the value of R_2 and C_1. Of course, this produces a slight delay in the triggering operation when a brush makes, but the delay is not objectionable because the brush contact duration is considerably longer than required to turn the trigger ON.

The purpose of the RC combination R1-CR4 is to ground the CB's between pulses and thus prevent unstable operation resulting from "floating" lines when the CB's are open. The purpose of the resistor Rs in the screen and suppressor circuits of the 6SK7 is to prevent parasitic oscillations. The screen resistor also presents a means of producing equal current flow through all tubes used in parallel. For example, one tube's characteristic may be such that its screen and anode current during conduction are higher than the screen and anode current of other tubes. When all tubes are operated at the same voltage, the higher screen current of this tube will cause a greater voltage drop across the individual screen resistor for this tube and will thereby reduce the screen potential, resulting in a decreased anode current. Thus, variations in tube characteristics produce no variation in operation.

Read-In Pulse Circuit

The block diagram in Figure 95 indicates that the 9 pulses provided to control reading into a counter are directly from a CB cam contact. Actually, this is not true, because a cam contact is likely to be erratic because of contact bounce, and several pulses may be entered in a counter for one cycle point. To avoid this trouble, the CB's control a trigger which in turn controls a power tube to provide the pulses to control the read-in switch pentodes. A power tube is necessary because if a trigger is loaded, unstable operation results.

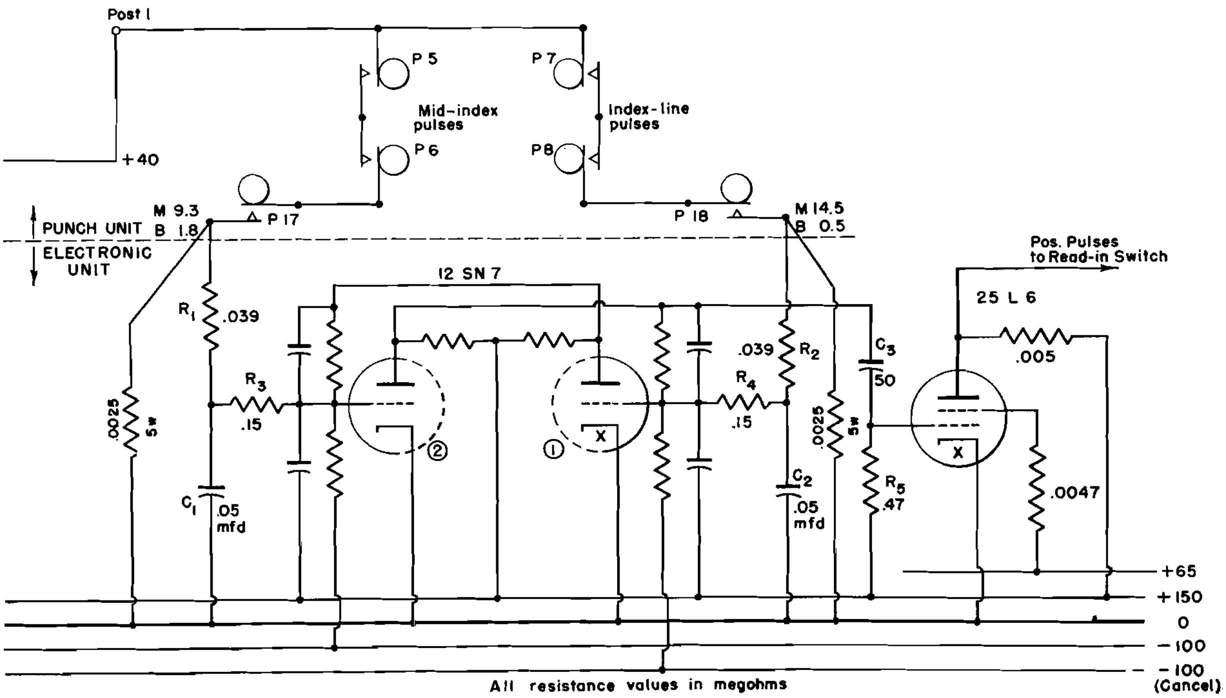


Figure 97. Read-in Pulse Circuit

As shown in Figure 97, a set of CB's (P5 and P6) make 5 teeth after each index line and break 8 teeth after. P17 cam contact allows only the pulses from 9.5 through 1.5 to pass. Each time the CB's make, the trigger is turned ON in exactly the same manner described in the section, *Counter Read-in from Card.*

Observe that the 25L6 power tube is normally conductive, since its control grid is tied to the +150 volt line. This means that its anode is normally at low potential. Also observe that the grid of the 25L6 is coupled to the anode of tube 2 of the trigger through coupling capacitor C_3. When the trigger goes ON, the anode of tube 2 drops suddenly from about +136 volts to +40 volts. This negative shift in voltage is passed through C_3 to the grid of the 25L6 and momentarily cuts it off. When the 25L6 stops conducting, its anode potential rises to +150 volts, and the resulting positive pulse is passed to the suppressors of all the switch tubes controlling the multiplier and multiplicand read-in.

Another set of CB's (P7 and P8) make at each index line and open three teeth after the line. P18 cam contact allows only the pulses from 9 through 0 to pass to the right side of the trigger. Each time that P7 and P8 make from 8 to 0, the trigger is turned OFF in exactly the same manner it was turned ON by P5 and P6. Consequently, the trigger goes ON at mid-index points from 9.5 through 1.5 and goes OFF at index points from 8 through 0, thus providing 9 pulses in synchronism with card movement through the punch for read-in control.

The by-pass capacitors C_1 and C_2 serve the same purpose as the by-pass capacitor C in Figure 96. As in the case of the read-in triggers, this method of generating pulses eliminates all trouble due to bouncing contacts. For example, once the trigger is turned ON by P5 and P6 making, it makes no difference if they do open and close because of a bounce. The trigger cannot be turned OFF by opening P5 and P6; it can be turned OFF only by P7 and P8 closing. Likewise, once the trigger is turned OFF by P7 and P8 making, any break in the circuit will not turn the trigger ON; only a circuit through P5 and P6 can turn it ON. The two .0025 megohm wire-wound resistors shown connected from ground to P17 and P18 are provided to maintain a sufficient flow of current through the contact points in order to prevent a film forming over these points when no current flows.

The read-in trigger and power tube are tubes B-35 and B-36 in the B chassis. The circuit is shown in Section 30B of the wiring diagram. Observe that the read-in pulse control trigger is a slow-speed trigger.

Counter Read-In at High Speed

When multiplying, high-speed pulses at the rate of 35,000 per second are fed to the multiplicand counter. For each cycle during which the multiplicand counter is to be "rolled," ten pulses are fed to the counter to provide a timed carry pulse and restoration of the counter back to its original setting. These ten pulses are positive pulses which are applied to the grid of a normally cut-off inverter triode. The positive pulses cause conduction through the tube, and the resulting negative pulses are fed to the counter through an anode resistor tap.

The complete wiring diagram for the multiplicand counter read-in controls in the D chassis may be seen in the circuit diagram in Sections 33 and 34. Posts 1, 5, 8, 12, 15, and 19 are connected to the multiplicand counter entry hubs on the control panel through the connecting cable. Posts 21, 26, 28, 33, 35, and 40 connect to the input of the six multiplicand counter positions. The indicator lights indicate which of the six read-in triggers (D1, D4, D7, D10, D13, D16) is ON, that is, which is accepting card read-in pulses. No indication is given of the high-speed read-in.

Only one voltage divider is used to furnish the –50 volt potential normally applied to all pentode suppressors. This divider is shown under tube D3 connected between the −100 volt line and ground. Also, only one input capacitor is used to feed the read-in pulses to all six suppressors. This same input capacitor is used to supply the read-in switches for the multiplier counter on the C chassis. Post 45 indicates this connection.

The tubes are arranged so that each horizontal row corresponds to one counter position as nearly as possible. Since only a triode is required to control the high-speed input for each position, only three 12SN7 twin triodes are used for the six positions, consequently, the line up of one row per position is not strictly true in the D chassis.

The ten high-speed pulses to roll the multiplicand counter originate in the B chassis and are fed in to post 2 through the 250 mmfd coupling capacitor to the input inverters D5, D11, and D14.

The grids of the input inverters are normally at about −35 volts since they all tie to the voltage divider shown under tube D5. This voltage divider is tied between ground and the −100 volt line and the grids are tapped approximately two-thirds of the way from the −100 volt line or at about −35 volts. Positive pulses entering post 2 drive all grids above cutoff simultaneously so that all six counter positions receive the rolling pulses. Note that the high-speed read-in control triodes utilize a portion

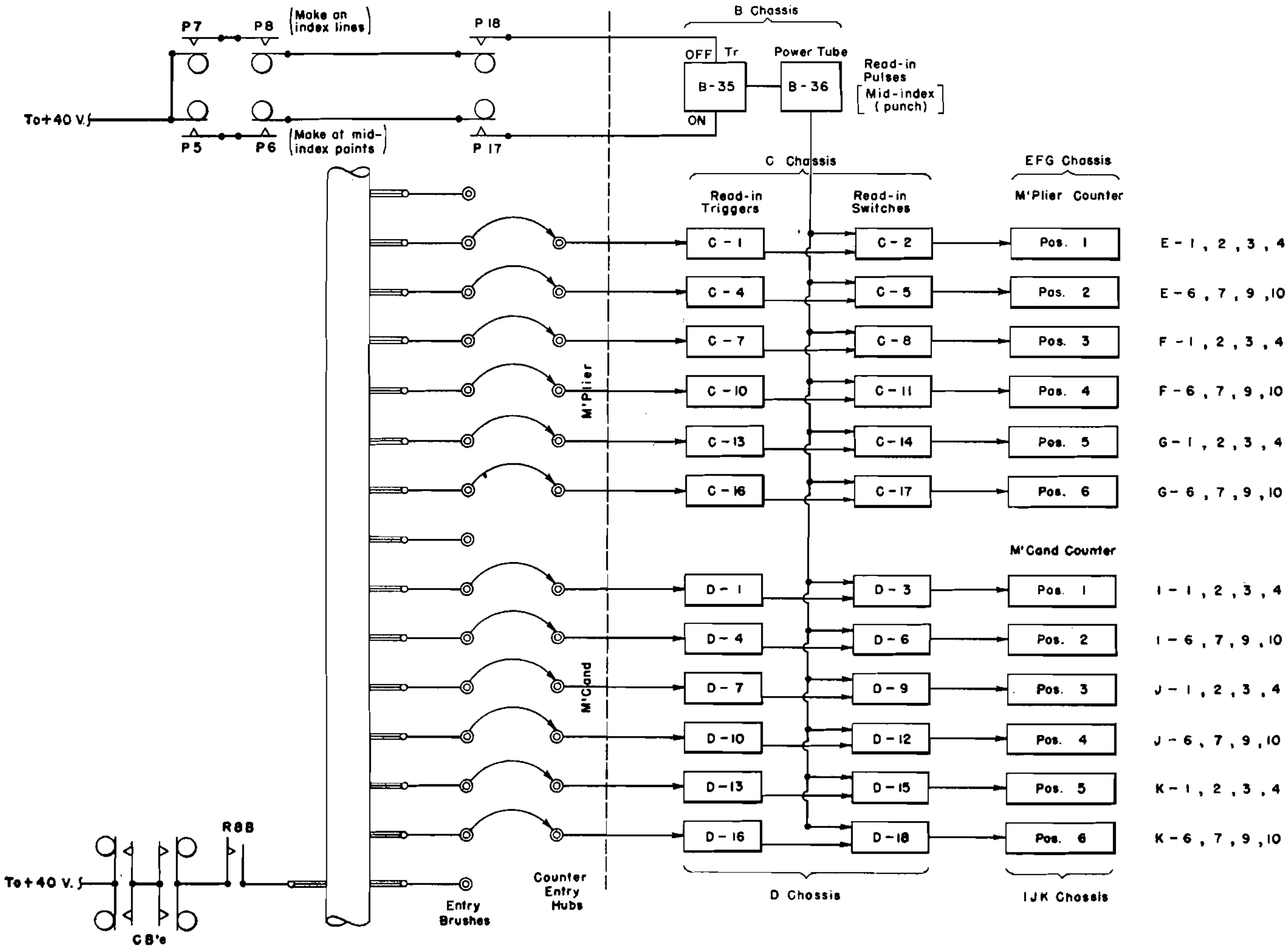


Figure 98. Block Diagram of Read-in Circuits

of the anode resistors in the switch tube anode circuit. Since only one circuit is in operation at the time, this permits simpler connections as only one counter input wire is required for both operations.

The multiplicand counter consists of six electronic counter positions on chassis I, J, and K, shown on Sections 43 through 48 of the wiring diagram. All counter positions are exactly the same; therefore, no effort will be made to repeat any counter operations.

The screen potential of the multiplicand read-in switches is under control of the factor reversal switch. When set for group multiplying, with the factor reversal switch ON, the screen supply is open on all cards except the rate card; the switch tubes are non-conductive. Observe that the +65 volt supply on the D chassis is connected to terminal CNp34. This connection places the +65 volt supply for the multiplicand read-in switches under the control of the group multiply and factor reversal relays.

The read-in controls for the multiplier counter appear on chassis C and circuits are shown in Sections 31 and 32. The multiplier read-in switches also have their screen supply connected through the group multiply and factor reversal relays in the punch unit through connector CNp32. This arrangement is used to permit conduction by the read-in switches only when a rate card passes the first set of brushes during a group multiplying run. Use is made of the fact that a 6SK7 will not conduct if there is no potential on its screen. The multiplier counter (chassis E, F, G) circuits are shown in Sections 35 through 40. Figure 98 is a block diagram of all read-in circuits, showing all tubes for all counter positions.

COMPUTING CIRCUITS

Multivibrator and Clippers

After the multiplier and multiplicand factors have been entered into their respective counters, the operation of the computing section is initiated by P24 cam contact at 11.5 on the index. Before explaining the starting of computations in detail, means of producing operating pulses for the computing section will be described.

A suitable oscillator is required as a parent source of pulses for performing the computations. The pulses must be square wave pulses for proper operation of triggers; consequently, a multivibrator type of oscillator is used. The multivibrator develops roughly square-topped waves of potential at the outputs of the two tubes, the waves at one output being 180° displaced in phase from those on the other output. In this machine two multivibrators are provided, one to generate square waves at approximately 35,000 per second for normal computations and one to generate 5 cycles per second for slow-speed operation, which permits visual observation of tube operations by watching the indicator lights. A dial switch is provided to switch from one multivibrator to the other.

Fluctuations in the frequency of the multivibrator do not affect the accuracy of the computing operations since the multivibrator is itself the master timer of all computing operations.

As the output of the multivibrator is not a true square wave, some means must be provided to shape the pulse into a square wave. This is done by means of clippers, which utilize only a portion of the wave from the multivibrator and thus produce an almost perfect square wave. The theory of operation of both multivibrators and clippers follows. Thorough knowledge of the theory of operation of multivibrators and clippers is not es-

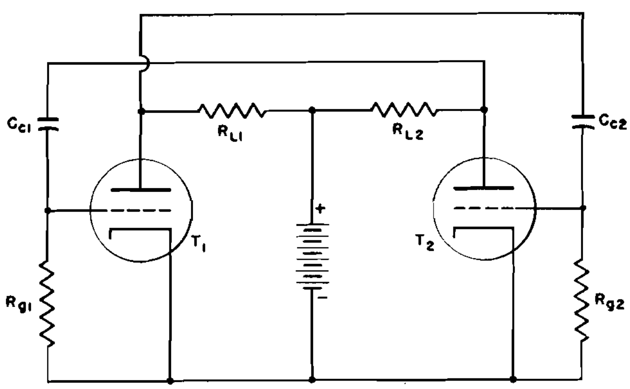


Figure 99. Basic Form of Multivibrator

sential to repair the machine and may be skipped if desired. However, for the benefit of those who wish a thorough explanation, the complete theory of operation is discussed.

The basic form of a multivibrator is shown in Figure 99. By comparing this circuit with a trigger circuit, it will be observed that the multivibrator circuit is derived from the Eccles-Jordan trigger circuit by removing the grid-to-anode coupling resistors. In this manner the circuit *reverses itself* as fast as the coupling capacitors charge and discharge, instead of depending upon externally applied pulses.

In order to understand the operation of the multivibrator, assume that on applying power both tubes start conducting and that the coupling capacitors Cc charge. Note that the voltage across T_1 is applied to the Rg_2-Cc_2 combination and that the voltage across T_2 is applied to the Rg_1-Cc_1 combination. Also remember that it takes time for the voltage across a capacitor to change. Consequently, once the Cc capacitors are charged, a voltage change at the anode of either tube will be transmitted through the Cc capacitor and be felt instantaneously at the opposite grid. With both T_1 and T_2 conducting, assume there is a momentary increase in anode current through T_1 caused by a sudden increase in emission. The starting of oscillation actually depends on the fact that no two tubes are exactly alike in characteristics. Any increase in current flow through RL_1 increases the IR drop across RL_1 and thereby reduces the potential at the anode of T_1. This reduction in potential is transmitted through Cc_2 to the grid of T_2. The reduction in potential at the grid of T_2 lowers the anode current through T_2, which results in a lower IR drop across RL_2 and an increased potential at the anode of T_2. This increased potential is transmitted via Cc_1 to the grid of T_1, and it results in a further increase in anode current through T_1. This continues until T_2 is completely cut off. The process is cumulative and with proper design the action is almost instantaneous.

When T_2 is cut off, it remains so as long as the charge on Cc_2 keeps the grid of T_2 below cutoff value. Once T_2 is cut off, Cc_2 starts discharging as indicated in Figure 100A, and as soon as sufficient charge has leaked off through Rg_2, the grid potential on T_2 rises above cutoff, and anode current again starts to flow through T_2. This decreases the potential at the anode of T_2; and since the voltage across Cc_1 cannot change instantaneously, this decrease in potential at the anode of T_2 is transmitted through Cc_1 to the grid of T_1, resulting in a decreased anode current through T_1. The decrease in anode current through T_1 increases its anode potential; this increase is transmitted through Cc_2 to the grid of T_2, which in turn further increases the anode current through T_2 and lowers the potential at the anode of T_2 which in turn makes the grid potential of T_1 more negative. This cumulative process continues until T_1 is cut off; T_1 remains cut off until Cc_1 discharges (Figure 100B), and the cycle repeats itself.

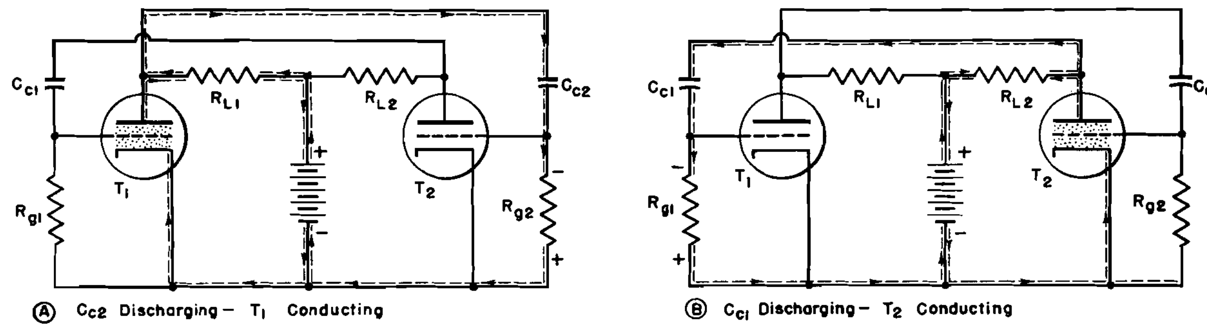


Figure 100. Current Flow in Multivibrator

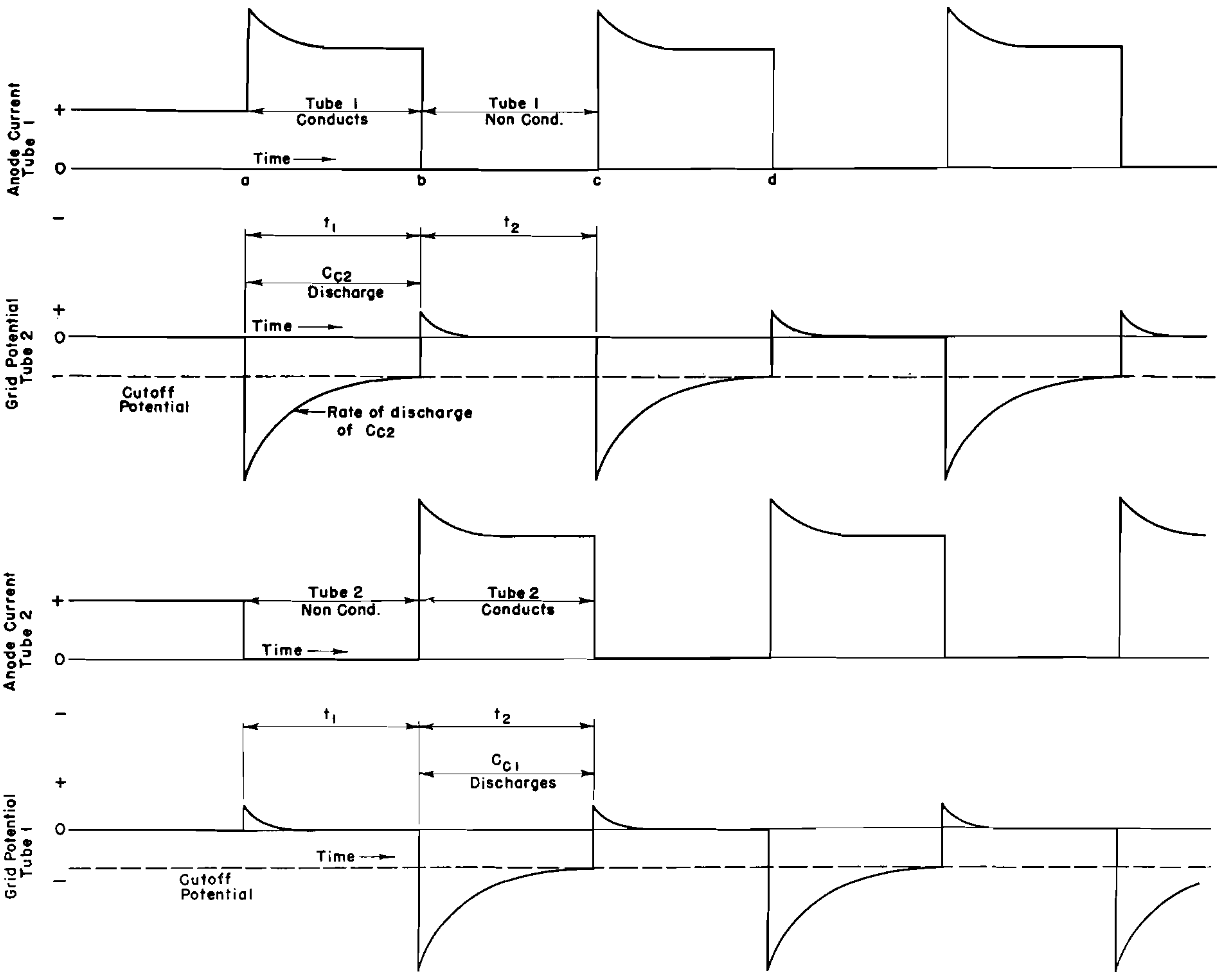


Figure 101. Voltage and Current Curves for Multivibrator

The time interval between the triggering operations, that is, the frequency of oscillation, is determined primarily by the value of Rg and Cc and to a small extent by the value of RL and the supply voltage. The time interval that T_1 conducts can be made different from the time interval that T_2 conducts by varying the values of Cc_1 and Cc_2. In this application, the two time intervals must be the same; consequently, the two sides of the multivibrator must be symmetrical.

The voltage across RL_1 rises and falls exponentially because of the charge and discharge of Cc_2. If RL_1 is sufficiently small in comparison with Rg_2 so that the capacitor current does not greatly affect the voltage drop across RL_1, the voltage pulse across RL_1 is approximately rectangular. Therefore it is important to have the value of the RL resistors much smaller than the Rg resistors if a rectangular wave form is desired.

Figure 101 shows the theoretical grid potential and anode current curves for a typical multivibrator. The graphs assume that on starting both tubes are conducting; at time *a*, the first triggering takes place because of an increase in current through tube 1 and continues at regular intervals. Note that the anode current is not constant during conduction. This is due to the discharging current of the capacitors. From Figure 100 it will be observed that the direction of capacitor discharge current flow through the RL resistors is the reverse of the direction of tube current flow.

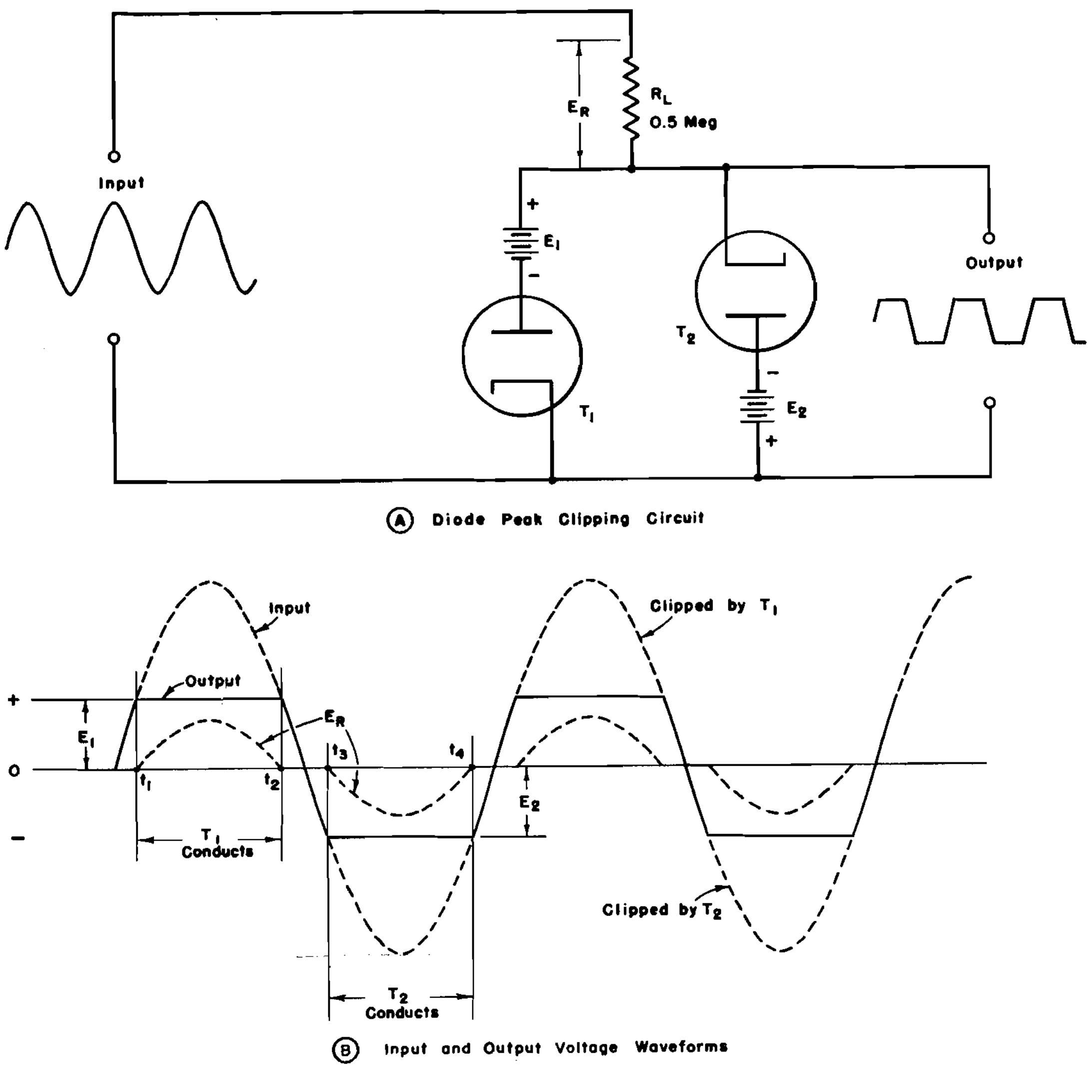


Figure 102. Principle of Peak Clipping Circuits

Hence the net anode current is less than the amount normally flowing through the tube.

The low grid potential during the positive half of the grid potential waveform is explained by the flow of grid current which rises rapidly with an increase in positive grid potential and produces an IR drop across the Rg resistor, thus keeping the grid potential from rising very far above zero.

The change in grid potential during the positive half of the cycle is more rapid than during the negative half. This is explained also by the flow of grid current. When grid current is flowing in T_2, the grid resistance of T_2 is much lower than the resistance of Rg_2; therefore during this time, T_2 effectively shunts Rg_2, and the charging current of Cc_2 is limited almost entirely by RL_1 which is low compared with Rg_2. During the negative half of the cycle, the grid resistance of T_2 is almost infinite and the discharge current is limited by RL_1 and Rg_2. Since Rg_2 is much larger than RL_1, the capacitor charges much more rapidly than it discharges. Since the grid potential of the conducting tube drops to zero more rapidly than the negative grid potential of the other tube rises above cutoff, triggering is determined by the grid potential of the non-conducting tube, and the frequency of oscillation is determined by the rate of rise of the negative grid potential. This time interval is indicated as t_1 and t_2 in Figure 101.

The voltage output at any point on a multivibrator is approximately a square wave, but not sufficiently so to use directly for operating triggers. For this reason, the pulses must be shaped to a true square wave. This is done by a *peak clipping* circuit. A simple form is illustrated in Figure 102, together with the voltage waveforms. The diode clipper shown illustrates the clipping of a sine wave and converting it into a flat top wave approximating a square wave. The output voltage exactly follows the input voltage until the impressed voltage reaches the point where conduction starts through one of the diodes, and the resulting IR drop across RL prevents any further rise of the output voltage. This is true because with an increase in current, the IR drop across RL increases rapidly owing to the large value of RL, but the voltage change across the diode is negligible.

The graphs in Figure 102B show the action of the clipping circuit. If it is desired to clip only the top of the positive half of the wave, only tube T_1 is necessary. The purpose of the batteries E_1 and E_2 is to establish the voltage amplitude at which clipping occurs. In practice, these would be replaced by capacitors.

A triode clipping circuit is illustrated in Figure 103. Observe that the grid of T_1 is connected midway between the −100 volt line and the +150 volt line through the equal resistors R_1 and R_2 so that the grid approaches +25 volts. Grid current maintains the grid potential at approximately zero. Consequently, T_1 is normally conductive, and point A_1 is normally at about +50 volts (100 volt drop across RL_1 resulting from anode current through T_1). Now observe that the grid of T_2 is connected between the −100 volt line and the anode of T_1 (point A_1), through equal resistors R_3 and R_4. With point A_1 at +50 volts, the grid of T_2 (point G_2) is at −25 volts, that is, half-way between −100 volts and +50 volts. The cutoff potential of the T_1 and T_2 triodes is −8 volts, consequently, T_2 is cut off as long as T_1 conducts and point A_2 is at +150 volts.

Now assume the output from a multivibrator with a waveform as shown at A in Figure 104 is applied to the grid of T_1 through coupling capacitor C shown in Figure 103. (This capacitor is large enough to maintain its charge during a half cycle so that point G_1 can be held to the applied potential for the duration of the pulse.) A positive pulse applied at C will have little effect because

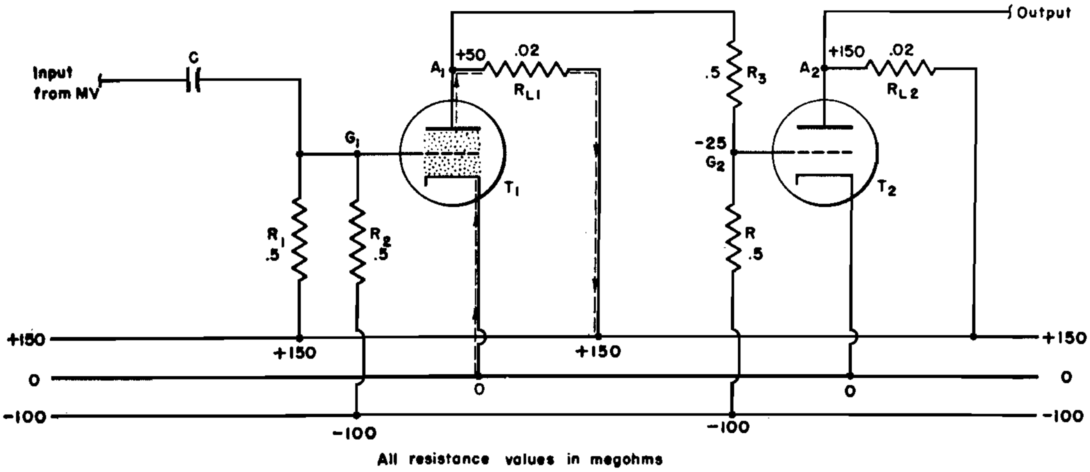


Figure 103. Triode Clipping Circuit

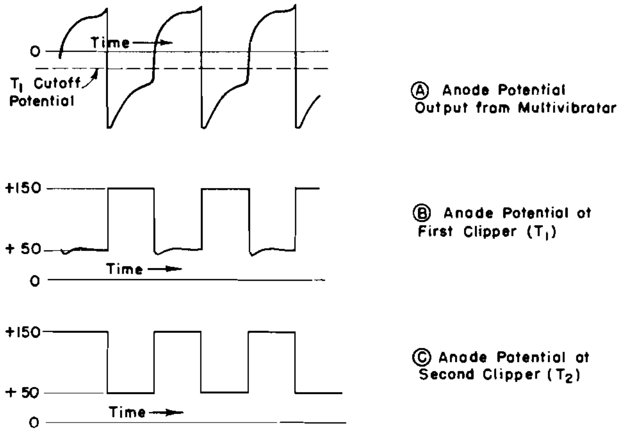


Figure 104. Output Voltages of Multivibrator and Triode Clippers

grid current will increase rapidly and cut down the potential at G_1 rapidly. The slight increase in anode current through T_1 resulting from a positive pulse will produce a slight drop in anode potential at point A_1. However, a negative pulse applied at C will drive the grid of T_1 negative. If the negative pulse is of more than 8 volts, T_1 will be cut off. Actually, the negative pulse from the multivibrator may approach −100 volts and be an almost instantaneous shift; hence, T_1 is almost instantaneously cut off, and point A_1 rises almost instantaneously to +150 volts (ignoring the bleeder circuit from the −100 volt line through R_4, R_5, RL_1 to the +150 volt line). Point A_1 remains at approximately +150 volts as long as point G_1 is at −8 volts or less, consequently whatever the shape of the applied waveform is below the −8 volt line, the output of T_1 will be a square-topped wave. This is indicated at B of Figure 104. However, to obtain a truly square wave the output of T_1 must pass through T_2 so that the lower portion can be clipped.

As previously mentioned, T_2 cannot conduct as long as T_1 conducts. However, when T_1 cuts off, point A_1 rises to approximately +150 volts and point G_2 becomes positive, thus making T_2 conductive. When T_2 conducts, point A_2 is at approximately +50 volts. Since T_2 cuts off at -8 volts and the pulse from T_1 is approximately 100 volts, the variation from a square wave in the waveform from the output of T_1 will not be reflected in the output of T_2, and a true square wave is obtained at the output of T_2 as indicated in Figure 104C. Bear in mind that the waveforms shown in Figure 104 are theoretical. Practical waveforms differ somewhat because of inductive effect, interelectrode capacity, etc.

As both the multivibrator and clippers are voltage devices, their output cannot be utilized directly as a source of pulses for the electronic unit. To actually supply the pulses for the unit, power tubes controlled by the clippers are used.

The actual circuit for the generation of pulses in this unit is shown in Figure 105. This circuit is taken from the A chassis circuit (Section 23B). Observe that the cathodes of the multivibrator are tied to the −100 volt line and that the anodes are tied to the anode of a VR-150 tube. Thus, the anode voltage supply is taken across the VR-150 voltage regulating tube. The voltage regulating tube is a gas-filled, cold cathode tube which has the property of maintaining a constant voltage drop within its operating limits. The amount of the voltage drop is determined by the gas used and the physical structure of the tube elements. The VR-150 "fires" at 185 volts and then maintains a constant drop of 150 volts within the range of 5 through 40 milliamperes anode current. This method provides a constant anode voltage for the multivibrator even with variations in the supply and thus maintains a constant oscillating frequency. The 3000 ohm resistor between the +150 volt line and the VR-150 anode limits current through the VR-150 to 30-35 ma and provides the means for compensating for supply voltage fluctuations. Variations in supply voltage result in variations in current through the VR-150 and in proportional variations in IR drop across the 3000 ohm resistor, thus maintaining a constant IR drop across the VR-150.

The voltage pulses at the anode of tube 2 of the

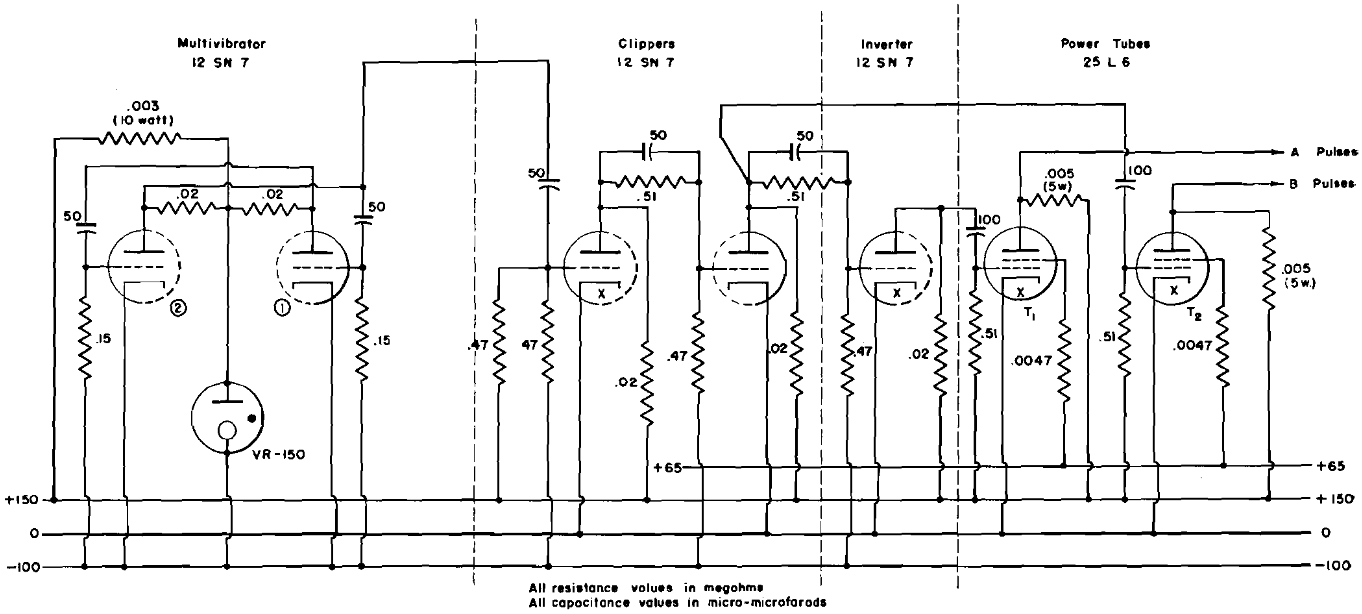


Figure 105. Generation of A and B Pulses

multivibrator are passed on to the grid of the first stage of the clipper by means of a coupling capacitor. The output of the first stage is direct-coupled to the second stage, and the voltage output of the second stage is capacity-coupled to power tube T_2. The output of the second stage of the clipper is also fed by direct coupling to the grid of the inverter whose output is in turn capacity-coupled to power tube T_1. Thus power tubes T_1 and T_2 produce square wave pulses displaced in phase by 180° from each other. The square waves from T_1 will be known as "A" pulses, and any pulses, regardless of their source, may be called A pulses if in phase with the A pulses. The square waves from T_2 are known as "B" pulses, and any pulse may be called a B pulse if it is in phase with the B pulses. Remember that the A and B pulses are 180° out of phase with each other; consequently, when an A pulse is fed to the grid of a tube, it appears at the anode as a B pulse. The reason for the two types of pulses is to permit a switch to be conditioned prior to sending any pulses through it. Thus, a switch may be conditioned by an A pulse and then B pulses are passed through it.

The purpose of the 50mmfd capacitors across the .51 megohm resistors in the clipper and inverter circuits is to balance the interelectrode capacitors and thus permit the grids to follow the applied pulses without lag.

A study of Section 1 of the A chassis circuit diagram (Section 23) will show that Figure 105 is taken directly from there. Only the switching arrangement to permit switching from the 35KC multivibrator to either hand pulsing or to the 5-cycle multivibrator is omitted in Figure 105. Observe from the A chassis circuit that tube A10 is the 35KC multivibrator and that the VR-150 is in position A7, while the 5-cycle multivibrator is tube A9 and the manual pulse trigger is A8. A trigger is necessary when manual pulsing is used to provide a true square wave voltage and eliminate multiple pulses passing through the contact because of contact bounce. A neon bulb indicates the status of the manual pulse trigger.

Regardless of which source is used for pulses, the dial switch routes the pulses through the clipper A11 from where the pulses pass to power tube A18 to produce B pulses, and through inverter A17 to power tube A16 to produce A pulses.

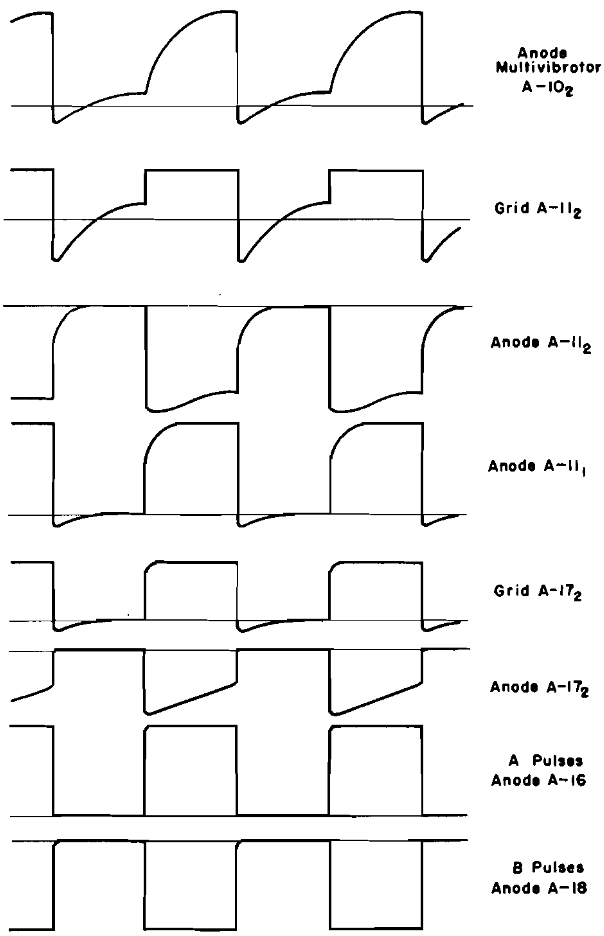


Figure 106. Oscillograms Taken During Actual Operation

It may be observed that the 5 cycle multivibrator utilizes half of the A17 tube as a follower to permit direct coupling to the clippers. This is necessary at the extremely low frequency to produce a true square wave.

Figure 106 shows the actual waveforms adapted from oscilloscope patterns taken during actual operation. Note that the clipper output is not a true square wave owing to interelectrode capacity. This is not important, however, as only the output of the A16 and A18 power tubes is used, and these outputs are square waves. Note the effect of grid current by comparing the potential curve at the anode of $A10_2$ with the potential at the grid of $A11_2$. The potential at the grid of $A11_2$ cannot rise because grid current prevents the grid going positive.

Electronic Timers

There are three electronic timers used in this circuit, namely the primary, secondary, and tertiary timers. The primary timer establishes the basic adding cycle of 16 pulses, while the secondary timer determines that there are 10 primary cycles within each column shift cycle (secondary cycle). The tertiary timer advances the column shift and determines that the multiplication is finished after completing six column shift cycles. Each timer is merely an electronic counter; the reading of the counter at any point determines the point in the computing cycle. Thus, if the primary timer reads 5, it indicates that 5 pulses of the 16 constituting an adding (or primary) cycle have been fed to the timer. If the secondary timer stands at 8, it indicates that the machine has completed the 8th adding cycle within a column shift cycle, etc.

The primary timer is a straightforward binary counter with 4 trigger stages connected as illustrated in Figure 89. As explained with reference to Figure 89, a 4-stage binary counter returns to its 0 status every sixteen pulses; consequently it can be used to establish a sixteen point cycle. In order to establish definite points within a cycle, certain combinations of triggers are used, or use is made of the fact that certain triggers are ON only during a given time, i.e., only after a definite number of pulses have been applied to the timer. For example, the last stage of a 4-stage binary counter goes OFF only on the 16th pulse (or 0 time) and goes ON only on the 8th pulse. In this manner, 0 and 8 time within a primary cycle can be established. Also, 3 time can be established by the fact that at 3 time, the 1st and 2nd stages only go ON; at other times that the 1st and 2nd stages go ON, other triggers are also ON. In this manner any cycle point within the primary cycle can be established by determining the reading in the binary counter composing the primary timer.

The reason 16 pulses are required for a primary cycle is that 10 are necessary for the adding portion of a cycle, 4 are used for carrying and 2 are nec-

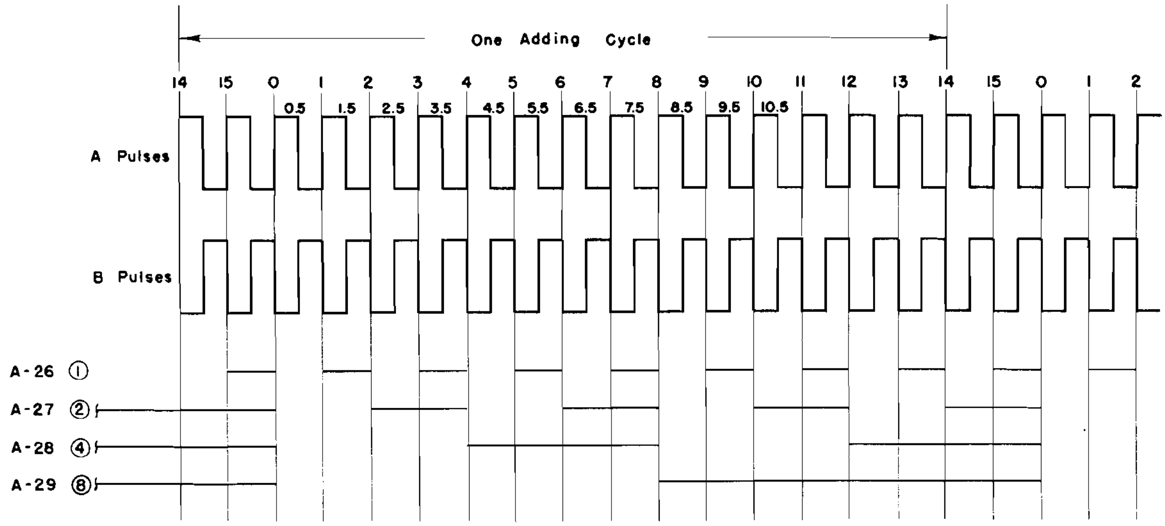


Figure 107. Use of Primary Timer to Establish Sixteen-point Adding Cycle (Primary Cycle)

essary to permit certain operations being performed before addition actually starts. In order to allow the cycle point number to correspond to the number of the pulse entering a counter, the primary cycle is actually started at 14. This permits certain operations to be performed at 15 and 0 time and then the first pulse to be added in a counter can be at 1 time. The ten possible adding pulses are then pulses numbered 1 through 10. Starting a cycle at 14 is simply accomplished by cancelling the last three stages of the primary timer ON ($8 + 4 + 2 = 14$) and the first stage OFF. Then the first pulse applied to the primary timer advances it to 15, the next to 0 (16), the next to 1, etc. Figure 107 shows how one primary cycle is established by the primary timer. Observe that the pulse number is analogous to index points in a mechanical cycle. The primary timer may be used as the index of the electronic computing operations. Note also that index points occur at positive A pulses (or negative B pulses). Mid-index points occur at negative A or positive B pulses.

One primary cycle is required to add any number into a counter once. Since over-and-over addition is used to multiply, it means that the multiplicand may have to be rolled into the product counter as many as nine times. This means at least nine primary cycles are required to multiply by one digit. To permit half-entry and to permit the multiplier to return to its original reading after rolling, ten primary cycles are used within each column shift cycle. To establish the ten primary cycles, and thus indicate when the column shift is to occur, a secondary timer is used. The secondary timer must count to 10, consequently a conventional one-position decimal counter is used.

Every time the primary timer completes a cycle (at 14) the secondary timer receives a pulse. When the tenth primary cycle is completed, the tenth pulse is passed to the secondary timer, the secondary timer advances from 9 to 0, and a carry is signalled. This carry is a signal to column shift, and the carry pulse is therefore passed to the tertiary timer which controls column shift.

There are six positions in the multiplier counter, therefore a maximum of six column shift cycles are necessary. A 3-stage binary counter capable of counting to 8 is used for the tertiary timer. Actually it never goes to 8, because computations are stopped at the end of the 6th column shift cycle. Again, by reading the tertiary timer, the column shift cycle can be determined. When the tertiary timer advances from 6 to 7, computing is stopped. This means that computing is stopped on the cycle point that the secondary timer carries. Since the secondary timer receives advancing pulses at 14, it also carries at 14; and consequently computing will stop at 14 in the primary cycle, thus leaving the primary timer where it started (at 14).

Compute Start Control and Primary Timer

Referring to Section 25 of the circuit, it will be observed that the primary timer consists of four triggers in tandem, namely, A26, A27, A28, and A29. The A26 trigger is normally OFF, while the others are normally ON. The A28 OFF side utilizes half of A20 as a follower, while the two triode sections of A34 are used as a follower for the ON and OFF side of A29. Followers are used to avoid loading the triggers, as excessive loading of a trigger results in erratic operation. Note that the indicator block in position A30 is used to indicate the status of the primary timer at any time.

Operation of the primary timer is effected by negative B pulses developed by a pentode switch tube A25 (Section 23A) after computing is initiated under control of the punch unit. The grid of the A25 switch is connected to the grid of the ON side of A31 trigger, and consequently follows it in potential. Since A31 is normally OFF, A25 cannot conduct, thus preventing response of A25 to the A pulses applied to its suppressor.

The grid of tube 1 of trigger A31 is coupled to the anode resistor of tube 2 of trigger A32, which is also normally OFF. The grid of tube 2 of trigger A32 is directly coupled to P24 cam contact through R1BU contact in the punch unit. With a card at the die card lever, when P24 makes at 11.5 on the punch index, a circuit is completed from the +40 volt line to the grid of $A32_2$, and trigger A32 is turned ON to initiate computing. The manner in which trigger A32 goes ON is exactly the same as described in connection with the read-in triggers.

When A32 goes ON, the potential at the $A32_2$ tube drops, and a negative pulse is transmitted to A31 trigger (OFF side) from a tap on the load resistor of $A32_2$. A31 is thus turned ON, and the grid of tube 2 rises to cathode potential as does the grid of the A25 switch. With the grid of A25 above cutoff, A25 will respond to any pulses applied to its suppressor. The suppressor of A25 is normally at −50 volts, which is sufficient to block conduction. However, the suppressor is also connected by a capacitor to the anode of A16, the source of the A pulses.

Each time the A pulse goes positive, A25 conducts, and the potential at its anode drops. Hence A25 inverts these A pulses to B pulses, which in turn are taken from a midpoint tap on the load resistor for A25 and fed to A26, the first stage trigger of the primary timer. As previously explained, the positive pulses applied to the primary timer are of insufficient amplitude to affect its status; only negative pulses will be recognized by the primary timer triggers.

Remember from Figure 107 that the cycle points represent negative shifts in the B pulses or positive shifts in the A pulses. A positive shift in the B pulses or negative shift in the A pulses occurs at half time, that is, 1.5, 2.5, etc.

The first positive A pulse applied to A25 after computing is initiated, produces a negative B pulse to advance the primary timer to 15 by turning A26 ON, as indicated in Figure 107. Since A27, A28, and A29 are already ON when computing starts, all triggers will be ON after the first B pulse. The second B pulse developed by A25 turns A26 OFF, and the potential at the $A26_1$ anode drops, producing a negative pulse. This negative pulse is taken from the midpoint of the load resistor for $A26_1$ and passes to A27 trigger, turning A27 OFF. As A27 turns OFF, its tube 1 develops a negative pulse which is applied to the third-stage trigger, A28, turning it OFF. Follower tube A20 starts conducting and a negative pulse appears at the anode of A20, which is passed on to A29 to turn it OFF. Therefore, after two B pulses are applied to the primary timer, all triggers are OFF and the timer is at 0.

The next negative pulse applied to A26 trips it

ON at 1 time of a computing cycle. As A26 turns on, tube A26 produces a positive pulse which has no effect on the next stage, A27. Another negative pulse is applied at 2 time to stage A26, returning it to OFF status. At this point a negative pulse from A26 is applied to A27 to turn it ON. Thus, each applied negative pulse reverses A26 but the next stage A27 is reversed only once for every two pulses applied to A26. Similarly, A28 is reversed once for every two tripping pulses applied to A27 while A29 is reversed once for every two tripping pulses received by A28. The combinational patterns of ON and OFF states of the stages of the primary timer are indicated in Figure 107. It is seen that there is a different pattern at each of the cycle points, 0 through 15, of the sixteen-point computing cycle.

The primary commutator will continue to function as long as trigger A31 remains ON. Trigger A31 is turned OFF, in a manner explained later, when the multiplication is completed. On the other hand, the trigger A32 is turned OFF by cancelling upon removal of negative potential from the −100 (cancel) line which occurs upon the opening of main cancel cam contact P10 in the punch unit.

If A32 were to control tube A25 directly instead of through trigger A31, then termination of computing operations would be timed by the restoration of A32 which is under control of a cam in the punch unit. It is necessary, however, to terminate computing operations under control of the computing circuits; for this reason, trigger A31 is introduced between A32 and A25, and means are provided in the computing section to turn A31 OFF at a predetermined point of a computing cycle after termination of the computing operations. It must be remembered that the entire computation only requires about 27 milliseconds, which is only 6 teeth of movement of the punch index. Consequently, it must be possible to stop computing, even though the compute start cam contact or manual control switch is still made. This is made possible by using two triggers. A31 can be turned OFF regardless of the status of A32.

NOTE: The .0025 megohm resistor shown between post 48 (Section 23A) and ground has been removed and should be disconnected on any machines which have this resistor installed. The resistor was added to maintain a current flow through P24 at all times, but it was found that it upset the operation of the start trigger A32 occasionally. Instead, to insure more positive operation, the resistor has been removed and a silver point installed in P24.

Secondary and Tertiary Timers

As previously mentioned, the secondary timer is a conventional ten-point counter just exactly as described under *Electronic Counters*. For this reason it is not necessary to repeat the principle of operation.

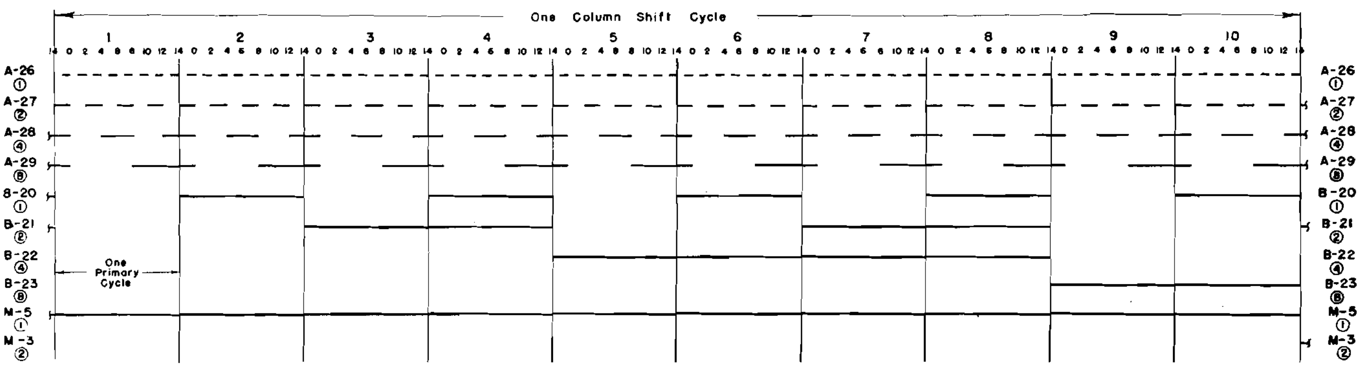


Figure 108. Relationship Between Primary and Secondary Timers

The secondary timer consists of triggers B20 through B23, blocking tube B27, and follower B24 shown in Section 29 of the circuit diagram. The indicator block in socket B18 indicates the status of the secondary timer. The follower B24 follows the OFF side of B23, the last stage of the secondary timer. It is used to avoid loading the trigger B23. A negative pulse appears at the anode of B24 and at the anode of B23, tube on the tenth pulse applied to the secondary timer. These negative pulses are the carry pulses and are used to advance the column shift (tertiary timer) and to turn OFF trigger B17.

The secondary timer is cancelled to 0 and advances 1 point at 14 of each primary cycle. The means of producing this −14 pulse will be discussed shortly. The tenth pulse from the primary timer to the secondary timer causes the secondary timer to advance from 9 to 0 and a carry is signalled. This is a signal to column shift and to start a new series of ten primary cycles. The timing relationship existing between the primary and secondary timers is shown in Figure 108. A careful study of this timing chart is essential to the proper understanding of the sequence of operations.

The tertiary timer is a three-stage binary counter which cancels to 1 so that the reading of the counter indicates the column shift position. The tertiary timer consists of triggers M2, M3, and M5 along with followers M1, M4, and M6. The circuits are shown in Section 51.

Multiplier Advancing Pulses

From the section on Multiplying Principles it will be remembered that in order to determine how many times the multiplicand is to be added into the product counter, the multiplier counter must be "rolled" by adding 10 pulses to each position successively. One pulse is added during each adding cycle, and the column shift control determines which position of the multiplier receives the advancing pulses.

The block diagram and sequence chart in Figure 109 indicates how the primary timer controls the

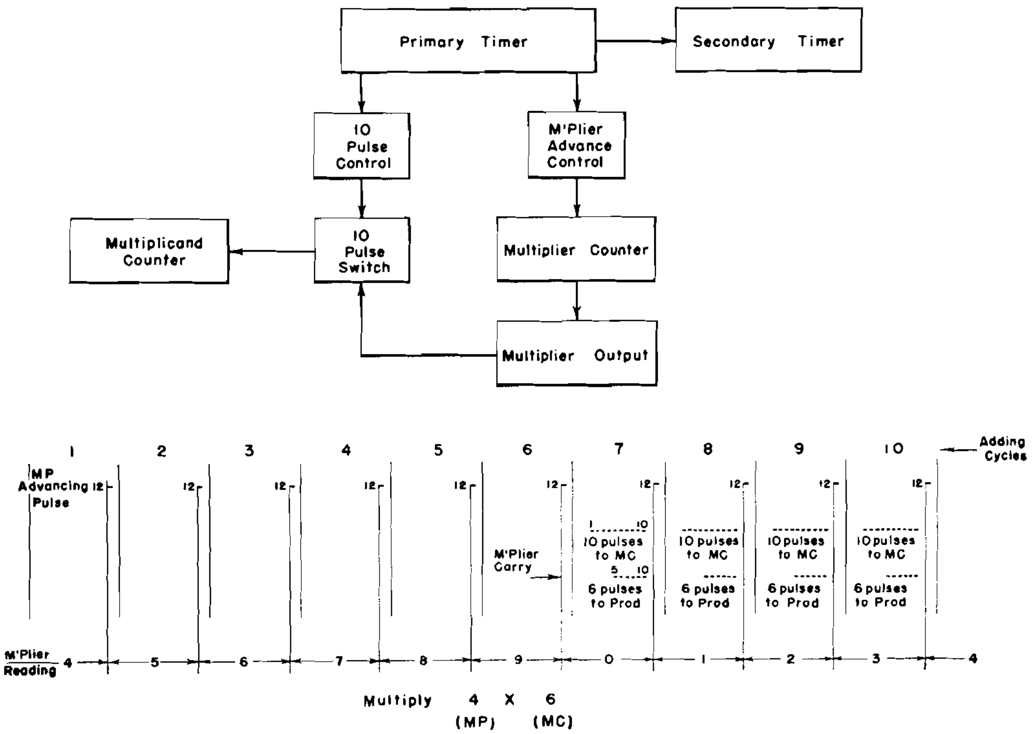


Figure 109. Block Diagram of Multiplier Advancing

number of times that the multiplicand counter is rolled. A group of 10 pulses to roll the multiplicand counter is fed to the 10-pulse switch each adding cycle, but the 10 pulses cannot enter the multiplicand counter until the 10-pulse switch is opened by the carry-over of the multiplier counter. The multiplier counter position by which multiplication is taking place receives an advancing pulse at 12 of each cycle, as indicated in the sequence chart in the lower section of Figure 109. Observe that no rolling pulses can ever enter the multiplicand counter during the first adding cycle of a column shift cycle, because the first multiplier advancing pulse does not come until 12 of the first adding cycle, and this is after the adding portion of the cycle. The first adding cycle is used for half-entry during the 6th column shift cycle.

The multiplier digit always advances from 9 to 0 in that adding cycle of the set of ten which is the tens complement of the controlling multiplier digit. Multiplicand entries start on the succeeding cycle, so that the number of multiplicand entries in any column shift cycle equals the value of the multiplier digit. As shown in Figure 109 at 12 of the sixth adding cycle, the multiplier position containing a 4 advances from 9 to 0. Consequently, during the 7th through 10th adding cycles, the multiplicand will receive 10 rolling pulses. However, only 6 of these pulses will reach the product counter during each adding cycle because of the 6 standing in the multiplicand counter. This part of the operation is explained later with reference to the multiplicand read-out.

Observe also from Figure 109 that the multiplier advancing pulse during the 10th primary cycle is used only to bring the multiplier reading back to its original reading. This is necessary when group multiplying, because the same multiplier is used for a group of cards.

The circuit for producing the multiplier advancing pulse at 12 is shown in the A chassis circuit (Section 24A) and consists of trigger A35 and power tube A36. Note that indicator light 7 in socket A13 shows the status of A35. Figure 110 shows the same circuit together with the timing chart for the operation. The pulse produced is used to control a switch, therefore, a positive pulse must be produced at 12 of each primary cycle. Trigger A35 is initially OFF by cancelling, hence, neither positive nor negative pulses applied to the ON side ($A35_2$) will have any effect until A35 is turned ON. A35 is turned ON by the first negative pulse applied to its OFF side ($A35_1$); positive pulses have no affect as has been pointed out previously. $A35_1$ receives a + pulse at 0 and a − pulse at 8 from A29, the fourth stage of the primary timer; consequently A35 goes ON at 8. Observe from the timing chart that $A35_2$ also receives a +8 pulse. This will not affect the operation. When A35 goes ON, a positive pulse is produced at the anode of $A35_1$ as the potential rises from about +40 volts to +140 volts. This pulse is transmitted to the grid of power tube A36 but it has no effect since A36 is normally conducting.

The next negative pulse to $A35_2$ from A28 (the third stage of the primary timer) comes at 12; consequently A35 goes back to its OFF status at 12. At this time the potential at the anode of $A35_1$ drops, and this negative pulse is transmitted to the grid of A36. A36 momentarily stops conducting, thus permitting the potential at its anode to rise to +150 volts and producing a positive pulse at 12 to pass on to the multiplier entry switches. A35 repeats this operation once for each primary cycle.

The multiplier input switches for controlling entries to the multiplier counter are located on the C chassis and consist of 6SK7 type switch tubes; C3, C6, C9, C12, C15, and C18 for the first through sixth positions of the multiplier counter respectively.

The read-in triggers and switches shown on the C chassis are exactly the same as the ones on the D chassis and have already been explained. Note that the multiply control switches utilize the same load resistors as the read-in switches. This is per-

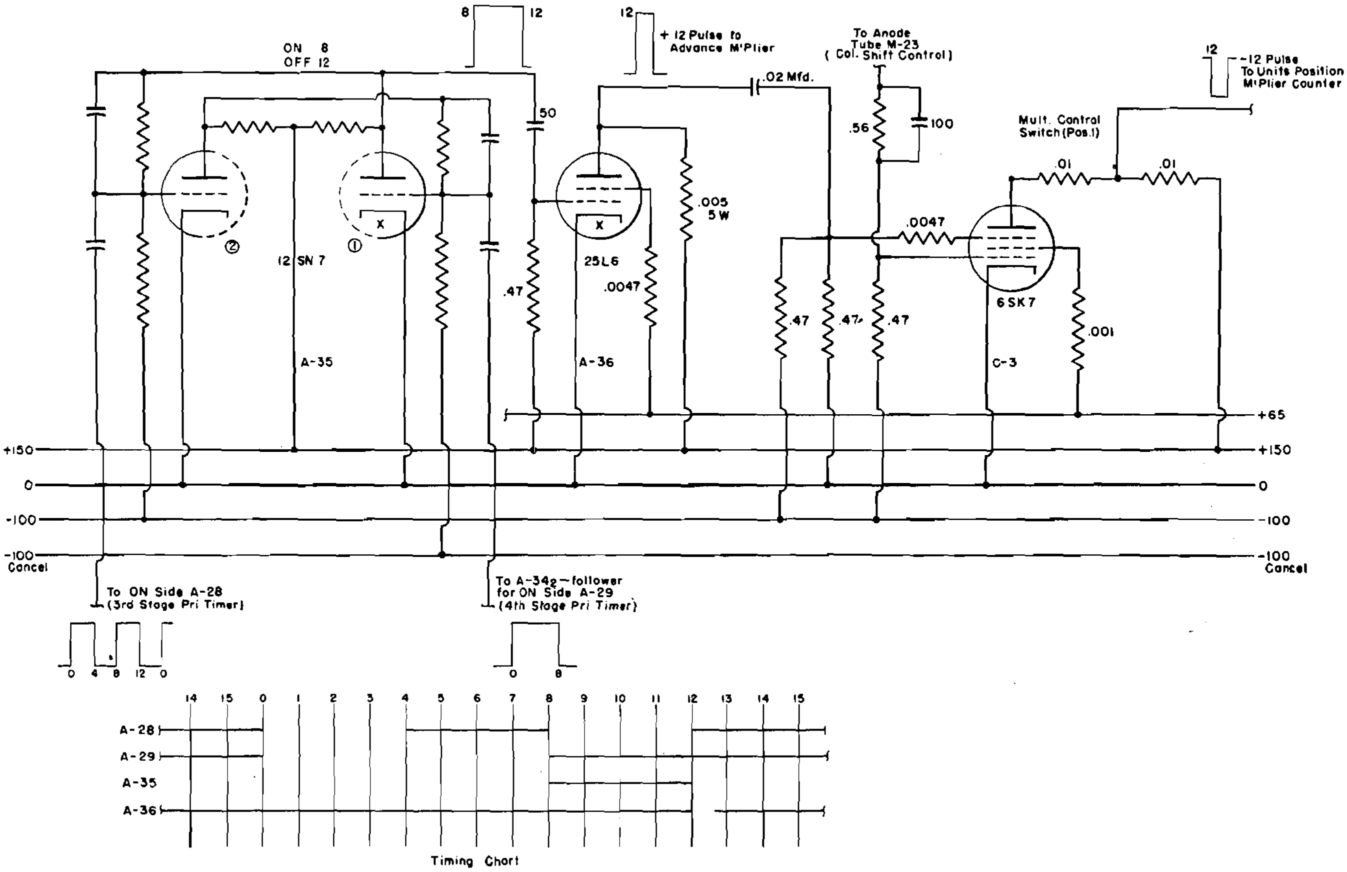


Figure 110. Multiplier Advancing Pulses

missible since the two switches never operate at the same time.

The grids of the multiply control switches are directly coupled to column shift control tubes in the M chassis. Each grid is controlled by a different tube in the M chassis, corresponding to the different column shift cycles. The sixth position of the multiplier counter is conditioned first and the first position last. As long as the column shift control tube in the M chassis is conducting, the corresponding multiply control switch is cut off since the potential at the grid will be approximately −30 volts. This is determined as follows: the top of the .56 megohm resistor is tied directly to the anode of the column shift control tube in the M chassis. The potential at this anode is less than +50 volts while this tube is conducting. The lower part of the .47 megohm resistor is tied to the −100 volt line. From the ratio of the resistances, the potential at the grid of the switch tube is found to be approximately −30 volts.

When the column shift control tube stops conducting, the potential at its anode rises to essentially +150 volts (ignoring the effect of its load resistor); then the grid of the corresponding multiply control switch rises above cutoff and the switch is conditioned to conduct, subject to the pulses applied to the suppressor. The grid of any one switch remains conditioned throughout a complete column shift cycle, i.e., 10 primary cycles. However, the suppressor will rise above cutoff only once (at 12) during each primary cycle, consequently the multiplier position in operation receives only one pulse per primary cycle.

The suppressors of all the multiply control switches are tied together to the voltage divider shown under switch C3 (Section 32A). This voltage divider consists of equal resistors between the −100 volt line and ground; consequently, all suppressors are normally at −50 volts which is well below cutoff for this element. All suppressors receive a +12 pulse through the .02mfd coupling capacitor, which transmits pulses from the multiplier advancing power tube A36. Each time A36 produces a positive pulse, all suppressors rise above cutoff. However, only the switch conditioned for operation during the given column shift cycle can conduct. This switch will then conduct for a brief instant at 12 and produce a −100 volt negative pulse at its anode. Since triggers are operated on −50 volt pulses, the output to the multiplier counter is taken from the midpoint of the load resistor for the multiplier input switch. From this it is evident that one position of the multiplier counter will advance 1 at 12 of each primary cycle, the particular position being determined by the column shift cycle.

The purpose of the 100 mmfd capacitor across the .56 megohm resistor in the grid circuit of the C18 tube shown in Figure 110 is to permit instantaneous changes at the grid by counteracting the effects of interelectrode capacitances. The 4700 ohm resistors in the suppressor circuit prevent parasitic oscillations.

The multiplier counter, which receives its entry pulses from the C chassis, consists of six standard electronic counter positions on chassis E, F, and G. The multiplier counter chassis are identical to the counters previously described. It might be mentioned that no provision is made for carry in the multiplier counter because there is no need for carrying in this counter or the multiplicand counter.

Figure 111 shows a block diagram of the multiplier advancing circuits, indicating all tubes involved as well as the operations. The section to the right shows how the multiplier output control determines the number of times the multiplicand receives rolling pulses. This operation is discussed in detail in the following paragraphs.

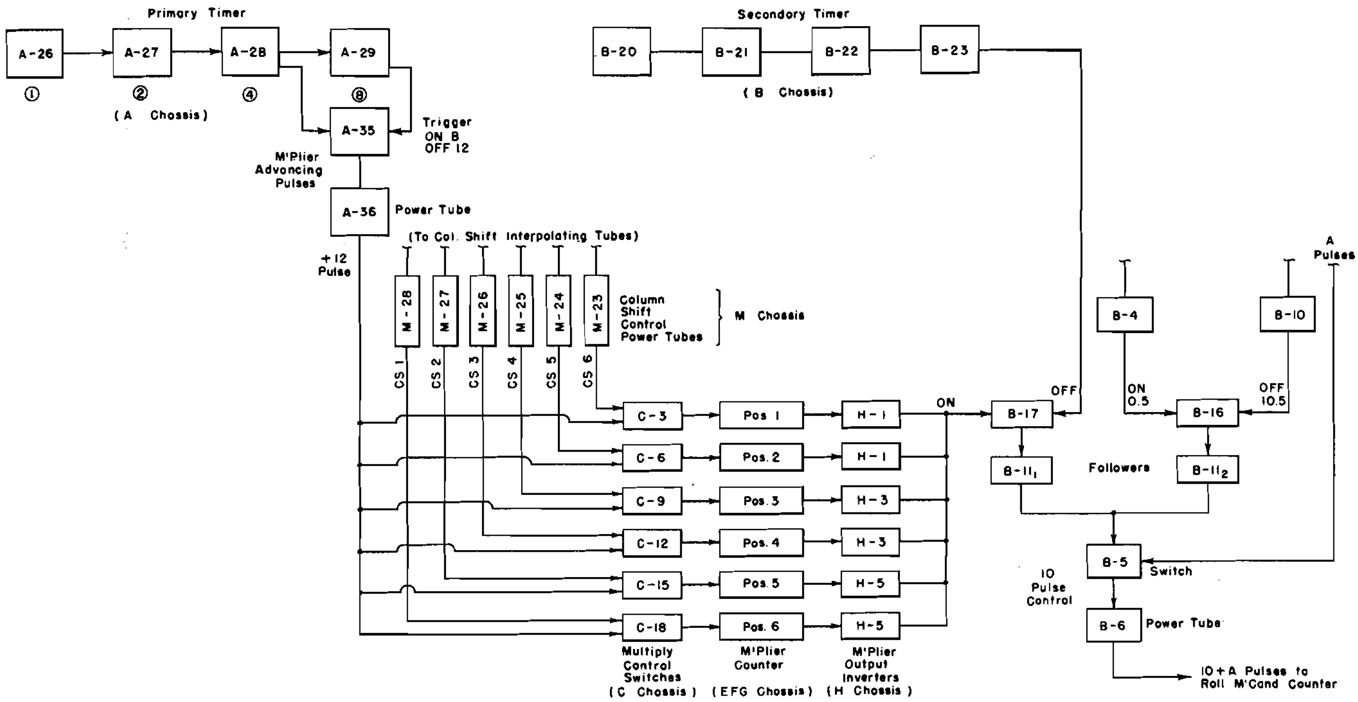


Figure 111. Block Diagram of Multiplier Advancing Circuits

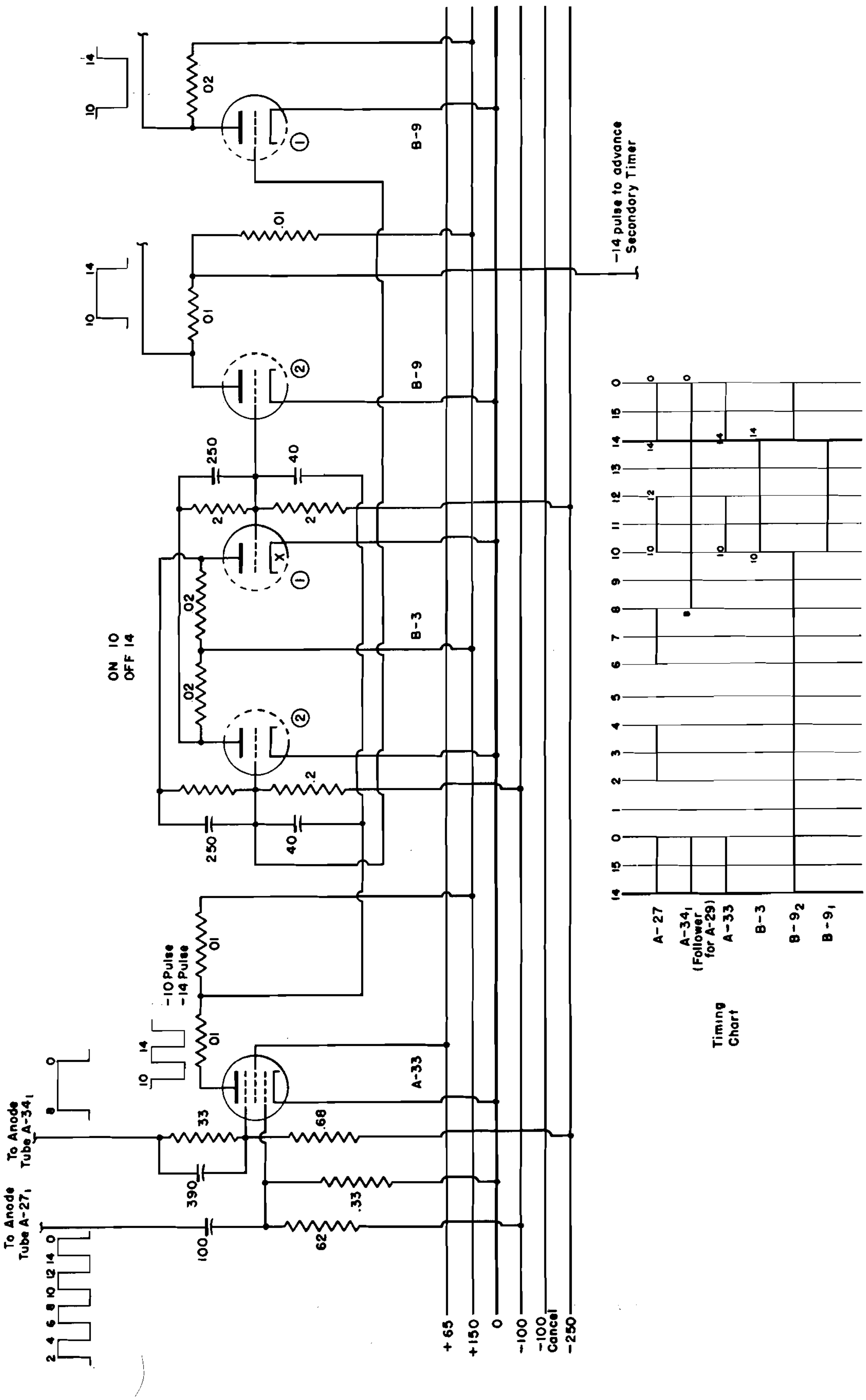


Figure 112. Operation of B3 Control Triggers and Followers

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

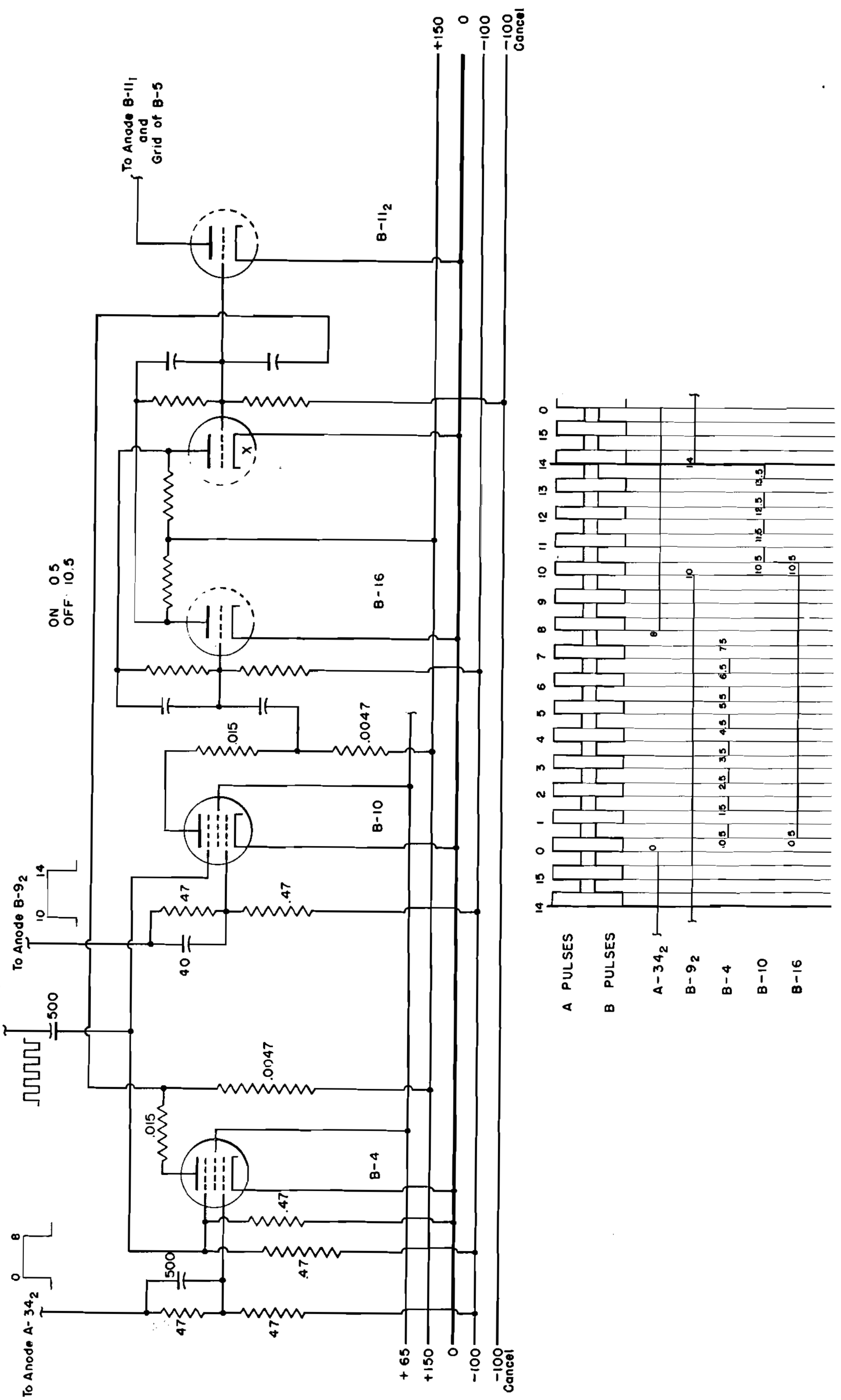


Figure 113. Ten-Pulse Control Trigger

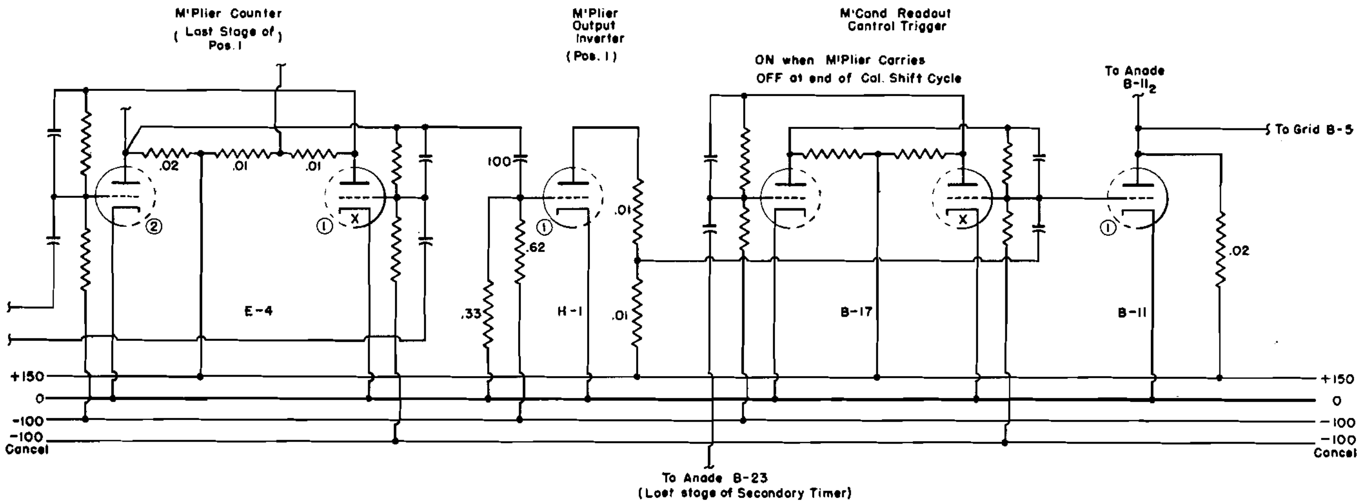


Figure 114. Multiplier Output Circuit

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

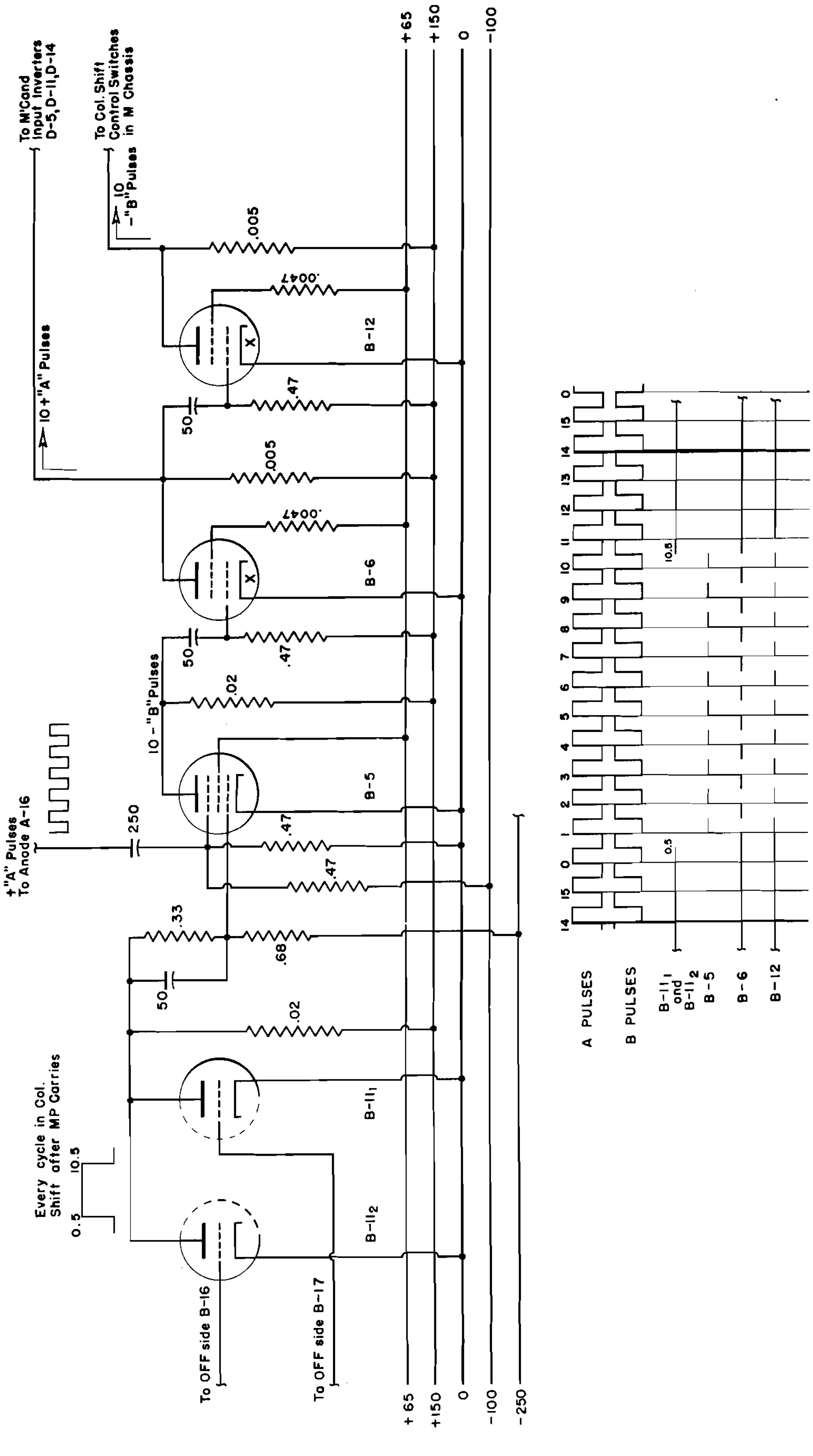


Figure 115. Ten-Pulse Control Switch and Power Tubes

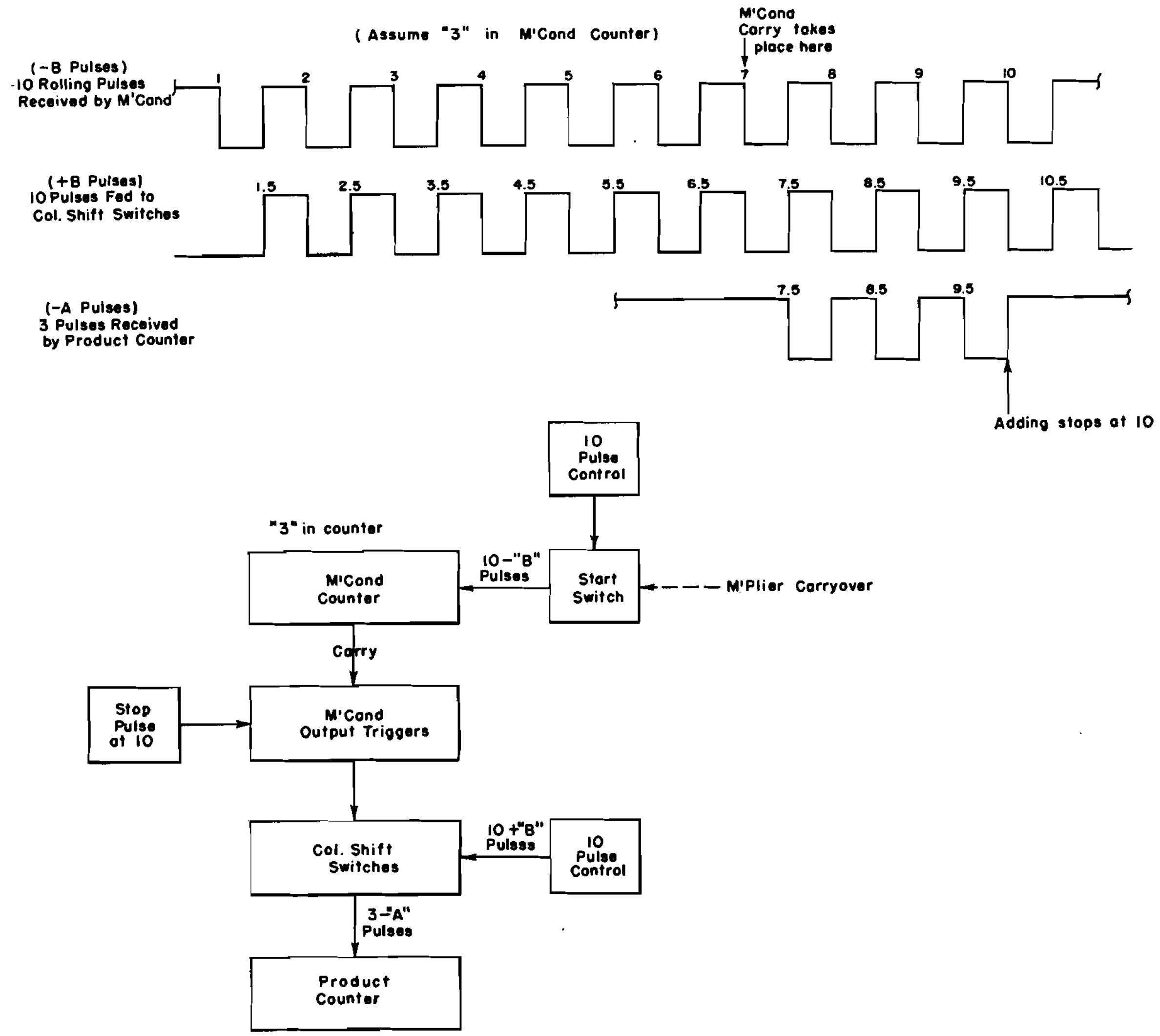


Figure 116. Multiplicand Output to Product

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

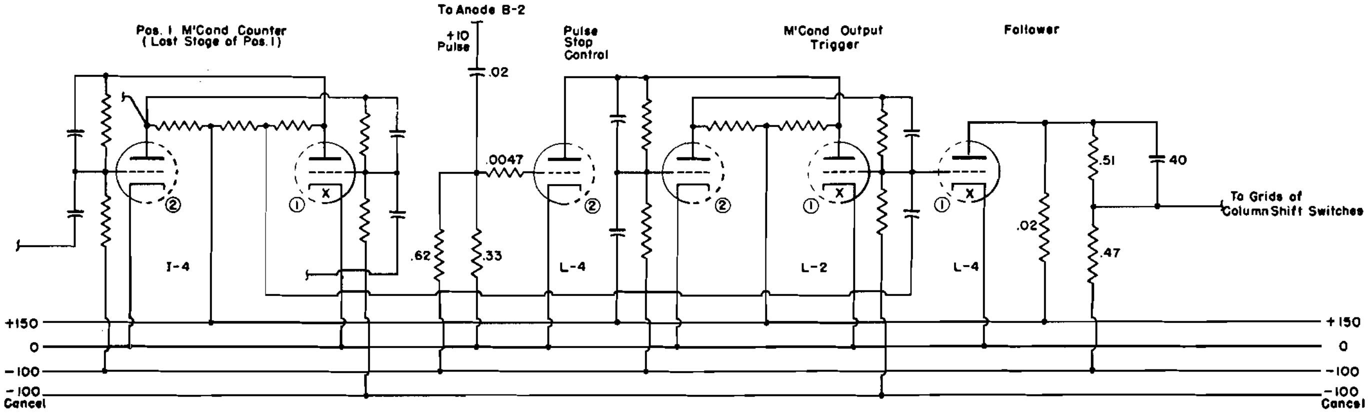


Figure 117. Multiplicand Read-out Controls

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-

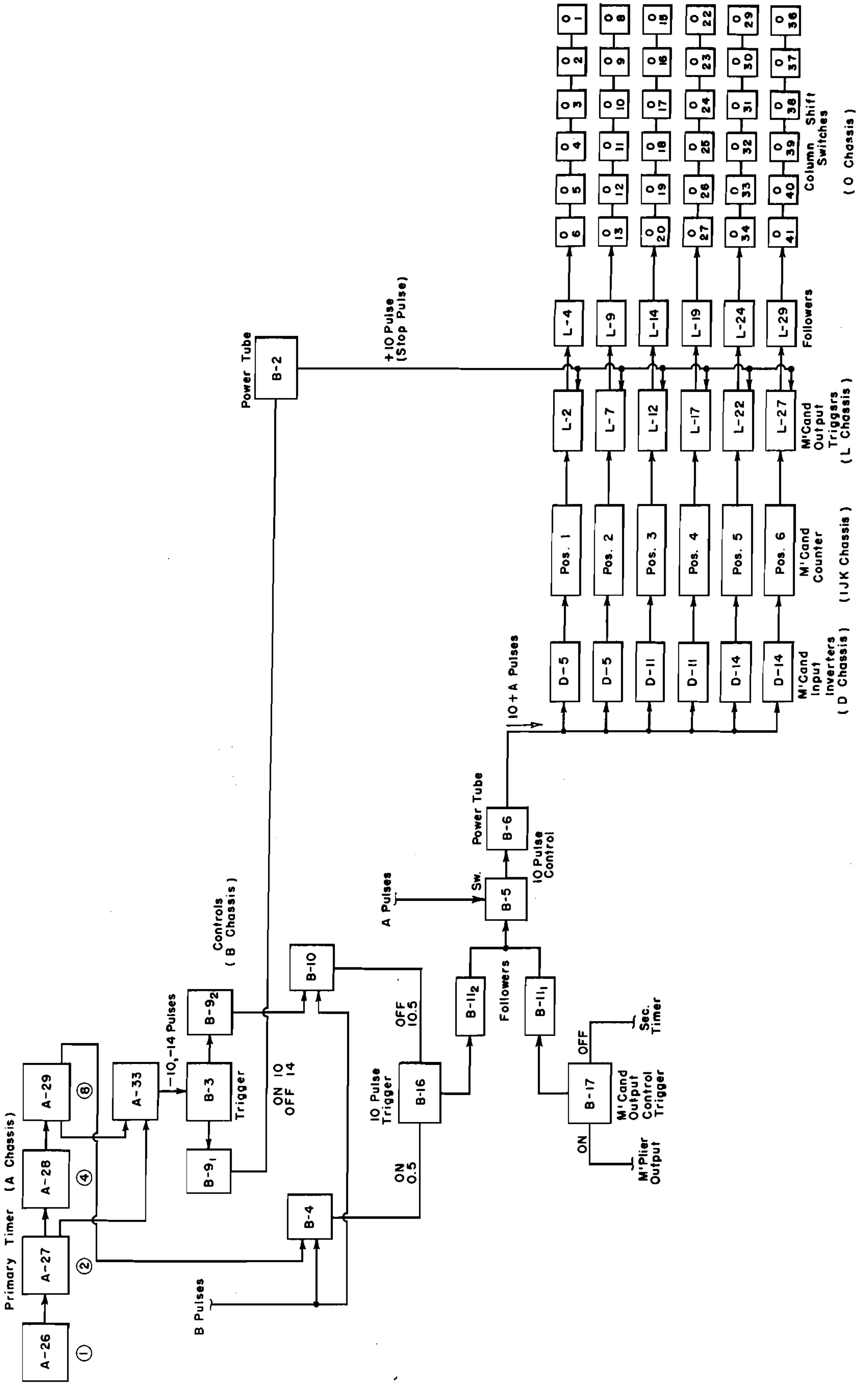


Figure 118. Block Diagram of MC Rolling and Output Circuits

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-

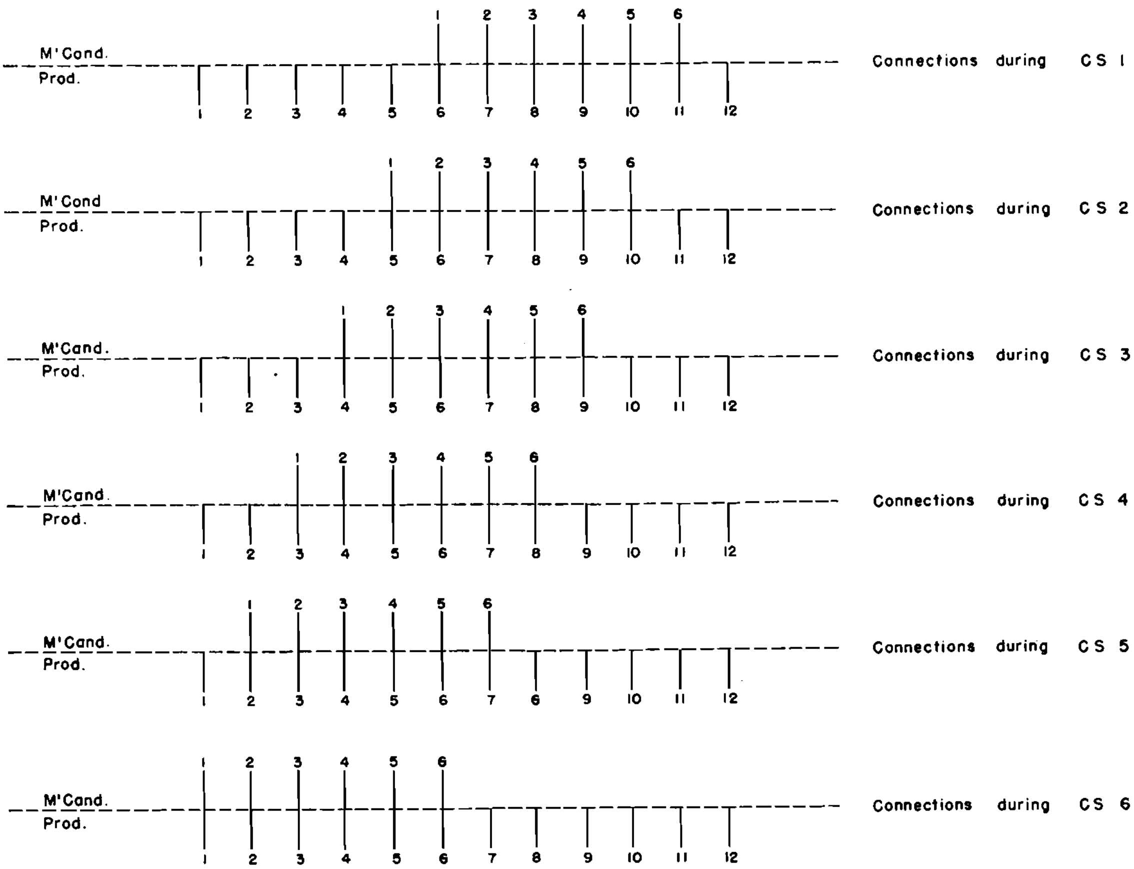


Figure 119. Principle of Column Shift

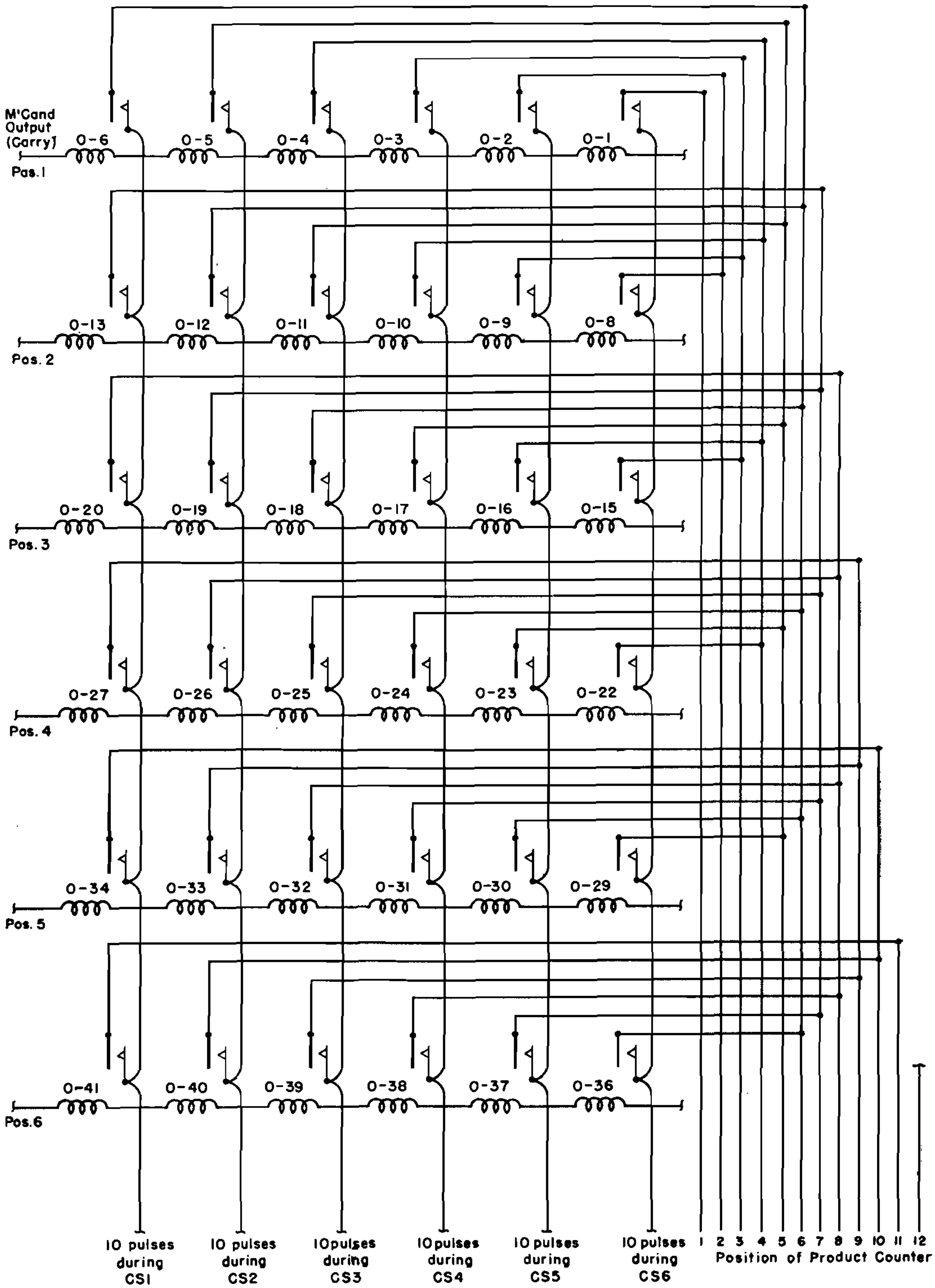


Figure 120. Schematic of Column Shift Switches

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

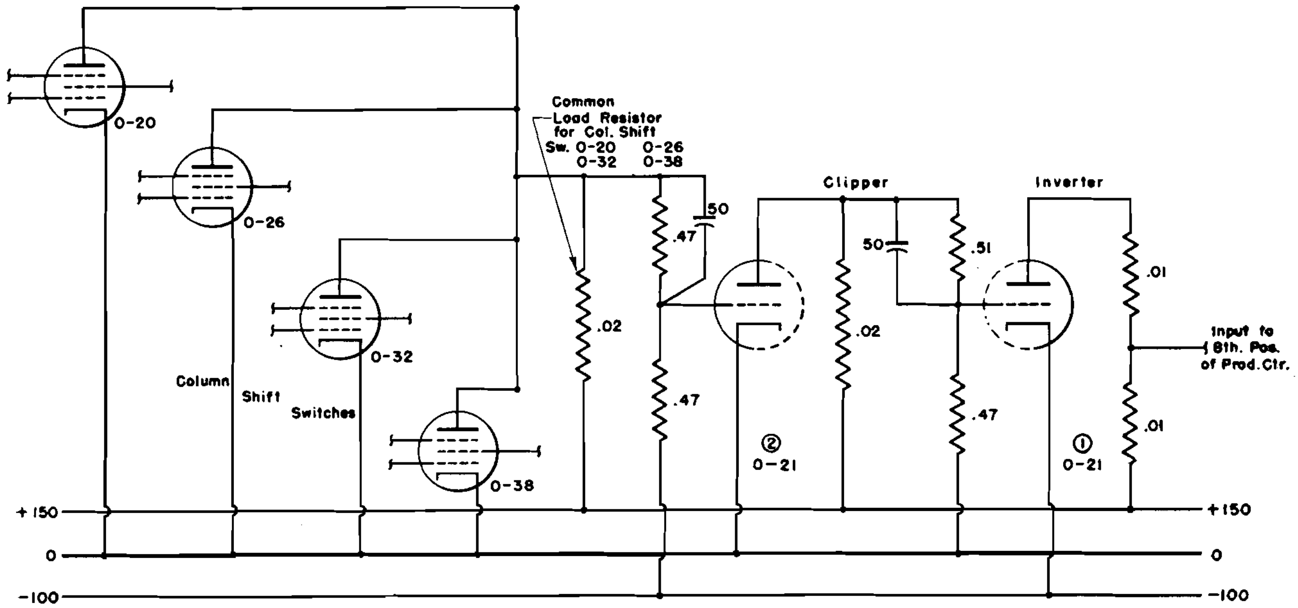


Figure 121. Clipper and Inverter between Column Shift Switches and Product Counter

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

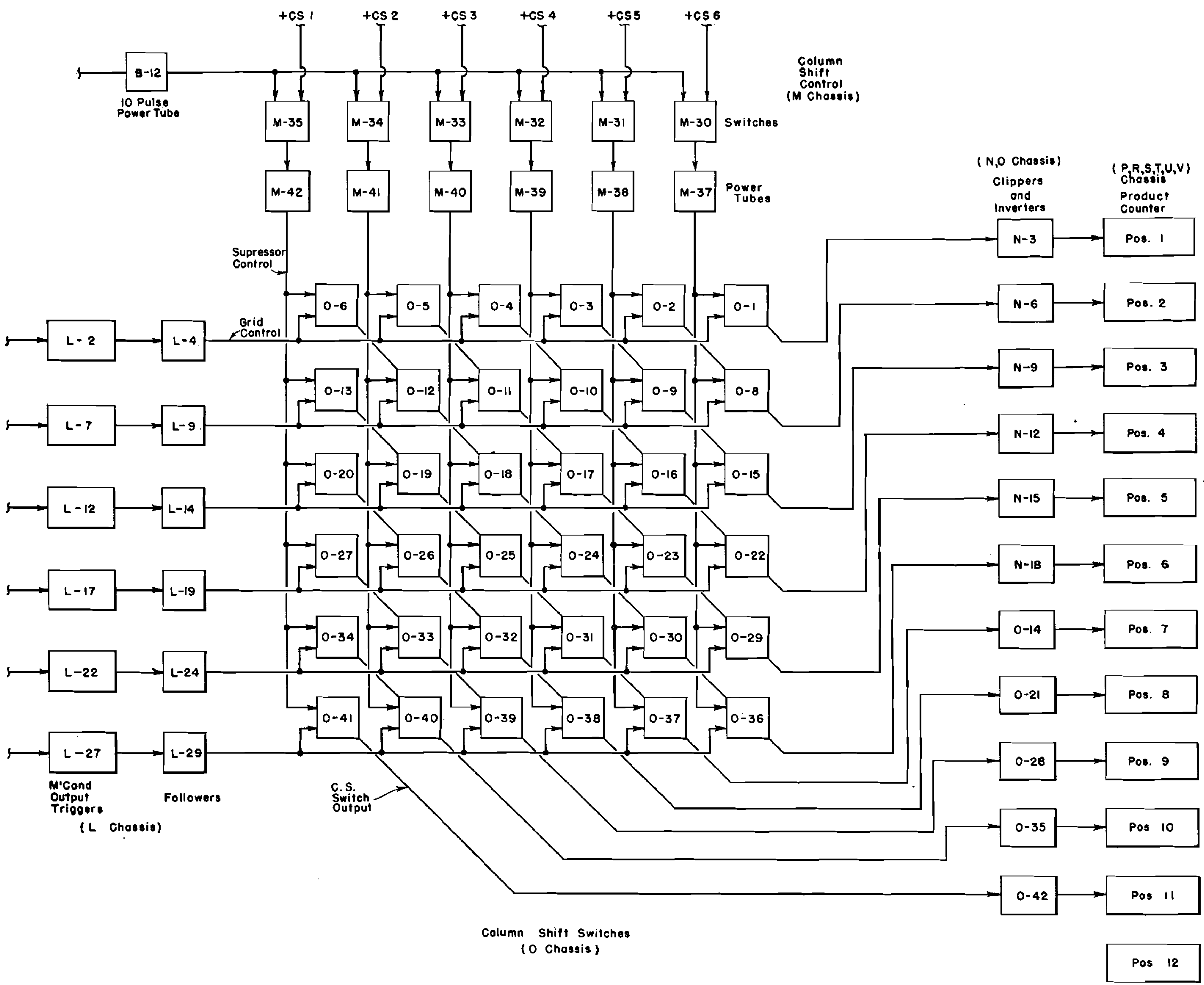


Figure 122. Block Diagram of Column Shift Switches

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

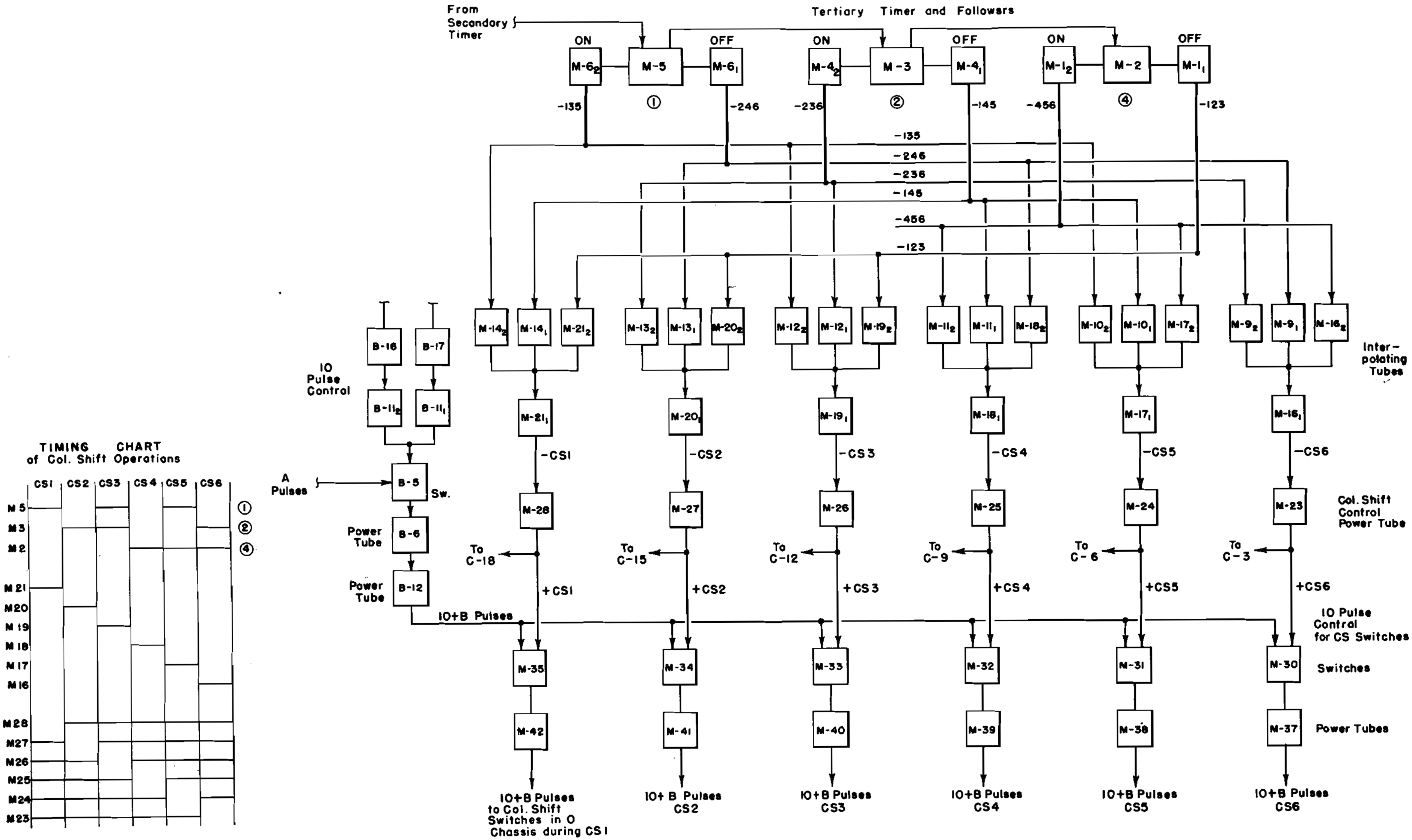


Figure 123. Block Diagram of Tertiary Timer and Column Shift Controls

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).

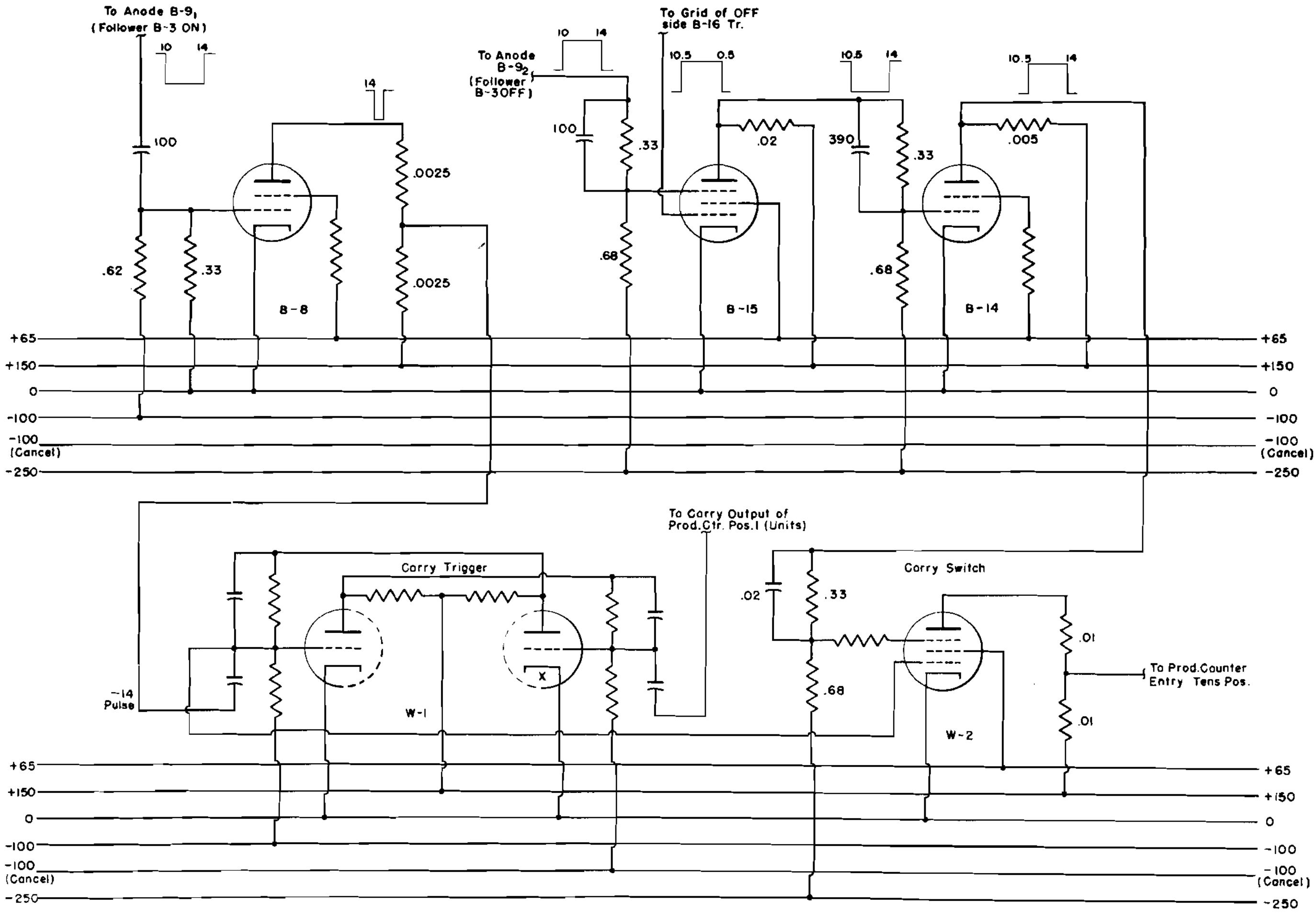


Figure 124. Carry and Carry Control Circuit

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.

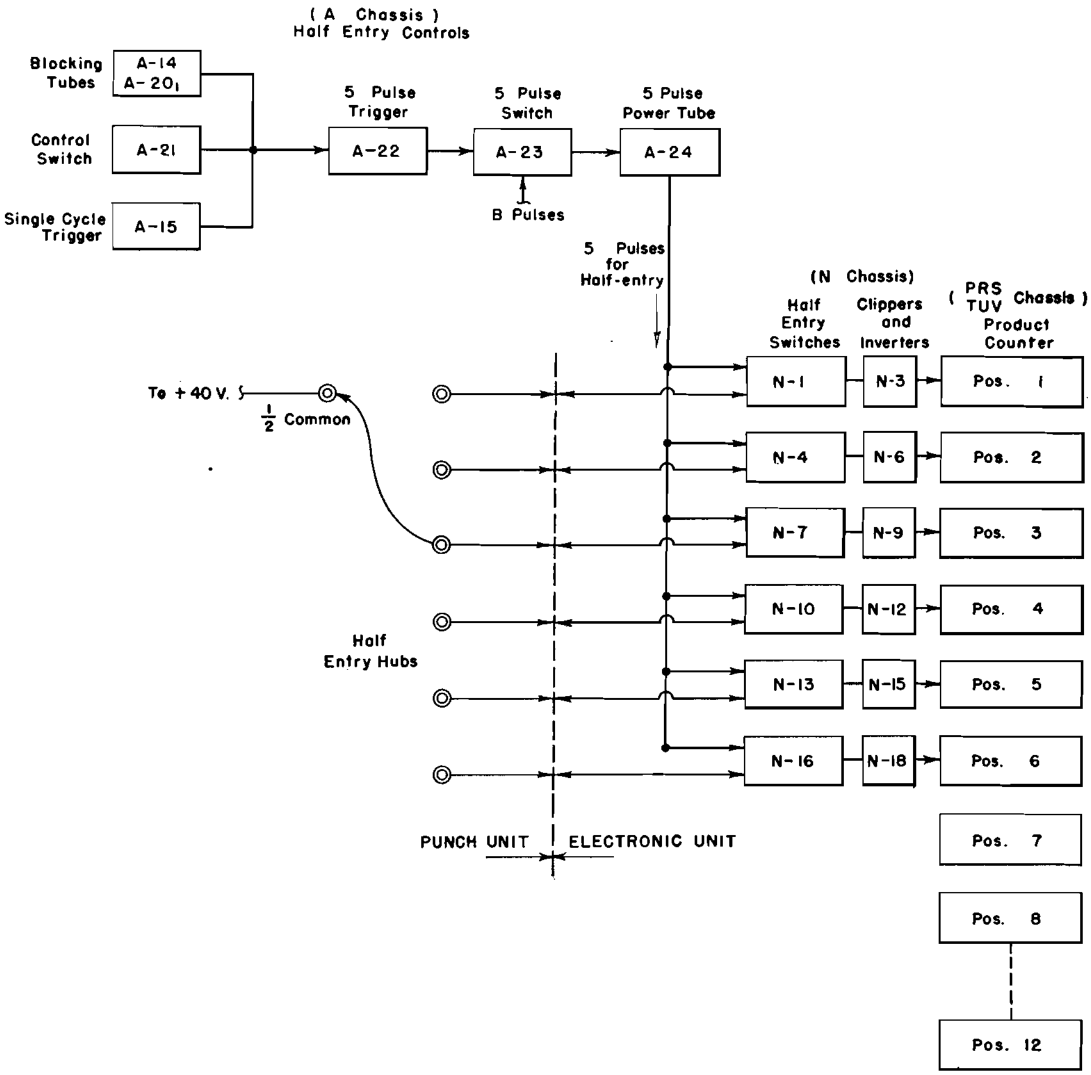


Figure 125. Block Diagram of Half-Entry Circuits

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.

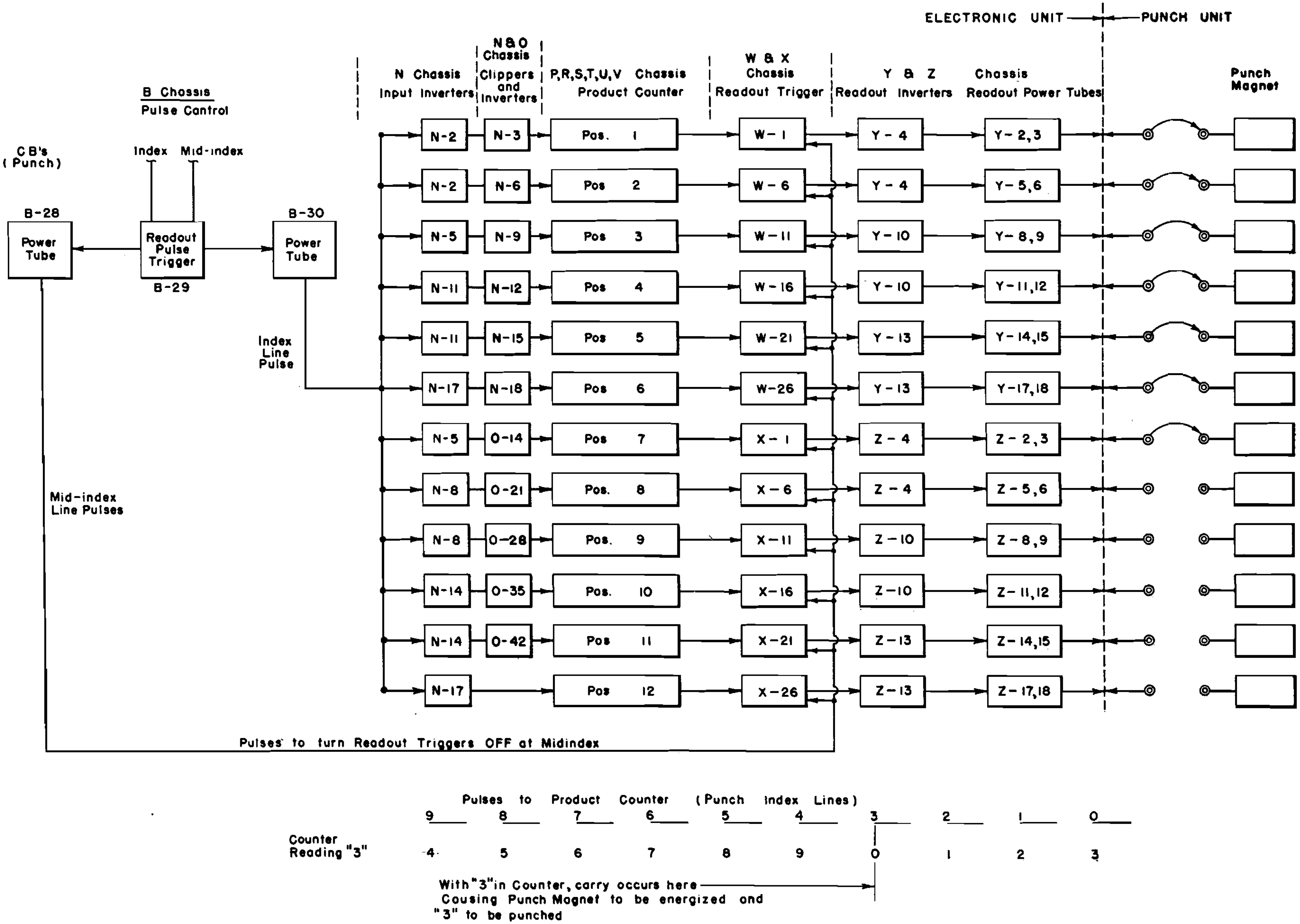


Figure 126. Block Diagram of Read-out Circuits

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

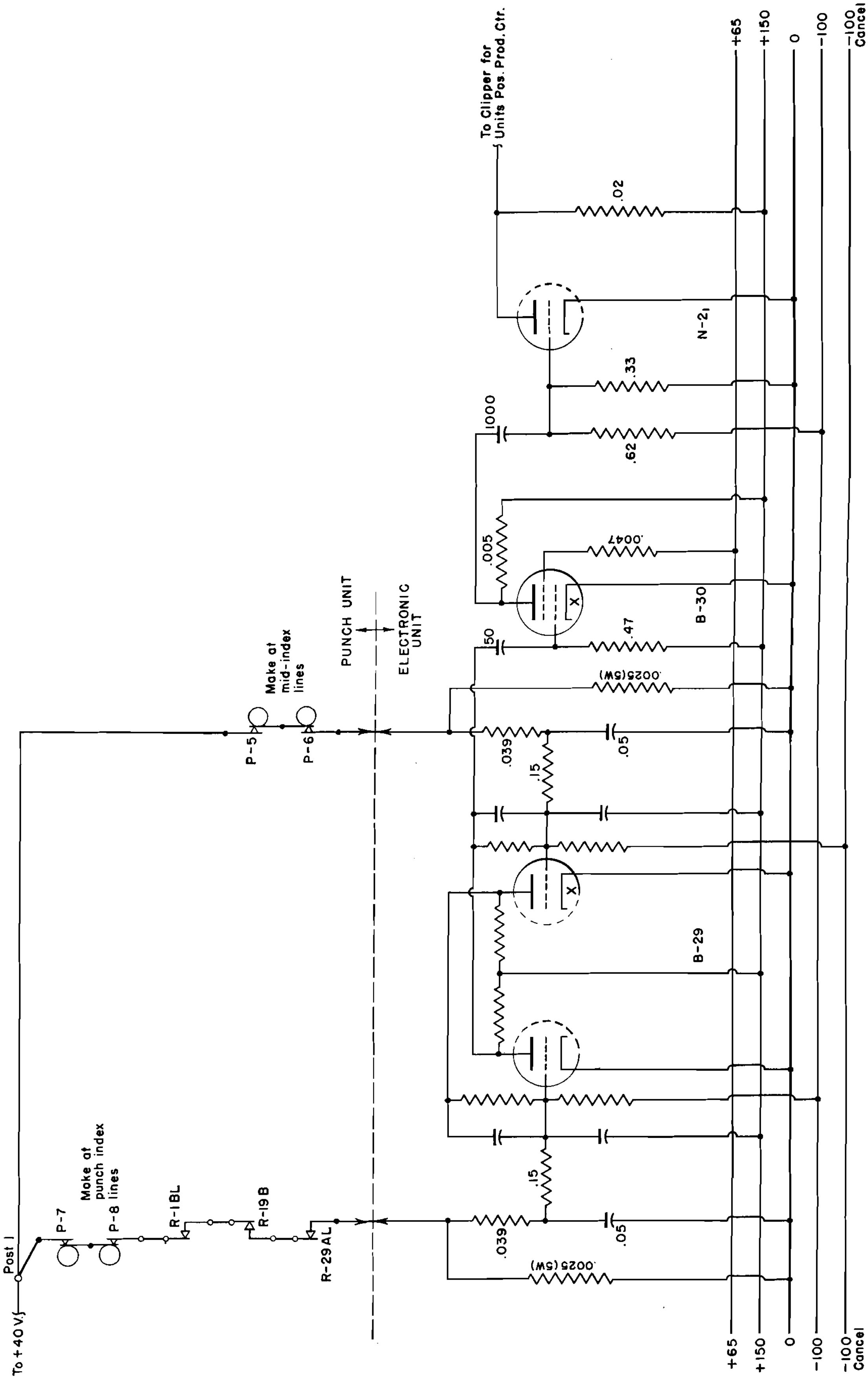


Figure 127. Product Counter Read-out Pulses

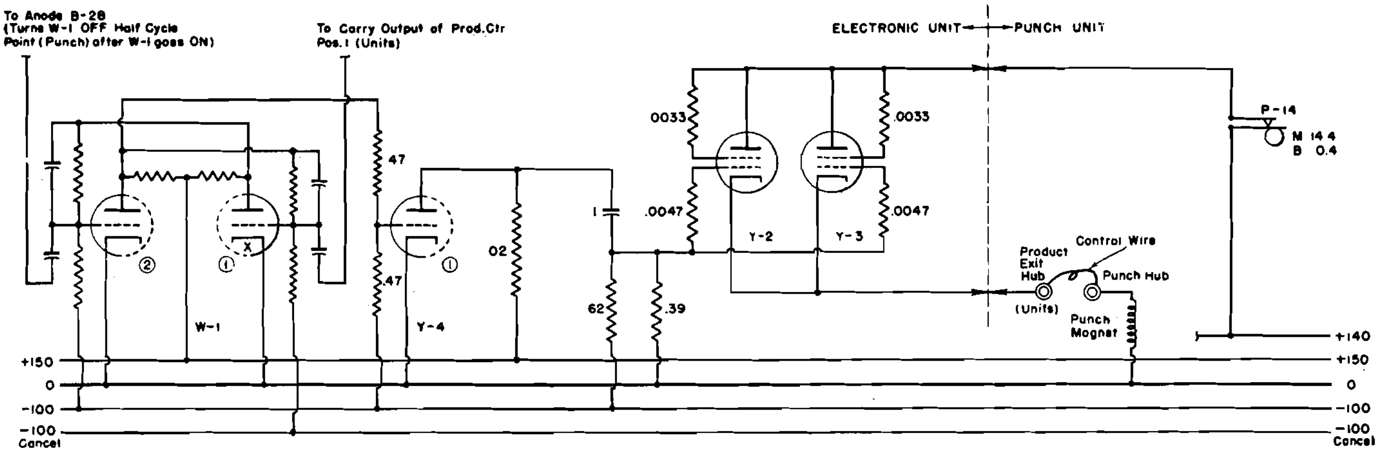


Figure 128. Product Counter Read-out Circuit

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.

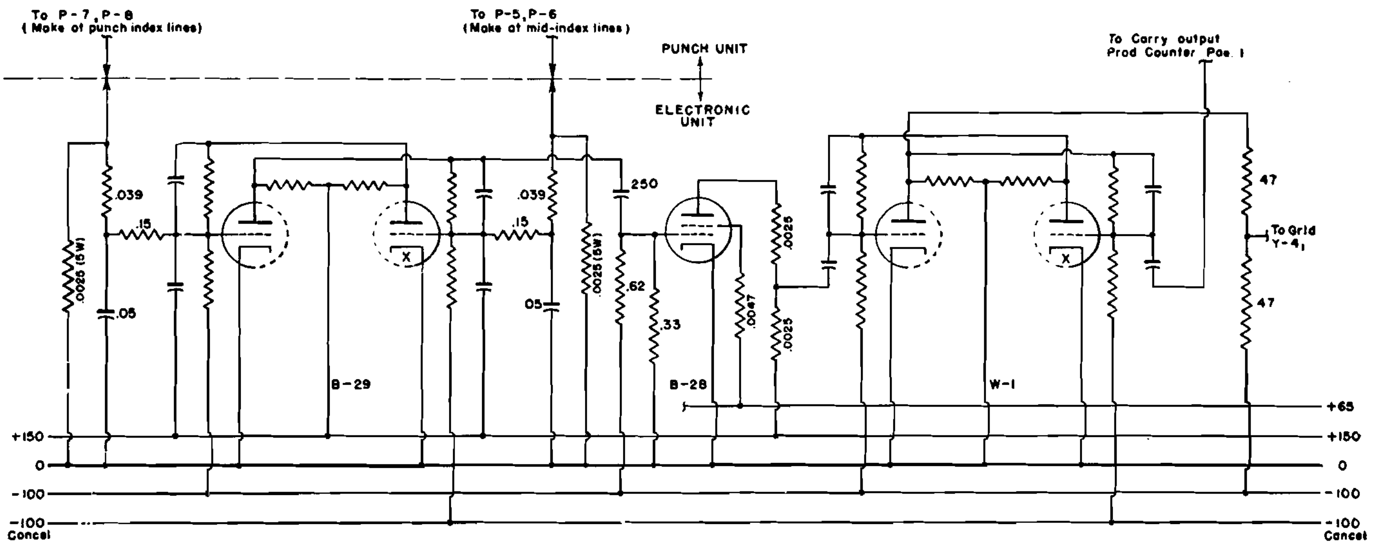


Figure 129. Triggering Off of Read-out Triggers at Mid-Index

PROCEDURES for testing will be given only for the electronic computing unit and the punch circuits which tie the two units together. The use of a multiplying test deck will aid in checking and analyzing the multiplying circuits. The test deck should be punched (wherever possible) with the multiplier and multiplicand factors in the same card columns which the customer uses. The control panel is set up for individual multiplication, using the full capacity of the machine.

Table I shows the multiplier and multiplicand factors together with the individual products and accumulated products appearing in the product counter. If the multiplier, multiplicand, and product are punched in each card and interpreted on the card, all the information will be available on the test deck. Then as the cards are run through the machine, the machine may be stopped at any point and the product in the counter compared with the amount punched in the card. (The products counter is read from bottom to top, since the first counter position is at the top.) The progressive totals appearing in the product counter, if the counter is not cleared, are also shown in the Table I. If desired, the product summary switch may be wired ON, and the individual totals will accumulate in the product counter. The machine may be stopped at any point and the total checked against the amount shown in the table below. The last card of the test deck may be X (or digit) punched to cause automatic clearing of the product counter after all cards have been multiplied. Otherwise, the product counter may be cleared manually by means of the product cancel push button.

If the individual products are punched in the test deck, it is possible to test the machine with all covers on. By wiring the machine for double punch detection and re-punching the product in

Multiplier	Multiplicand	Individual Product	Progressive Total
111111	111111	012345654321	012345654321
111111	222222	024691308642	037036962963
111111	333333	037036962963	074073925926
111111	444444	049382617284	123456543210
111111	555555	061728271605	185184814815
111111	666666	074073925926	259258740741
111111	777777	086419580247	345678320988
111111	888888	098765234568	444443555556
111111	999999	111110888889	555554444445
222222	111111	024691308642	580245753087
222222	222222	049382617284	629628370371
222222	333333	074073925926	703702296297
222222	444444	098765234568	802467530865
222222	555555	123456543210	925924074075
222222	666666	148147851852	074071925927
222222	777777	172839160494	246911086421
222222	888888	197530469136	444441555557
222222	999999	222221777778	666663333335
333333	111111	037036962963	703700296298
333333	222222	074073925926	777774222224
333333	333333	111110888889	888885111113
333333	444444	148147851852	037032962965
333333	555555	185184814815	222217777780
333333	666666	222221777778	444439555558
333333	777777	259258740741	703698296299
333333	888888	296295703704	999994000003
333333	999999	333332666667	333326666670
444444	111111	049382617284	382709283954
444444	222222	098765234568	481474518522
444444	333333	148147851852	629622370374
444444	444444	197530469136	827152839510
444444	555555	246913086420	074065925930
444444	666666	296295703704	370361629634
444444	777777	345678320988	716039950622
444444	888888	395060938272	111100888894
444444	999999	444443555556	555544444450
555555	111111	061728271605	617272716055
555555	222222	123456543210	740729259265
555555	333333	185184814815	925914074080
555555	444444	246913086420	172827160500
555555	555555	308641358025	481468518525
555555	666666	370369629630	851838148155
555555	777777	432097901235	283936049390
555555	888888	493826172840	777762222230
555555	999999	555554444445	333316666675
666666	111111	074073925926	407390592601
666666	222222	148147851852	555538444453
666666	333333	222221777778	777760222231
666666	444444	296295703704	074055925935
666666	555555	370369629630	444425555565
666666	666666	444443555556	888869111121
666666	777777	518517481482	407386592603
666666	888888	592591407408	999978000011
666666	999999	666665333334	666643333345
777777	111111	086419580247	753062913592
777777	222222	172839160494	925902074086
777777	333333	259258740741	185160814827
777777	444444	345678320988	530839135815
777777	555555	432097901235	962937037050
777777	666666	518517481482	481454518532
777777	777777	604937061729	086391580261
777777	888888	691356641976	777748222237
777777	999999	777776222223	555524444460
888888	111111	098765234568	654289679028
888888	222222	197530469136	851820148164
888888	333333	296295703704	148115851868
888888	444444	395060938272	543176790140
888888	555555	493826172840	037002962980
888888	666666	592591407408	629594370388
888888	777777	691356641976	320951012364
888888	888888	790121876544	111072888908
888888	999999	888887111112	999960000020
999999	111111	111110888889	111070888909
999999	222222	222221777778	333292666687
999999	333333	333332666667	666625333354
999999	444444	444443555556	111068888910
999999	555555	555554444445	666623333355
999999	666666	666665333334	333288666689
999999	777777	777776222223	111064888912
999999	888888	888887111112	999952000024
999999	999999	999998000001	999950000025
123456	123456	015241383936	015191383961
234567	234567	055021677489	070213061450
345678	345678	119493279684	189706341134
456789	456789	208656190521	398362531655
567891	567891	322500187881	720862719536
678912	678912	460921503744	181784223280
789123	789123	622715109129	804499332409
891234	891234	794298042756	598797375165
912345	912345	832373399025	431170774190
010101	010101	000102030201	431272804391
020202	020202	000408120804	431680925195
030303	030303	000918271809	432599197004
040404	040404	001632483216	434231680220
050505	050505	002550755025	436782435245
060606	060606	003673087236	440455522481
070707	070707	004999479849	445455002330
080808	080808	006529932864	451984935194
090909	090909	008264446281	460249381475
101010	101010	010203020100	470452401575
202020	202020	040812080400	511264481975
303030	303030	091827180900	603091662875
404040	404040	163248321600	766339984475
505050	505050	255075502500	021415486975
606060	606060	367308723600	388724210575
707070	707070	499947984900	888672195475
808080	808080	652993286400	541665481875
909090	909090	826444628100	368110109975

Table I

the same field as it is already punched, any errors will be indicated by the machine's stopping and showing an error light.

Progressive punching may be checked in the same manner described above if the product summary is wired ON and the R19B points are shorted. Progressive punching may also be obtained by leaving the product summary unwired and shorting either R19A points or P11 cam contact.

If wrong results are being obtained, an effort should be made to determine the type of trouble before removing any covers. In any event, all voltages should be checked before any analyzing is done. In this way, blown fuses, wrong voltage adjustments, or any trouble in the power supply can be detected before any time is spent attempting to find troubles in the electronic unit.

To eliminate carry and also to provide a product easily calculated manually, a 111111 x 111111 card should be used to check computing. By working out the problem in detail manually it is often possible to determine the type of trouble.

When covers are removed from the electronic unit, it is possible to check the values read into the multiplier and multiplicand counters and computed product in the product counter before punching. To avoid any possible change in the multiplier and multiplicand counters during computing, read-in should always be checked before computing. This can be easily done by setting the manual control dial switch OFF. If read-in is correct and it is desired to start computing, it is only necessary to turn the switch to MANUAL for an instant and back to OFF.

Before looking very far for trouble in the electronic unit, a visual check should be made for an open filament circuit. The individual tube in an open string may be found by substitution or by means of an ohmmeter.

If the multiplier or multiplicand is reading in wrong, the factor reversal switch may be set ON, and the factors again read in. If the trouble shifts to the other counter, it is obvious that the trouble is in the punch unit. Then by crossing control panel wires or using different brushes, the trouble can be readily localized.

If a counter position fails to receive a reading and it is known to be in the electronic unit, first check the counter read-in trigger indicator lights. If the read-in triggers turn ON, but the counter fails to receive a reading, the read-in switch tube should be exchanged with a good one.

If the trouble is in the counter, it may be localized to one position by crossing the input wires on the counter chassis terminals. Once it is localized to a counter chassis, the tubes may be checked by exchanging all the tubes in one position with all the tubes in another position that is working properly. Then the trouble may be localized to an individual tube by exchanging tubes one at a time.

If a read-in trouble is localized to one counter position and the tubes are good, the trouble should be in the components wired to the tube sockets. A visual check should locate such troubles as broken wires, shorts between components, loose solder connections, "burned" resistors, etc. The values of resistors may be checked with an ohmmeter if no trouble is located visually. It must be kept in mind that exact readings cannot be obtained in many cases because of back circuits. However, sufficiently accurate readings can be obtained to indicate whether or not a resistor is within operating range. In checking capacitors, shorted capacitors can be detected with an ohmmeter. Open capacitors can be easily detected by substituting a good capacitor across the suspected one. For a quick check there is no need to solder the substitute capacitor in place; it may be held across the suspected capacitor while the circuit operation is checked. If trouble is located in a trigger circuit, it must be kept in mind that the trigger circuit must be symmetrical; therefore, resistors or capacitors should be replaced in correspondingly matched pairs. A tube socket may be ordered with all trigger components mounted on the socket. In many cases of trouble in the trigger circuit, it may be wise to replace the tube socket with all trigger circuit components mounted on it.

If after a reasonable length of time, the trouble cannot be found in a counter, it may be necessary to replace the counter chassis and return the old chassis to Endicott or repair the old chassis in the local office.

Read-in trouble affecting both multiplier and multiplicand counters can be in either the punch or the electronic unit. By observing the indicator light for the read-in pulse trigger, it can be determined whether this trigger is operating. If the trigger is operating properly and no pulses are getting to the counters, the power tube may be at fault. If the trigger fails, either the cam contacts in the punch unit are at fault, or the trigger tube or circuit is at fault.

If read-in is found to be correct, but the wrong product is obtained, the computation should be repeated at 5 cycle per second frequency. Visual observation of the indicator lights will show up any obvious troubles, such as failure of the primary or secondary timers, failure of any or all positions of the multiplier counter to advance, failure of any positions of the multiplicand counter to roll, failure of multiplicand read-out triggers, failure to column shift, etc. Once the trouble is localized to a certain function, visual observation of the indicator lights will show whether or not certain timing triggers are functioning, such as B3, A35, B16, B17, etc. Once a trouble is localized to a certain area, defective tubes may be easily found by exchanging suspected tubes with good tubes. Any trouble behind the chassis can be found by methods already discussed.

In some cases it may be desirable to resort to handpulsing so the computation may be stopped at any point desired. A microswitch mounted in a convenient holder is provided for manual pulsing. The switch is arranged so it may be jack-plugged in the chassis and placed in operation by setting the dial switch on the A chassis to KEY. When the microswitch is depressed, the manual pulse trigger goes ON and the indicator light on the A chassis glows. This produces a negative B pulse (or a positive A pulse) throughout the machine, provided the start trigger is ON. When the switch button is released, the manual pulse trigger again goes OFF, and a positive B pulse (or negative A pulse) is produced. Thus, the depressed position of the microswitch corresponds to index line pulses (0, 1, 2, 3, etc. on electronic cycle), while the normal position of the microswitch corresponds to mid-index line points (0.5, 1.5, etc.).

Often it may be helpful in analyzing a trouble, to stop computing after 1, 2, 3, 4, 5, or 6 column shifts either at 5-cycle speed or 35kc speed. Computation may be easily stopped after any column shift by removing the wire to post A45 (compute stop wire) from post C23. Then by means of a clip lead, attach the compute stop wire to post C38 to stop after the 1st column shift; to post C37 to stop after the 2nd column shift; to post C31 to stop after the 3rd column shift; to post C30 to stop after the 4th column shift; to post C24 to stop after the 5th column shift. No half-entry position should be wired when this is done.

Once computing stops after a given number of column shifts, trigger A32 is ON; therefore, a problem cannot be continued by merely turning the manual control dial switch to MANUAL. In order to carry a problem through one column shift at the time, proceed as follows:

1. Set manual control dial switch OFF.
2. Clip compute stop lead to post C38.
3. Read multiplier and multiplicand factors in by feeding card through entry brushes.
4. Turn manual switch to MANUAL for a moment and back to OFF; this will cause computation to go through 1st column shift leaving A32 triggers ON.

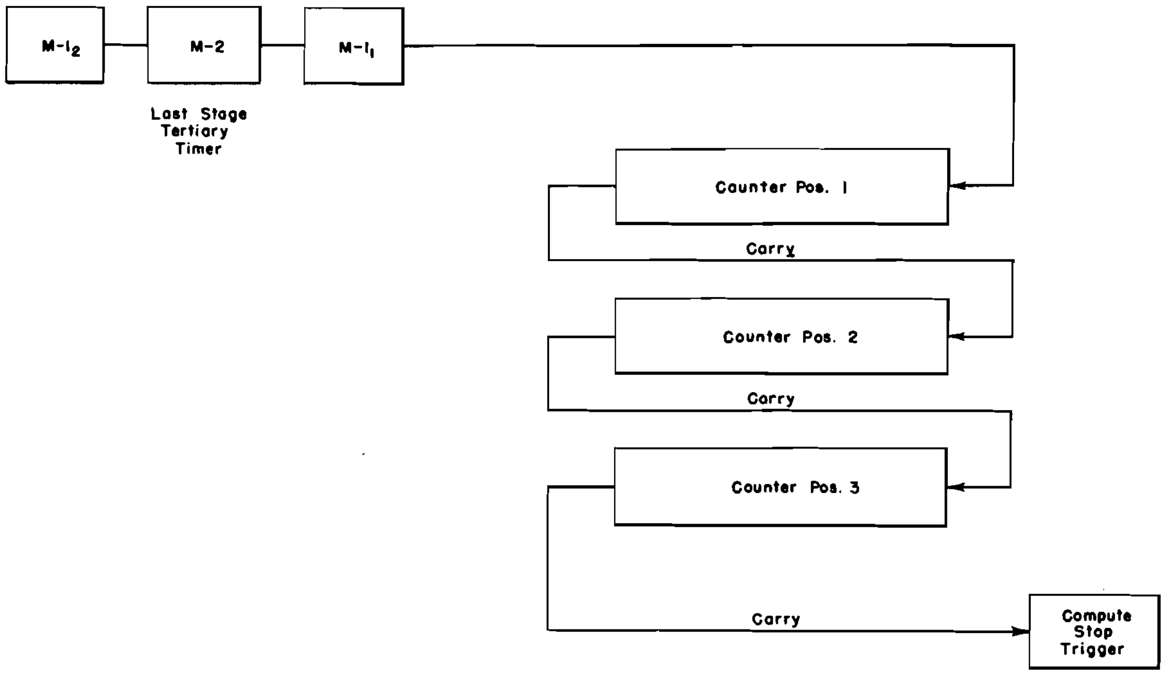


Figure 130. Connections for Manual Checking of Multivibrator Frequency

5. Turn trigger A32 OFF manually by touching the grid pin on the OFF side of A32 (pin 4) with a test lead clipped to +65 volts. (A test lead is provided with the machine for this purpose. A 0.2 megohm resistor is wired in the prod to limit grid current and to prevent a short in case the test lead is connected across "hot" terminals.)
6. Move compute stop lead to post C37.
7. Turn manual switch to MANUAL for a moment and back to OFF; this will cause computation through the 2nd column shift.
8. Repeat above process on through 6th column shift.

Of course it is not necessary to go through all these steps if a new card is fed through the punch after each computation. For example, clip the compute stop wire to post C38 and set dial switch to NORMAL. Then when a card is fed, the machine will compute the problem through the 1st column shift. Now move the compute stop wire to post C37 and feed a new card. This time the problem will be computed through the 2nd column shift. This may be repeated through the six column shifts.

If it is found that the computation is correct at 5-cycle speed, but fails at high speed, it may be that capacitance effect, weak triggers, etc., are at fault. In this case it may be necessary to resort to an oscilloscope. The use of an oscilloscope will be discussed in a later section. One of the first things that should be checked, when failure occurs at high speed only, is the frequency of the multivibrator. In case trouble develops in the multivibrator, resulting in a considerable increase in speed, trouble may be caused by exceeding the frequency rating of the triggers. Also, it is conceivable that the frequency may drop to such an extent that the computation is not finished before cancelling. Of course, this will show up only on automatic operation. In any event, the frequency of the multivibrator can easily be checked without instruments provided the machine is going through a problem properly as far as compute start, column shift, and compute stop are concerned. This is done by performing a problem 1000 times and timing the operation. Then, knowing the total number of cycles taken, it is only a matter of dividing the time into the total number of cycles taken during that time to obtain the frequency. The connections necessary to perform this test are indicated in Figure 130. To make the necessary connections, proceed as follows:

1. The compute stop wire is removed from post A45.
2. The input and output jumpers are removed from the first 3 positions of the multiplier (or multiplicand) counter.
3. Then clip a test lead from the output of counter position 1 (−50 volt output) to the input of counter position 2, and from the output of position 2 to the input of position 3. This will provide three counter positions in tandem, and starting from 0, 1000 pulses applied to the input of the 1st counter position will result in a carry pulse from the 3rd position.
4. The output of the 3rd counter position is clipped by a test lead to the input capacitor at the ON side of compute stop trigger A31. A convenient place to clip this lead is at the midpoint of the two .015 megohm resistors shown under A31 on the circuit diagram. When the 3rd position carries, computation will stop.
5. The input of the first counter position is wired to the anode of tube M1 (pin 5) by means of a test lead. M1 is the follower for the OFF side of trigger M2, which is the last stage of the tertiary timer. Each time M2 goes OFF, a negative pulse is produced at the anode of M1, to cause *1* to add in counter position 1.

With the above connections, the counters connected in tandem will count the computations. Only six column shifts are required to complete a problem; however, the tertiary timer returns to *0* at the 8th pulse and it is necessary to go through 8 column shifts for each computation. This is of no consequence, because nothing happens during the 7th and 8th column shifts except for advancing the timers. This does mean, however, that for each computation 1280 pulses (16 x 10 x 8) are required instead of 960 pulses. (The fact that the first computation starts with the tertiary timer at *1* does not change the total number of cycles taken sufficiently to take it into consideration.) Then, knowing that each computation requires 1280 pulses, it is obvious that 1000 computations represent 1,280,000 pulses.

With the above setup, the manual control dial switch is set to OFF and the frequency control dial switch is set to 35 KC. Then a card is fed through the punch. The manual switch is set to MANUAL and the time is observed. By watching the tertiary timer indicator lights (or the compute stop trigger indicator light), it can be easily determined when computation stops, and the time is again noted. By dividing the elapsed time in seconds into 1,280,000, the frequency is obtained. For example, if 40 seconds are required to complete a computation 1000 times, then the multivibrator frequency is 1,280,000/40 or 32,000 cycles per second. This frequency is not critical. A tolerance of ± 10% from the rated frequency is permissible.

The above method provides a medium for a test of the electronic unit. Of course, only three positions of the multiplier (or multiplicand) counter can be used for computing. After the problem has been computed 1000 times, the result in the product counter should be the same as for one computation with the decimal stepped over three places to the right, that is, with three zeros to the right.

Use of Neon Indicator Bulb, Voltmeter, and Oscilloscope

A neon indicator bulb which requires at least 90 volts to glow is a very useful tool in analyzing certain troubles. With this indicator the status of any trigger or tube can be determined by placing the leads of the indicator bulb between the ground and the anode of the tube in question. If a tube is conducting, the bulb will not glow, since the potential at the anode is considerably below +90 volts. On the other hand, the indicator bulb will glow if a tube is cut off, since the potential at the anode will be essentially +150 volts. In using a neon indicator, it must be borne in mind that a pulse passing through a small capacitor (50 – 250 mmfd) will not indicate, because the duration of the pulse is not sufficiently long to be visible.

It is not necessary to have a neon indicator bulb in the tool kit; one of the unused indicator bulbs on the electronic unit may be used. For example, bulb 5 in the indicator block in the A13 position is not used; consequently this bulb can be used as an indicator. By plugging the cable extension plug in socket A13, the indicator block can be carried to the rear of the chassis for observation. (An extension cable for the indicator blocks is furnished with each machine.) Since one side of all the bulbs in the indicator block is already grounded, it is necessary only to clip one test lead to pin 5 of the socket in A13. To prevent damage to the bulb, at least 0.2 megohm should be wired in series with the test lead. If the test lead with a 0.2 megohm resistor internally wired is clipped to pin 5 of socket A13, then the prod can be used as a pointer and by observing bulb 5 in the indicator block, the status of various tubes can be determined.

A volt-ohmmeter is an indispensable tool in servicing the electronic unit. For most uses a meter with as low a sensitivity as 1000 ohms per volt can be used. However, in order to check potentials in very high resistance circuits, such as grid circuits, it is necessary to have a high sensitivity of around 20,000 ohms per volt. Since it is not often necessary to determine grid potentials, it is not necessary to have a meter with a sensitivity as high as 20,000 ohms per volt for ordinary trouble shooting.

The anode potential of the 25L6's varies from about +150 volts, when non-conducting to about +20 to +30 volts when conducting. The anode potential at either anode of a trigger changes from approximately +40 volts to approximately +140 volts as the trigger goes ON and OFF. The potential at the anode of 6SK7's and triode sections of 12SN7's varies between approximately +50 volts and +150 volts as the tube goes from conducting state to non-conducting.

As in the case of the neon indicator, a meter cannot follow a pulse through a capacitor. The fastest speed that a meter can be expected to follow is about 2-3 pulses per second. When computing at 5-cycle speed, it is possible to check most operations by means of a voltmeter, since most operations occur at speeds less than 3 per second. Remember, though, that *a meter cannot detect pulses through a capacitor.* Only an oscilloscope will show pulses through a capacitor. Another very important fact to remember is that a low sensitivity meter will draw sufficient current to cause a trigger to operate when the meter lead is touched to the anode of the non-conducting tube of a trigger. Therefore, care must be exercised when checking the status of triggers with a meter; a false impression may be obtained if the voltmeter causes a trigger to trip.

Since grid current prevents grid potential from rising above cathode potential, the actual potential that a voltage divider produces cannot be checked with a tube in place. It is convenient to have a dummy tube with all base pins clipped except the heater pins for such purposes as checking positive potentials at grids, or to stop certain operations. The heater pins must be left in place because the tube filaments are wired in strings, and tubes other than the desired one may be rendered ineffective.

As already mentioned in connection with trouble analysis, an ohmmeter is quite useful in checking for shorted capacitors and resistors, or for shorted tube elements. Resistance values can also be determined, as well as open resistors or open circuits of any type.

The discussion of the use of an oscilloscope is limited to the use for the particular job of locating trouble on the computing unit under actual operating conditions. If it is desired to accurately reproduce square waves, an oscilloscope (usually abbreviated scope) must have an amplifier with an extremely flat characteristic up to several megacycles. Other than exact reproduction of waveform, however, any reasonably good scope can be used to view operations at high speed.

In order to attach significance to the scope pattern, it is necessary to calibrate the screen both horizontally and vertically. The signal input is applied to the vertical deflection plates through the vertical amplifier. Since a vertical deflection represents voltage, it is possible to apply a known voltage and calibrate the screen. The Y-gain switch (vertical amplifier) can be adjusted to produce a desired deflection on A or B pulses (post A54 or A53) and then left at this setting. The A and B pulses are known to be approximately 120 volts; therefore, the two extremes of the pulses can be marked on the screen, and a center line can be indicated as the reference. (Care must be exercised to remain on the flat surface of the screen as much as possible.) With these marks as guides, the voltage of any applied pulses can be determined fairly accurately.

In order to show phase relationships, it is necessary to use external synchronization. The best point to connect for external synchronization is at the indicator light for the last stage of the primary timer (A29). This connection is desirable because the 1 megohm resistor between the indicator light and the trigger isolates the scope and prevents any possible interference with the operation of the primary timer.

Since one problem requires such a short time, it is necessary to keep the unit in a computing state to view the patterns on a scope screen. The easiest method of doing this is to disconnect the wire on post M46, which is the input to the tertiary timer. Thus, the column shift cannot advance and once computation starts, the problem is repeated over and over in the first column shift. If it is desired to view operations in any other column shift, the column shift may be advanced by turning M5 OFF and ON manually by using the test lead with a 0.2 megohm resistor internally wired.

The horizontal deflection represents time, and by proper setting of the frequency range switches and by proper synchronizing, a steady pattern of one cycle or hundreds of cycles can be shown on the screen. Since the basic adding cycle consists of 16 cycles of the multivibrator, it is desirable to calibrate the screen into 16 pulses to represent the 16 points of the adding cycle.

In order to set up a cycle that has significance, it is necessary to reproduce on the scope screen patterns that exist at known times in the electronic cycle. For instance, the last stage of the primary timer goes ON at 8 and OFF at 0; therefore the pattern produced by applying the potential at the anode of either tube of trigger A29 to the scope can be used to establish 0 and 8 points of the cycle. Similarly, the output from other triggers or tubes can be used to establish all the points of the cycle. These points are calibrated on the scope screen and can then be used for timing reference.

It may be found easier to establish a fixed pattern of one cycle on the screen by first setting up a fixed pattern of 32 pulses (two primary cycles). Then by means of the horizontal location switch and the horizontal gain switch, the pattern can be spread out and located exactly where desired. Once a fixed pattern for one cycle is established, by applying the potential at various points the pattern for the multiplier advancing pulse, multiplicand rolling pulses, carry pulse, etc. may be viewed on the scope screen.

The table below shows where to touch the scope input prod to obtain the pattern indicated:

A pulses —Post A54
B pulses —Post A53
Input to primary timer —Midpoint of A25 load resistor
First stage of primary timer —Pin 2 or 5 of A26
Second stage of primary timer —Pin 2 or 5 of A27
Third stage of primary timer —Pin 2 or 5 of A28
Last stage of primary timer —Pin 2 or 5 of A29
Multiplier advancing trigger —Pin 5 of A35
Multiplier advancing pulse (+12) —Post A33
Pulses to B3 trigger (-10, -14) —Post A49
*Half-entry pulses —Post A34
B3 trigger —Pin 2 or 5 of B3
B16 trigger (0.5-10.5) —Pin 5 of B16
10A pulses to roll multiplicand —Post B22
10B pulses to column shift switches —Post B58
+10 pulse to turn OFF multiplicand output triggers —Post B45
-14 pulse to turn OFF carry triggers —Post B50
Carry control pulse —Post B51

Input to multiplier counter —Post E1, E6, F1, F6, G1, G6
Input to multiplicand counter —Post I1, I6, J1, J6, K1, K6
Output from multiplicand counter —Post I21, I26, J21, J26, K21, K26
Input pulses to column shift switches —Post O61 (during CS1)
O60 (during CS2)
O59 (during CS3)
O58 (during CS4)
O57 (during CS5)
O56 (during CS6)
Output from column shift switches (before clipping) —Anode load resistors in N and O chassis for switch tubes in O chassis.
Input to product counter from column shift switches and carry —Post P1, P6, R1, R6, S1, S6, T1, T6, etc.

* To view half-entry pulses a dummy tube must be inserted in place of A14 to prevent blocking the A22 trigger.

PURPOSE OF TUBES IN THE COMPUTING SECTION

A1. Not used.

A2. Not used.

A3. Neon indicating bulb for manual pulser.

A4. Dial switch.

A5. Jack-plug for manual pulsing contact.

A6. Test Socket position for MP counter input triggers in C chassis.

A7 (*VR-150*). Voltage regulator tube for multivibrator to maintain +150 volts at anodes of MV to insure frequency stability.

A8 (*12SN7*). Manual pulse trigger to provide true square wave output from manually controlled pulser.

A9 (*12SN7*). 5 cycle multivibrator used for visual observation of computation when dial switch is set to 5 cycles.

A10 (*12SN7*). 35,000 cycle multivibrator used as master timer for all computations; generates essentially square waves of 35,000 cycles per second frequency.

A11 (*12SN7*). Clipper for multivibrator output; provides square wave output at anode of second stage.

A12. Not used.

A13. Test socket position for control triggers in A chassis.

$A14_1$ (*12SN7*). Blocking tube for A22 trigger to prevent A22 from turning ON as long as $A20_1$ is non-conductive, and thus allows A22 to turn ON only in 6th column shift cycle.

$A14_2$ (*12SN7*). Follower tube which conducts when A15 trigger is ON; provided to block the A22 trigger from turning ON again at *0* of 2nd through 10th primary cycles during 6th column shift cycle.

A15 (*12SN7*). Trigger controlling single entry of half-correction pulses through $A14_2$ follower tube; allows five half-entry pulses to enter product counter only once. Turned ON at *5* during the 1st primary cycle of the 6th column shift cycle from a negative pulse from A22 trigger; turned OFF by cancelling.

A16 (*25L6*). Power tube controlled by clipper output; produces square wave A pulses for operation of computing section.

$A17_1$ (*12SN7*). Follower for right-hand tube of 5 cycle MV; provides 5 cycle pulses to clippers and is necessary because direct coupling is required for such slow operation.

$A17_2$ (*12SN7*). Inverter from second stage of clipper to provide pulses of proper phase to A16 power tube.

A18 (*25L6*). Power tube controlled by clipper output; produces square wave B pulses for operation of computing section. B pulses are 180° out of phase with A pulses.

A19. Not used.

$A20_1$ (*12SN7*). Normally non-conducting triode which controls $A14_1$ blocking tube; prevents A22 trigger turning ON until 6th column shift cycle when $A20_1$ is conductive.

$A20_2$ (*12SN7*). Follower tube for $A26_1$, the OFF tube of the first stage of the primary timer. Used to avoid loading of trigger; conducts when A26 trigger is OFF.

A21 (*6SK7*). Switch tube providing negative pulses at *5*, *7*, *13*, and *15*; turns trigger A22 OFF at *5* after A22 has been turned ON. Negative pulses at *7*, *13*, and *15* are not used.

A22 (*12SN7*). Trigger controlling five pulses for half-correction; ON from *0* through *5* of 1st primary cycle during 6th column shift and conditions A23 switch to accept *5* B pulses for half-correction.

A23 (*6SK7*). Switch controlling pulses for half-entry; suppressor receives continuous stream of B pulses but grid conditions switch only when A22 trigger is ON.

A24 (*25L6*). Power tube controlled by A23 switch; provides 5 positive pulses to half-entry switches in N chassis.

A25 (*6SK7*). Start switch providing pulses to primary timer under control of trigger A31; A pulses applied to suppressor are inverted to B pulses for primary timer.

A26 (*12SN7*). First stage trigger of primary timer which turns ON every odd-numbered pulse from A25 switch and turns OFF at every even-numbered pulse, thus going ON eight times in each primary cycle.

A27 (*12SN7*). Second stage of primary timer which triggers when A26 goes OFF, therefore going ON every 4 pulses from A25 switch beginning at *2* and going OFF every 4 pulses beginning at *4*.

A28 (*12SN7*). Third stage of primary timer which triggers when A27 goes OFF, therefore going ON every 8 pulses from A25 switch beginning at *4* and going OFF every 8 pulses beginning at *8*.

A29 (*12SN7*). Fourth stage of primary timer which triggers when A28 goes OFF, therefore being ON from 8 to 0 of each primary cycle.

A30 Test socket position for primary timer.

A31 (*12SN7*). Trigger controlling starting and stopping of computations by conditioning A-25 start switch to accept A pulses; turned ON when A32 trigger goes ON and turned OFF at end of computation by negative pulse from column shift control.

A32 (*12SN7*). Compute start trigger under control of P24 cam contact in punch unit; turned ON by P24 and cancelled OFF. This trigger is necessary to permit the computation to terminate before P24 (or the manual control switch) opens.

A33 (*6SK7*). Switch providing negative pulses at *10* and *14* under control of primary timer to turn B3 trigger ON *and* OFF.

$A34_1$ (*12SN7*). Follower tube for OFF side of A29 trigger in primary timer; used to relieve load on trigger.

$A34_2$ (*12SN7*). Follower tube for ON side of A29 trigger.

A35 (*12SN7*). Control trigger for A36 power tube; ON at *8* and OFF at *12*. Conduction through A36 stops at 12 when A35 goes OFF.

A36 (*25L6*). Normally conducting power tube which stops conducting at *12* when A35 goes OFF to provide a positive pulse to advance the multiplier counter *1* for each primary cycle.

B1. Not used.

B2 (*25L6*). Stops conducting at *10* under control of $B9_1$ to provide a positive pulse to the L chassis for stopping the output of pulses from the multiplicand when transferring the multiplicand to the product counter.

B3 (*12SN7*). Control trigger ON from *10* through *14;* controls other tubes through the follower tubes $B9_1$ and $B9_2$.

B4 (*6SK7*). Switch tube for turning trigger *B16* ON at 0.5. Grid of B4 is conditioned by $A34_2$ from *0* through *8* and suppressor receives B pulses; only the *0.5* pulse is used to turn B16 ON.

B5 (*6SK7*). Switch providing 10 pulses from *0.5* through *10.5* under control of $B11_1$ and $B11_2$. A pulses are fed to the suppressor of B5; 10 are passed and fed to power tube B6 as B pulses.

B6 (*25L6*). Power tube providing ten A pulses for rolling multiplicand counter when transferring from MC to product counter. Ten B pulses applied to the grid of B6 appear as ten A pulses at the anode of B6.

B7 Test socket position for control triggers on B chassis.

B8 (*25L6*). Conducts at *14* under control of $B9_1$ to provide a negative pulse at *14* to turn OFF any carry triggers in W and X chassis which may be ON at end of adding cycle.

$B9_1$ (*12SN7*). Follower for ON side of trigger B3. Anode potential is low when B3 is ON from *10* through *14;* controls B8 and B2 power tubes.

B9₂ →

$B9_2$ (*12SN7*). Follower for trigger B3 OFF side. Anode potential is high from *10* through *14* to condition B15 switch and B10 switch; also provides a negative pulse at *14* to advance the secondary timer.

B10 (*6SK7*). Switch controlling B16 trigger; turns B16 OFF at *10.5*. Grid of B10 is conditioned to conduct from *10* through *14* by $B9_2$ and suppressor receives B pulses, thus providing 4 negative pulses at *10.5*, *11.5*, *12.5*, and *13.5* to turn B16 OFF. Only the *10.5* pulse is used.

$B11_1$ (*12SN7*). Works in conjunction with $B11_2$ to condition the grid of B5 switch; allows B5 to accept A pulses only in the primary cycles following a carry-over in the multiplier counter. $B11_1$ is cut off and its anode is at high potential when trigger B17 is ON.

$B11_2$ (*12SN7*). Works in conjunction with $B11_1$ to condition the grid of B5 switch; allows ten A pulses to be passed by B5 provided B5 is not blocked by $B11_1$. $B11_2$ is cut off and its anode is at high potential when trigger B16 is ON.

B12 (*25L6*). Power tube providing ten B pulses to the column shift control tubes. The A pulses from B6 are inverted to B pulses for the column shift control tubes.

B13. Not used.

B14 (*25L6*). Cuts off from *10.5* through *14* under control of B15 switch to provide positive pulse for carry control; carry switches are conditioned to conduct by B14.

B15 (*6SK7*). Switch provided to control the carry control power tube B14; controlled by $B9_2$ and B16. $B9_2$ permits conduction from *10* through *14* by suppressor control, and B16 permits conduction from *10.5* through *0.5* by grid control, thus B15 can conduct only from *10.5* through *14*. The B16 control provides a half-cycle delay to insure that carry cannot occur until adding is complete.

B16 (*12SN7*). Trigger providing 10 pulse control; ON from *0.5* through *10.5* of every adding cycle under control of B4 and B10 switches.

B17 (*12SN7*). Multiplicand read-out control trigger provided to control the cycle during which the multiplicand starts receiving rolling pulses. B17 is turned ON by carry pulses from the multiplier counter at *12* and turned OFF by the secondary timer at the end of a column shift cycle.

B18. Test socket for secondary timer.

B19. Not used.

B20 (*12SN7*). First stage trigger of secondary timer which triggers at *14* of each primary cycle, going ON and OFF alternately.

B21 (*12SN7*). Second stage trigger of secondary timer which triggers when B20 goes OFF, therefore going ON at the second and sixth primary cycles. B27 blocks B21 on the tenth cycle.

B22 (*12SN7*). Third stage of secondary timer; triggers when B21 goes OFF, therefore going ON at the fourth primary cycle and remaining ON through the eighth.

B23 (*12SN7*). Fourth stage of secondary timer; ON during the 8th and 9th primary cycles under control of B20 and B22. When B23 goes OFF, a negative pulse is provided to turn B17 trigger OFF and to advance the tertiary timer.

B24 (*12SN7*). Follower for ON side of B23 trigger in the secondary timer. Provides advancing pulses for the tertiary timer (column shift control) at the end of the 10th primary cycle.

B25. This position is used for the voltage adjusting potentiometer in the +65 volt power supply.

B26 (*6SJ7*). Voltage control pentode for voltage regulating circuit providing +65 volt supply.

B27 (*12SN7*). Blocking tube to prevent B21 trigger from turning ON for the 10th primary cycle; used to make a scale of ten counter from a straight binary counter.

B28 (*25L6*). Normally non-conducting power tube which conducts when B29 trigger goes OFF; provides negative pulses at mid-index lines in synchronism with card movement through punch to turn OFF any carry and punch control triggers in W and X chassis which happen to be ON, thus preventing under-punching of card.

B29 (*12SN7*). Trigger providing 10 index lines pulses for read-out control; turns ON at punch index lines *9* through *0* when P7 and P8 make and turns OFF at mid-index points beginning at *9.5* when P5 and P6 make. Provides negative pulses at index lines to B30 power tube and positive pulses at mid-index lines to B28 power tube.

B30 (*25L6*). Normally conducting power tube providing 10 positive pulses at index lines in synchronism with card movement through punch for rolling the product counter when reading out. Negative pulses produced when B29 goes ON control B30.

B31 through B34 (*25L6*). Power tubes for voltage regulating circuit used to provide +*65* volts. Four tubes are used to furnish the necessary current demand.

B35 (*12SN7*). Trigger providing 9 pulses at punch mid-index time for read-in control from card; turns ON when P5 and P6 make at mid-index lines *9.5* through *1.5*, and turns OFF when P7 and P8 make at *8* through *0*. Negative pulses cut off B36 power tube each time B35 trigger goes ON.

B36 (*25L6*). Normally conducting power tube providing 9 positive pulses at mid-index times in synchronism with card movement through punch for read-in control. Positive pulses are applied to the suppressors of the multiplier and multiplicand read-in switches.

C1 (*12SN7*). Multiplier read-in trigger for units position of multiplier counter; turned ON when brush wired to this position makes contact through the hole in the card and turned OFF by cancelling.

C2 (*6SK7*). Multiplier read-in switch provided to control the number of pulses entering the units position of the multiplier counter; its grid is conditioned by C1 being ON and suppressor receives read-in pulses from B36.

C3 (*6SK7*). Multiplying control switch controlling entry of pulses for rolling the units position of the multiplier counter; its grid is conditioned by the column shift controls to conduct only during the 6th column shift cycle and its suppressor receives a positive pulse at *12* of each primary cycle from A36 to advance the multiplier counter by *1*.

C4, C7, C10, C13, and C16 (*12SN7*). Same as C1 for 2nd through 6th multiplier counter positions.

C5, C8, C11, C14, and C17 (*6SK7*). Same as C2 for 2nd through 6th counter positions.

C6, C9, C12, C15, and C18 (*6SK7*). Same as C3 for 2nd through 6th counter positions.

D1 (*12SN7*). Multiplicand read-in trigger for units position of multiplicand counter; turned ON when brush wired to this position makes contact through a hole in the card and turned OFF by cancelling.

D2. Test socket for multiplicand input triggers.

D3 (*6SK7*). Multiplicand read-in switch provided to control the number of pulses entering the units position of the multiplicand counter.

D4, D7, D10, D13, and D16 (*12SN7*). Same as D1 for 2nd through 6th positions of multiplicand.

$D5_1$ (*12SN7*). Read-in inverter to feed ten B pulses to first position of the multiplicand counter for rolling the counter when transferring the multiplicand to the product counter. Ten A pulses from B6 are inverted to B pulses for rolling the counter.

$D5_2$, D11, and D14 (*12SN7*). Same as $D5_1$ for 2nd through 6th position of multiplicand counter.

D6, D9, D12, D15, and D18 (6SK7). Same as D3 for 2nd through 6th positions of multiplicand counter.

D8 and D17. Not used.

E, F, G, chassis are the multiplier counter chassis. The purpose of any tube in any counter position is the same as the corresponding tube in the secondary timer, which is a decimal counter.

$H1_1$ (12SN7). Multiplier output inverter provided to signal carry-over from units multiplier counter position; negative pulse at anode of $H1_1$ turns B17 trigger ON when units position of multiplier counter carries.

H_2, H3 and H5 (12SN7). Same as $H1_1$ for 2nd through 6th positions of multiplier counter.

H2, H4, and H6. Not used.

I, J, K chassis are the multiplicand counter chassis.

L1. Not used; spare 12SN7 tube is mounted in this position.

L2 (12SN7). Output trigger for the units position of the multiplicand counter; turned ON when units position of multiplicand counter carries and turned OFF at *10* under control of $L4_2$ by pulse from B2. L2 controls the number of pulses passed to the product counter under control of the units position of the multiplicand counter.

L3. Not used; spare 12SN7 tube is mounted in this position.

$L4_1$ (12SN7). Follower for the OFF side of trigger L2, provided to condition all column shift switches connected to the units position of the multiplicand. When L2 is ON, $L4_1$ is nonconducting, and its high anode potential conditions the corresponding column shift switches.

$L4_2$ (12SN7). Blocking tube controlling the OFF side of L2 trigger. A positive pulse at *10* from B2 causes momentary conduction through $L4_2$ and the drop in the anode potential of $L4_2$ triggers L2 OFF, thus stopping further pulses from passing to the product counter through the column shift switches. Also, $L4_2$ blocks L2 from turning ON when transferring 0's. When transferring 0's, carry comes at *10* to turn $L2_2$ ON but $L4_2$ is conducting at *10* time and blocks L2 from turning ON.

L5. Test socket for multiplicand output triggers.

L6, L8, L10, L11, L13, L15, L16, L18, L20, L21, L23, L25, L26, L28, and L30. Not used; spare 12SN7 tubes mounted in these positions.

L7, L12, L17, L22, and L27 (12SN7). Same as L2 for 2nd through 6th positions of multiplicand.

L9, L14, L19, L24, and L29 (12SN7). Same as $L4_1$ and $L4_2$ for 2nd through 6th positions of multiplicand.

$M1_1$ (12SN7). Follower for OFF side of M2 trigger (third stage of tertiary timer) provided to control interpolating tubes in column shift control circuit.

$M1_2$ (12SN7). Follower for ON side of M2 trigger (third stage of tertiary timer) provided to control interpolating tubes.

M2 (12SN7). Third stage of tertiary timer which turns ON when M3 goes OFF, stays ON for the 4th, 5th, and 6th column shift cycles, and is cancelled OFF.

M3 (12SN7). Second stage of tertiary timer which triggers when M5 goes OFF, therefore being ON for the 2nd, 3rd, and 6th column shift cycles.

$M4_1$ (12SN7). Follower for OFF side of M3 trigger.

M4 (12SN7). Follower for ON side of M3 trigger.

M5 (12SN7). First stage of tertiary timer which triggers each time secondary timer carries over; ON for the 1st, 3rd, and 5th column shift cycles.

$M6_1$ (12SN7). Follower for OFF side of M5 trigger.

$M6_2$ (12SN7). Follower for ON side of M5 trigger.

M7. Test socket for indicator lights for tertiary timer.

M8. Not used; spare 12SN7.

$M9_1$ (12SN7). Interpolating tube blocking tube $M16_1$ in conjunction with $M9_2$ and $M16_2$ to permit $M16_1$ to conduct only during the 6th column shift cycle.

$M9_2$ (12SN7). Interpolating tube which blocks $M16_1$ in conjunction with $M9_1$ and $M16_2$ to permit $M16_1$ to conduct only during the 6th column shift cycle.

$M10_1$ (12SN7). Interpolating tube blocking $M17_1$ in conjunction with $M10_2$ and $M17_2$ to permit $M17_1$ to conduct only during the 5th column shift cycle.

$M10_2$ (12SN7). Interpolating tube which blocks $M17_1$ in conjunction with $M10_1$ and $M17_2$ to permit $M17_1$ to conduct only during the 5th column shift cycle.

$M11_1$ (12SN7). Works with $M11_2$ and $M18_2$ to permit $M18_1$ to conduct only during 4th column shift cycles.

$M11_2$ (12SN7). Works with $M11_1$ and $M18_2$ to permit $M18_1$ to conduct only during the 4th column shift cycle.

$M12_1$ (12SN7). Works with $M12_2$ and $M19_2$ to permit conduction by $M19_1$ only during 3rd column shift cycle.

$M12_2$ (12SN7). Works with $M12_1$ and $M19_2$ to permit conduction by $M19_1$ only during 3rd column shift cycle.

$M13_1$ (12SN7). Works with $M13_2$ and $M20_2$ to permit conduction by $M20_1$ only during 2nd column shift cycle.

$M13_2$ (12SN7). Works with $M13_1$ and $M20_2$ to permit conduction by $M20_1$ only during 2nd column shift cycle.

$M14_1$ (12SN7). Works with $M14_2$ and $M21_2$ to permit conduction by $M21_1$ only during 1st column shift cycle.

$M14_2$ (12SN7). Works with $M14_1$ and $M21_2$ to permit conduction by $M21_1$ only during 1st column shift cycle.

M15. Not used; spare 12SN7.

$M16_1$ (12SN7). Conducts during 6th column shift cycle only, when all interpolating blocking tubes are non-conducting. Cuts off power tube M23 to provide high potential on 6th column shift at anode of M23.

$M16_2$ (12SN7). Works with $M9_1$ and $M9_2$ to permit $M16_1$ to conduct only during 6th column shift cycle.

$M17_1$ (12SN7). Conducts during 5th column shift cycle, when all blocking tubes are non-conducting, to cut off power tube M24.

$M17_2$ (12SN7). Works with $M10_1$ and $M10_2$ to permit $M17_1$ to conduct only during 5th column shift cycle.

$M18_1$ (12SN7). Conducts during 4th column shift cycle when all blocking tubes are non-conducting, to cut off M25.

$M18_2$ (12SN7). Works with M11 to permit $M18_1$ to conduct during the 4th column shift cycle.

$M19_1$ (12SN7). Conducts during the 3rd column shift cycle when all interpolating blocking tubes are non-conducting to cut off M26.

$M19_2$ (12SN7). Works with M12 to permit $M19_1$ to conduct during the 3rd column shift.

$M20_1$ (12SN7). Conducts during 2nd column shift cycle when all interpolating blocking tubes are non-conducting to cut off M27.

$M20_2$ (12SN7). Works with M13 to permit $M20_1$ to conduct during the 2nd column shift cycle.

$M21_1$ (12SN7). Conducts during 1st column shift cycle only when all blocking tubes are non-conducting to cut off power tube M28.

$M21_2$ (12SN7). Works with M14 to permit $M21_1$ to conduct only during the 1st column shift cycle.

M22. Not used; spare 12SN7 tube mounted in this position.

M23 (25L6). Power tube controlling 6th column shift; stops conducting when $M16_1$ conducts and thus conditions units position multiply input switch C3, column shift control switch M30, and half-entry control $A20_1$ for conduction during 6th column shift cycle. M23 also turns A31 OFF at end of 6th column shift cycle to stop computations.

M24 (25L6). Stops conducting when $M17_1$ conducts during 5th column shift cycle to condition multiply input switch C6 and column shift control switch M31.

M25 (25L6). Stops conducting when $M18_1$ conducts during 4th column shift cycle to condition multiply input switch C9 and column shift control switch M32.

M26 (25L6). Stops conducting when $M19_1$ conducts during 3rd column shift cycle to condition multiply input switch C12 and column shift control switch M33.

M27 (25L6). Stops conducting when $M20_1$ conducts during 2nd column shift cycle to condition multiply input switch C15 and column shift control switch M34.

M28 (25L6). Stops conducting when $M21_1$ conducts during the 1st column shift cycle to condition multiply input switch C18 and column shift control switch M35.

M29. Not used; spare 12SN7 mounted in this position.

M30 (6SK7). Switch controlling stream of 10 pulses to column shift switches for adding into product counter on 6th column shift cycle; suppressor is conditioned to conduct by M23 and grid receives ten B pulses.

M31 through M35 (6SK7). Same as M30 for 5th through 1st column shift cycles.

M36. Not used; spare 12SN7 tube mounted in this position.

M37 (25L6). Power tube supplying ten B pulses to column shift switches in O chassis during the 6th column shift cycle under control of switch M30.

M38 through M42 (25L6). Same as M37 for 5th through 1st column shift cycles.

N1 (6SK7). Half-entry input switch for first position of products counter; 5 pulses from A24 during first primary cycle of last column shift cycle are passed to units position of product counter provided the units position is wired for half-entry.

$N2_1$ (12SN7). Inverter controlling read-out pulses from B30 to units position of the product counter for rolling product counter when punching; positive pulses from B30 are inverted to negative pulses for operating the triggers in the counter.

$N2_2$, N5, N8, N11, N14, and N17 (12SN7). Same as $N2_1$ for 2nd through 12th positions of the product counter.

$N3_1$ (12SN7). Clipper for re-shaping the output from column shift switches in O chassis to 1st position of product counter. Because of the internal capacity of the parallel switches in the O chassis, the waveform leaving the O chassis is far from a square wave and the voltage amplitude of different positions varies; therefore the output from the O chassis must be re-shaped before entering the products counter.

$N3_2$ (12SN7). Inverter for clipper $N3_1$. Required because of phase reversal by clipper; the A pulses leaving the column shift switches are inverted to B pulses by the clipper, hence they must be inverted again to A pulses before entering the products counter.

N4, N7, N10, N13, and N16 (6SK7). Same as N1 for 2nd through 6th positions of product counter.

N6, N9, N12, N15, and N18. Same as $N3_1$ and $N3_2$ for 2nd through 6th positions of product counter.

O1 through O6 (6SK7). Column shift switches controlling exit from first position of multiplicand counter to 1st through 6th positions of product counter. Grids of these switches are all conditioned by multiplicand output trigger and follower $L4_1$; suppressors successively receive stream of ten B pulses in reverse order O6, O5, etc. from proper column shift control power tube in M chassis.

O7 (*12SN7*). Dummy tube for filling out filament string.

O8 through O13 (*6SK7*). Same as O1 through O6 for exit from 2nd position of multiplicand to 2nd through 7th positions of product.

O14 (*12SN7*). Same as N3; clipper and inverter for output to 7th position of products counter.

O15 through O20 (*6SK7*). Same as O1 through O6 for exit from 3rd position of multiplicand to 3rd through 8th positions of product.

O21 (*12SN7*). Clipper and inverter for output to 8th position of product counter.

O22 through O27 (*6 SK7*). Same as O1 through O6 for exit from 4th position of multiplicand to 4th through 9th positions of product.

O28 (*12SN7*). Clipper and inverter for output to 9th position of product.

O29 through O34 (*6SK7*). Same as O1 through O6 for exit from 5th position of multiplicand to 5th through 10th positions of product.

O35 (*12SN7*). Clipper and inverter for output to 10th position of product.

O36 through O41 (*6SK7*). Same as O1 through O6 for exit from 6th position of multiplicand to 6th through 11th positions of product.

O42 (*12SN7*). Clipper and inverter for output to 11th position of product.

P, R, S, T, U, V, chassis are the product counter chassis.

W1 (*12SN7*). Carry and read-out trigger which turns ON when 1st position of product counter carries. Controls read-out from 1st position of product counter and carry from 1st to 2nd position. When carrying, W1 turns OFF at *14* of each adding cycle by pulse from B8; when reading out, turned OFF by B28 at punch mid-index point following carry.

W2 (*6SK7*). Carry switch controlling carry from 1st to 2nd position of product counter; W1 trigger conditions grid and suppressor is raised above cutoff from *10.5* through *14* by B14 to permit carry.

W6, W11, W16, W21, and W26 (*12SN7*). Same as W1 for positions 2 through 6 of product counter.

W7, W12, W17, W22, and W27 (*6SK7*). Same as W2 for positions 2 through 6 of product counter.

W13. Test socket for carry and read-out triggers in W chassis.

All other tubes in W chassis not used; spare 6SK7 and 25L6 tubes are mounted in these positions.

X1, X6, X11, X16, X21, and X26 (*12SN7*). Same as W1 for positions 7 through 12 of product counter.

X2, X7, X12, X17, and X22 (*6SK7*). Same as W2 for positions 7 through 11 of product counter.

X3. Test socket for carry and read-out triggers in X chassis.

X27 (*6SK7*). Dummy tube to fill out filament string.

All other tubes in X chassis not used.

Y1. Not used.

Y2, Y3 (*25L6*). Power tubes in parallel used to energize punch magnet wired to 1st position of product counter under control of $Y4_1$.

$Y4_1$ (*12SN7*). Inverter controlling Y2 and Y3 power tubes; conducts normally and is cut off when carry and read-out trigger for units position of product counter goes ON. When $Y4_1$ stops conducting, the positive pulse at its anode is transmitted to the grids of Y2 and Y3 to allow conduction and thus energize the punch magnet.

$Y4_2$ (*12SN7*). Same as $Y4_1$ for 2nd position of product counter.

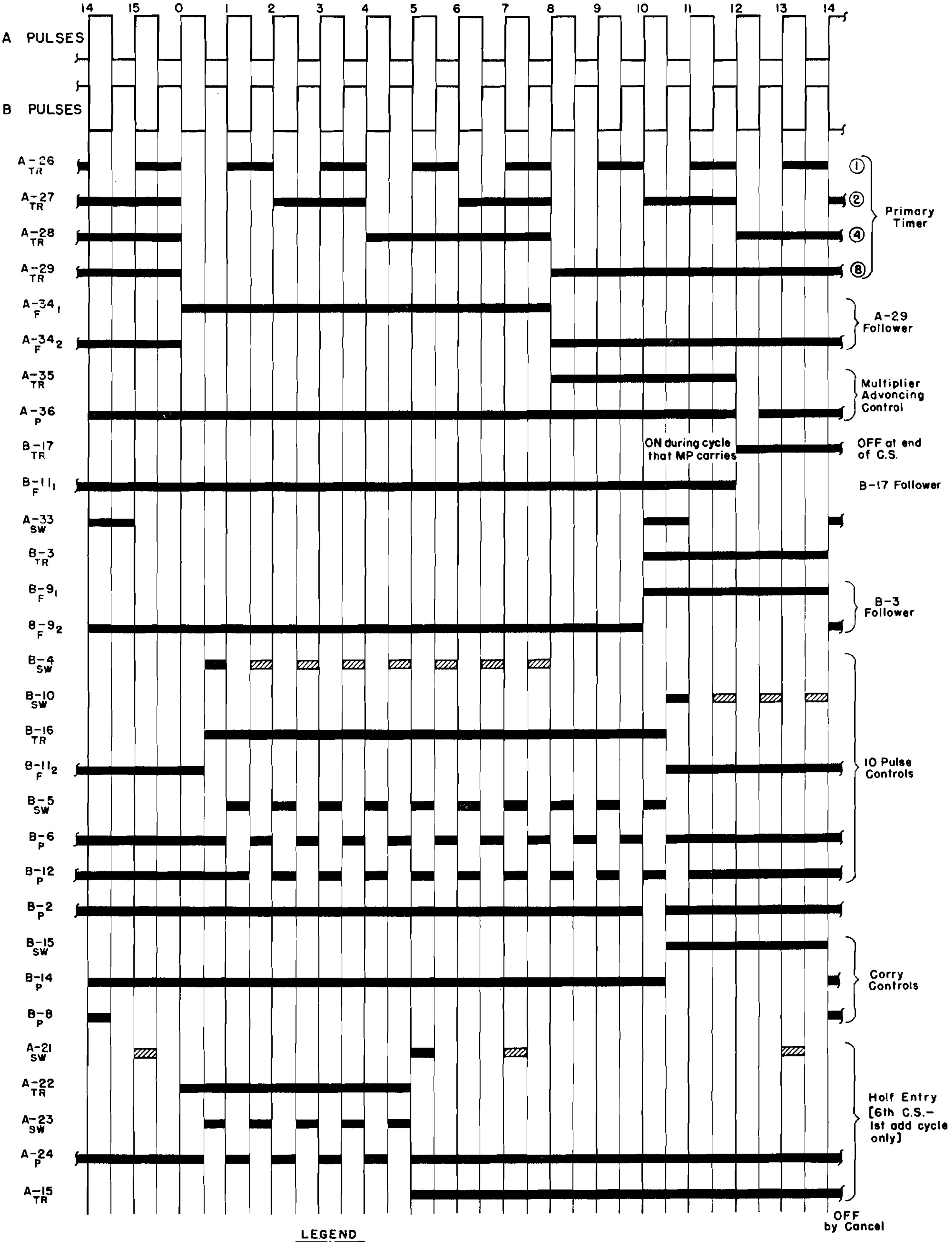
Y5, Y6, Y8, Y9, Y11, Y12, Y14, Y15, Y17, and Y18 (*25L6*). Same as Y2 and Y3 for 2nd through 6th positions of product counter.

Y7, Y16. Not used.

Y10, Y13 (*12SN7*). Same as $Y4_1$ for 3rd through 6th positions of product counter.

Z chassis is arranged just like the Y chassis and serves exactly the same purpose for product counter positions 7 through 12.

603 ELECTRONIC TIMING CHART



LEGEND
TR - Trigger
SW - Switch
F - Follower
P - Power Tube

Indicates tube is conducting (ON side in case of trigger)
Indicates pulses produced but not used