Punched Card Data Processing Principles

Section 5: The IBM Calculator

IBM Personal Study Program

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IBM Personal Study Program

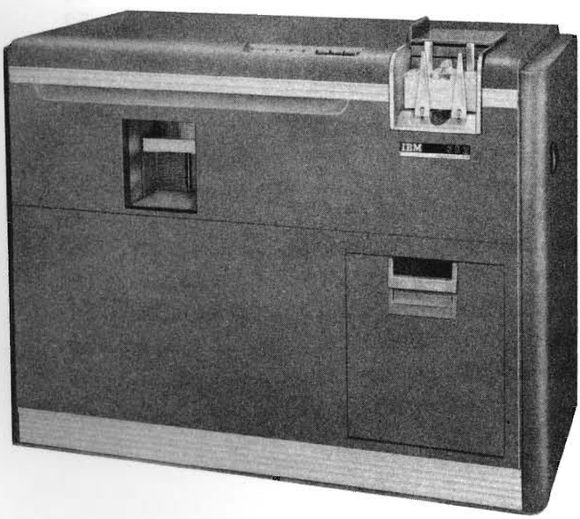
The IBM Personal Study Program offers the opportunity to develop an understanding of and an appreciation for the tools of data processing, their operation and application. In recent years, the use of automatic data processing equipment has been extended into almost every area of business, government and science. As a result, the need for people knowledgeable in the subject has multiplied manifold—and is continuing to multiply.

The purpose of the IBM Personal Study Program is to help satisfy this need by providing simplified self-study texts covering the fundamentals of data processing. With the background these texts provide, the interested student will be prepared to delve further into those areas of greatest interest to him and his career.

Section 5 describes the IBM 604 Electronic Calculating Punch and the IBM 602 Calculating Punch. The discussion of the 604 is presented first because of its simplified sequence of operations. Thus the 604 text should be regarded as a prerequisite to the discussion of the 602.

Contents

IBM 604 Electronic Calculating Punch



IBM 602 Calculating Punch

Section 5: The IBM Calculator

The IBM 604 Electronic Calculating Punch

Modern civilization, comprising finance, commerce, industry, science, government, business, would be impossible without calculations—simple calculations like adding, subtracting, multiplying and dividing.

One of the most often performed computations in the United States concerns the amount of money to which each employee is entitled. Calculating the weekly pay of a company employee and updating his earnings and tax records, at first glance, appears complex and difficult. Actually, the procedure comprises the four basic arithmetic operations. The complexity, then, involves the correct sequence of these operations. Suppose, for example, that an employee receives his pay on an hourly basis, that is, hours x rate. This multiplication is only the beginning of the weekly pay calculation and gives a product called gross pay.

> 1. *Multiply hours (38.65) times rate (2.625) to obtain gross pay. Round off to the nearest cent.**

The amount of take-home pay or "net pay" is usually less than gross pay. The conditions that make it less are the mandatory deductions such as Federal Income Tax (FIT) and Federal Insurance Contribution Act (FICA) tax for social security. In calculating the amount of these deductions one must consider the gross pay, the number of dependents that the employee claims, the total amount of FICA tax deducted to date for the current year, etc. Thus the amount of the deduction must be calculated also.

The updating of earnings in a payroll application involves the addition of the current gross pay to the gross pay earned in all the preceding weeks of the year. This accumulated amount is often referred to as the year-to-date gross or, simply, YTD gross. Also, the calculated deduction amounts are not only used in determining the current week's net pay, but must also be used to update the year-to-date Federal Income Tax (YTD FIT) and the YTD FICA.

*Review questions have been interspersed throughout the text. If, as in this case, the question is marked with an asterisk, the answer is supplied at the end of the book. If the question is not marked with an asterisk, the answer can be found in the text preceding the question. When the book is completed, answer all questions again—this time without using the book. Then compare your answers with those in the book.

Calculating the employee's net pay and updating his earnings and tax records, then, requires the following payroll information about the employee:

1. Hours worked
2. Rate of Pay
3. Tax Class (T/C—number of dependents claimed)
4. YTD Gross
5. YTD FICA
6. YTD FIT

In addition to these six factors, several others are required. These are appropriately listed in the following discussion.

The gross pay to be used in the example of this text has already been calculated—that is, 101.45625 rounded off to $101.46. This amount represents the basis for all the other payroll calculations.

Calculating the FIT

The amount that the employee has deducted weekly for federal income tax depends primarily on the number of exemptions. Each dependent allows $13.00 to be subtracted from gross pay before the tax deduction amount is calculated. Thus, if the employee has a wife and two children, he may legally claim four dependents, and

$$13.00 \times 4 = \$52.00$$

of his weekly pay is exempt from FIT calculations.

The difference between the calculated gross pay and the exempt amount:

$$101.46 - 52.00 = \$49.46$$

is the amount which is to be taxed. The actual tax is calculated by multiplying the difference by the tax rate which is 18% (or 0.18). The result of this calculation is

$$49.46 \times 0.18 = 8.9028 \text{ rounded off to } \$8.90$$

*2. Calculate the FIT for the two following cases:**

	(a)	*(b)*
HOURS	*40.00*	*36.25*
RATE	*1.40*	*2.25*
T/C	*5*	*5*

As the answer to the above question indicates, no FIT is to be deducted when the difference between the gross pay and the exempt amount is negative (that is, the exempt amount is greater than the gross pay).

Calculating the FICA

In the year 1961, each employee must contribute to FICA until the amount of the contribution is $144. When this amount has been deducted from his earnings, no further deductions are made. But until then, the employee has three percent of his gross pay deducted each week.

In the case of this example

$$101.46 \times 0.03 = 3.0438 \text{ rounded off to } \$3.04$$

is the calculated contribution amount. Before the $3.04 is subtracted from gross pay, however, it is advisable to check the previous YTD FICA.

In checking the YTD FICA of an employee, it is possible to arrive at one of three conclusions regarding the current calculated deduction:

1. That all of it should be taken.
2. That some of it should be taken.
3. That none of it should be taken.

Each of the conclusions can be arrived at arithmetically. Observe the results of three YTD FICA amounts, the addition of the current calculated amount to them, and the subsequent subtraction of the FICA limit of $144.

I	II	III
95.00	142.79	144.00
+ 3.04	+ 3.04	+ 3.04
98.04	145.83	147.04
− 144.00	− 144.00	− 144.00
− 45.96	+ 1.83	+ 3.04

An analysis of the three results reveals that one of the answers is negative, which indicates that *all* of the current calculated FICA amount should be deducted.

To resolve the problem of *some* or *none* requires a little more arithmetic. Taking the last result, subtracting the current calculated amount and observing the answer, provides the solution.

1.83	3.04
− 3.04	− 3.04
− 1.21	+ 0.00

This indicates that a negative amount means to deduct *some*. How much *some* is supposed to be, can be quickly ascertained by taking the value with the negative sign and making it a positive amount.

Calculating the Net Pay

To arrive at the net pay amount requires only a simple crossfooting operation (crossfooting is the addition or subtraction of several factors).

$$\text{Gross pay} - \text{FIT} - \text{FICA} = \text{Net Pay}$$
$$101.46 - 8.90 - 3.04 = 89.52$$

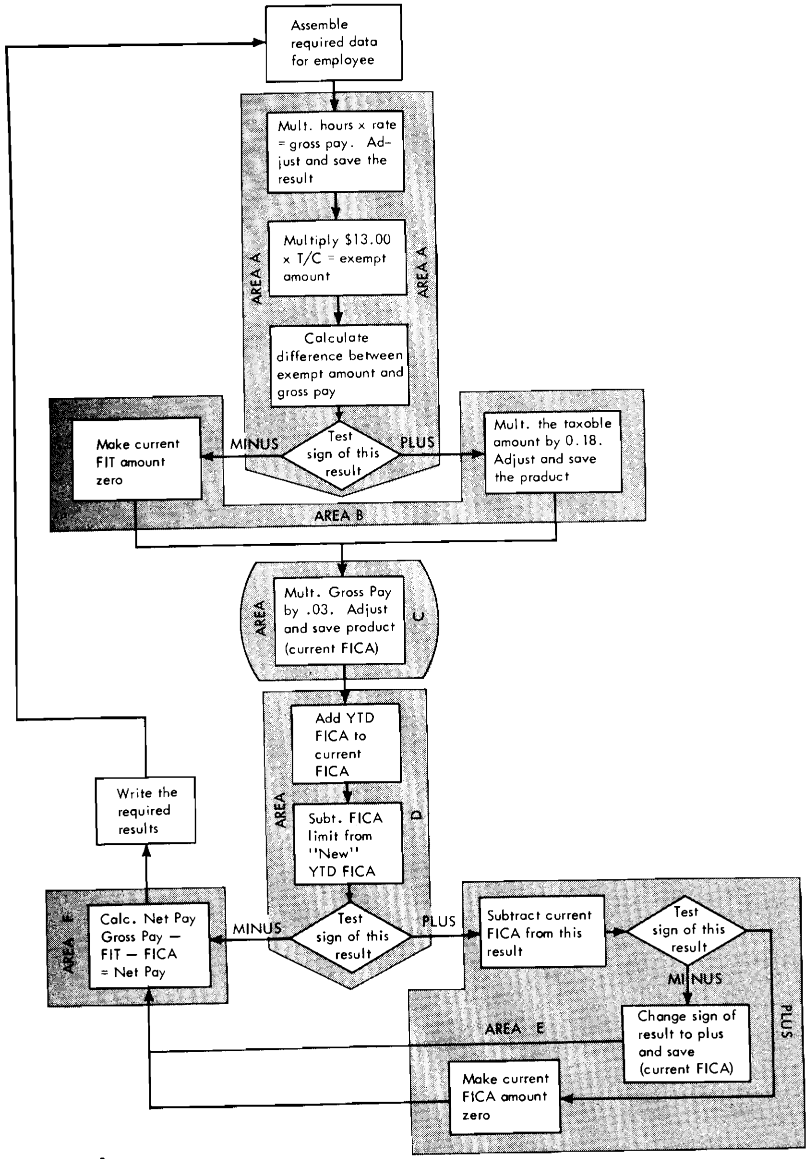

Assemble required data for employee
Mult. hours x rate = gross pay. Adjust and save the result
Multiply $13.00 x T/C = exempt amount
AREA A
AREA A
Calculate difference between exempt amount and gross pay
Test sign of this result
MINUS
PLUS
Make current FIT amount zero
Mult. the taxable amount by 0.18. Adjust and save the product
AREA B
AREA
C
Mult. Gross Pay by .03. Adjust and save product (current FICA)
Add YTD FICA to current FICA
AREA
D
Subt. FICA limit from "New" YTD FICA
Write the required results
Test sign of this result
MINUS
PLUS
AREA E
Calc. Net Pay Gross Pay — FIT — FICA = Net Pay
Subtract current FICA from this result
Test sign of this result
MINUS
PLUS
AREA E
Change sign of result to plus and save (current FICA)
Make current FICA amount zero

Figure 1.

3. *Calculate the net pay of the following employees and write the results in the appropriate columns.**

Employee Number	Hours	Rate	YTD FICA	T/C	Current FICA	Current FIT	Current GROSS	Current NET
00001	*40.00*	*2.550*	*108.90*	*2*				
00002	*40.00*	*2.625*	*143.17*	*4*				
00003	*40.00*	*2.850*	*144.00*	*3*				
00004	*40.00*	*2.500*	*144.00*	*8*				
00005	*40.00*	*2.050*	*79.50*	*0*				

The block diagram in Figure 1 illustrates a systematic procedure for calculating net pay from the necessary ingredients.

4. *Trace through the block diagram for each of the employees of the previous question. Whenever the instruction "save the results" appears,* check the calculation with the previously written results.

Figure 2 shows two cards that are used for each employee in the partial payroll procedure just described. From the personnel card comes the hourly rate and the tax class. Notice that no results of the calculation are punched into this card. From the year-to-date card comes the regular hours worked and the YTD FICA. Into this card are punched the results as described by the block diagram of Figure 1.

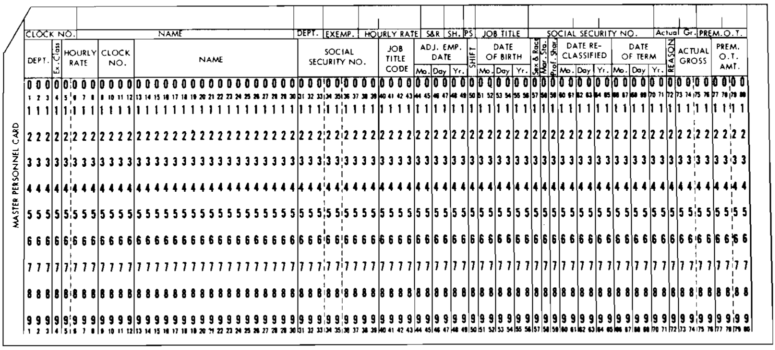
NOTE: The term net pay, as used in this text, means the difference between gross pay and the mandatory deductions of FICA and FIT. Many companies have set up a plan for voluntary deductions such as bonds, insurance premiums, community chest, etc. Voluntary deductions are not used in the calculations of this text.

The IBM 604 Electronic Calculating Punch reads information from IBM punched cards and performs the arithmetic operations of addition, subtraction, multiplication and division. The 604 can test the algebraic sign of a value and, as a result of the test, perform alternate calculations.

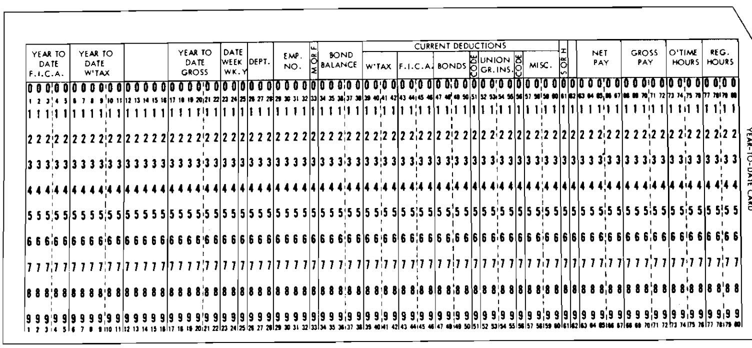
The results of the calculations can be punched into the same card from which the factors were read or into cards which follow it.

Card Path

The path of each card through the IBM 604 is illustrated in Figure 3. The three stations are synchronized—that is, when the brushes at the first reading station are reading the 9 row of a card, the punches are over the 9 row of the card at the punching station, and the brushes at the second reading station are reading the 9 row of the card there. Notice that there is no distinct "calculation station." Calculating starts



Personnel Card (X31)



Year-to-Date Card (NX31)

Figure 2.

after the 9 row is read and continues until just before the 11 row of the card is under the punches.

5. *What row is read by the second reading brushes when column 5 is being punched with a 3?*

Because the information read from the card by the reading brushes is to be used during calculation, the information must be directed into *storage units*.

Storage Units

In the 604 Electronic Calculating Punch, the storage units are used for three functions:

1. Accepting factors as they are read from the card.
2. Storing intermediate results during calculation.
3. Providing results to the punching mechanism.

Since the cards are read row by row (12 edge first), the storage units contain the factors in the cards only after all the rows have been read.

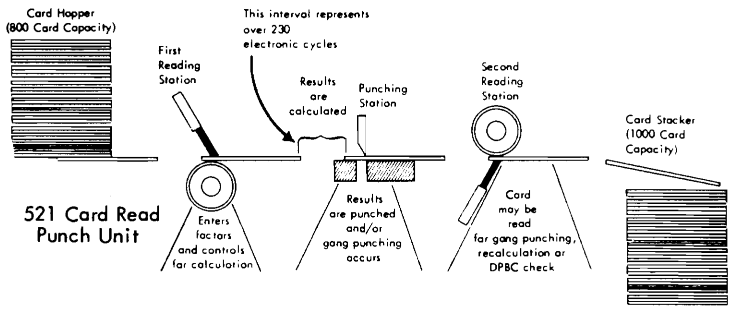


Figure 3. The IBM 604 Electronic Calculating Punch consists of the 604 Electronic Calculating Unit and the 100-card-per-minute IBM 521 Card Read Punch.

In order to allow information to enter into a storage unit, a control impulse is needed (see Figure 4).

6. *What three functions do the storage units perform?*
7. *What must the timing of the read-in impulse be? What two operations take place when a storage unit is impulsed to read in?*

Representing Numbers in Storage

The IBM 604 is called the "Electronic Calculating Punch" because its arithmetic and storage units are made up of electronic tubes. An electronic tube has two states—on and off. Obviously, one electronic tube cannot store much information. If one tube were to be used for a storage device, it could store either a 0 (off) or a 1 (on), as shown in Figure 5. By combining a certain number of tubes, however, and using the various on-off combinations, the digits 0-9 can be represented.

8. *What is the number of on-off combinations possible with two tubes? three? four?**

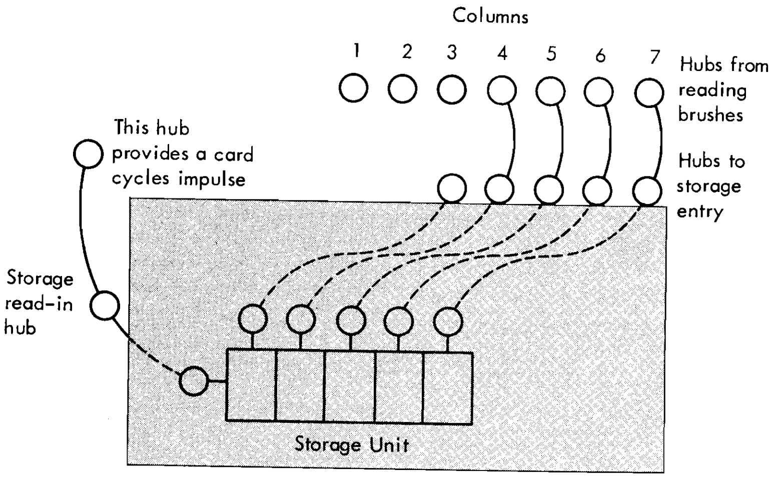


Figure 4. In order for a storage unit (1) to be cleared of its previous contents, and (2) to be receptive to information available at its entries during card reading, the storage unit must receive a control impulse at its read-in hub. The read-in hub can receive an impulse only at a certain time. This time occurs simultaneously with the reading of the 11 row of the card. An impulse called card cycles emits an impulse which starts just before the 11 row is read and lasts until after the 9 row is read. Because part of its total impulse occurs at the correct time, a card cycles impulse is frequently used to control a storage unit to read in.

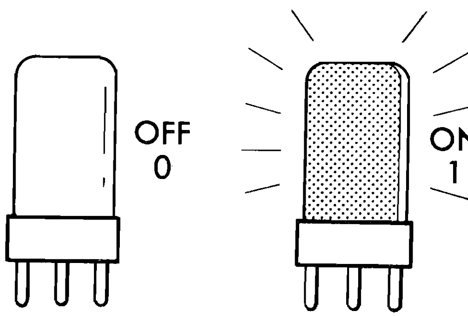


Figure 5.

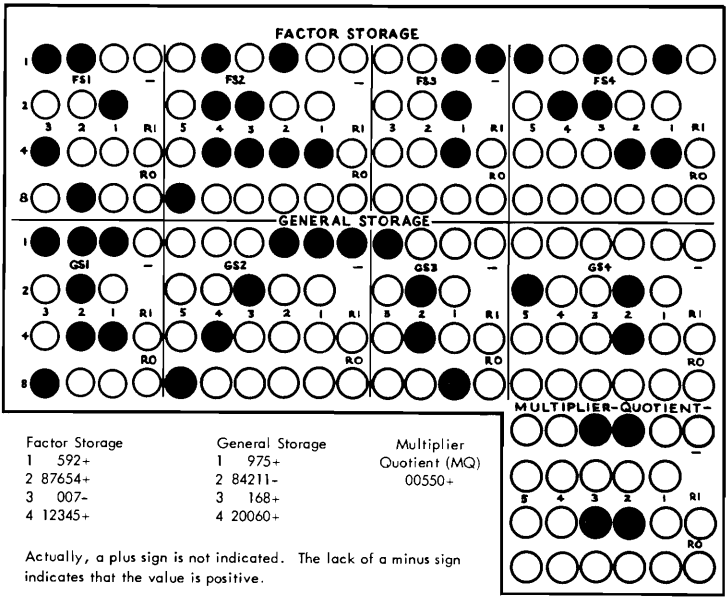


Figure 6.

In the IBM 604 the individual sets of four electronic tubes each are combined to make up the storage units. These units are referred to as the factor storage units (FS), of which there are 4; general storage units (GS), of which there are also 4; and multiplier-quotient (MQ), of which there is one. The factor storage units are referred to as FS1, FS2, FS3 and FS4; units 1 and 3 can store up to three digits each and units 2 and 4 up to five digits each. The general storage units are referred to as GS1, GS2, GS3 and GS4. The capacities of these are identical to those of factor storage. The multiplier-quotient unit is referred to as the MQ unit and has a capacity of five digits. Some of the storage units can be coupled together to provide a capacity up to eight digits. The technique for doing this will be explained later. Figure 6 represents values as they appear in the factor, general and MQ storage units.

Since the storage units have three different names, they apparently serve different functions. This is indeed the case. Although factor storage, general storage, and MQ storage all can accept information from a card as it is being read or during calculation, the punches can be actuated only from general storage, and only the MQ unit can be used for the multiplier or for developing the quotient.

> 9. *What is the maximum number of columns that can be stored from a card being read?**

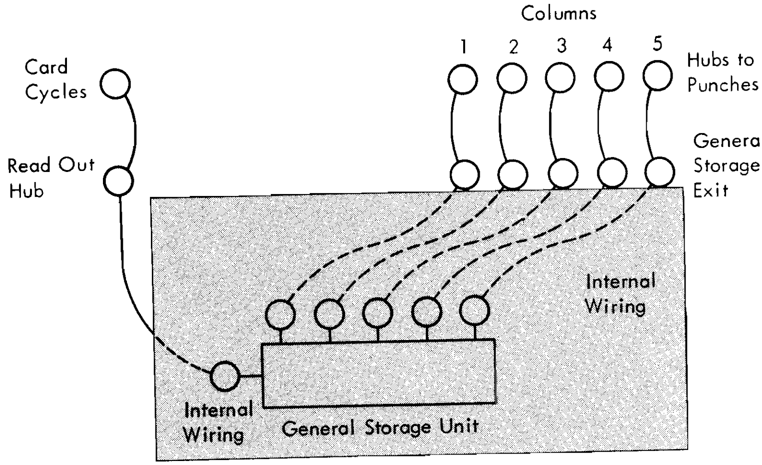


Figure 7. In order for general storage to make its contents available for punching, the general storage read-out hub must be impulsed. The actual contents are not read out, but rather an exact copy. No matter how many successive read-outs are executed, the original still remains in storage. Remember, only a read-in clears storage. On the 604, the general storage read-out hubs must be impulsed by a card cycles impulse only, for punching the contents of the storage unit.

Punching from Storage

One of the devices on the IBM 604 which can supply calculated data to the punches is general storage. In order to make the contents of general storage available to the punching mechanism, a *read-out* is required (Figure 7).

Calculating

Calculations in the 604 are made during the time interval between reading factors from the card and punching the results (Figure 3).

This time interval represents over 230 electronic cycles. One electronic cycle is the amount of time required to perform an addition or subtraction or to move data between storage units or from counter to storage. The number of electronic cycles required by multiplication and division depends on the digits involved.

A more convenient way of designating the amount of calculating ability is by indicating the number of *program steps.* All problems, simple or complex, can be reduced to a *series of simple arithmetic operations,* and it is this series of operations that is called the program. Each operation is called a program step (see Figure 8). On the IBM 604 it is possible to have 20, 40 or 60 program steps, depending upon the model selected. In this text, the 40-step model is used.

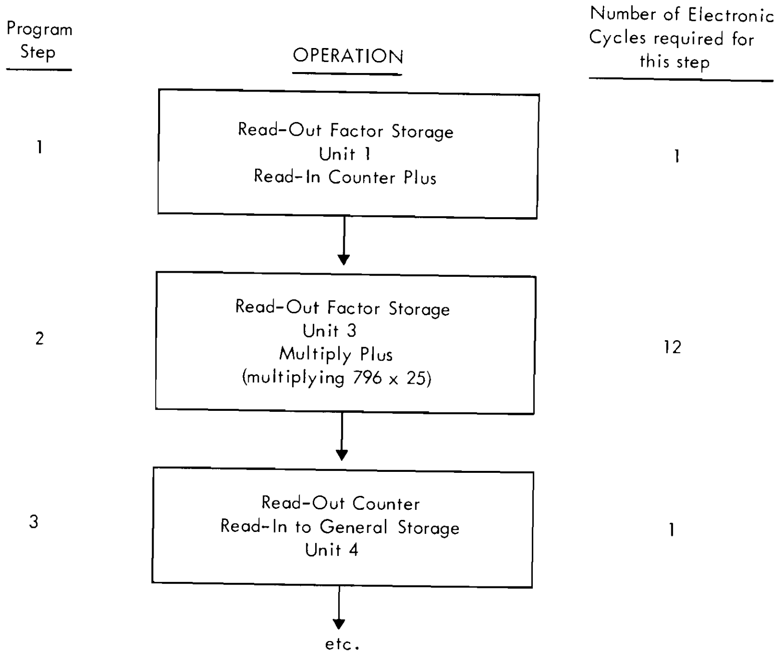


Figure 8. This figure illustrates that a program step may comprise one or many electronic cycles. If many large multiplications are executed, it is possible that the 604 may exceed the number of electronic cycles before all the program steps have been completed. The 604 has been designed so that if the electronic cycles have been exceeded, it can be detected for corrective action.

Immediately after a card has been read, the 604 begins calculating at program step 1. When the instruction at program step 1 is completed, the calculating unit automatically progresses to program step 2, and so on. As was previously mentioned, all program steps require only one electronic cycle (even if a program step is unused, one electronic cycle is taken) for all operations except multiplication and division. Again, for these two operations the number of electronic cycles taken depends on a certain characteristic of the multiplier or of the quotient. A method for determining the number of electronic cycles required for these operations will be discussed later.

On any program step only one arithmetic operation or other distinct operation involving the movement of data may be accomplished. That is, the operation may be addition *or* subtraction, *or* multiplication, *or* division, *or* transmission of data from one storage unit to another, *or* from the counter to a storage unit.

> *10. Is it possible to add and subtract on the same program step?*

The IBM 604 Counter

The counter of the 604 has 13 positions and is used in performing the four basic arithmetic operations. Factors *cannot* be read from the card into the counter, but results developed in the counter during calculation may be punched into the card. (Information enters the IBM 604 counter only during the calculating phase.)

A positive amount in the counter appears as a nines complement. A nines complement of any value is the result obtained when subtracting that value from all nines. For example, the value +369145 appears as:

$$\begin{array}{r} 9999999999999 \\ 0000000369145 \\ \hline 9999999630854 \end{array}$$

The use of complements for positive values facilitates the design of the counter.

A negative amount in the counter appears as a true (uncomplemented) figure with a minus sign. For example, the value −88527 appears as −0000000088527.

> 11. *What do the following values in the counter represent?**
>
> *a)* −0000376039821
> *b)* −9999632000357
> *c)* +9999632000357

When the contents of a counter, plus or minus, are read out, the true figure always emerges. For punching, if the value is negative, an X is automatically punched over the units position to identify its negativity.

The algebraic sign of the counter can be determined on any program step. With sign-determination ability it is possible to control the succeeding program steps.

12. *Can the counter receive information from a card as it is being read?*
13. *What type of storage unit may be used to deliver results to the punches?*
14. *Can the counter provide the punches with results?*

Channel for Transmitting Data

During the calculations, data is moved between storage and counter over a channel. The channel is an electronic "conveyor belt" with eight parallel slots (see Figure 9). For example, suppose that a value of 763 is read into FS1 from a card and that program step 1 is instructed to perform the following:

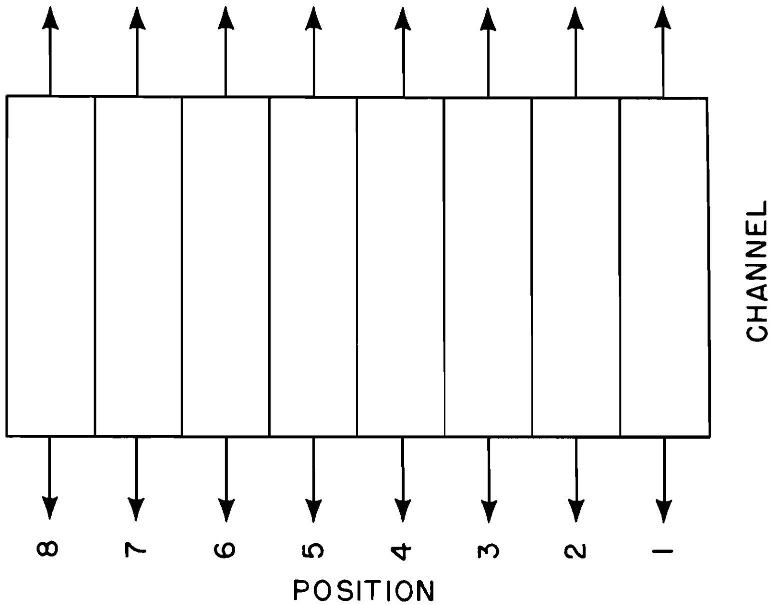


Figure 9.

1. Read out the contents of FS1.
2. Read into the counter, plus.

The contents of FS1 are placed on the common channel, position for position. That is, the units position of FS1 enters the units position of the channel, the tens position of FS1 enters the tens position of the channel, etc. Figure 10 shows the relationship of the FS1, the channel and the counter.

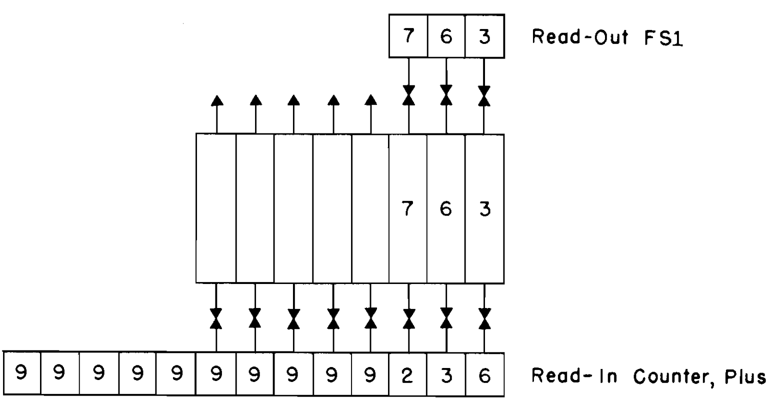


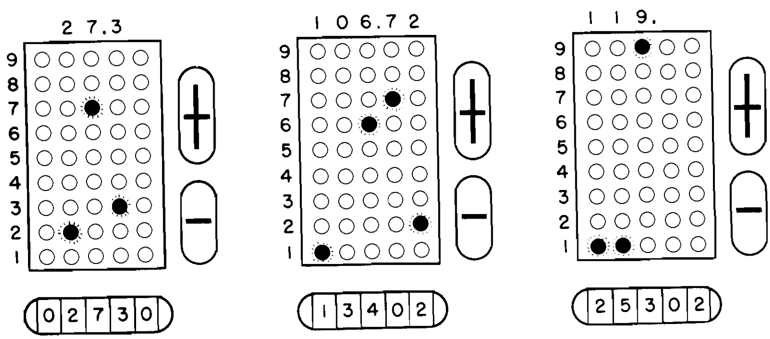
Figure 10.

Lining Up Decimals

A common requirement is an arithmetic operation involving factors with a differing number of decimal places. Suppose, for example, that it is required to add the following values: (a) 27.3, (b) 106.72, (c) 119. In this example the units position of the first number contains a 3, the units position of the second number a 6, and the third a 9. Also, the first number has one decimal place, the second number has two decimal places, and the third number has none. Figure 11 illustrates how an adding machine would be operated to combine these values.

To add these factors together in the IBM 604 counter requires the same kind of manipulation. This is accomplished by shifting the connectors of the channel to the appropriate position of the counter. Figure 12 illustrates the relationship of storage, channel and counter in performing the addition of the three numbers. (Although positive amounts enter the counter in complement form, the values are shown uncomplemented.)

> 15. *Suppose that the value 34.76328 were in the counter. Draw a counter-channel-storage schematic to show how 34.7 would be read out of the counter and into GS3.**



Here, the units position of the first value is entered into the tens or 2nd position.

Here, the units position of the second value is entered into the units or 1st position — the usual or normal operation.

Here, the units position of the 3rd value is entered into the hundreds or 3rd position.

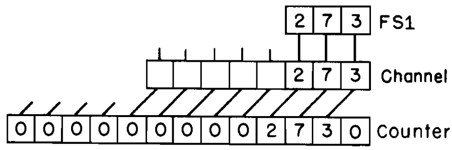
Figure 11.

If the three values used in the adding-machine illustration (27.3, 106.72, and 119.) were in FS1, FS2, and FS3 respectively, they would be entered into the 604 counter as per the following:

PROGRAM STEP

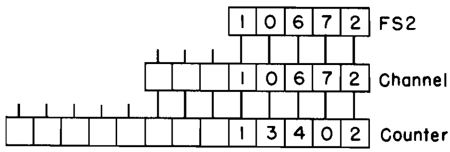
Read Out FS1
Read In Counter +
Read Units Into 2nd Position

(Note that the connectors of the channel shift one position)



Read Out FS2
Read In Counter +

(Since no shift was required, the channel-counter read-in relationship remains normal.)



Read Out FS3
Read In Counter +
Read Units Into 3rd Position

(Note that the connectors of the channel shift two positions.)

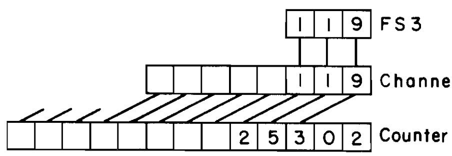


Figure 12.

Multiplication

One of the factors in any multiplication operation is the multiplier. This factor must be in the MQ storage unit before the IBM 604 is instructed to multiply.

Multiplication on the IBM 604 is done automatically by a method called repetitive addition and involves a simple concept. Figure 13 illustrates the repetitive addition concept as applied to multiplication on the IBM 604.

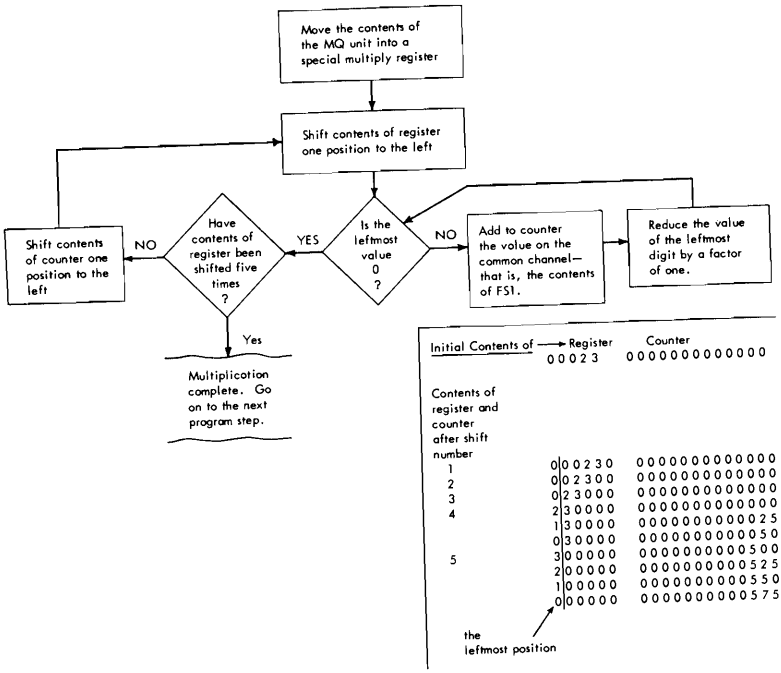
Division

The 604, when instructed to divide, produces a quotient of five digits. The dividend is entered into the counter. The divisor may be in any storage unit except the MQ unit where the quotient is developed. Thus when the 604 is instructed to divide, the storage unit containing the divisor is read out and the quotient is developed in the MQ unit by a method of repetitive subtraction.

Adjusting a Product

Many multiplications involve factors with several decimal places each. The number of decimal places in a product is the sum of the decimals of the multiplier and the multiplicand. For example, in multiplying

Assume the contents of the MQ unit to be 00023, and that this is multiplied by the contents of FS1, which is 025. The product 0000000000575* is developed in the counter according to the block diagram:



Initial Contents of →	Register	Counter
	00023	0000000000000
Contents of register and counter after shift number		
1	0 00230	0000000000000
2	0 02300	0000000000000
3	0 23000	0000000000000
4	2 30000	0000000000000
	1 30000	0000000000025
	0 30000	0000000000050
5	3 00000	0000000000500
	2 00000	0000000000525
	1 00000	0000000000550
	0 00000	0000000000575

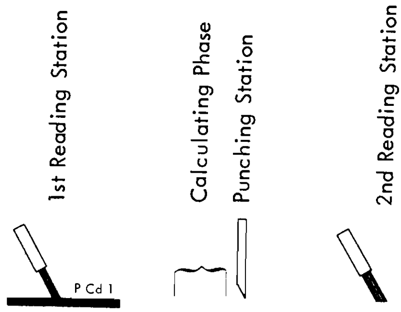
Figure 13.

hours x rate (38.65 x 2.625) the product has five decimal places (101.45625). The gross pay to be used in further calculations is $101.46, which represents the *adjusted* product. Manual adjusting is done by observing the position just to the right of the *eventual* units (the penny) position. If the observed position is a 5 or greater, a 1 is added to the eventual units position. If the observed digit is a 4 or less, nothing is added. Then the unwanted decimals are "dropped." This process is called "rounding off."

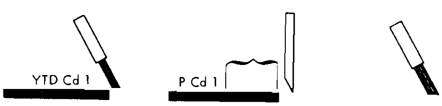
Rounding off or adjusting in a calculator is accomplished by adding a 5 to the observed position (which is to say, a ½ to the eventual units position). Of course if the value at this observed position is a 5 or greater, the addition of the adjusting 5 causes a carry of 1. Likewise, if the value to which the adjusting 5 is added is 4 or less, no carry is generated. In the 604, adjusting is accomplished by a technique called "half adjust."

Setting Up the 604 for Calculating Net Pay

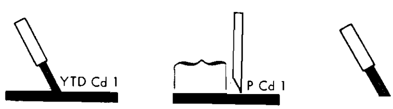
Calculating the net pay for each employee is based on the information in two cards. The order in which the cards enter the 604 is (1) personnel card, and (2) year-to-date card. The manner in which each group of two cards passes through the 604 is described as follows:

1) 

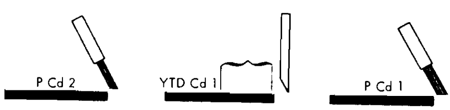
The personnel card of the first employee (P Cd 1) is being read.

2) 

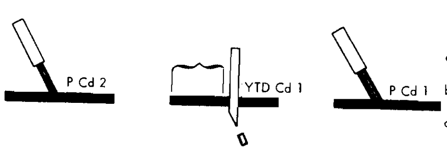
a) P Cd 1 is going through the calculating phase. Each step of the 604 program is taken.
b) The year-to-date card of employee 1 (YTD Cd 1) is about to be read.

3) 

a) P Cd 1 is going under the punches. The punches must be inactive. Otherwise, needless holes will be punched, thus rendering the personnel card useless for future processing.
b) YTD Cd 1 is being read.

4) 

a) P Cd 1 has passed the punches.
b) YTD Cd 1 is going through the calculating phase.
c) P Cd 2 is about to be read.

5) 

a) P Cd 1 is being read at the second reading station.
b) YTD Cd 1 is being punched with the calculated results.
c) P Cd 2 is being read at the first reading station.

The description of events of each two-card group shows that the personnel card goes through the calculating phase. (Using an auxiliary information card—as in this case of the personnel card—is not unusual. In a majority of such cases, the execution of the 604 program on the auxiliary information card has no effect in arriving at the correct results and all the program steps are left active. However, if the nature of the program is such that the execution of any given program steps during the calculating phase of the auxiliary card has an undesirable effect in obtaining the results, the program steps in question can be inactivated. The sample payroll problem to be discussed here has three such steps that must be suppressed.)

Reading the factors, calculating the required results, and then punching these results on the 604 requires:

1. Entering the factors for calculation into the storage units during card reading.
2. Calculating the results (using the plan shown in Figure 1 as a guide).
3. Punching the results into the YTD card.

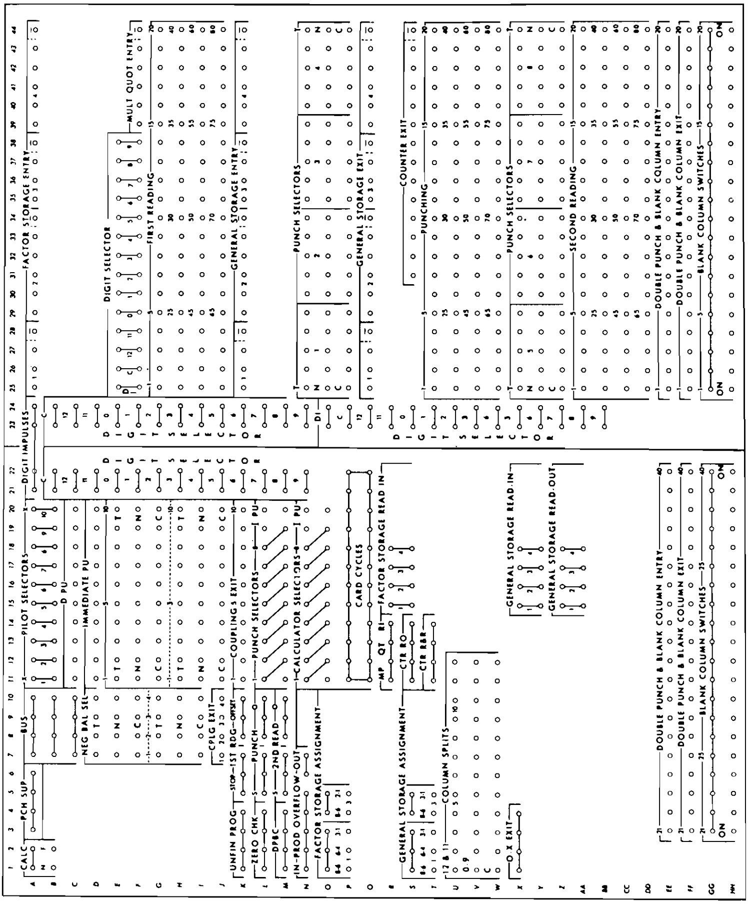
Two topics, "The Control Panel" and "The Planning Chart," are briefly presented now in preparation for the discussion on setting up the 604 to calculate the payroll problem.

The Control Panel

There are two control panels for the 604. One is referred to as the *punch control panel* and is located in the 521 Punching Unit. Its primary function lies in the reading and punching of data. The other control panel is called the *calculator control panel* and is located in the 604 Electronic Calculating Unit. Its function is to supply the calculating unit with instructions (see Figure 14).

The punching unit has a double panel and the calculating unit a single panel. Letters down the side and numbers across the top of each panel facilitate reference to specific hubs which in the text will be preceded by *Cal* for the calculator control panel or *Pch* for the punch control panel.

> *16. What is the primary function of the punch control panel? The calculator control panel?*



521 Card Read Punch Control Panel

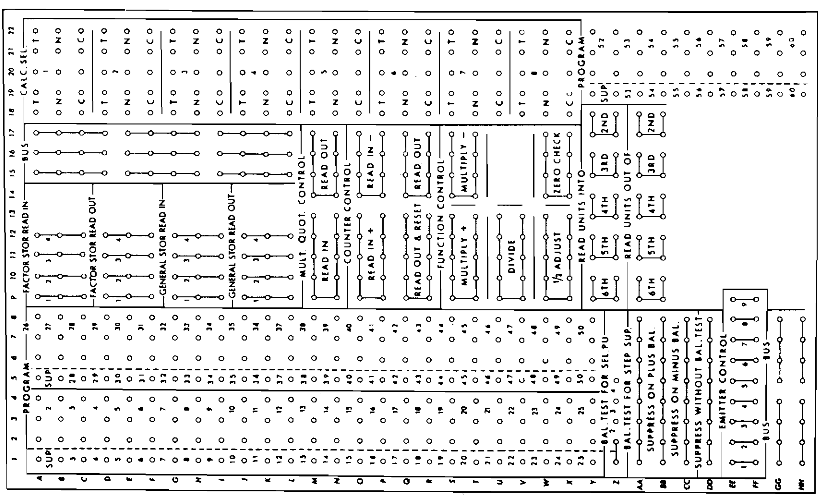


Figure 14. 604 Calculator Control Panel

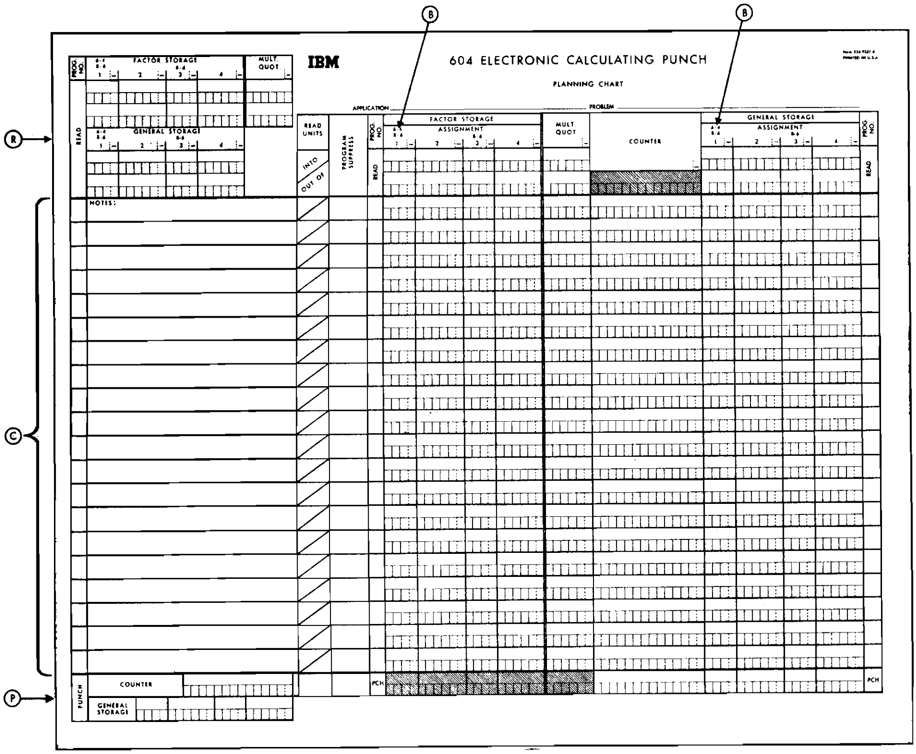


Figure 15.

The Planning Chart

The planning chart (see Figure 15) has been designed to assist the 604 programmer in analyzing and setting up the problem. It is used to indicate exactly what happens to data:

1. From the time it is entered into storage during reading Ⓡ
2. Through the time it spends in calculation Ⓒ
3. Until the time it is punched Ⓟ

The part of the planning chart that will be discussed later is at B, that is, the small numbers 6-4 and 8-6.

Planning Chart Layout

The part of the planning chart which is described in this section concerns the headings PROG. NO., OPERATION NOTES, READ UNITS INTO/OUT OF, PROGRAM SUPPRESS, FACTOR STORAGE, MULT. QUOT., COUNTER, and GENERAL STORAGE.

PROG. NO. refers to the step the 604 is taking. The R stands for the reading step. Following R are blank spaces, in each of which is to be written the program step number. The P at the bottom of the chart stands for the punching step.

NOTE: *It should be unfailingly remembered that although the planning chart is for indicating what happens to a single card, punching and reading take place simultaneously for two different cards (see Figure 3).*

In OPERATION NOTES will be written precisely what happens on the step. What happens during the reading and punching steps is straightforward. The operation notes for the calculating steps indicate, among other things, where the information is coming from, where it is going and what arithmetic operation is to be performed.

In READ UNITS INTO/OUT OF is written the single digit number to indicate the relationship required between the unit being read out of and the channel or the unit being read into and the channel.

Since every program step is taken, PROGRAM SUPPRESS provides a means to inactivate a step when certain conditions occur. A step is usually suppressed when the counter was, according to the requirements of the program, plus or minus on some previous step. For example, if step 15 is to be suppressed when the counter sign is negative on step 12, a −12 may be written in the program suppress box of step 15. Also, certain steps must be suppressed during the calculating phase of a particular card (usually identified by an X punch) so that the correct calculations will be performed.

With the writing of each proposed step on the planning chart, information that is entered into, or extracted from, FACTOR STORAGE, MULT. QUOT., COUNTER, and GENERAL STORAGE should be exactly noted in the appropriate boxes.

Note that on the horizontal line for the read step, the counter spaces are darkened to indicate that information cannot be entered into the counter on the read step. Likewise, on the horizontal line for the punch step, the factor storage and multiplier-quotient spaces are darkened to indicate that information cannot be punched from these units.

Although positive values in the 604 counters are a nines complement, true figures are usually shown on the planning chart. The algebraic sign can be noted in the box following the dotted line just to the right of the units position.

Writing the 604 Program

The program presented here for calculating gross pay, FIT, FICA, and net pay has 29 program steps and exemplifies the calculating ability of a 604 with 40 program steps. The program, in its entirety, is presented first (see Figure 16). The values used in the program plan are the same as those used earlier in the text.

It is recommended that you study the program plan with only moderate diligence before consulting the succeeding explanations. The explanation of the program plan is divided into parts which correspond to the areas of Figure 1.

Entering Factors into Storage during Card Reading

The units used for storing the required data are shown in Figure 17.

From the X31 card hourly rate is entered into the MQ unit and tax class is entered into FS1.

From the NX31 card regular hours are entered into FS2 and YTD FICA is entered into FS4. Note that columns 4 and 5 of each of the two cards provide some of the required data.

Emitting on the 604 is similar to emitting on the IBM 514. (Emitting is used whenever constant data is required.) A 13 is emitted into FS3 and a .18 is emitted into GS1. Observe that the contents of FS3 are 13, and not 13.00. During the calculating phase, the contents of FS3 (13) are transferred to the MQ unit as 13.00.

Planning for the Calculation of Gross Pay and Taxable Gross

Figure 18 is the part of the planning chart which corresponds to Area A of Figure 1.

Step 1. The contents of FS2 (hours) are multiplied by the contents of the MQ unit (rate). The product (gross pay) is developed in the counter by the repetitive addition method.

Step 2. A 5 is entered into the third position of the counter for adjusting the product.

Step 3. The adjusted product is read out of the counter (which is reset). The last three positions are dropped by regarding the units digit as being in the 4th position of the counter. The product is now stored in GS4, a storage unit which may be used for punching.

Step 4. The exempt amount per employee is read out of FS3 (13) and entered into the MQ unit as 1300. Step 4 must be suppressed during the calculating phase of an X31 personnel card.

Step 5. The number of dependents or tax class in FS1 is multiplied by the contents of the MQ to develop a *negative* product.

Step 6. The gross pay in GS4 is added to the contents of the counter. Because the nontaxable amount is negative, the addition of gross pay to it results in a difference which is the taxable amount. Testing the algebraic sign (balance test) is done at the end of the step (after the result has been developed). What is done with the result of the test is shown later.

> 17. *Why is it necessary to suppress (inactivate) step 4 when a personnel card is going through the calculating phase?**

PROG. NO.	OPERATION NOTES	READ UNITS (INTO / OUT OF)	PROGRAM SUPPRESS	FACTOR STORAGE 1: T/C	FACTOR STORAGE 2: HRS	FACTOR STORAGE 3: EX. AMT.	FACTOR STORAGE 4: YTD FICA	MULT QUOT: RATE	COUNTER	GENERAL STORAGE 1: FIT %	GENERAL STORAGE 2	GENERAL STORAGE 3	GENERAL STORAGE 4
R	READ: X-31: RATE-MQ, T/C-FS1; NX31: RG. HRS-FS2, YTD. FICA-FS4; EMIT: 13-FS3, 18-GS1			4	3865	13	9500	2625		18			
1	ROFS2, MULT +				RO				MULT + 10145625				
2	1/2 ADJUST	3 /							5 10146125				
3	ROR, RIGS4	/ 4							RO R				RI 10146
4	ROFS3, RIMQ	3 /	X31 CD			RO		RI 1300					
5	ROFS1, MULT −			RO					MULT − 5200−				
6	ROGS4, RICTR +, BAL. TEST								+ 10146 4946+				RO
7	ROR, RIMQ		X31 CD					RI 4946	ROR				
8	ROGS1, MULT +								MULT + 89028	RO			
9	1/2 ADJUST	2 /							5 89078				
10	ROR, RIGS2	/ 3							ROR		RI 890		
11	RIGS2		+6										
12	EMIT 3, RIMQ		X31 CD					RI 3					
13	ROGS4, MULT +								MULT + 30438				RO
14	1/2 ADJUST	2 /							5 30488				
15	RORCTR, RIGS3	/ 3							ROR			RI 304	
16	ROFS4, RICTR +						RO		+ 9500				
17	ROGS3, RICTR +								304 9804			RO	
18	EMIT 1, RICTR −	5 /							10000− 196−				
19	EMIT 4, RICTR −	4 /							4000− 4196−				
20	EMIT 4, RICTR −, BAL. TEST	3 /							400− 4596−				
21	ROGS3, RICTR −, BAL. TEST		−20										
22	RORCTR, RIGS3		−20										
23	ROGS3, RICTR		−20										
24	RORCTR, RIGS3		−20										
25	RIGS3		−20 −21										
26	ROR								ROR				
27	ROGS4, RICTR +								+ 10146				RO
28	ROGS2, RICTR −								− 890 9256		RO		
29	ROGS3, RICTR −								304 8952			RO	
P	PUNCH								8952 (NET PAY)		890 (FIT)	304 (FICA)	10146 (GROSS PAY)

Figure 16.

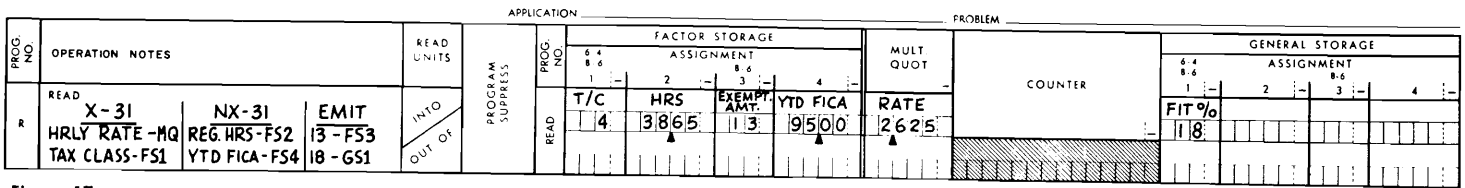


Figure 17.

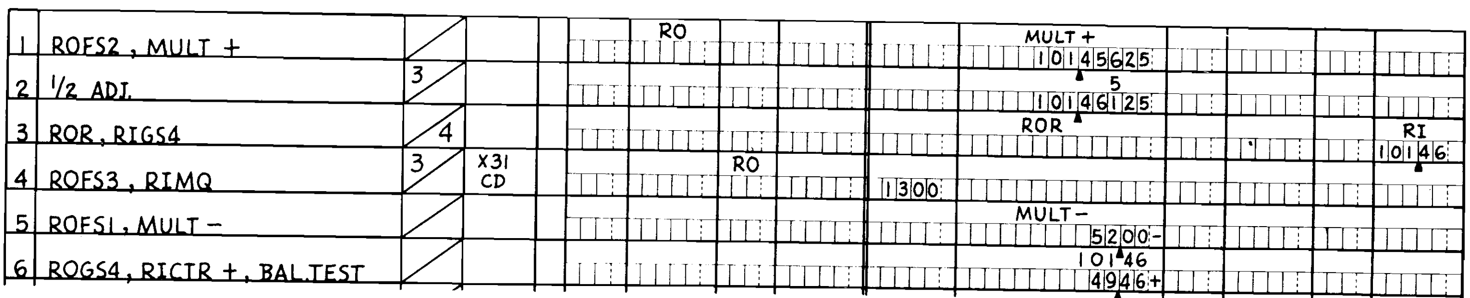


Figure 18.

Planning for the Calculation of FIT

As has been previously mentioned, the 604 takes each program step in succession. Thus the 604 program steps that correspond to Area B of Figure 1 are successive. The 604 is able to simulate the plus/minus branch by a method called step suppression. For example, if the algebraic value in the counter is positive (as it is in this case of program step 6) the program step (step 11) for storing zeros for FIT must be suppressed. Figure 19 is the part of the planning chart which corresponds to Area B of Figure 1.

Step 7. The counter is read out (taxable amount) and reset. The taxable amount is read into the MQ unit for multiplication. This step is suppressed during the calculating phase of a personnel card for the same reason that step 4 is suppressed.

Step 8. The FIT is developed as a positive product in the counter by multiplying the tax per cent (18) in GS1 by the contents of the MQ unit (taxable amount).

Step 9. The second position of the counter is adjusted by adding a 5.

Step 10. The counter is read out (FIT) and reset; two positions are dropped by reading out of the 3rd position. The result is read into GS2.

Step 11. This step must be suppressed when step 6 is plus. When step 6 is negative, however, step 11 is used to read in GS2. This resets GS2 to zero and, because nothing was read out onto the channel, GS2 is reset to zero.

> 18. *Why is it* not *necessary to suppress steps 7-10 when step 6 is minus?**

Planning the Calculation for Current FICA

It was previously mentioned that in checking the YTD FICA of an employee, it is possible to arrive at one of three conclusions regarding the current calculated deduction. In any event, the current FICA must be calculated before the conclusion can be arrived at. In Figure 20 steps 12-15 show how the 604 executes the calculations corresponding to Area C of Figure 1.

Step 12. As can be seen from Figure 16, a 3 for FICA percent was not emitted during card reading. The 604 is able to emit during calculation, one digit per step, into any storage unit or counter. In this case it is emitted into the MQ unit. This step is suppressed on an X31 card.

Step 13. The gross pay calculated as a result of step 1, stored in GS4, is multiplied by the contents of the MQ unit (3%) to produce the current FICA amount.

Step 14. The second position of the counter is adjusted by adding a 5.

Step 15. The adjusted product is read out of the counter and stored in GS3. The counter is reset.

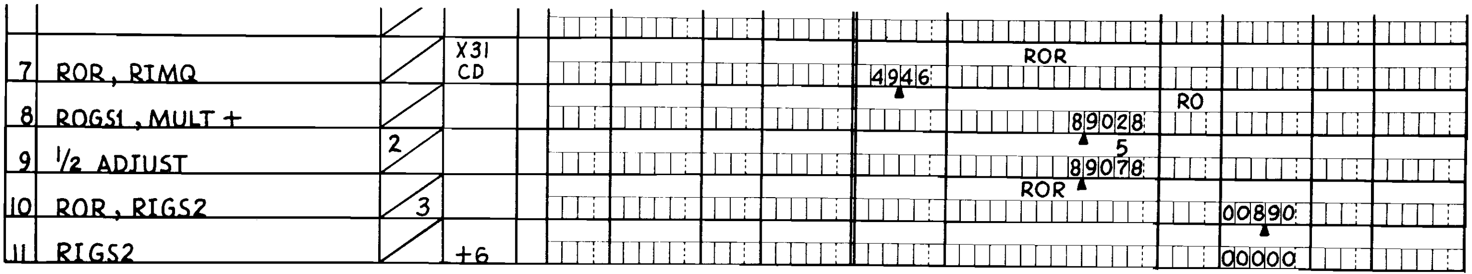


Figure 19.

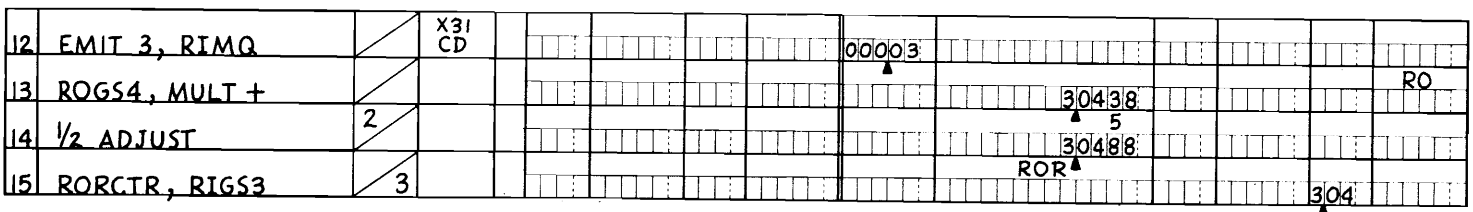


Figure 20.

Planning the First FICA Test

The next five steps (16-20) shown in Figure 21 are devoted to setting up a test, the results of which determine whether all of the calculated FICA is to be deducted from gross pay (in Figure 1, this is Area D):

Step 16. The contents of FS4 (YTD FICA) are entered into the counter as a positive amount.

Step 17. The current calculated FICA amount (stored in GS3) is added to the YTD FICA already in the counter.

Step 18. The FICA limit of 144.00 dollars, to be subtracted from the amount in the counter, must be emitted. Since only one digit can be emitted at a time *during calculation*, three steps are required to subtract the limit. On this step, a 1 is subtracted from the fifth position of the counter (that is, the amount subtracted is 100.00).

Step 19. A 4 is subtracted from the fourth position of the counter (that is, the amount subtracted is 40.00, making the total subtracted thus far 140.00).

Step 20. A 4 is subtracted from the third position of the counter (that is, the amount subtracted is 4.00, making the total subtracted so far 144.00). The Bal Test (balance test) is executed at the conclusion of the step. What is done with the result of the test is shown later.

> 19. *What is the difference between emitting during card reading and emitting during calculations?**

Planning the Second FICA Test

Steps 21-25 (Figure 22) of the 604 program correspond to Area E of Figure 1. Area E concerns the FICA calculations when either *some* or *none* of the previously calculated current FICA amount is to be taken. Notice that steps 21-25 are suppressed when step 20 is negative. If they were not suppressed, an incorrect amount would be stored into GS3.

Step 21. This step is executed if step 20 is positive. The current FICA amount, previously stored in GS3, is subtracted from the previous results in the counter. A balance test is made, the result of which is to be used to control the following four steps.

Step 22. If step 21 is negative, then *some* of the calculated FICA amount is to be used. The *some* is already in the counter, however, with the wrong sign. This step is the first of three to change the sign. The contents of the counter are read out (1.21−) and reset, and GS3 is read into.

Step 23. By *subtracting* a negative quantity (1.21− in GS3) from zero (the contents of the counter), the sign is reversed. Thus, at the end of this step, the contents of the counter are 1.21+.

Step 24. The contents of the counter are read out (1.21+) and reset, and GS3 is read into.

Step 25. If step 21 is positive, then *none* of the calculated FICA

(A) ALL

16	ROFS4, RICTR +		9500	RO
17	ROGS3, RICTR +		304 9804	RO
18	EMIT 1, RICTR −	5	196−	
19	EMIT 4, RICTR −	4	4196−	
20	EMIT 4, RICTR −, BAL. TEST	3	4596−	

(B) SOME

16	ROFS4, RICTR +		14279+	RO
17	ROGS3, RICTR +		304 14583+	RO
18	EMIT 1, RICTR −	5	4583+	
19	EMIT 4, RICTR −	4	583+	
20	EMIT 4, RICTR −, BAL. TEST	3	183+	

(C) NONE

16	ROFS4, RICTR +		14400+	RO
17	ROGS3, RICTR +		304 14704+	RO
18	EMIT 1, RICTR −	5	4704+	
19	EMIT 4, RICTR −	4	704+	
20	EMIT 4, RICTR −, BAL. TEST	3	304+	

Figure 21.

amount is to be used. By impulsing GS3 to read in only, it is cleared to zero. This step must be suppressed when step 21 is minus.

Planning the Final Net Pay Calculation

Steps 26-29, shown in Figure 23, are for calculating the net pay and represent merely a simple crossfooting operation.

Step 26. The counter is read out and reset. (Its contents are entered on the channel but go nowhere.)

Step 27. Gross pay, stored in GS4, is entered into the counter.

Step 28. The calculated FIT amount, stored in GS2, is subtracted from the counter.

Step 29. The calculated FICA amount, stored in GS3, is subtracted from the contents of the counter. The value in the counter is net pay.

Steps 30-40 are taken, whereupon the results are ready for punching—that is, gross pay, FIT, FICA and net pay.

Planning the Punching

The units used for punching the calculated data into the YTD card are shown in Figure 24:

From GS4 (gross pay) to columns 68-72.
From GS3 (FICA) to columns 44-46.
From GS2 (FIT) to columns 39-42.
From counter (net pay) to columns 63-67.

Wiring the Punch Control Panel for Entering the Factors

To enter the factors for the calculation requires that the storage units receive the information from the first reading brushes and the emitter by the proper control panel wiring. In addition, the storage unit must be impulsed to read in.

To enhance your understanding of the required wiring, diagram one of the 521 punch control panel diagrams provided in the supplies packet as follows (if possible, use a red pencil):

1. From first reading 1-3 to the three leftmost positions of FS4 entry.
2. From first reading 4 to the units position of FS1 entry *and* to the tens position of FS4 entry.
3. From first reading 5 to the units position of FS4 entry *and* to the thousands position of the MQ unit entry.
4. From first reading 6-8 to the hundreds, tens and units positions, respectively, of the MQ unit entry.
5. From first reading 77-80 to the appropriate positions of FS2 entry.

The diagramming of the above five steps represents the required wiring for connecting the card columns and the storage units. Before pro-

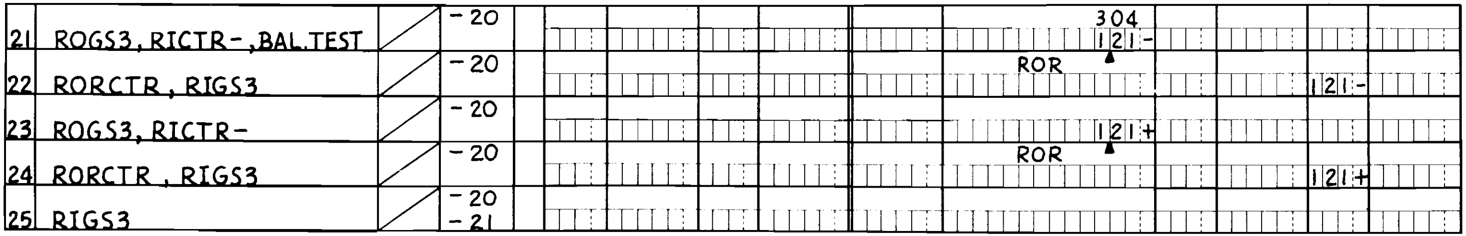


Figure 22.

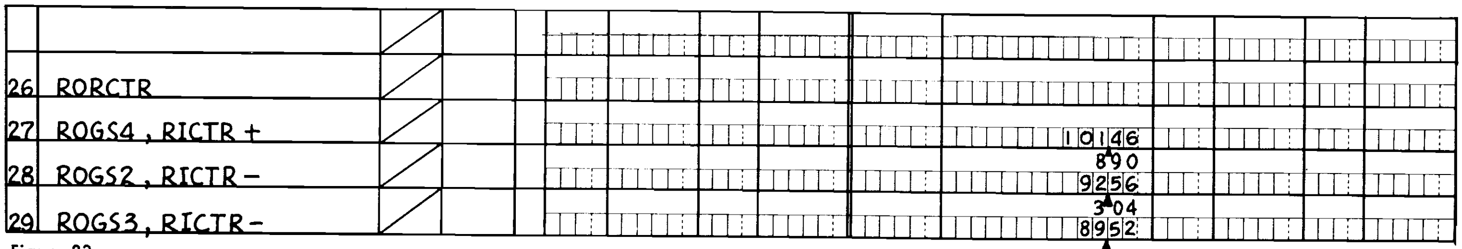


Figure 23.

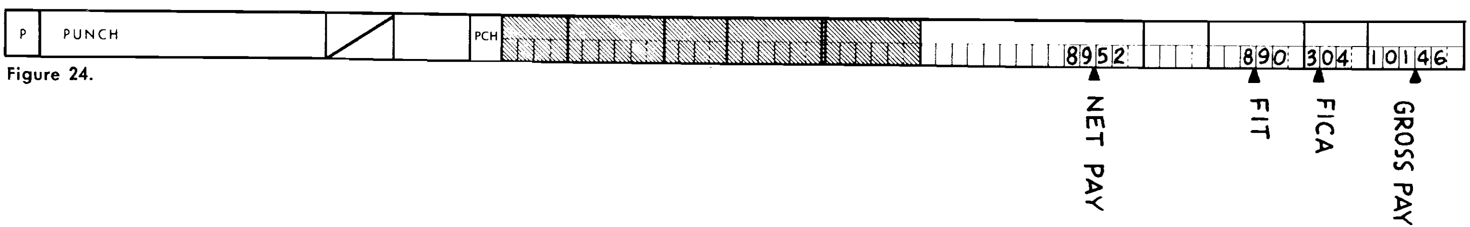


Figure 24.

ceeding further, check the Read portion of the planning chart of Figure 16, the above five instructions, and your execution of them.

6. To emit the required digits requires, of course, a digit emitter. Although there is no digit emitter per se on the 604, one can be simulated as follows: Wire one of the digit impulse hubs (A, 21-24) to one of the C hubs (B, 21-22), in each case choosing the leftmost hub. Now there is a digit emitter (C-N, 21-22).

(It should be recalled from Figure 28, Section 3, that a digit emitter has a *built-in* source of digit impulses. For several reasons the 604 does not have a *built-in* source and, therefore, the digit impulse must be provided for by means of control panel wiring.)

7. Wire from the left 1 hub of the digit "emitter" (DE) to the tens position of FS3 entry and from the left 3 hub of the DE to the units position of FS3 entry.

8. Wire from the right 1 hub of the DE to the tens position of GS1 entry and from the right 8 hub of the DE to the units position of GS1 entry.

Now the wiring so far only makes the data available to the storage units. In order to allow the data to enter them, the storage units must be instructed to read in. Care must be taken that the read-in hubs are impulsed only at the time that the desired information is available. Remember that the first event that takes place when a storage unit is impulsed to read in is that it is reset to zero.

9. When a personnel card is read at first reading, an X-timed impulse is available from column 31. Since storage unit read-in hubs recognize only X-timed impulses, and since the MQ unit and FS1 should accept data only from an X31 card, draw a wire from first reading 31 to the bottom Factor Storage Read-In hub (S, 15) and then continue the wiring from the top Factor Storage Read-In hub to the adjacent MP QT RI (MQ unit Read-In) hub.

When the second card of the group (the YTD card) is read by the first reading, nothing will enter FS1 or the MQ unit because there is no X in column 31 to instruct these storage units to read in.

10. It is of no consequence if FS2, 3 and 4 and GS1 accept information during the reading of the personnel card. This is because the information from the YTD card will replace the information from the personnel card before the calculation begins. Therefore, wire Factor Storage Read-In hubs 2, 3 and 4 from the card cycles hubs immediately above them and wire General Storage Read-In 1 hub from another card cycles hub.

The above ten items indicate how the data is controlled to enter the various storage units and indicate also the source of the data. To identify the contents of the storage units for future references to them, write the name of the information that is to be stored in them above the Factor Storage Entry hubs.

Wiring the Punch Control Panel for Punching the Results

To cause the calculated results to punch into the chosen columns also requires control panel wiring. Add to the control panel diagram the following wires (use a blue pencil):

11. From the four low-order positions of the GS2 exit to Punching 39-42.

12. From the GS3 exit to Punching 44-46.

13. From the GS4 exit to Punching 68-72.

14. From the five low-order hubs of the Counter exit to Punching 63-67.

15. From the lower left card cycles hub to the CTR R&R (Counter Read-Out and Reset) hub (T, 11-14). Then, continue the card cycles impulse by connecting the rightmost CTR R&R hub to General Storage Read-Out (GS RO) 2 (Z-AA, 16) (use the bottom hub). Then connect the upper GS RO 2 hub to the adjacent GS RO 3 hub, and the lower GS RO 3 hub to the adjacent GS RO 4 hub.

The wiring of item 15 indicates that GS2, GS3, GS4 and the counter cause the punches to be active on every card cycle. It has been previously mentioned that punching must be suppressed when the X31 personnel card is under the punches. Otherwise, the personnel card will be ruined.

The complete suppression of all punching for any given card may be accomplished by wiring any digit- (0-9), X-, or 12-timed impulse from first reading to punch suppress (A, 3-6).

The one definite distinguishing characteristic is the X punch in column 31 of the personnel card. It is this X punch that is used to suppress the punching of the personnel card. Therefore, wire first reading 31 (its available extension is the leftmost MP QT RI hub) through a column split (U-W, 1-12) to PCH SUP.

> *20. Why is it necessary to impulse the punch suppress hubs with an impulse that originates during first reading?**
>
> *21. Why is it necessary, in this example, to wire column 31 from first reading through a column split to punch suppress?**

Wiring the Punch Control Panel for Controlling Step Suppression

The *detection* of the X punch for suppressing steps 4, 7 and 12 is accomplished by the punch control panel. The *suppressing* of these steps is accomplished by the calculator control panel. Since these three steps are to be suppressed during the calculation phase of one card but not the other, the suppression impulse must be selected. As is the case with all selectors regardless of the IBM machine, a selector is *normal* unless the selector's pickup is impulsed. Thus, by utilizing the common, normal and transferred points of a selector located on the calculator control panel, the pickup of which is located on the punch control panel, it is possible to suppress steps 4, 7 and 12 during the calculating phase of an X31 card only.

The pickup hubs of the calculator selectors are located at (N-O, 11-19). The pickup recognizes *any* impulse that occurs during the reading of the card. The selector (on the calculator control panel) transfers just before the calculating phase begins and remains transferred until just after the calculating phase ends. Execute the wiring instruction now for item 16.

16. Wire from the punch suppress hub (the extension of the X impulse which originates at first reading 31) to the pickup of calculator selector number 1. Note that having previously column-split first reading 31 is an important consideration here. If first reading 31 *had not been* column-split, calculator selector 1 would be picked up on each and every card, since column 31 of the YTD card is punched with a digit, and a digit punch is recognized by the calculator selector pickup.

Wiring the Calculator Control Panel

The calculator control panel is wired directly from the planning chart. In order to keep the calculator panel diagram as neat and legible as possible, the "wiring" is noted as shown in Figure 25. Instead of drawing lines from each program step to the operation hub, a small encircled number, equivalent to the step on which the operation is to be executed, is drawn through one of the operation hubs. For example, a ① is drawn through a FACTOR STOR READ OUT 2 hub and a ① is drawn through a MULTIPLY+ hub to represent the program step wiring. In order to certify that a step (as planned on the planning chart) is "executed" on the calculator diagram, a program hub is penciled-in after writing the corresponding encircled number.

To highlight the wiring technique required for step suppression, lines are to be drawn rather than writing encircled numbers. Execute the following in Figure 25.

1. On step 6 a balance test is made. If the result of the balance test is plus, step 11 must be suppressed. An actual test is made by impulsing BAL. TEST FOR STEP SUP. (AA, 1-8) from a program step. Thus, for this problem, wire step 6 to a balance test for step suppression hub.

2. Starting with the step that follows the one on which the test was made, either SUPPRESS ON PLUS BAL. (BB, 1-8) or SUPPRESS ON MINUS BAL. (CC, 1-8) emits. The appropriate one continues to emit as a result

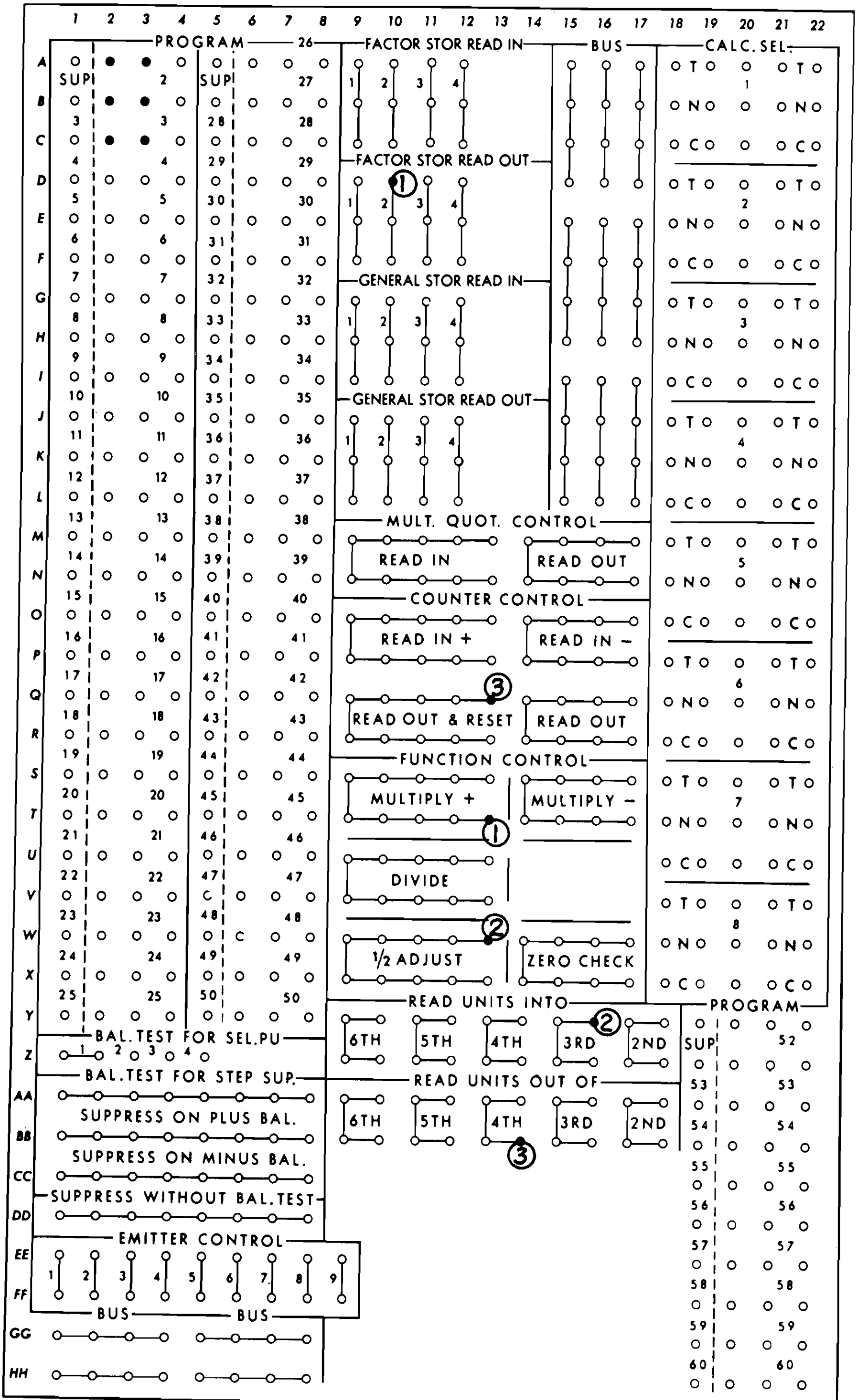

PROGRAM
FACTOR STOR READ IN
BUS
CALC. SEL.
FACTOR STOR READ OUT
GENERAL STOR READ IN
GENERAL STOR READ OUT
MULT. QUOT. CONTROL
READ IN
READ OUT
COUNTER CONTROL
READ IN +
READ IN −
READ OUT & RESET
READ OUT
FUNCTION CONTROL
MULTIPLY +
MULTIPLY −
DIVIDE
½ ADJUST
ZERO CHECK
READ UNITS INTO
6TH
5TH
4TH
3RD
2ND
READ UNITS OUT OF
BAL. TEST FOR SEL. PU
BAL. TEST FOR STEP SUP.
SUPPRESS ON PLUS BAL.
SUPPRESS ON MINUS BAL.
SUPPRESS WITHOUT BAL. TEST
EMITTER CONTROL
BUS
SUP

Figure 25.

of the balance test until another balance test is made (which nullifies the previous one), or until the end of the calculating phase. Thus, for the problem, wire from one of the SUPPRESS ON PLUS BAL. hubs to the PROGRAM SUP. hub (K, 1) of step 11.

3. Wire from program step 20 to BAL. TEST FOR STEP SUP.

4. Wire from five of the SUPPRESS ON MINUS BAL. hubs to the PROGRAM SUP. hubs of 21, 22, 23, 24 and 25.

5. Wire from program step 21 to BAL. TEST FOR STEP SUP.

The SUPPRESS WITHOUT BAL. TEST (DD, 1-8) hubs emit on every program step regardless of the algebraic sign of the counter. The impulses emitted from these hubs are often selectively used to suppress program steps during the calculating phase of certain cards. For this example they are used (through selector 1) to suppress program steps 4, 7 and 12 during the calculating phase of X31 cards. Add the following diagramming to Figure 25:

6. Wire from three of the SUPPRESS WITHOUT BAL. TEST hubs to three common hubs of calculator selector 1 (CAL. SEL. 1), and then from the three corresponding transfer hubs, to the program suppress hubs of program steps 4, 7 and 12.

> 22. *Trace through the program for each of the employees of question 3. For each employee, write the results of each step on a separate planning chart from the supplies packet.*

At this point you have sufficient knowledge to analyze and set up many basic calculation problems for the IBM 604.

It may seem that a lot of work is involved in setting up a problem for the 604. Remember, though, that once the problem has been analyzed and the control panels have been checked out, the 604 makes all the calculations necessary to produce 100 sets of results per minute (or 200 cards per minute using the 541).

Other Considerations

The discussion of 604 operation has been related to a portion of one data processing application to show its calculating ability and the problem analysis that is required before setting up the calculator. The 604 has been designed to solve a large variety of any type of problem. Selectors have been included in its design to allow punching into different card columns (or from different storage units into the same columns) upon recognizing certain characteristics in the card or the recognition of a characteristic during calculation. Selectors can also be used to determine which columns to read into storage from cards of different format.

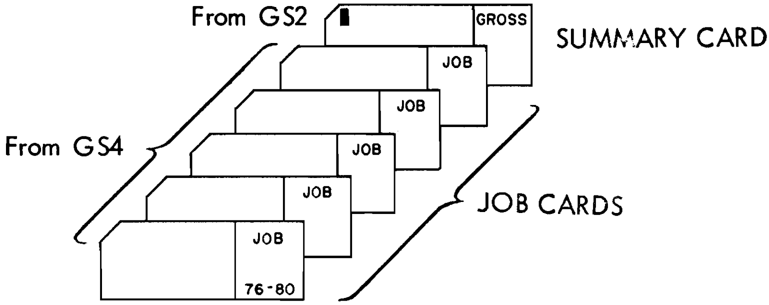


Figure 26. A procedure used by many concerns to keep track of specific labor costs is to record, on punched cards, the coded operation or job number, job rate, hours and employee number of each specific job performed. All the job cards of each employee are grouped together. Following the last card of each group is a summary gross pay card. As each group passes through the 604, job rate is multiplied times hours to equal job amount, and the individual job amounts of each card are accumulated. In this illustration, job amount is punched from GS4 into card columns 76-80 of each job card and the summary gross pay amount is punched from GS2 into the same numbered columns of the summary card.

Selecting the Storage Unit for Punching from a Card Characteristic

A common calculating requirement concerns a "combination" job operation cost (hours $\times$ job rate $=$ job amount) and the accumulation of all job amounts with which each employee is credited (see Figure 26).

The illustration shows the summary card with an X punch to indicate that GS4 is to be selected for punching into columns 76-80 of a job card and GS2 for punching columns 76-80 of a summary card requires the combined use of two different selectors.

One of these is a pilot selector (A-K, 11-20). There are five 2-position pilot selectors standard. Each pilot selector has three kinds of pickup hubs. These are called the X pickup hubs (A-B, 11-20), the D pickup hubs (C, 11-20), and the Immediate pickup hubs (D, 11-20). The X pickup recognizes only impulses occurring at X or 12 time. The D pickup recognizes any impulse that occurs while the card is under the reading brushes. The Immediate pickup is similar to the D pickup in that it too recognizes any impulse that occurs during card reading (see Figure 27). The difference between them, however, is very important: Impulsing the Immediate pickup of a pilot selector causes the selector to transfer immediately; it automatically returns to normal at the end of the cycle on which it was impulsed. For example, if the Immediate pickup of a pilot selector is impulsed at the time the 7 row of a card is being read, the selector transfers right then. It will remain transferred during the reading of the 8 and 9 rows and returns to normal just after the 9 row is read.

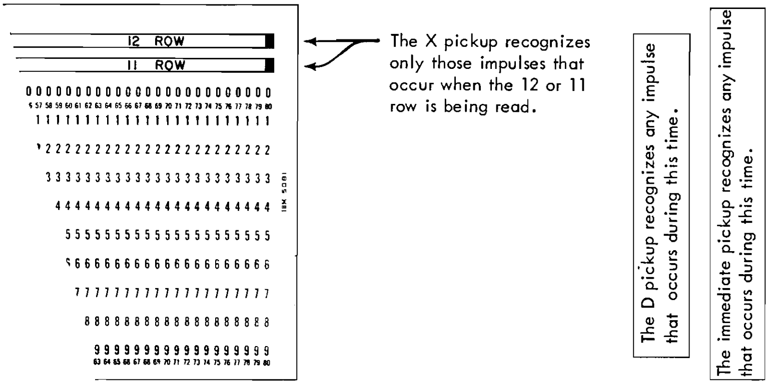


Figure 27. Note that the Immediate pickup has an acceptance range slightly longer than that of the D pickup. Although no impulses originate from the card at 14 time (the imaginary row above the 12 row), they can be generated by the 604 when certain conditions arise.

When the D pickup is impulsed, the selector does not transfer until 12 time of the following cycle. The selector remains transferred during the entire following cycle and returns to normal just after 9 time. No matter when the impulse reaches the D pickup, the selector's transfer is delayed until 12 time of the following cycle.

Except for the fact that the X pickup recognizes only impulses occurring at 12 or X time, it controls the selector in the same way as the D pickup.

The X and D pickup of each pilot selector also affect another hub, the coupling exit (K, 11-20). Whenever a selector is transferred as a result of impulsing the X or D pickup, the coupling exit of the selector emits an impulse which starts before the 12 row is under the punches and continues until the X row is under the punches.

23. *What is the timing of the impulses which is acceptable to the X pickup of the pilot selector?*
24. *When does the armature of a pilot selector transfer upon being impulsed by an X punch?*
25. *What is the timing of the impulses which is acceptable to the D pickup? To the Immediate pickup?*
26. *When does the armature of a pilot selector transfer upon being impulsed at the D pickup? The I pickup? In each case, how long does the armature remain transferred?*

The other type of selector required is a *punch* selector. Its characteristics are similar to a pilot selector when the Immediate pickup is used. It differs in that each punch selector pickup controls five sets of com-

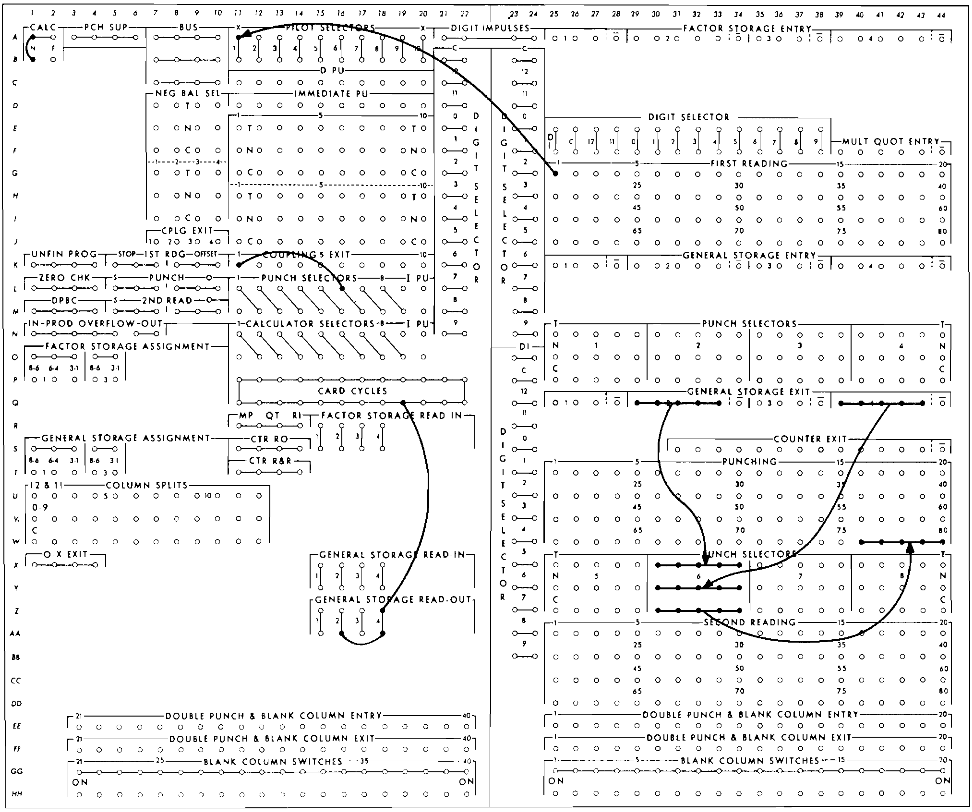


Figure 28. The X in column 1 of the summary card causes pilot selector 1 to transfer just before row 12 of the summary card goes under the punches. At that time, the coupling exit of pilot selector 1 emits. The impulse causes punch selector 6 to transfer immediately. The punch selector stays transferred until the 9 row of the card has been punched.

mon, normal and transferred points, whereas the Immediate pickup controls only two sets. The pickup hubs are located at (L-M, 11-19); and the transferred, normal and common points are located at (N-P, 25-44) and (X-Z, 25-44).

The manner in which a pilot selector and a punch selector are used in combination to perform the job card/summary card punching is shown in Figure 28.

27. *How soon after its pickup hub is impulsed does a punch selector transfer? When does a transferred punch selector return to normal?*

28. *When does the coupling exit of a pilot selector emit?*

Selecting the Punching of an X from a Condition Arising during Calculation

As in the case of the partial payroll example, it is often necessary to develop intermediate results in the determination of the final answers. Since these intermediate results disappear before punching, they cannot be used directly to control punching. Suppose, for example, that it is required to identify a card with an X punch when an employee's YTD FICA reaches 144.00 dollars. The only time that this is known is at the end of step 21 (Figure 16).

On the calculator panel, it is possible to cause the transfer of a selector on the punch panel, by wiring a program step to BAL. TEST FOR SEL. PU (Z, 1-2). If the counter is minus on that step, the NEG BAL SEL (negative balance selector) on the punch panel (D-I, 7) transfers just before punching begins. (The coupling exit of the negative balance selector emits also at this time.) The selector remains transferred for one card cycle. Figure 29 shows how an X can be punched in column 1 when step 21 is negative.

Setting Up the Channel to Transport 6, 7 or 8 Digits

Quite often a value must be represented by 6, 7 or 8 digits. In order to accommodate this requirement, certain three-position storage units can be connected to positions 4, 5 and 6 or 6, 7 and 8 of the channel for receiving or providing information.

For example, suppose that it is required to subtract a six-digit field from a seven-digit field (as might be the case in some executive payroll application to determine the difference between the YTD gross—columns 1-7—and the YTD FIT—columns 8-13). Columns 1 and 2 could be read into the tens and units position of GS1 (a three-position storage unit) and columns 3-7 could be read into FS2 (a five-position storage unit) to store the YTD gross. Columns 8-10 could be read into FS1 (a three-position storage unit) and columns 11-13 could be read into GS3 (another three-position storage unit). (See Figure 30.) Then, during the calculating phase of the 604, the subtraction of the YTD FIT from the YTD gross would be accomplished according to the diagram in Figure 31.

The assignment of a storage unit is accomplished by control panel wiring. The factor storage assignment hubs are located at (O-P, 1-5) on the punch control panel. FS1 may be assigned to channel positions 8-6 or 6-4 and FS3 may be assigned to channel positions 8-6 only. (When none of these hubs is wired, these storage units use the normal channel positions of 3, 2 and 1.)

The general storage assignment hubs are located at (S-T, 1-5). GS1 may be assigned in a manner similar to FS1 and GS3 may be assigned in a manner similar to FS3.

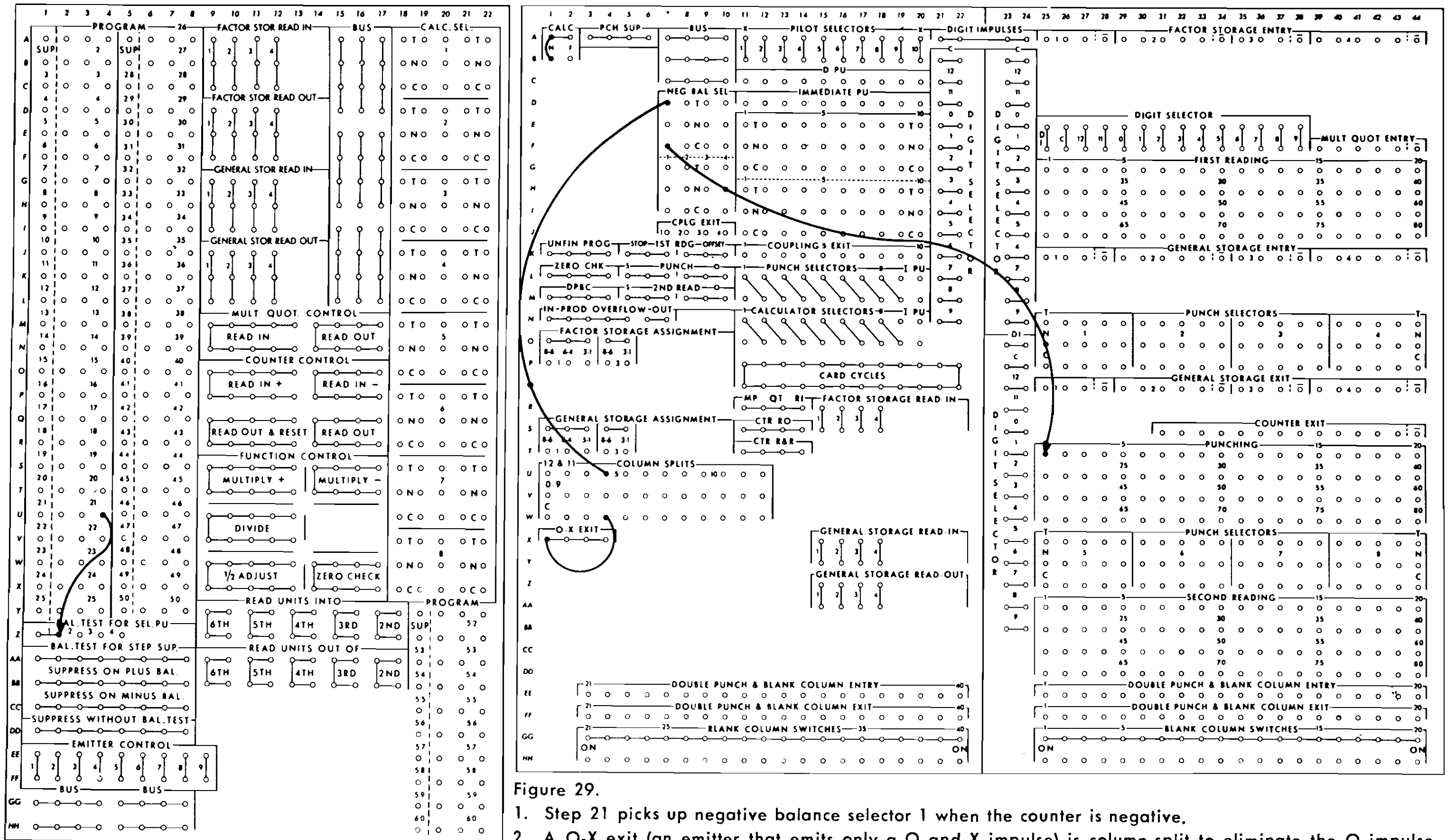


Figure 29.

1. Step 21 picks up negative balance selector 1 when the counter is negative.
2. A O-X exit (an emitter that emits only a O and X impulse) is column-split to eliminate the O impulse, wired through the transferred-common points of negative balance selector 1, to punch in column 1.

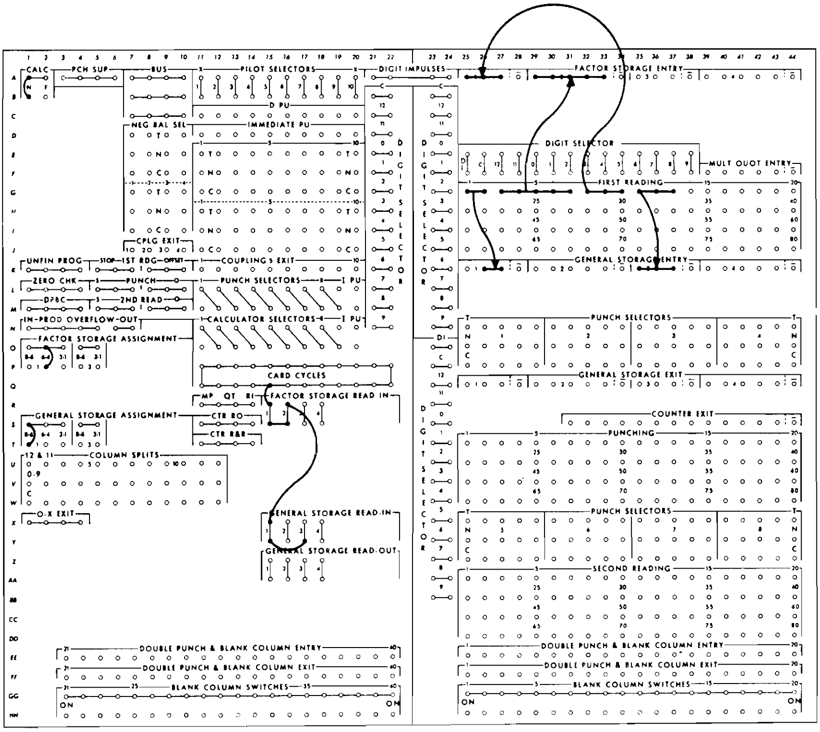
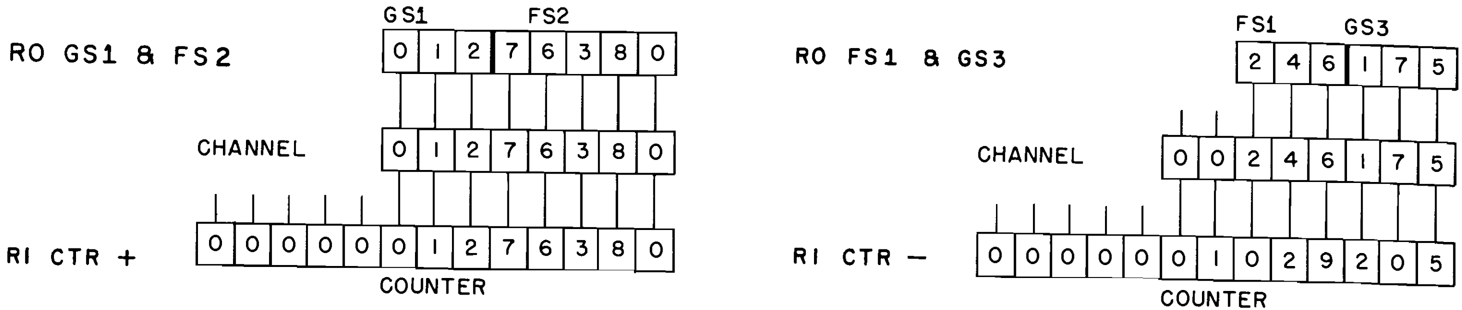


Figure 30.

Checking Operations

In any data processing installation it is always of utmost importance that calculated data be checked. On the 604 this may be done through a second calculation by one of two methods.

The first method is called double-punch, blank-column detection. The most effective way of employing this method is to use an alternate set of control panels. The wiring on these control panels should represent a different program approach—for example, interchange the multiplier and multiplicand, and interchange the storage units. Then, added to the punch control panel is the wiring from second reading (AA-DD, 25-44) to the appropriate double-punch and blank-column detection hubs. Thus, when the cards are punched a second time, no new holes should be created. If there are additional holes, the machine is instructed to halt. Likewise, if one of the punches is temporarily malfunctioning, a blank column is detected and this too causes the machine to halt.



This shows how GS1 is assigned to use channel positions 8, 7 and 6 or simply, 8–6.

This shows how FS1 is assigned to use channel positions 6, 5 and 4, or simply, 6–4.

Figure 31. Part I

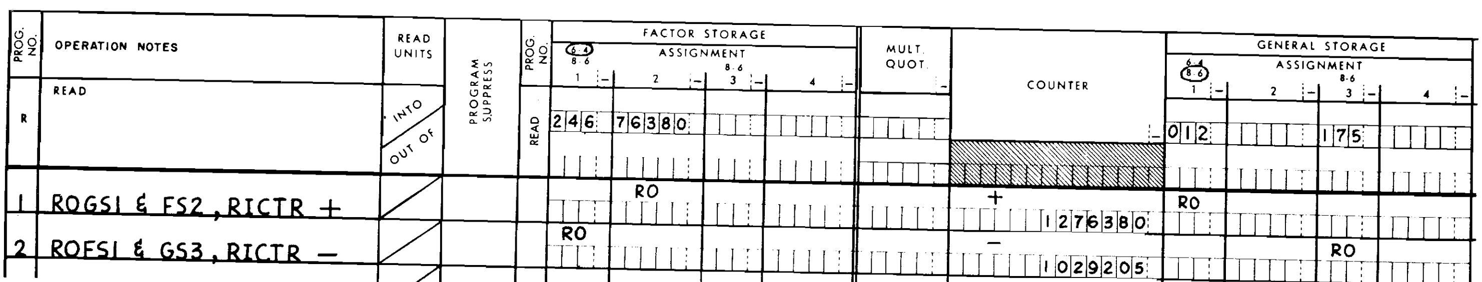


Figure 31. Part II

The second method is called the zero balance method. The cards are not punched a second time. However, the result is calculated again and the first result (punched on the first run) is subtracted from it. With some additional programming, the difference is tested for zero. If it is not zero, an impulse is available on the punch control panel (L. 1-4) which can be used to cause the machine to halt.

Overflow of Product

Although card fields are usually designed to accommodate the largest number of significant digits obtained from a calculation, there are occasions when this would not be in the best interests of card column conservation. Consider the problem of how many columns to allot for overtime pay. An analysis may indicate that 99½ percent of all overtime pay is $99.99 or less, an amount that can be punched into a four-column field. Naturally, the card field for overtime pay would be allotted four columns. The five-digit value that occurs one-half of one percent of the time must be recognized for special handling because it cannot be punched. On the IBM 604, detection of too large a calculated value is accomplished in the course of reading out the counter or general storage during the punching operation. Wiring from the high-order positions of the counter or general storage exit hubs (that are in excess of the number of hubs required to punch the result), to the product overflow IN (N, 1-7) hubs, causes the OUT hub to emit an impulse (that can be used to stop the 604) whenever any other digit than a zero is sensed from the excess positions.

The IBM 602 Calculating Punch*

The 602 performs the same arithmetic operations as the 604, but differs considerably in such areas as card path, operating speed, type of storage and counters, and control panel wiring.

The sequence of events of a card passing through the 604 is constant. That is, a card passes in order: (1) first reading and calculation, (2) punching, and (3) second reading. In the 602, the series of events is, to a certain degree, variable. The reason for the varying is due primarily to the design of the punching unit. Whereas in the 604 punching is done row by row (parallel), in the 602 it is done column by column (serial). Thus, to allow the speediest operation possible, a result can be punched as soon as it is calculated, and, while the punching is taking place, other results are calculated.

Path of Cards in the IBM 602

The illustration in Figure 32 shows the path a card takes in passing through the 602. An understanding of the relationship between the way a card is fed from the hopper, is read by the two sets of reading brushes, and goes through a combined calculation and punching phase, is required to properly plan and wire the 602 control panel.

The feeding of cards (face down, 9 edge first) is started by the depression of a start key. This action moves a card into the machine and past a reading station made up of 20 *control reading brushes.*

Just before the 9 edge of the card comes to the second reading station (reading brushes), the card stops. Then all the program steps that are wired on the control panel are executed. (No results are calculated, however, since no factors have been read in.) The reason for executing a "dummy" program is to reset (clear out) all the storage units and counters which are used with this control panel before the calculation of the first card. The last "dummy" command is to *read a card.* It causes the first card from the hopper to pass the reading brushes where the factors are read for making the calculation (see Figure 33).

> 29. *What is the difference between the punching techniques of the 604 and the 602?*
> 30. *How do the cards enter the 602?*
> 31. *How many control reading brushes are there?*
> 32. *What is the function of the "dummy" program?*

As soon as the card (card A) is read by the reading brushes, the 602 enters its first program step. On this program step the operations that may be executed or initiated are:

*The text on the 602 is prepared on the assumption that you have completed the first part of Section 5, dealing with the IBM 604.

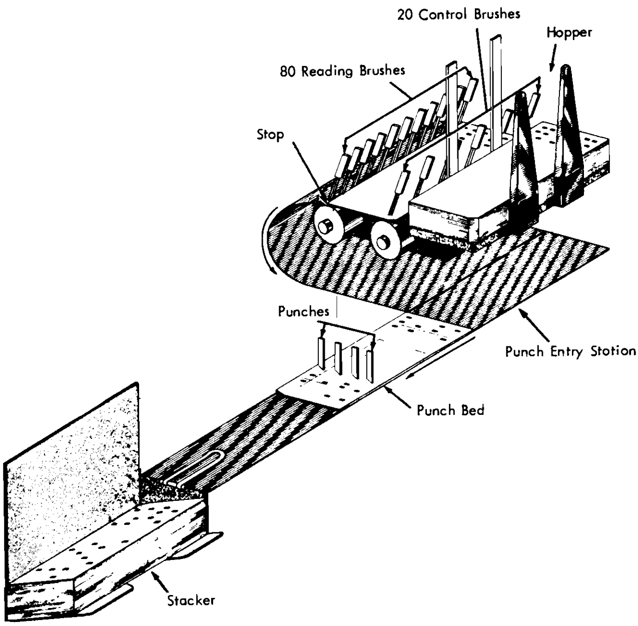


Figure 32.

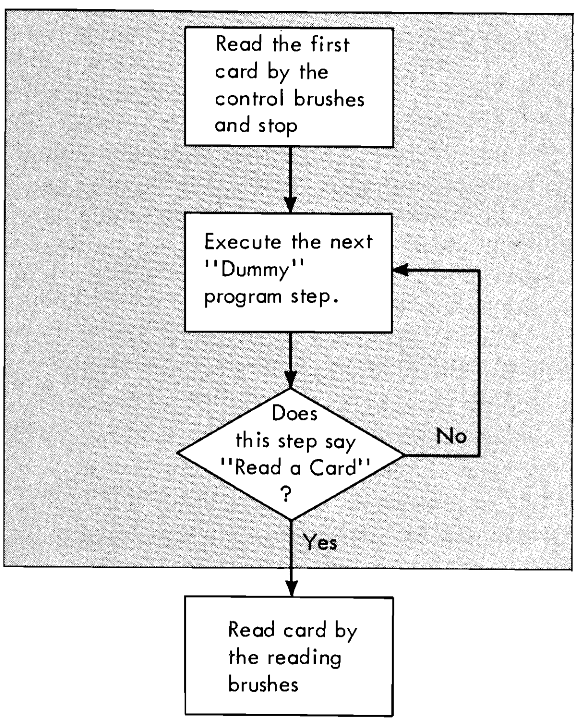


Figure 33. The section in the shaded part of the diagram is called the RUN-IN RESET.

1. Execution of an arithmetic operation.
2. Testing the algebraic sign of a value in a counter.
3. Initiating punching (a serial or column-by-column operation).
4. Initiating reading (a parallel or row-by-row operation).

At the same time that card A is continuing its path to the punch bed during the first program step, the next card (card B) is fed from the hopper and passes the control reading brushes.

> 33. *What operations are executed or initiated on a program step?*

While card A is traversing its semicircular path, the 602 consults its engineered logic to determine what it is to do next. If no previous card is being punched, card A passes, without stopping, to the punch bed, where it is positioned to be ready for punching the first column of the first result field. (If there is a previous card, card A is delayed at the punch entry station until the previous card is ejected into the stacker. Also, the reading of card B by the reading brushes can take place only after the "previous" card is in the stacker.)

> 34. *How many cards may be in the 602 (that is, between hopper and stacker) at one time?*

Operating Speed of the 602

All operations of the 602 are performed in steps or operating cycles which occur at the rate of 200 per minute. Thus, there are 200 machine cycles per minute. (This is the most common way of stating the capacity of the 602.) Whereas the 604 processed cards at the rate of 100 per minute, the 602 processes cards at a maximum rate of 50 per minute. (The processing rate of the 602 is reduced in proportion to the increased complexity of the calculation and the increase in the number of columns that have to be punched.)

The least amount of time required to get a card from the hopper to the stacker is four machine cycles. This includes reading, some basic calculation, and the punching of not more than two columns. The relationship of the punching rate to machine cycles is approximately four to one. That is, four columns can be punched during one machine cycle.

The addition or subtraction of two numbers requires one machine cycle. The number of machine cycles required for multiplication and division depends on the size of the factors used in these operations.

> 35. *How many 602 machine cycles are there in one minute?*
> 36. *How many cards can the 602 process in one minute?*
> 37. *How many columns can be punched during one machine cycle?*
> 38. *How many machine cycles are required for each arithmetic operation?*

Storage Units

In the 602 Calculating Punch, the storage units are used for the same functions as on the 604, namely:

1. Accepting factors as they are read from the card.
2. Storing intermediate results during calculation.
3. Providing results to the punching mechanism.

Also as in the case of the 604, a control impulse is required to enter information into the storage units.

In the 602 Calculating Punch, the storage units are made up of "number wheels." Each circular number wheel is divided into ten equal portions on which are inscribed the numerals 0-9. Individual sets of wheels are combined to make up the storage units. On a standard 602 there are six storage units, each consisting of twelve positions or number wheels. The storage units are called 1, 2, 3, 4, 6 and 7.

Each of the six 12-position storage units is divided into a left (L) and right (R) section. The left and right sections of storage units 2, 3, 4, 6 and 7 are made up of six positions each. The left section of storage units 1 (1L) is made up of four positions and the right section (1R) is made up of eight positions. In a multiply operation, one of the factors must be in 1R. In a divide operation, the divisor must be in 1R.

When a storage unit is impulsed to *read in,* both the left and right sections reset to zero before new information enters. The right and left section of each storage unit can be read out separately. (Remember that when a storage unit is impulsed to read out, it is not the contents, but an exact copy of the contents, that is read out.)

Storage units 6 and 7 provide the punch mechanism with the calculated results.

39. *How many storage units are in a standard 602?*
40. *What is the maximum number of significant digits which may make up the multiplier or divisor?*
41. *How many positions are cleared when a storage unit is impulsed to read in?*
42. *Which storage units are used for punching results?*

The IBM 602 Counters

All addition, subtraction, multiplication and division is done in counters, of which there are six on a standard 602. Three of the counters have six positions each and three of the counters have four positions each. These counters may be operated separately, or they may be coupled together to perform as larger-capacity counters. Factors may be entered into the counters from a card, but the punches can not be actuated from the counters.

43. *How many positions can be accumulated when all the counters are coupled together?*

Counter Operation, Addition

Addition and subtraction are accomplished at the rate of 200 per minute. The value to be added or subtracted may come from a card, a storage unit, another counter or from the emitter.

A positive amount (including zero) appears in the counter as a nines complement and a negative amount appears as a true (uncomplemented) figure. (In this respect, the 604 counter and the 602 counters are similar.)

The counters of the 602 consist of wheels for accumulating the digit values. Each wheel is divided into ten equal parts and on each part is inscribed one of the digits, 0-9. When a counter is instructed to add or subtract, the wheels are put into motion. The direction of rotation is the same whether adding or subtracting; the difference in the counter's action is in the start and stop time of the wheels. To illustrate the action of a four-position counter when a value (25) is added to it, fill in the boxes of Figure 34, a counter schematic, according to the following instructions:

1. As soon as the 9 row (9 time) of the card is read, the counter wheels are set in motion. To indicate this, write an encircled nine ⑨ in each box.
2. At 8 time each wheel has advanced one position to 0. Write a 0 in each of the boxes. Whenever a counter wheel goes from 9 to 0, a carry of 1 is generated. Write a 1 in each of the boxes at Carry.
3. At 7 time each wheel advances one position. Write 1111 to indicate this.
4. At 6 time each wheel advances one position. Write 2222 to indicate this.
5. At 5 time each wheel advances one position. Write 3333 to indicate this. It is at 5 time that a 5 punch is detected in the card column that supplies the units position of the counter with data. When the digit is detected, the counter wheel is impulsed to stop for the rest of this addition. To indicate this, draw a square around the 3 in the units position.
6. At four time, each wheel that is not impulsed to stop advances one position. Write 4443 to indicate this.
7. At 3 time each wheel not impulsed to stop advances one position. Write 5553 to indicate this.
8. At 2 time, each wheel not impulsed to stop advances one position. Write 6663 to indicate this. It is at 2 time that a 2 punch is detected in the card column that supplies the tens position of the counter with data. To indicate that the wheel is to stop, draw a square around the 6 in the tens position.
9. At 1 time, each wheel not impulsed to stop advances one position. Write 7763 to indicate this.
10. At 0 time, each wheel not impulsed to stop advances one position. Write 8863 to indicate this.

Carry

At carry time any carry generated is *automatically* added to the position to the left. Thus the units carry is added to the 6 in the tens position, the tens carry is added to the 8 in the hundreds position, and the hundreds carry is added to the 8 in the thousands position. The carry in the high-order position does not have a position to its left. Yet, in order to produce the correct result, the carry must be directed to the units position. This can be accomplished by control panel wiring. The CI hub makes this impulse available at the control panel. By connecting the CI hub to the C hub (draw a line to indicate this), the carry impulse enters the units position.

After the carries are added, the result in the counter is 9974†. Write this to complete Figure 34.

*44. Prepare a counter schematic to illustrate the motion of the counter when a 268 is added to the result obtained in Figure 34.**

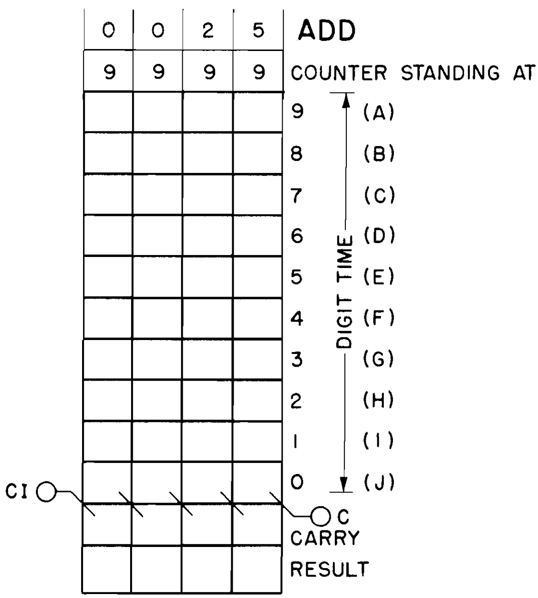


Figure 34.

The action of a counter for an addition operation is summarized as follows:

Counter wheels start in motion at 9 time.

Counter wheels stop when a digit is recognized. Stop takes precedence over start when there is "conflict." This would be the case when a digit 9 is being added.

†The number 9974 represents 0025. If the counter were now instructed to *read out* (for example, into a storage unit), the storage unit would contain 0025.

Carries are automatically added to the position to the left. To correct the units position of the counter requires "Cl to C" control panel wiring.

Counter Operation, Subtraction

When a counter is impulsed to subtract, the counter wheels do not start moving until the digit is detected. The operation of counter during subtraction is illustrated in Figure 35.

Note that at 0 time the counter stands at 9914. When the carry that was generated in the units position is added to the tens position, a 2 results. When the carry that was generated in the tens position is added to the 9 in the hundreds position, a 0 *and a carry result.* This carry is added to the 9 in the thousands position. The addition of this carry results in a further carry, which is directed by control panel wiring to the units position which contains the 4. The result, standing in the counter after the subtraction, is 0025.

45. *Prepare a counter schematic to illustrate the motion of the counter when a 268 is subtracted from the result obtained in Figure 35.**

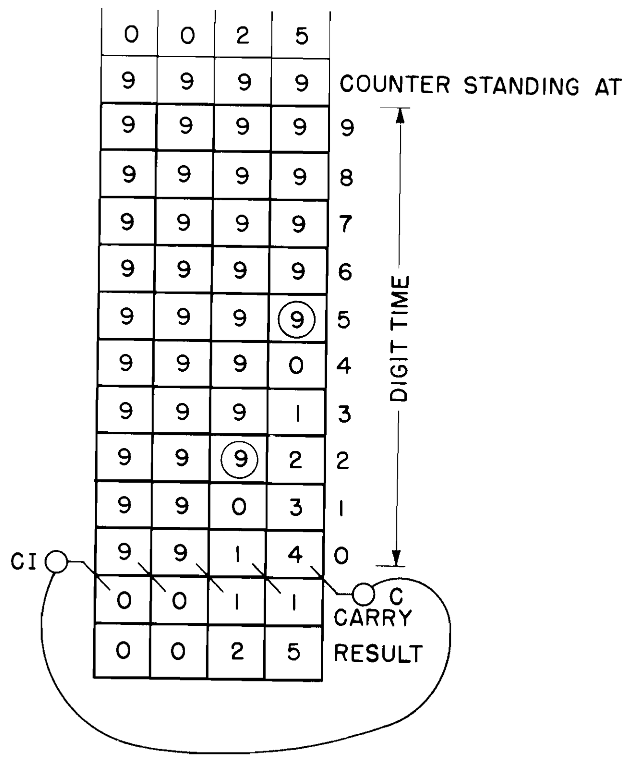


Figure 35.

Coupling Counters

An accumulating capacity in excess of six digits is a frequent requirement. The technique of "making" two or more counters into a larger one is referred to as counter coupling. Coupling the counters is accomplished by control panel wiring. For example, it may be required that two 4-position counters (4 and 5) accumulate from a six-card-column field. Figure 36 shows the counter action up to carry time. Notice that the units position of counter 4 is the ten thousands position of the coupled counter. Since there is no *automatic* path for the carry in the thousands position to the ten thousands position, one must be created by control panel wiring. To accomplish this, draw a connecting "wire" between the CI of counter 5 and the C of counter 4. To complete the "control panel" wiring, draw a line from the CI of counter 4 to the C of counter 5.

Counters 1, 2 and 3 must be coupled for a division operation. It is in these coupled counters that the dividend (of up to 15 digits) must be placed.

> 46. *"Wire" Figure 37 for coupling counters 3, 4 and 5 to receive data for accumulation from columns 1-8.**

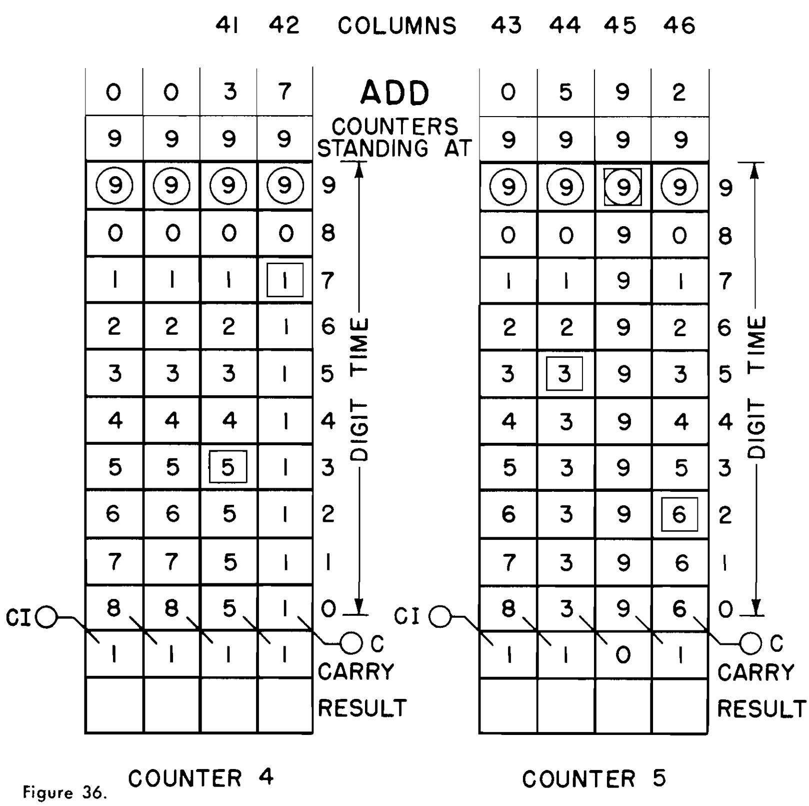


Figure 36.

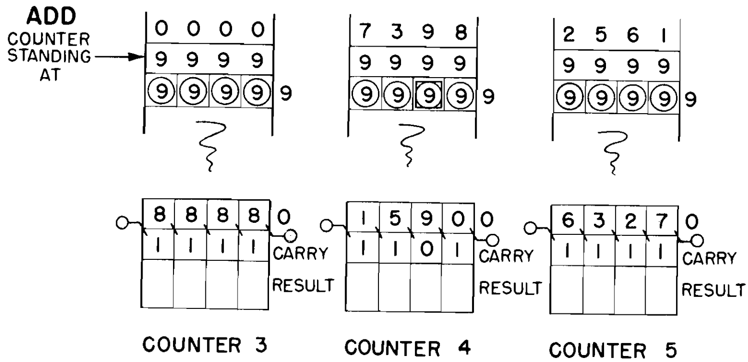


Figure 37.

Multiplication

The 602 does not use the repetitive addition technique for multiplication. Rather, the 602 is equipped with a "multiplication table" which is examined for each multiplier digit. On the average, 1.4 machine cycles are required for each multiplier digit.

It is possible to develop a 30-digit product by multiplying an eight-digit multiplier times a 22-digit multiplicand and producing the product in the counters, all of them coupled together.

The multiplicand may (1) be in the storage units, (2) be emitted, or (3) be in a counter. When the multiplicand counter is read out during the multiplication, it cannot be reset. If the multiplicand counter is instructed to reset, it will do so on the first cycle and thus develop an erroneous product.

Division

It is possible to develop an eight-digit quotient by dividing a 15-digit dividend by an eight-digit divisor. Since the dividend must be in coupled counters 1, 2 and 3, the quotient must be developed in counters 4, 5 or 6 (either individually or coupled as required).

The 602 uses built-in divisor tables to develop the quotient. Each digit of the divisor is considered separately and the dividend is reduced by repeated subtractions until the remainder is less than the divisor. A count of the number of subtractions necessary to make this reduction becomes the quotient. It takes 5.4 cycles to develop a quotient of 1 or 2 digits. Each additional quotient position requires 0.9 cycles.

47. *What is the maximum size of each of the following: multiplier, product, divisor, dividend, quotient?*
48. *How many machine cycles are required to multiply by an eight-digit multiplier? How many cycles are required to develop an eight-digit quotient?*

Transmitting Data

In the 604, data is moved between storage units and counter during calculation, over a *channel*. In the 602, the "channel" must be simulated by control panel wiring. For example, suppose that a value of 763 is read into 2R from a card and that program step 1 is instructed to:

1. Read out the contents of 2R.
2. Read into counter 4, plus.

The contents of 2R are available at the control panel. Entering these contents into counter 4 requires control panel wiring to connect the storage exits of 2R with the counter 4 entry (see Figure 38).

Thus the number of "channels" on the 602 depends upon the control panel wiring. In this way, of course, the 602 differs considerably from the 604. For example, in the 604, only one device can be read out and one read into on one program step, because there is only one channel. In the 602, it is possible to read out several devices and to read into several devices on one program step. For example, read out counter 6, read in 2L; read out and reset counter 5, read in 2R; read out 3R, read in counter 1, plus. (Of course, one specific counter could not accept information from two storage units at any one time.)

Whenever a 602 calculation requires multiple "channels," great care must be taken in planning the control panel wiring to avoid back circuits. There is no rule of thumb to guide you in avoiding back circuits. A good technique to follow is this: Each time a new "wire" is added to the control panel diagram, analyze the effect an impulse traveling through it would have on the previously proposed wiring. If a back circuit is a definite possibility, the use of selectors may be required to break the circuit. Sometimes it may be necessary to take a different approach to the entire problem. Often it is not evident that a control panel wiring approach must be scrapped until after some effort has been expended.

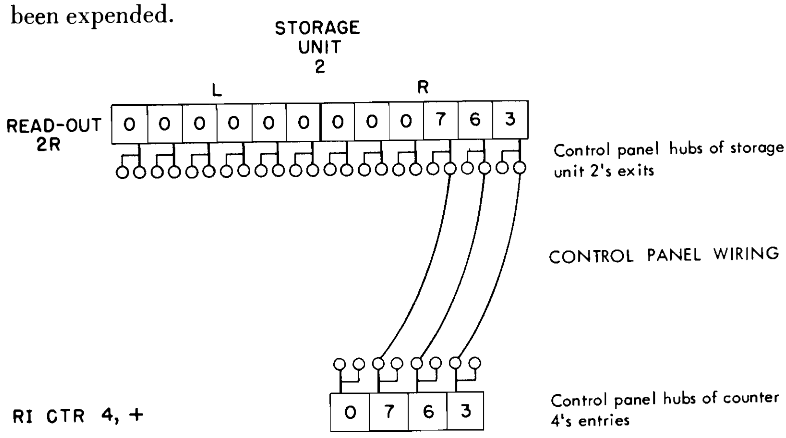


Figure 38.

Lining Up Decimals

If the values shown in Figure 12 are located in 2L, 2R and 3L and are to be added in counter 6, it is necessary to provide a path for the digit impulses by control panel wiring to the units position of counter 6 from

1. The tens position of 2L.
2. The units position of 2R.
3. The hundreds position of 3L (see Figure 39).

Sometimes during a calculation, it is necessary to use a storage unit more than once where, for each use, the units must be read out of a different position. For example, it may be that 2L provides counter 6 with a two-decimal digit on step 3 (35.67) and a one-decimal digit on program step 7 (392.3). This means that the *destination* of the units position (and all the other positions) of 2L must be *selected* to accomplish the same thing that impulsing READ UNITS INTO/OUT OF does on the 604 (see Figure 40).

Adjusting a Product

Entering a 5 into a 602 counter to adjust a product is done *before* the product is developed. Whenever *any* counter is reset, the 602 emits a *reset to* 5 impulse. By entering a *reset to* 5 impulse to a counter position, that position resets to 5 rather than zero when any counter is reset.

Calculating

There are twelve program steps on a standard 602, and they are used to instruct the machine to calculate a given set of factors. Each program step is equivalent to one machine cycle except when multiplying or dividing.

The program unit is designed to permit the steps to be taken in sequence or to skip steps (not suppress, but skip over) when it is desirable to eliminate program steps under certain conditions.

Not all of the twelve available steps may be necessary to complete a given problem; consequently, the series of steps may be ended by control panel wiring.

49. *What is the difference between the 602 and 604 in regard to transmitting data between storage units and counters during calculation?*
50. *How can the relationship between counters and storage be altered on different program steps to provide for proper alignment of decimals?*
51. *When must a 5 be entered into a counter for half-adjusting purposes?*
52. *What is the number of program steps on a standard 602? How many of these are taken for each problem?*

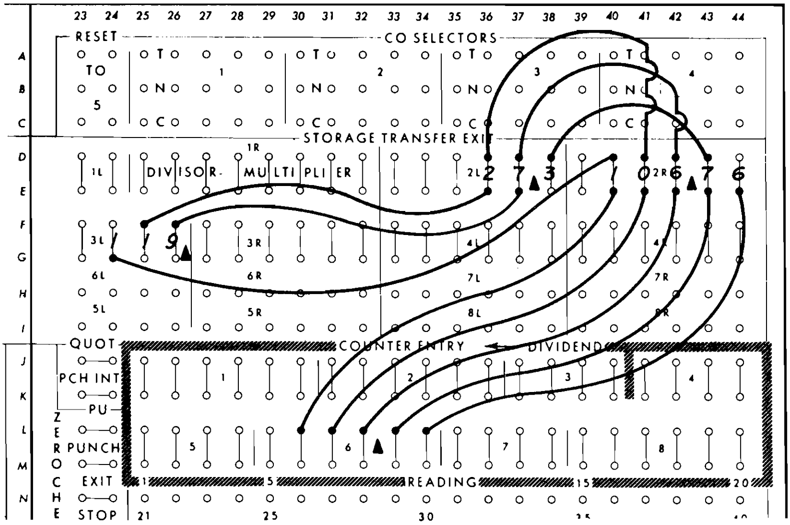


Figure 39. Trace the wiring for each factor to assure yourself that the decimals are properly aligned.

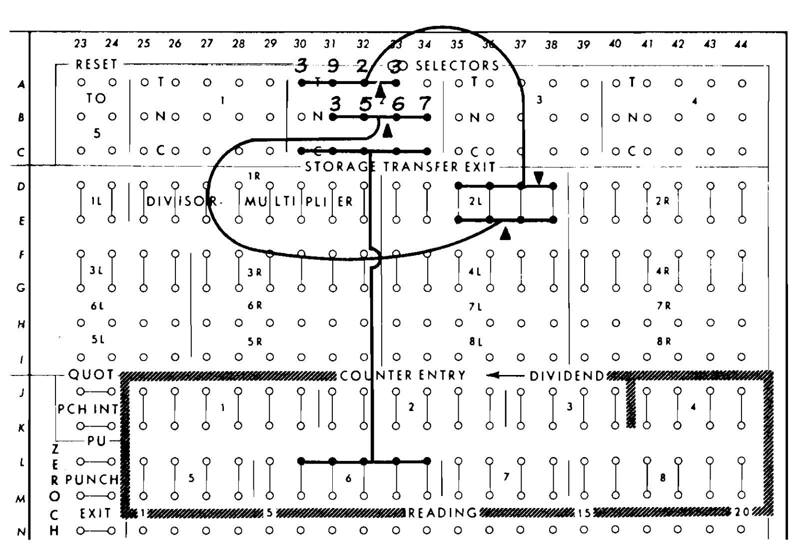


Figure 40. On program step 7 the selector would be transferred to allow the decimal alignment as shown. On program step 3 (and all others except 7) the selector would be normal to allow the decimal alignment as shown.

Punching

Calculated information to be punched must be in storage unit 6 or 7. The program step on which the calculated data is transmitted to 6 or 7 is usually the same step on which 6 or 7 is impulsed to punch. It is on the step which follows, however, that punching actually begins. This is necessary to allow the transmitted data to enter storage unit 6 or 7.

Setting Up the 602 for Calculating Net Pay

The same payroll problem is used for discussing the 602 as was used for the 604. The same conditions must be met for calculating net pay on the 602 as on the 604. That is, the personnel card, after it is read to provide the tax class and hourly rate, passes through the punch unit without being punched. Also, in the 602 all of the program steps are avoided for the personnel card.

One important consideration concerns the punching of gross pay. It has already been mentioned that the 602 punches column by column. Although gross pay is the first result calculated, it is the last result to be punched (see Figure 2). Therefore, gross pay must be held until it can be punched. In this problem, punching the first calculated result last, does not create any problems. However, there are cases where it is necessary to punch results in the sequence in which they are calculated. Thus it is recommended that careful consideration be given to the design of a card when it is to be processed by the 602.

Planning Chart and Control Panel (Diagram)

The planning chart (Figure 41) has been designed to assist the 602 programmer in analyzing and setting up the 602 and to indicate exactly what happens to data:

1. From the time it is entered into storage during reading
2. Through the time it spends in calculation and is punched.

The control panel (Figure 42) is used to perform both the reading and calculating and punching functions. Letters down the middle and numbers across the top of the panel diagram facilitate reference to specific hubs which are mentioned in the text.

Writing the 602 Program

The program presented here for calculating gross pay, FIT, FICA and net pay has twelve program steps and is an example of the calculating ability of a standard 602. The values used in the program plan are the same ones used in the 604 program.

Because it is often possible to perform several functions on a single program step, the 602 program is not identical in sequence to the 604 program. (Indeed, it could not be; for whereas the 604 program con-

APPLICATION ______________________ PROBLEM ______________________

IBM INTERNATIONAL BUSINESS MACHINES CORPORATION
PLANNING CHART: 602 CALCULATING PUNCH
WITH 8 COUNTERS & STORAGE UNITS

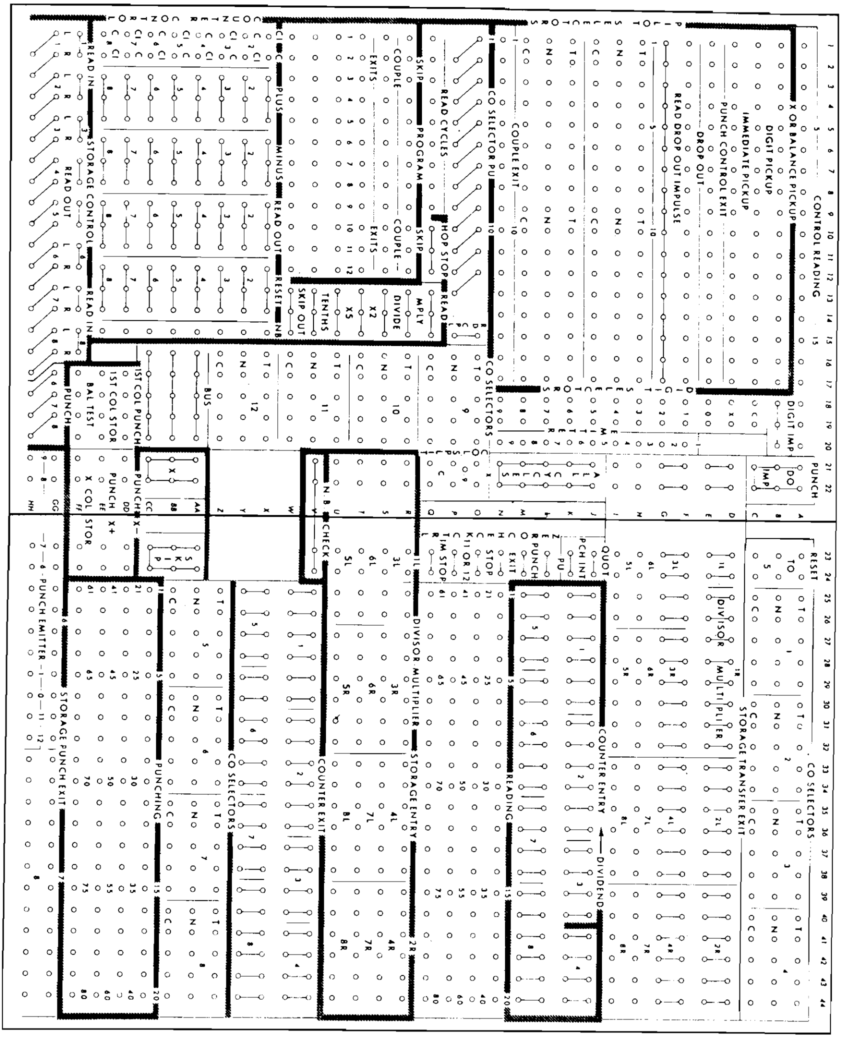
Form X26-6040-2
Printed in U.S.A.

PROGRAM SUPPRESS	PROG. STEP	OPERATION	STORAGE UNIT		COUNTERS								STORAGE UNITS								PUNCH UNITS *UNITS POSITION MUST BE WIRED TO PUNCH					
			DIVR.-MULT.		DIVIDEND																					
			1L	1R	1	2	3	4	5	6	7	8	2L	2R	3L	3R	4L	4R	5L	5R	6L	6R	7L	7R	8L	8R
		READ CYCLE																								
	1																									
	2																									
	3																									
	4																									
	5																									
	6																									
	7																									
	8																									
	9																									
	10																									
	11																									
	12																									

Figure 41.

602 CALCULATING PUNCH CONTROL PANEL

WITH 8 COUNTERS & STORAGE UNITS



ELECTRO NO	CARD NAME OR FUNCTION	X OR D CODE				NOTES

Name ______________________ Dept ______________________

Use ______________________ No. ______________________

Figure 42.

sists of 29 program steps, the 602 must execute the program in not more than twelve steps.)

In working out the plan of a fairly complex 602 program such as this one, continuous modification is usually necessary. The program shown in Figure 43 is the result of several hours of planning by an experienced person. The first time an attempt was made to write the program, the 602 would have required 15 program steps.

Now, carefully study the program in its entirety before consulting the explanations which follow. Do not be concerned at this time with what the control panel wiring will look like.

Explanation of the 602 Program

Read Cycle

Two cards are read for each employee, an X31 personnel card and an NX31 year-to-date card, in that order. 1R accepts information from columns 5-8 of an X31 card only (hourly rate). Coupler counters 3 & 4 (indicated as coupled on the planning chart by means of a dark line between the counter identification numbers) accept information from columns 1-5 of a NX31 card only (YTD FICA).‡ 2R accepts information from column 4 of an X31 card only (tax class). 3L and 3R, respectively, receive information from 77-80 of NX31 card only (regular hours)and from the emitter (FICA maximum).

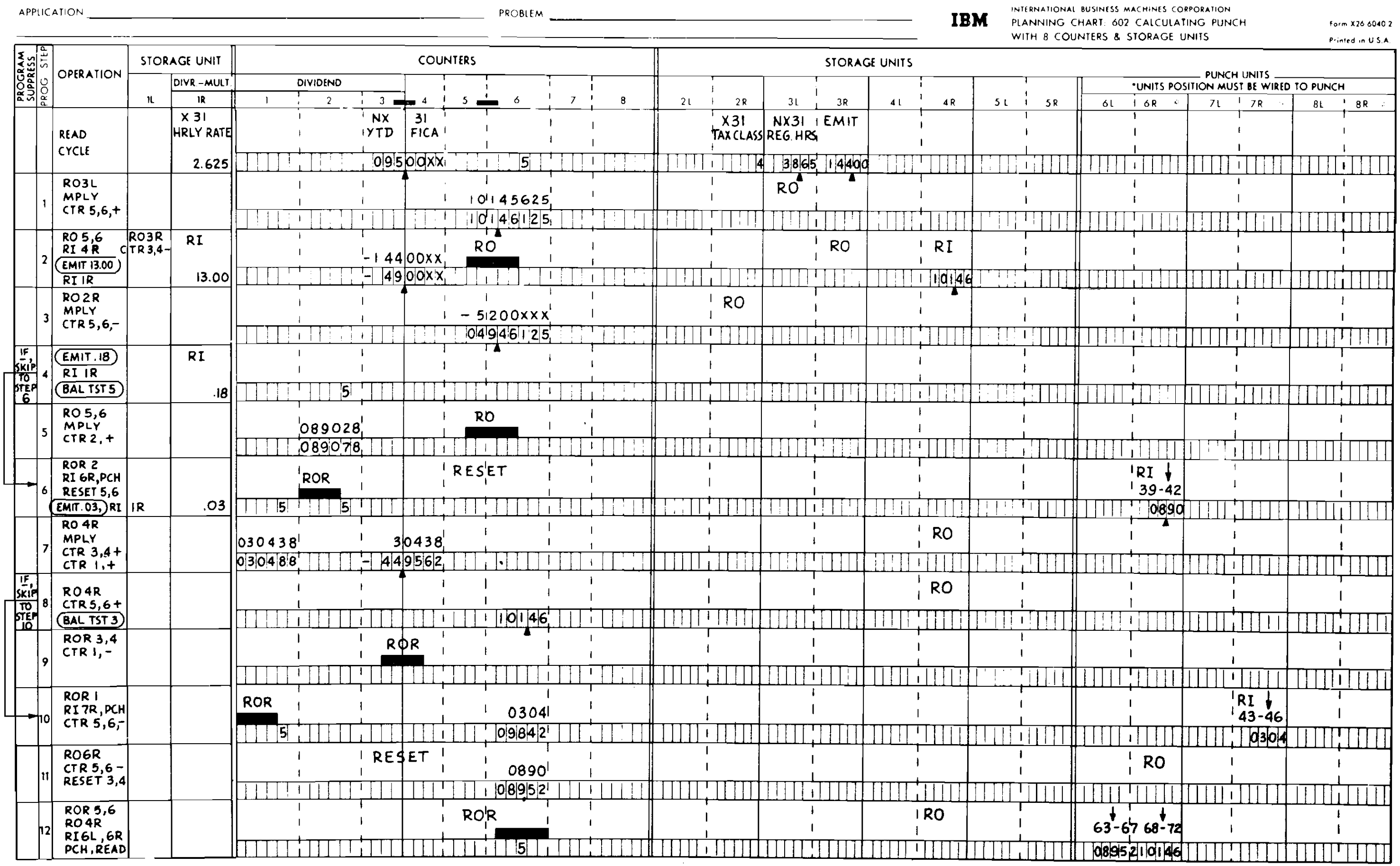
Program Step 1

3L (regular hours) is read out, multiplied by the contents of 1R, and the product developed in (coupled) counters 5 and 6. Note that there is a 5 for half-adjust in the hundreds position of counter 6. It was placed in the counter during step 12 of the "dummy" program.

Program Step 2

The three rightmost positions of counters 5 and 6 are "dropped" while these counters are read out. The information is transmitted to 4R (gross pay). The tax-exempt amount (13.00) for each dependent claimed by the employee is emitted to 1R. The contents of 3R are read out (FICA maximum) and subtracted from counters 3 and 4 which contain the YTD FICA amount. The value in counters 3 and 4 now represents the difference between the amount of FICA deducted so far this year and the maximum deductible amount for the year.

‡Notice where the decimal point is located. This was done so that when the FICA percent (two decimals) is multiplied by the gross pay (two decimals), the resulting current FICA amount (four decimals) will be decimally aligned with the YTD FICA.



APPLICATION
PROBLEM
IBM
INTERNATIONAL BUSINESS MACHINES CORPORATION
PLANNING CHART: 602 CALCULATING PUNCH
WITH 8 COUNTERS & STORAGE UNITS
Form X26 6040 2
Printed in U.S.A.
PROGRAM SUPPRESS
PROG. STEP
OPERATION
STORAGE UNIT
DIVR.-MULT.
1L
1R
COUNTERS
DIVIDEND
STORAGE UNITS
PUNCH UNITS
*UNITS POSITION MUST BE WIRED TO PUNCH
X 31 HRLY RATE
NX YTD
31 FICA
X31 TAX CLASS
NX31 REG. HRS
EMIT
READ CYCLE
RO3L MPLY CTR 5,6,+
RO 5,6 RI 4R EMIT 13.00 RI IR
RO3R CTR 3,4-
RO2R MPLY CTR 5,6,-
IF -, SKIP TO STEP 6
EMIT .18 RI IR BAL TST 5
RO 5,6 MPLY CTR 2,+
ROR 2 RI 6R, PCH RESET 5,6 EMIT .03 RI IR
RO 4R MPLY CTR 3,4+ CTR 1,+
IF -, SKIP TO STEP 10
RO4R CTR 5,6+ BAL TST 3
ROR 3,4 CTR 1,-
ROR 1 RI 7R, PCH CTR 5,6,-
RO6R CTR 5,6 - RESET 3,4
ROR 5,6 RO4R RI6L, 6R PCH, READ
2.625
13.00
.18
.03
RI
0950 0XX
10145625
10146125
-1 4400XX
- 4900XX
- 5200XXX
04946125
089028
089078
RESET
030438
30438
030488
- 449562
10146
ROR
RO
RI
0304
09842
0890
08952
3865
14400
39-42
43-46
63-67 68-72
0895210146

Figure 43.

Program Step 3

2R (tax class) is read out, multiplied by the contents of 1R, and the *negative* product developed in counters 5 and 6. The negative product (nontaxable amount) and the gross pay amount already there form the result, which is the taxable amount.

> 53. *Why was YTD FICA read into counters 3 and 4 with four decimal places rather than two decimal places?*

Program Step 4

The FIT factor (.18) is emitted into 1R. Counter 5 is tested for its algebraic sign. If the sign is minus, it means that the FIT amount is zero. Because step 5 (the next step) performs the FIT calculation, it is to be avoided by skipping around it when the sign of counter 5 is minus on step 4.

Program Step 5

This step is executed whenever there is a positive taxable amount. The contents of counters 5 and 6, which contain the taxable amount, are read out, multiplied by the contents of 1R, and the product (current FIT) is developed in counter 2. The adjusting 5 is already there as a result of a previous reset of counter 2.

Program Step 6

Counter 2, which contains the FIT amount, is read out (and reset to 5 in the tens position) and transmitted to 6R, the storage unit from which the FIT is to be punched. Storage unit 6 is impulsed to punch. Counters 5 and 6 are reset at this time. The FICA factor (03) is emitted into 1R.

> 54. *What will be read out of counter 2 on step 6 if counter 5 is minus on step 4?**
> 55. *Why are counters 5 and 6 not reset on step 5?**

Program Step 7

The gross pay amount in 4R is multiplied by the contents of 1R and the result is developed in two places: (1) in counter 1, where it appears as the current FICA amount, and (2) in coupled counters 3 and 4, where it is added to the difference between previous YTD FICA and the FICA maximum. The result that is developed in counters 3 and 4 is the basis of the test for determining how much of the calculated current FICA amount to deduct from the employee's gross pay.

Program Step 8

To start the calculation of net pay, the contents of 4R are read out (gross pay) and entered into counters 5 and 6. Counter 3 is tested for its algebraic sign. If it is positive, it means that only *some* (or *none*) of the calculated current FICA amount is to be deducted. Arriving at the *some* or *none* is done on step 9. Step 9 is skipped if step 8 is negative, which means take all!

Program Step 9

This step is executed only when counter 3 is positive on step 8. The value in counters 3 and 4 represents the amount by which the calculated current FICA amount in counter 1 is to be reduced.

Program Step 10

Counter 1, which contains the FICA amount to be deducted from the employee's gross pay, is read out (and reset to 5 in the tens position), subtracted from the contents of 5 and 6 and transmitted to 7R for punching. Storage unit 7 is impulsed (to start punching on the next step).

56. *Using two planning charts from the supplies packet, write the counter activities when the YTD FICA is 142.79 dollars and when it is 144.00 dollars, for steps 2, 7-10.**

Program Step 11

The contents of 6R (FIT) are read out and subtracted from counters 5 and 6 to provide the net pay result. Because step 9 may have been skipped as the result of a negative balance of counter 3 on step 8 (where counters 3 and 4 were to be reset), step 11 is used to reset counters 3 and 4.

Program Step 12

Storage unit 6 receives data from counters 5 and 6, which are read out (and reset to 5 in the hundreds position) and from storage unit 4R. Storage unit 6 is impulsed to start punching on the next step (a read step) and the 602 is notified that a new card is to be read.

Wiring the Control Panel

CI and C Wiring

The planning chart indicates that counters 1 and 2 are used separately and that counters 3 and 4 are coupled, as are 5 and 6.

*57. On a 602 control panel diagram from the supplies packet, indicate the necessary CI to C wiring for the counters. (The CI and C hubs are located at X-EE, 1-2.)**

Wiring the Control Panel for Read-In of Data from a Card

When a card passes the reading brushes, the *read cycles* hubs (Q, 1-9) emit an impulse in two parts (see Figure 44). It is the first part of this impulse that is required to control a storage unit to read in (FF, 1-16). (The later part of the impulse has no effect on storage read-in.)

In order to cause a counter to read in (either add or subtract), it is the later part of a cycles impulse that is required. (The early part of the impulse has no effect on counter read-in.)

According to the planning chart, a read cycles impulse should cause storage units 1 and 2 to read in only when an X31 card passes the reading brushes. Also, a read cycles impulse should cause counters 3 and 4 and storage unit 3 to read in only when an NX31 card passes the brushes.

*58. Since the cards are read 9 edge first, where must the detection of the X in column 31 take place to control the read cycles impulse?**

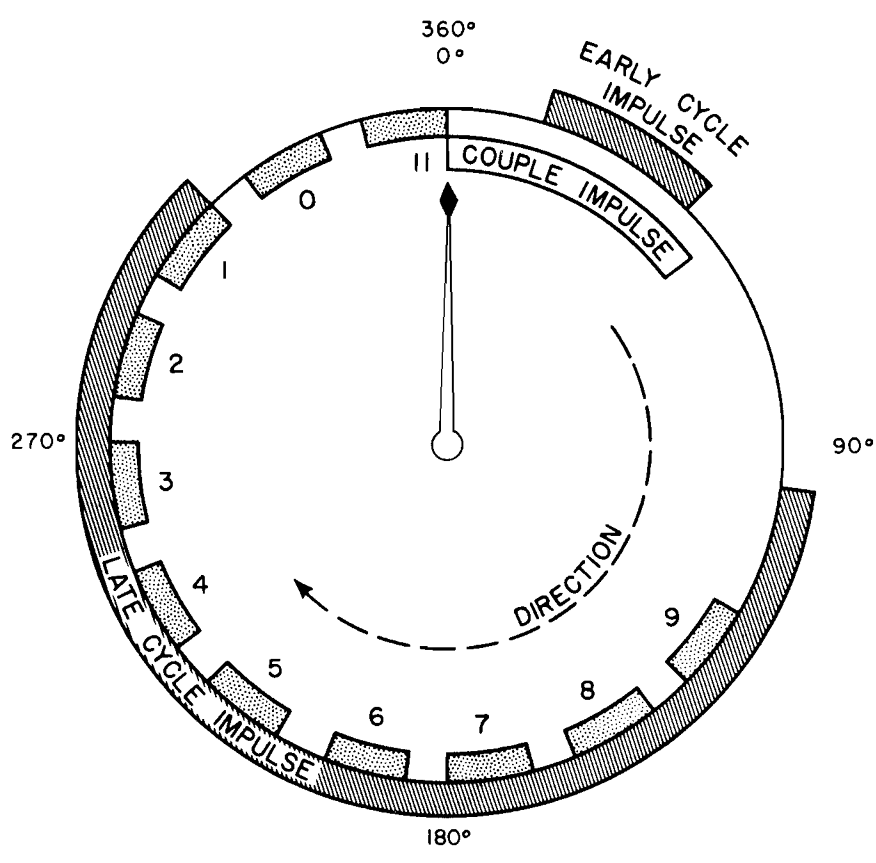


Figure 44. The master "time wheel" of the 602 is like a clock with a reverse face.

A read cycles impulse, entered into one of the common hubs of a selector under the control of the X punch in column 31, should emerge from the normal to impulse counters 3 and 4 to read in plus. The read cycles impulse, which emerges when the selector is transferred, should be wired to storage control read-in 1. A second read cycles impulse entered into the other common of the same selector, should emerge out of normal to impulse storage control read-in 3. When the selector is transferred, this second read cycles impulse must be used to control the read-in of storage unit 2.

The *X or balance pickups* of a selector recognize only X-timed impulses. When the pickup receives an X-timed impulse, the selector transfers on the next machine cycle. It stays transferred until it is instructed to return to normal. This is accomplished by impulsing the selector's *drop-out* hub. When a selector has been transferred to control some function during a read operation, it is usually dropped out with a *read drop-out impulse.* The read drop-out impulse is of short duration and occurs just before the 9 edge of the card is to be read. When the drop-out hub receives this impulse, it makes the selector return to normal at the end of the cycle on which it was received.

59. *When does a selector transfer if its X pickup is impulsed? How long does it remain transferred?*
60. *When does a selector return to normal if its drop-out hub receives a read drop-out impulse?*
61. *Figure 45 is the suggested control panel wiring for impulsing storage units 1, 2 and 3 and counters 3 and 4 during the reading of cards. Add this wiring to the diagram you used for question 57. Now reread the two paragraphs preceding question 59.*

Skipping Calculation and Punching

As soon as the X31 (personnel) card has been read, it should be sent to the stacker without further processing. This can be accomplished by impulsing *skip-out* to eliminate the punching, and by impulsing *read* to eliminate the calculation. During the reading of a card, the read hubs recognize only an X impulse. When *read* receives an acceptable impulse, all the following program steps are avoided and another card will be read by the reading brushes. *Skip-out* recognizes any impulse which occurs during the reading of the 9 to 11 rows of the card. If column 31 were wired directly to *skip-out,* NX31 as well as X31 cards would cause an erroneous skip-out. (Column 31 of the NX cards is part of the employee number field, which always contains a 0-9 punch.) Therefore, column 31 must be column-split before impulsing *skip-out.*

62. *What happens when* skip-out *is impulsed on a read cycle? What is the timing of the impulses that it recognizes?*

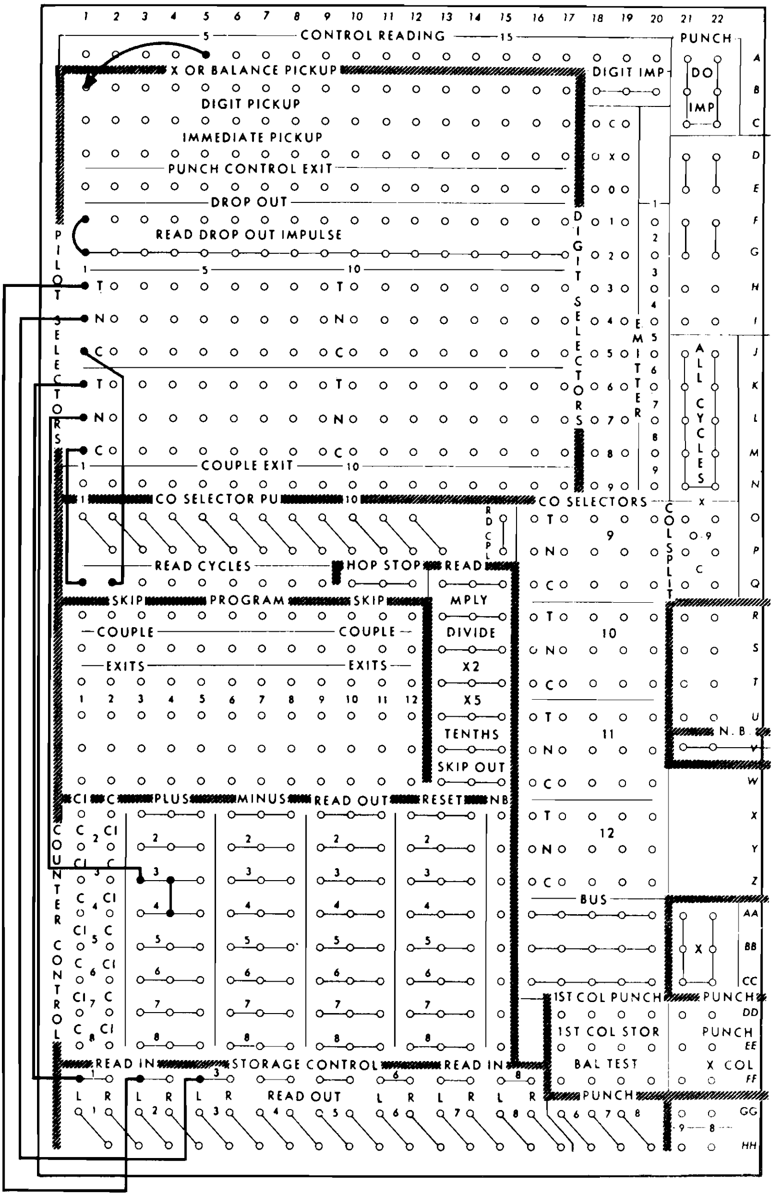

CONTROL READING
PUNCH
X OR BALANCE PICKUP
DIGIT IMP
DO
IMP
DIGIT PICKUP
IMMEDIATE PICKUP
PUNCH CONTROL EXIT
DROP OUT
READ DROP OUT IMPULSE
PILOT SELECTORS
DIGIT SELECTORS
EMITTER
ALL CYCLES
COUPLE EXIT
CO SELECTOR PU
CO SELECTORS
CO SPLIT
RDCPL
READ CYCLES
HOP STOP
READ
SKIP
PROGRAM
SKIP
MPLY
COUPLE
COUPLE
DIVIDE
EXITS
EXITS
X2
X5
TENTHS
SKIP OUT
N.B.
CI
C
PLUS
MINUS
READ OUT
RESET
NB
COUNTER CONTROL
BUS
1ST COL PUNCH
PUNCH
1ST COL STOR
PUNCH
BAL TEST
X COL
READ IN
STORAGE CONTROL
READ IN
READ OUT
PUNCH

Figure 45.

63. *What happens when* read *is impulsed? What is the timing of the impulse that* read *accepts during reading?*

64. *Add to the diagram of question 57 the wiring shown in Figure 46. Now reread the section "Skipping Calculation and Punching."*

Punching

The planning chart shows that the column-by-column punching is initiated three times for each YTD card—the first time from storage unit 6 to punch columns 39-42, the second time from store unit 7 to columns 43-46, and the third time from storage unit 6 to punch columns 63-72.

To indicate to the 602 where the first column of a field to be punched is located, requires a skip bar (see Figure 47).

65. *Into which numbered slots of the skip bar must the small inserts be placed for this problem?**

As the answer to the previous question implies, the punch mechanism advances one column at a time. If it is required to advance more than one column (as in this case, in going from column 46 to column 63), a *skip* impulse is required. The column following the last one punched must be wired to skip. (When column 80 is punched, skip must be connected to column 1.)

66. *Add to the diagram of question 57 the wiring shown in Figure 48. Now reread the section on punching.*

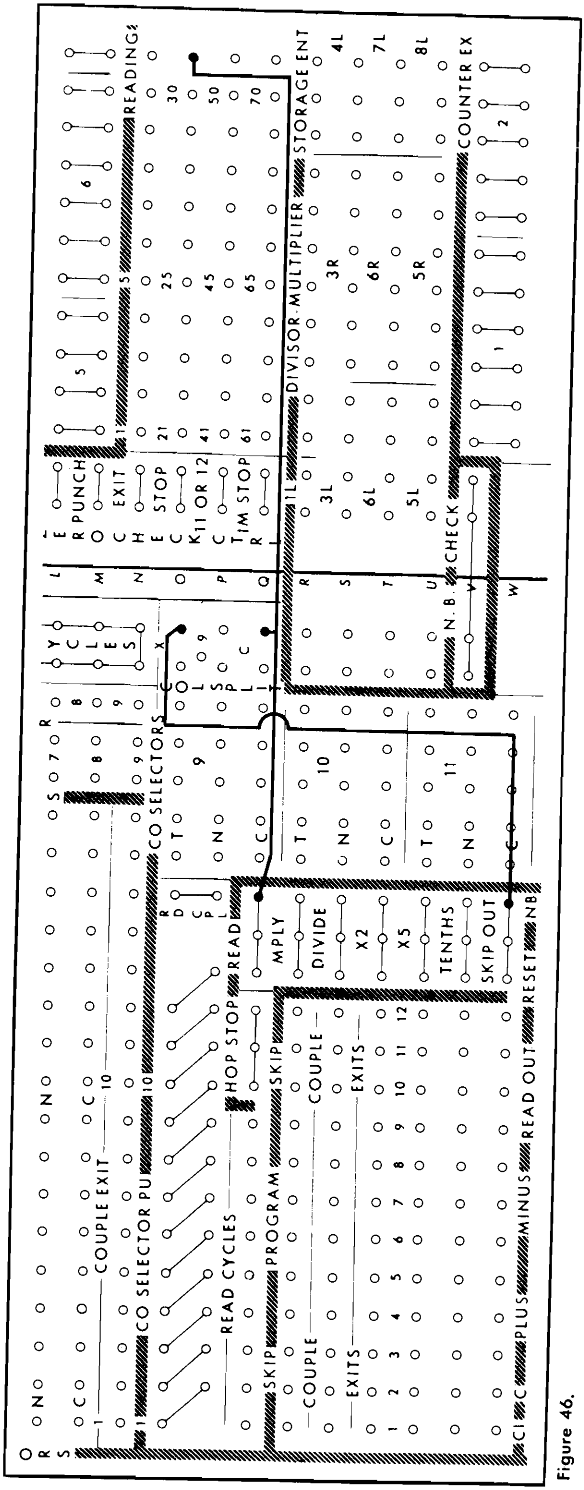
Program Steps

There are twelve program steps on the standard 602. These steps occur in numerical sequence in increments of one unless wired otherwise on the control panel. Each of these hubs emits an impulse identical to the one emitted from the read cycles hubs.

The wiring of the program exits to control the counters and storage units can be practically "copied" from the planning chart. For diagramming problems with only a few program steps, it is customary to draw lines between the program exit hubs and the control hubs of counters and storage units. For problems involving many steps, the diagramming is usually done with encircled numbers at the control hubs. The number in the circle indicates the program step.

Occasionally more than four exits are required for a program step. It is possible by control panel wiring to simulate additional exits. The 602 emits *all cycles* impulses which occur on every machine cycle. These impulses are identical to the impulses emitted by the read cycles hubs and the program exit hubs.

By controlling a selector to be transferred on only the desired pro-



COUPLE EXIT
CO SELECTOR PU
CO SELECTORS
READ CYCLES
HOP STOP
READ
PROGRAM
SKIP
COUPLE
EXITS
MPLY
DIVIDE
X2
X5
TENTHS
SKIP OUT
PLUS
MINUS
READ OUT
RESET
NB
PUNCH
EXIT
STOP
11 OR 12
TIM STOP
READINGS
DIVISOR-MULTIPLIER
STORAGE ENT
COUNTER EX
N. B.
CHECK

Figure 46.

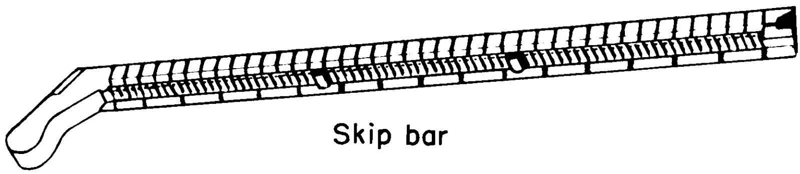


Figure 47. The skip bar has 80 numbered slots, one for each column of the card, into which a small insert is placed for the first column of each field to be punched.

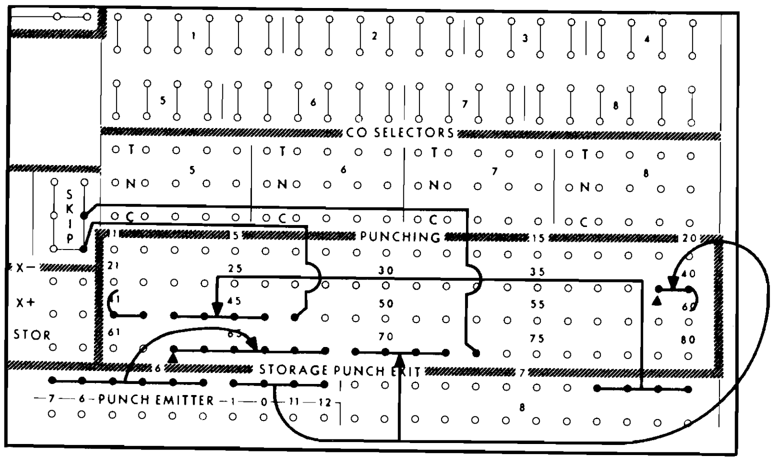


Figure 48.

gram step (or read step), an *all cycles* impulse can be entered into the common hub and out of the transfer hub to perform like another program exit (or read cycle) impulse.

The selector used for this purpose is called a coselector. On a standard 602 there are eight. The pickup hub controls five selector positions (each position consisting of a common, normal and transferred point). When a coselector pickup receives an impulse, the selector transfers immediately. The most common impulse used for picking up a coselector is a *couple*-type impulse (see Figure 44). When a coselector is transferred, it returns to normal at the end of the cycle on which it was picked up. (When a coselector is controlled by the couple exit of a pilot selector, the coselector remains transferred until the pilot selector drops out.)

67. *In what way are read cycles impulses, program exit impulses and all cycles impulses similar? In what way are they different?**

68. *If a coselector pickup receives an impulse, when does the coselector transfer? How long does it stay transferred?*

69. *If a coselector pickup receives an X-timed impulse, how long will it remain transferred?*
70. *Add to the diagram of question 57 the wiring shown in Figure 49. Then reread the section on program steps.*

Negative Balance Detection and Program Skip

On step 4 of the program, counter 5 is tested for a negative balance. If the counter is negative, step 5 is to be skipped. On step 8 of the program, counter 3 is tested for a negative balance. If the counter is negative, step 9 is to be skipped.

At the end of the machine cycle on which a counter turns negative, an X-timed impulse is available from the counter's NB (negative balance) hub. Testing for plus or minus balances may be done on any program step except those used for multiplication or division. (The reason for this is that a multiplication requires several cycles. The table method of multiplication used by the 602 may turn a counter negative during one of these cycles, thus providing an erroneous detection of a negative value.) When counters are coupled, it is the counter with the high-order positions that should be tested because it contains the algebraic sign.

The *program skip* hubs recognize impulses that occur from 1 through X-time. When a *program skip* hub is impulsed, the program steps preceding it are skipped. When a program step is skipped, it is "eliminated."

71. *Which program steps are skipped in:*
    (a) *An X punch read in a card, wired to* program skip *6 hub?*
    (b) *An X-timed, negative balance impulse (from a counter that turns negative on step 3) to* program skip *7 hub?*
72. *According to the program, when might counters 5 and 6 turn negative during program steps 1 through 4?**
73. *Add to the wiring diagram of question 57 the wiring shown in Figure 50. Then reread the section "Negative Balance Detection and Program Skip."*

Setting Up Storage, Counter and Emitter

The "channels" for transmitting data between the various units of the 602 are control panel wires. This means that every position that is to receive a digit impulse and every position that is to provide a digit impulse, must have a control panel wire. The part of the control panel which is used for the actual transmission of data between units is READING (N-Q, 25-44), STORAGE ENTRY (R-U, 21-44), COUNTER ENTRY

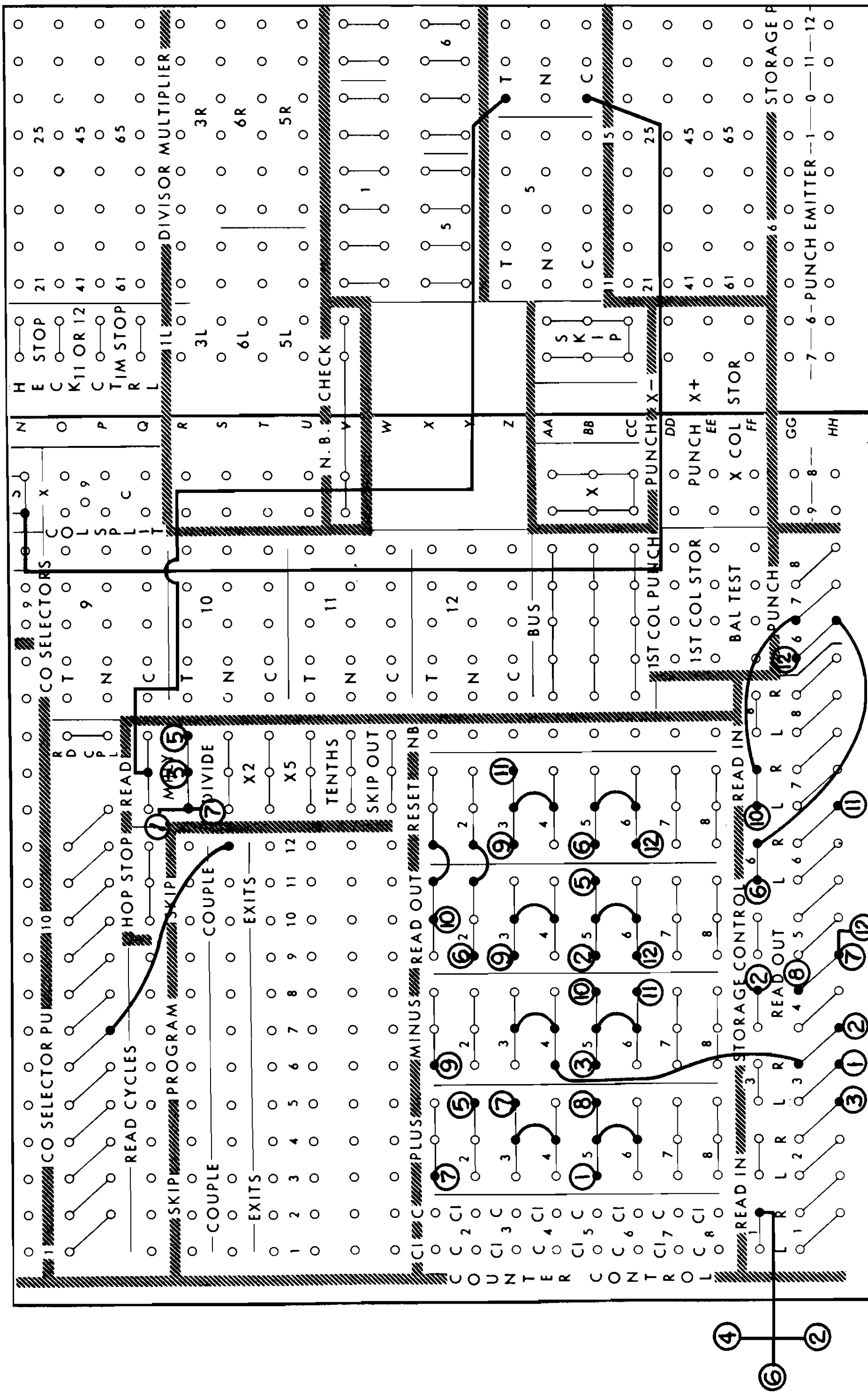

CO SELECTOR PU
READ CYCLES
HOP STOP
READ
SKIP
PROGRAM
COUPLE
EXITS
MPLY
DIVIDE
X2
X5
TENTHS
SKIP OUT
PLUS
MINUS
READ OUT
RESET
NB
COUNTER CONTROL
READ IN
STORAGE CONTROL
PUNCH
CO SELECTORS
BUS
1ST COL PUNCH
1ST COL STOR
BAL TEST
DIVISOR MULTIPLIER
N.B.
CHECK
STOP
11 OR 12
TIM STOP
X+
X−
STOR
X COL
PUNCH EMITTER
STORAGE P

Figure 49.

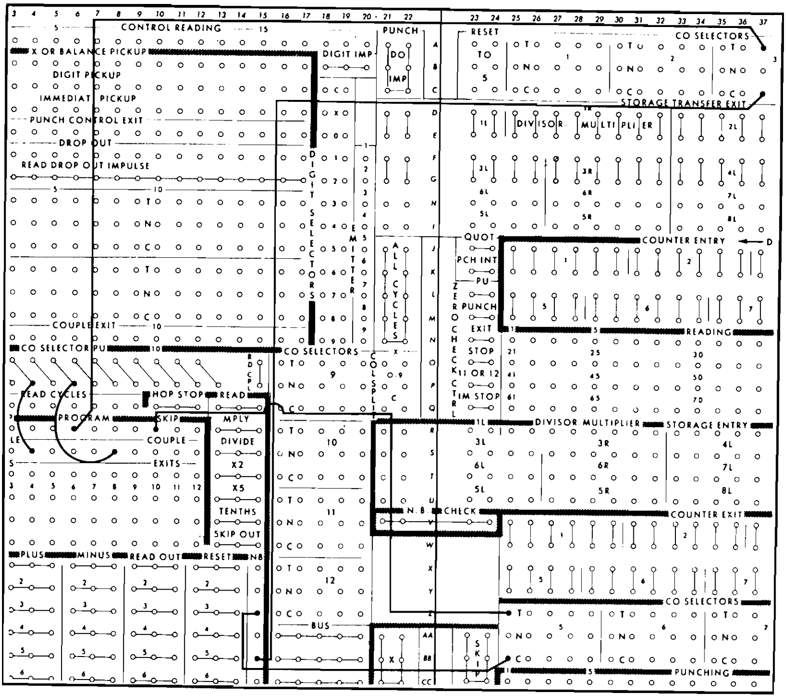


Figure 50.

(J-M, 25-44), STORAGE TRANSFER EXIT (D-I, 21-44), COUNTER EXIT (V-Y, 25-44) and the EMITTER (F-N, 20). (See Figure 42.)

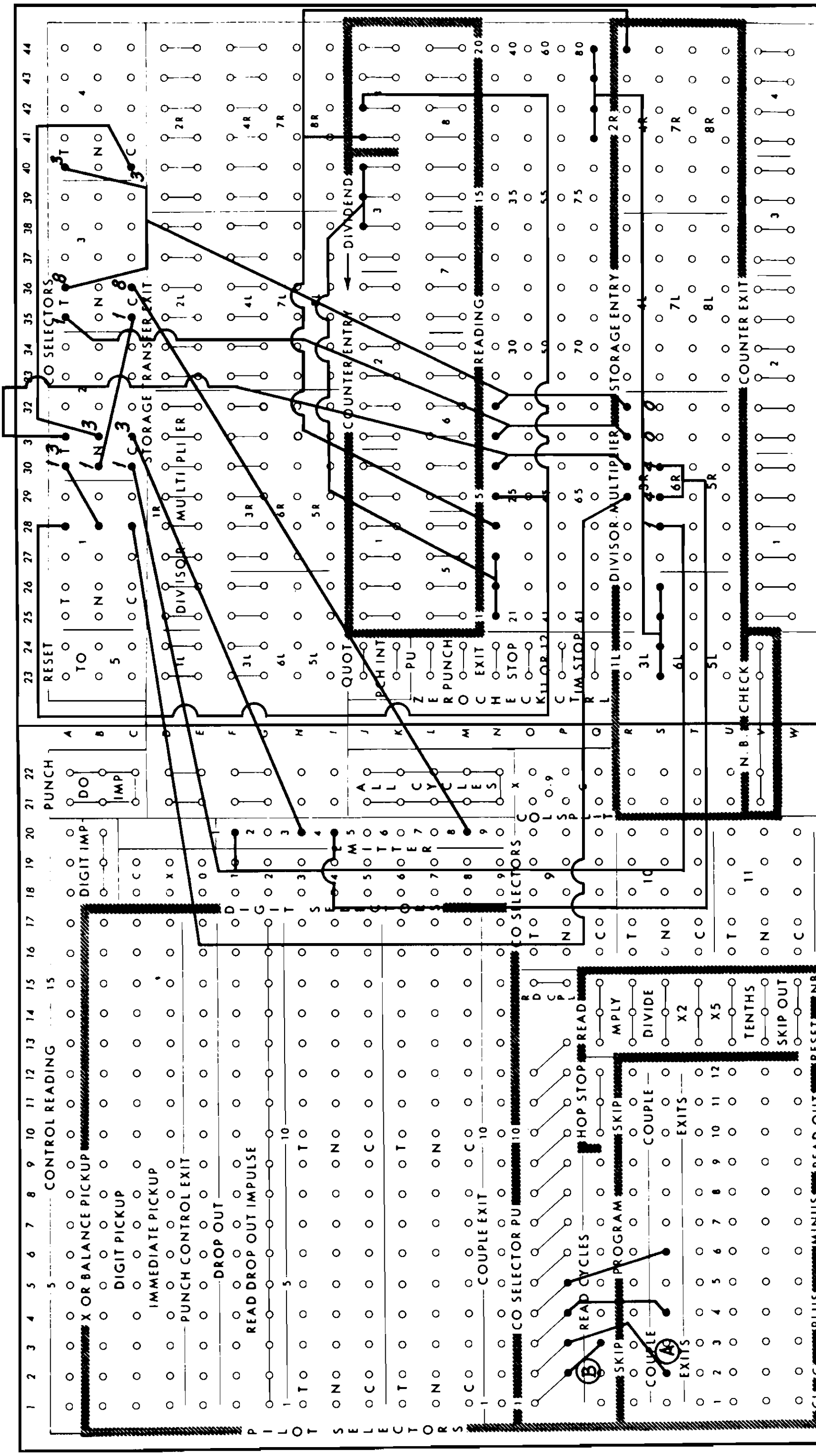
Wiring for Reading and Emitting

The reading hubs provide the data impulses during a read cycle. The storage exits and counter exits provide data impulses when they are instructed to read out. Storage entry and counter entry are receptive to data impulses when they are instructed to read in. The emitter provides impulses (digits 1-9) on *every* machine cycle automatically.

74. *Under what circumstances does the emitter emit the digits 1-9?*
75. *In addition to providing digit impulses to storage and counter entries, what else is required to allow the digits to enter?*

Figure 43 shows that the emitter is used four times—on the read cycle it provides 3R with 14400, on program step 2 it provides 1R with 1300, on program step 4 it provides 1R with 18, and on program step 6 it provides 1R with a 3.

In order to prevent the emitted digits from entering wrong positions, some of the emitted digits have to be *selected*. Figure 51 shows the



CONTROL READING
X OR BALANCE PICKUP
DIGIT PICKUP
IMMEDIATE PICKUP
PUNCH CONTROL EXIT
DROP OUT
READ DROP OUT IMPULSE
COUPLE EXIT
CO SELECTOR PU
CO SELECTORS
DIGIT IMP
PUNCH
RESET TO
STORAGE TRANSFER EXIT
DIVISOR MULTIPLIER
COUNTER ENTRY
DIVIDEND
QUOT
READING
STORAGE ENTRY
COUNTER EXIT
N. B. CHECK
HOP STOP
READ
MPLY
DIVIDE
TENTHS
SKIP OUT
PROGRAM
READ CYCLES
SKIP
COUPLE
EXITS
PLUS
MINUS
READ OUT
RESET

Figure 51.

control panel wiring necessary for reading the data from the two cards of each group, and emitting the data on the read cycle and various program steps, to storage and counter.

During the read cycle of an X31 card, storage units 1 and 2 are impulsed to read in. The units position of 2R receives its data from column 4. Storage unit 1R receives its data from reading columns 5-8. Notice that the hundreds, tens and units positions of 1R are also connected to various transferred positions of coselectors 2, 3 and 4. Since these selectors are normal during the read cycle, the wires from the transferred positions do not transport any impulses.

> 76. *Why doesn't the information in column 4 enter the thousands position of counter 4?**
>
> 77. *Why do none of the emitted digits enter 1R during the read cycle of either the X31 or NX31 cards?*

Reading 5 must be wired to the thousands position of 1R and to the hundreds position of counter 4. An emitted 1 must enter the thousands position of 1R on the second program step. On program step 2, counter 4 is impulsed to read in.

> 78. *Examine the proposed wiring in Figure 52. What is the source of the data that would enter the hundreds position of counter 4 on program step 2? The thousands position of 1R on program step 2?**

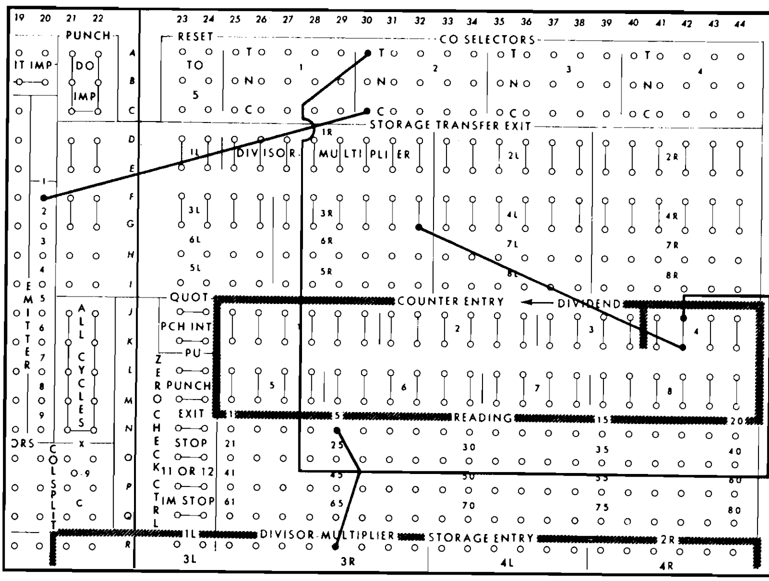


Figure 52.

The wiring diagram of Figure 51 shows how the condition mentioned in the answer to question 78 is eliminated. On program step 2, coselector 2 is transferred (see Ⓐ, Figure 51), and coselector 1 is normal (see Ⓑ, Figure 51).

79. *Why is coselector 2 normal on program step 2?**
80. *Draw a line (preferably with a red pencil) from the units position of 3R exit to the hundreds position of counter 4 entry.*

The wiring now of Figure 51 (with your addition) has no back circuit. The emitted digit 1 is available only to the thousands position of 1R. Likewise, the digit impulse from 3R, available to counter 4 entry, travels over the wire to the fourth transferred of coselector 1, a dead end. Coselector 1 is transferred only on a read cycle, thus allowing column 5 to enter 1R when it is impulsed on the read cycle of an X31 card.

During the reading of a NX31 card, counters 3 and 4 are instructed to accept impulses from columns 1-5 and storage unit 3 is instructed to accept impulses from columns 77-80 and from the emitter.

On program step 2 when only coselector 2 is transferred, 1300 enters 1R; on program step 4 when only coselector 3 is transferred, 18 enters 1R; on program step 6 when only coselector 4 is transferred, 3 enters 1R.

Wiring the "Channels" for Calculation

Figure 53 represents the control panel wiring for transmitting data between various units during program steps 1-12.

The contents of 3L are transmitted to the units, tens, hundreds and thousands positions of counter 6 for multiplication by wiring marked ①.

The contents of counters 5 and 6 are transmitted to 4R and the contents of 3R are transmitted to counters 3 and 4 by the wiring marked ②.

The contents of counters 5 and 6 are transmitted to counter 2 multiplication by the wiring marked ⑤.

The contents of counter 2 are entered into 6R by the wiring marked ⑥.

The contents of 4R enter counters 3 and 4 for multiplication by wiring marked ⑦ and (7a). The contents of 4R enter counter 1 by way of (7b) and (7c) to the common of selector 8. Selector 8 is normal on program step 7 and therefore the contents of 4R enter the units, tens, hundreds, thousands and ten thousands positions of counter 1.

The contents of 4R are transmitted over the same wiring used for program step 7, plus the wiring marked ⑧ to enter counters 5 and 6.

On program step 9, coselector 8 is transferred. The contents of

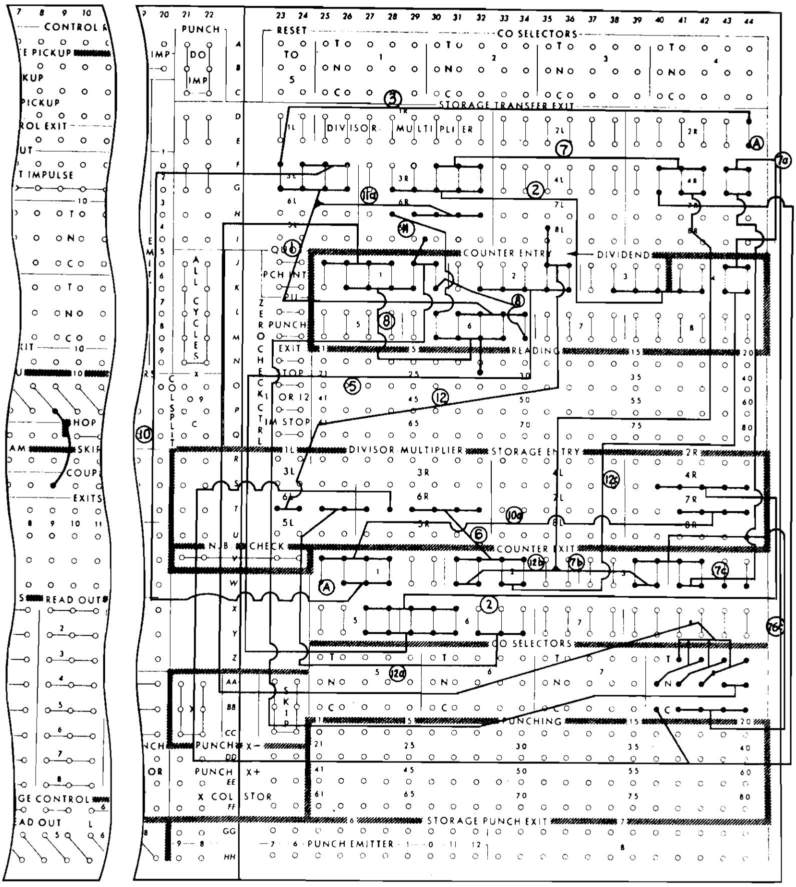


Figure 53.

counters 3 and 4 are transmitted over the wiring marked (7bc) and enter the common of selector 8. The impulses come out of the transferred positions and enter the hundreds, thousands, ten thousands and hundred thousands positions of counter 1.

The contents of counter 1 are transmitted to 7R by wiring marked (10a) and to counters 5 and 6 via wiring marked (10) and (1). Also, the high-order position of counter 1 finds its way to counter 6 by way of (3) and (1). (To indicate this, draw a red line between the (A)'s located at counter 1 exit and the exit of 2R.)

The contents of 6R enter counters 5 and 6 by way of the wiring marked (11) and (11a) and (1).

The contents of counters 5 and 6 enter 6L by wiring marked (5) and (12) and (12a). The contents of 4R enter 6R by wiring marked (12b) and (7a) and (12c).

Wiring for Reset-to-5

The planning chart indicates that counter 1 is to be reset-to-5 on program step 10, counter 2 is to be reset-to-5 on program step 6, and counters 5 and 6 are to be reset-to-5 on program step 12.

As was previously mentioned, all six reset-to-5 hubs (A-C, 23-34) emit an impulse whenever *any* counter is reset. Thus there should be a path for the reset-to-5 impulse to the counter entry position only on the step on which the specific counter is to be reset to 5. Figure 54 shows the wiring for resetting the required counter positions to 5.

The tens position of counter 1 receives a reset-to-5 impulse only on step 10. This is accomplished by wiring program couple 10 to the Immediate pickup of selector 2. (When the Immediate pickup of a selector is impulsed, it acts just like a coselector and therefore does not have to be dropped out.) The reset-to-5 impulse is entered into the common and taken from the transferred position to the tens position of counter entry 1.

The tens position of counter 2 receives a reset-to-5 impulse only on step 6. This is accomplished by wiring a reset-to-5 impulse through the transferred points of coselector 4, which is picked up by program couple 6 (see Figure 51).

The hundreds position of counter 6 receives a reset-to-5 impulse only on program step 12. This is accomplished by wiring a reset-to-5 impulse through the transferred points of coselector 6, which is picked up by program couple 12 (see Figure 48). You now have the knowledge to analyze and set up many basic calculation problems for the 602.

You have probably arrived at the conclusion that there is much to learn about the 602 . . . this is correct. But remember this: The 602 is a data processing machine capable of performing many calculations, and full use of its capacity requires that all its characteristics be known.

Other Considerations—Balance Conversion

It has been previously indicated that a negative number in a counter appears in true (uncomplemented) form. When a value emerges from a counter during read-out, it changes to its nines complement. Thus a negative result appears in storage as a nines complement. (The 602 punches the negative results in complement form unless a control panel technique called "balance conversion" is used.)

81. *How would these five-position values appear in counter 1, a six-position counter: +03607, +41954, −78031, −98791, −10030, +10030?**

602 CALCULATING PUNCH CONTROL PANEL

WITH 8 COUNTERS & STORAGE UNITS

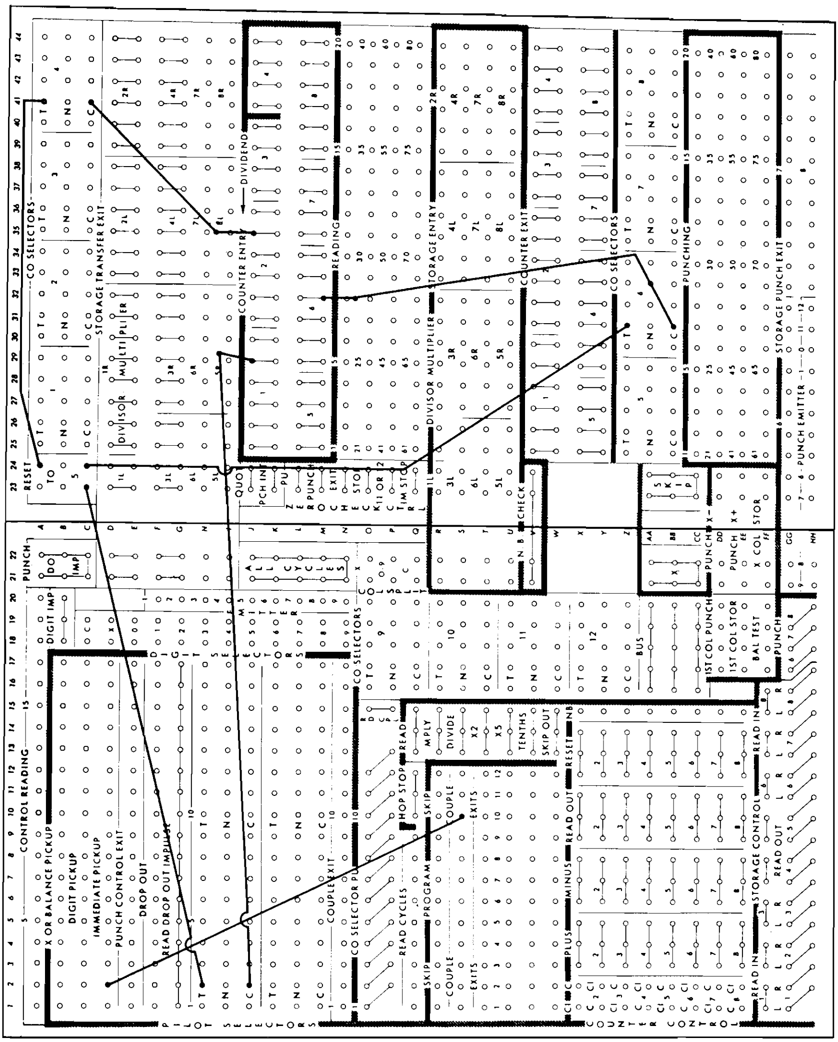


Figure 54.

The answer to question 81 shows that the hundred thousands position of the *counter* contains either a 9 (indicating that the value is positive) or a 0 (indicating that the value is negative).

> 82. *What would storage unit 6R look like if only five positions (the number of positions in the answer) were entered from the exit of counter 1? All six positions?**

Notice that when all six counter positions are read out, the hundred thousands position of storage unit 6R has either a 0, to identify a positive value, or a 9, to identify a negative value. When only the five-digit answer is read out, the hundred thousands position of storage unit 6R contains only 0 and there is no way of distinguishing a positive from a negative value. Thus it is always necessary to have one more position in a counter than is required to develop the answer when there is a possibility that the answer may be either plus or minus.

Figure 55 shows what control panel wiring is necessary to punch both plus and minus values as true figures and to identify a minus amount with an X punched over the units position.

The digit impulse (1) that is to be balance-tested is transmitted over this wire and is either a 0 or a 9. If it is a 9, the digit impulse from storage for punching the first column (2), is complemented and emerges from (3) to punch in column 5. The rest of the digits (4) are then automatically complemented, before punching columns 6, 7 and 8. The digit impulse from the units position of storage (5) is complemented and combined with an X impulse (6) to punch in column 9.

When the digit to be balance-tested is a 0, the digit impulse from storage for punching the first column (2) is *not* complemented and emerges from (3) to punch in column 5. Neither are any of the other digits (4) complemented. The digit impulse from the units position of storage is *not* complemented and does *not* combine with an X impulse before punching in column 9.

Checking Operations

The 602 uses a "zero check" method to verify a calculation from a previous run. The cards with the original factors and the calculated results are entered into the 602 a second time. Results are again calculated from the original factors. Then, the difference of the results is obtained and a series of two tests for algebraic sign is made. If the results of the test are unfavorable, the 602 can be instructed to stop (and not to stop if favorable). Or, the 602 control panel can be set up to punch either an X in a chosen column if the test is unfavorable, or a 12 if the test is favorable. When this method is used, a needle sort can be employed to separate the good cards from the bad cards. Also, punching either an X or 12 is a more positive way of identifying the good and bad cards.

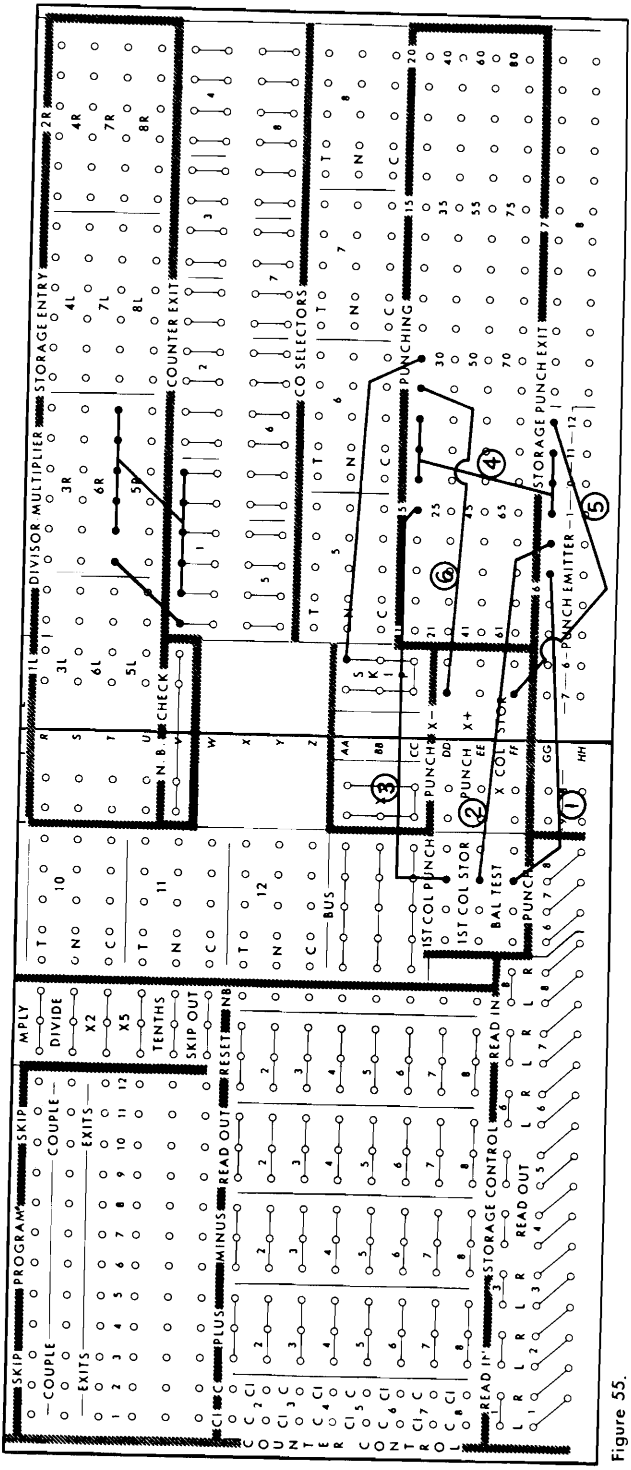

SKIP
PROGRAM
COUPLE
EXITS
MPLY
DIVIDE
X2
X5
TENTHS
SKIP OUT
PLUS
MINUS
READ OUT
RESET
NB
COUNTER CONTROL
READ IN
STORAGE CONTROL
READ OUT
BUS
1ST COL PUNCH
1ST COL STOR
BAL TEST
PUNCH
X COL STOR
X−
X+
N. B. CHECK
DIVISOR MULTIPLIER
STORAGE ENTRY
COUNTER EXIT
CO SELECTORS
PUNCHING
STORAGE PUNCH EXIT
PUNCH EMITTER
SKIP

Figure 55.

Answers to Asterisked Questions

1. The product of 38.65 (hours) times 2.625 (rate) is 101.45625. Rounded off to the nearest penny, the result is 101.46.

2. For (a), 40.00 (hours) times 1.40 (rate) equals 56.0000 (gross pay) rounded off to 56.00. The employee has five dependents, thus:

$$13.00 \times 5 = 65.00 \text{ is tax-exempt.}$$

The difference between calculated gross pay and the exempt amount is

$$56.00 - 65.00 = -9.00$$

and therefore his gross pay is not large enough to have anything deducted from it.

For (b), 36.25 (hours) times 2.25 (rate) equals 81.5625 (gross pay) rounded off to 81.56. The employee has five dependents, thus:

$$13.00 \times 5 = 65.00 \text{ is tax-exempt.}$$

The difference between calculated gross pay and the exempt amount is

$$81.56 - 65.00 = +16.56$$

Eighteen percent of this non-exempt amount is 2.98 and is the amount to be deducted for FIT.

3.

					Current			
Employee Number	Hours	Rate	YTD FICA	T/C	FICA	FIT	GROSS	NET
00001	*40.00*	*2.550*	*108.90*	*2*	***3.06***	***13.68***	***102.00***	***85.26***
00002	*40.00*	*2.625*	*143.17*	*4*	***0.83***	***9.54***	***105.00***	***94.63***
00003	*40.00*	*2.850*	*144.00*	*3*	***0.00***	***13.50***	***114.00***	***100.50***
00004	*40.00*	*2.500*	*144.00*	*8*	***0.00***	***0.00***	***100.00***	***100.00***
00005	*40.00*	*2.050*	*79.50*	*0*	***2.46***	***14.76***	***82.00***	***64.78***

8. The following indicates the number of possible combinations using various quantities of combined tubes. 0 indicates off; 1 indicates on.

Two Tubes

A	B
0	0
0	1
1	0
1	1

Three Tubes

A	B	C
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

Four Tubes

A	B	C	D
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1
1	0	0	0
1	0	0	1
1	0	1	0
1	0	1	1
1	1	0	0
1	1	0	1
1	1	1	0
1	1	1	1

Four combinations are possible with two tubes, eight combinations with three tubes, and 16 combinations with four tubes. Since the decimal number system comprises ten different characters (1, 2, 3, 4, 5, 6, 7, 8, 9, 0), a set of four tubes is required to represent all of the ten different decimal digits. The last six combinations are invalid and do not appear on the IBM 604. In order to better evaluate the combination, the "names" of the tubes are changed from A, B, C, D, to 8, 4, 2, 1. In order to determine the decimal value, then, merely add up those "names" which have a 1 ("on" condition).

N	1	0	1	0	1	0	1	0	1	0	1
A	2	0	0	1	1	0	0	1	1	0	0
M	4	0	0	0	0	1	1	1	1	0	0
E	8	0	0	0	0	0	0	0	0	1	1
		0	1	2	3	4	5	6	7	8	9

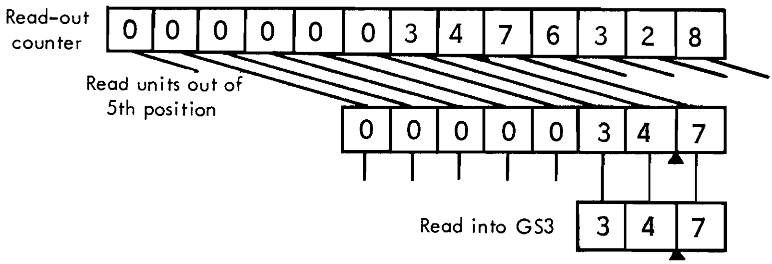
9. The maximum number of positions that can be stored from a card being read is 37—that is, 16 to factor storage, 16 to general storage, and 5 to the MQ unit.

11. (a) −376039821

(b) −9999632000357

(c) +367999642. Remember that a positive value in the 604 counter is represented by its nines complement. It is necessary to know this when checking out the calculator control panel with test cards.

15. The counter-channel-storage schematic for this operation is as follows:



As can be seen from the schematic, the four low-order positions of the counter are dropped.

17. Step 4 must be suppressed on an X31 card so that the hourly rate in the MQ unit is not "erased."

18. When step 6 is minus, the FIT amount to be stored is zero. Note that no matter what amount FIT may be calculated to be on steps 7, 8, 9 and 10, step 11 automatically wipes out the calculated amount. Thus it is all right to perform the calculations of steps 7-10 even though step 6 is minus.

19. The emitter used during card reading provides storage with digits by means of control panel wiring. The emitting is done in synchronism with the reading of the rows of the card—that is, a 0 is emitted during the reading of the 0 row, a 1 is emitted during the reading of the 1 row, etc. These emitted digits are entered into the required number of storage positions by control panel wires inserted by the person wiring the control panel.

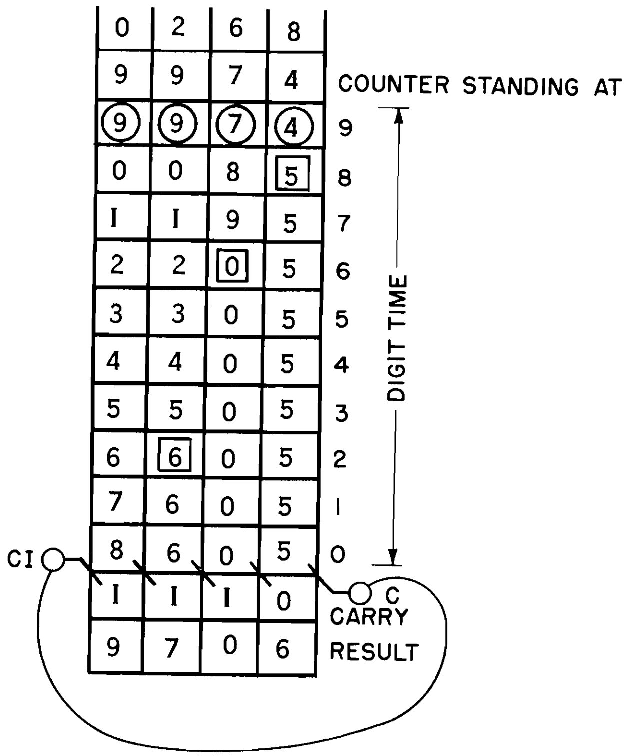
The emitter used during calculation provides storage or counter with electronic digits by means of the common channel. The electronic digits are all emitted simultaneously (whereas the emitter used during card reading emits the digits in order). Since there is no external control possible over the channel, only one of the nine simultaneously available electronic digits can be carried by the channel at a time. Thus, if it is required to emit three digits (as in this case), they must be emitted on separate steps because there is no way of indicating which storage position is to receive which digit of the multi-digit group.

20. It must be determined *before* a card arrives at the punches, that punching is to be suppressed. The station before punching is first reading. Thus an impulse originating at first reading and wired to a punch suppress hub sets up the punch suppression mechanism so that when

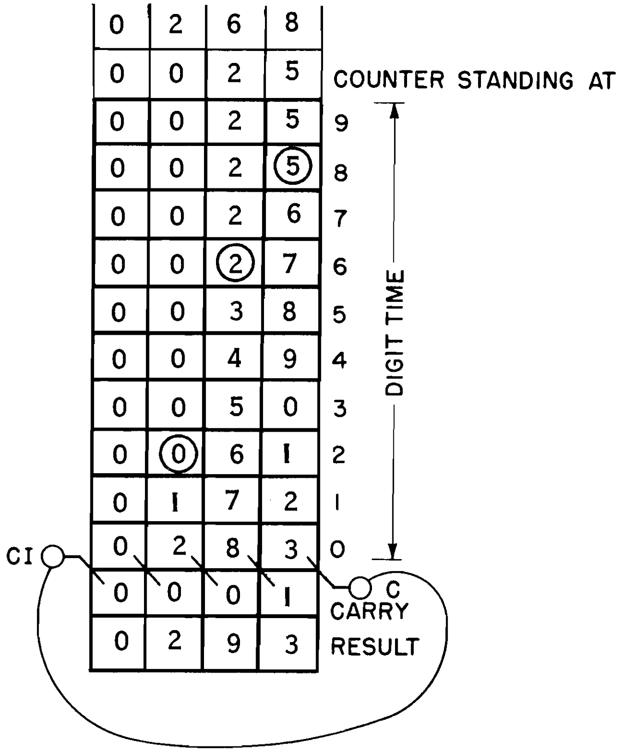
the card in question reaches the punches, punch suppression will be effective for one cycle.

21. In the discussion just prior to question 20, it was stated that the punch suppress hubs recognize any digit- (0-9), X-, and 12-timed impulses. When the YTD card is read at first reading, column 31 provides a digit impulse. Unless this digit impulse is eliminated, the punches will be suppressed each time a YTD card passes under them. By wiring the extension of first reading through a column split, the digit impulses are eliminated and only the 11-timed impulse emerges to impulse punch suppress.

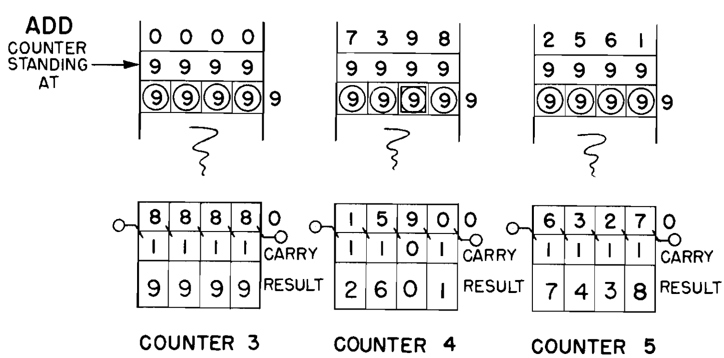
44.



45.


0 2 6 8
0 0 2 5
COUNTER STANDING AT
0 0 2 5
0 0 2 5
0 0 2 6
0 0 2 7
0 0 3 8
0 0 4 9
0 0 5 0
0 0 6 1
0 1 7 2
0 2 8 3
0 0 0 1
0 2 9 3
9
8
7
6
5
4
3
2
1
0
DIGIT TIME
CI
C
CARRY
RESULT

46.


ADD
COUNTER STANDING AT
0 0 0 0
9 9 9 9
9 9 9 9 9
8 8 8 8 0
1 1 1 1
CARRY
9 9 9 9
RESULT
COUNTER 3
7 3 9 8
9 9 9 9
9 9 9 9 9
1 5 9 0 0
1 1 0 1
CARRY
2 6 0 1
RESULT
COUNTER 4
2 5 6 1
9 9 9 9
9 9 9 9 9
6 3 2 7 0
1 1 1 1
CARRY
7 4 3 8
RESULT
COUNTER 5

54. If counter 5 is minus on step 4, it signifies that the tax-exempt amount is greater than the gross pay and thus the FIT amount should be zero.

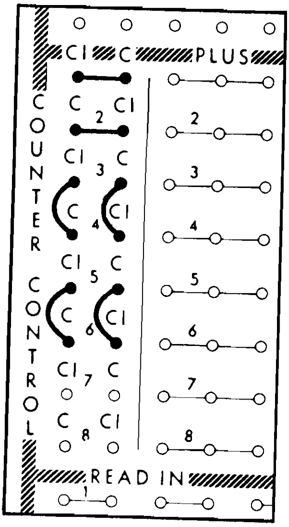
Because step 5 is skipped when counter 5 is minus on step 4, no product is developed in counter 2 and thus counter 2 remains at zero.

Then on step 6, when counter 2 is read out (and reset), it contains only zeros.

55. A counter which provides the multiplicand on a multiply operation must never be reset during the multiplication operation.

56. See pages 86, 87.

57.



58. The X must be detected at a previous reading station (the control reading brushes) for use in controlling a selector through which the read cycles impulses are wired.

65. The small inserts must be placed into slot numbers 39 and 63. An insert is not required in slot number 43 because, after column 42 is punched, the card advances to the next required column when another punch instruction is given.

67. These are similar in that they all last the same length of time. (Each has an early portion and a late portion as shown in Figure 44.) They differ in that all cycles occur 200 times a minute or once for every machine cycle, read cycles occur only when a card passes the reading brushes, and program exits emit when the particular program steps are being taken.

56.

APPLICATION #56 144.00

PROBLEM

IBM

INTERNATIONAL BUSINESS MACHINES CORPORATION
PLANNING CHART: 602 CALCULATING PUNCH
WITH 8 COUNTERS & STORAGE UNITS

Form X26-6040-2
Printed in U.S.A.

Program Suppress	Prog. Step	Operation	Storage Unit 1L	Storage Unit 1R (Divr.-Mult.)	Counters (Dividend 1–3; 4, 5, 6, 7, 8)	Storage Units (2L, 2R, 3L, 3R, 4L, 4R, 5L, 5R)	Punch Units (6L, 6R, 7L, 7R, 8L, 8R) *Units position must be wired to punch
		READ CYCLE			Ctr 3–4: 14400	3R: 14400	
	1						
	2	RO3R Ctr 3,4−			Ctr 3–4: 00000000		
	3					4R: 10146	
	4						
	5						
	6			.03			
	7	RO4R MPLY Ctr3,4+ Ctr1,+			Ctr 1: 030438 / 030438; Ctr 3–4: 00000000 / 00030438		
IF −, SKIP TO STEP 10	8	RO4R Ctr5,6,+ BAL TEST 3			Ctr 5–6: 10146		
	9	ROR3,4 Ctr1,−			Ctr 1: 000038; Ctr 3–4: ROR		
	10	ROR1 RI7R, PCH Ctr 5,6−			Ctr 1: ROR; Ctr 5–6: 000 / 10146		7R: RI ↓ 43-46; 000
	11						
	12						

56. continued

APPLICATION #56 $142.79 PROBLEM

IBM INTERNATIONAL BUSINESS MACHINES CORPORATION
PLANNING CHART: 602 CALCULATING PUNCH WITH 8 COUNTERS & STORAGE UNITS

Form X26-6040-2
Printed in U.S.A.

Program Suppress	Prog. Step	Operation	Storage Unit 1L	Divr.-Mult. 1R	Counters: Dividend 1–2	Counters 3–4	Counters 5–6	Ctr 7	Ctr 8	Storage 2L	2R	3L	3R	4L	4R	5L	5R	Punch Units 6L	6R	7L–7R	8L	8R
		READ CYCLE				14279							14400									
	1																					
	2	RO3R Ctr 3,4–				14400 -00121																
	3														10146							
	4																					
	5																					
	6			.03																		
	7	RO4R MPLY Ctr 3,4+ Ctr 1,+			030438 030438	-00121 +0018338																
IF – SKIP TO STEP 10	8	RO4R Ctr 5,6,+ BAL TEST 3					10146															
	9	ROR 3,4 Ctr 1,–			012138	ROR																
	10	ROR 1 RI 7R, PCH Ctr 5,6–			ROR		121 10025													RI ↓43-46 121		
	11																					
	12																					

*UNITS POSITION MUST BE WIRED TO PUNCH

72. It may turn negative during steps 1 and 3 even when the result at the end of the program step is positive. This is because of the multiplication technique employed by the 602.

Therefore, a coselector picked up with program couple 4 must be used, through which the NB impulse of counter 5 is wired.

A similar situation exists with counter 3. Therefore a coselector picked up with program couple 8 must be used, through which the NB impulse of counter 3 is wired.

76. Because counter 4 is not instructed to read in on an X31 card.

78. The wiring indicates that there is a path for the emitted 1 to counter 4 and storage unit 1R. Likewise, there is a path from 3R to counter 4 and storage unit 1R. Thus the digit-timed impulse that occurs *first* enters both 1R and counter 4 (on the 602, 9 time occurs first followed, in order, by 8 time, 7 time, etc.). For example, if 3R has a 7 in the units position, it enters 1R and counter 4; if 3R has a 0 in the units position, the emitted 1 enters 1R and counter 4. Thus it is necessary to "break the circuit" to eliminate this undesirable condition.

79. A coselector is transferred for the cycle on which it is picked up. Since coselector 2 is picked up on read cycles, it is normal on every cycle *except* read cycles.

81. (a) 996392 (b) 958045 (c) 078031 (d) 098791 (e) 010030 (f) 989969

82. Storage unit 6R would appear as

5 positions:	003607	041954	021968	001208	089969	010030
6 positions:	003607	041954	921968	901208	989969	010030

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International Business Machines Corporation
Data Processing Division
112 East Post Road, White Plains, New York

Printed in U.S.A. 320-1447