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By-Larsen, Lawrence A.

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This programed instruction course gives a basic introduction to solid state programing equipment. Course objectives include giving the student (1) a working knowledge of the various types of units used in building digital logic control systems and (2) an idea of how they interconnect to perform different functions. The course has no prerequisites and begins with basic concepts in electricity and electronics. Ideas developed include analog and digital concepts, binary numbers, the logic signal, the input, output and logic portions of a digital logic subsystem, programing strategems, and the design and solution of design problems. Review exercises for each section and a separate booklet of figures which refer to the program sequence are also provided. (GR)

N-X

IMRID

INSTITUTE ON MENTAL RETARDATION AND INTELLECTUAL DEVELOPMENT

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GEORGE PEABODY COLLEGE FOR TEACHERS/NASHVILLE, TENNESSEE 37203

AN INTRODUCTION TO LOGIC CONTROL SYSTEMS FOR THE BEHAVIORAL SCIENTIST

PART I - TEXT

by

Lawrence A. Larsen

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The author would like to gratefully thank the BRS-Foringer Company for permission to use portions of their Bits of Digi handbook, by Ronald C. Ray, in the construction of this program. Most of the circuit diagrams, as well as much of the explanatory frames on how they work, were obtained from this source.

Special thanks is also extended to Dr. William A. Bricker, under whose guidance this program was written. The original draft was developed in conjunction with a course in Programed Instruction, taught by Dr. Bricker.

This program was written while the author was supported by NICHHD Grant HD-43. Additional support, in the form of BRS logic units for the trainer, was obtained from NICHHD Grant HD-973.

I would also like to gratefully acknowledge the help of Evylin Herrell, who translated, organized, and typed an unwieldy manuscript into coherent, readable form.

Finally, to those hardy souls who served as students to test the original form of this program, namely Don Bartlette, Bill Dragoine, Mike Irwin, Tom Martin, Wayne Fox, Mike O'Malley, and Mike Brown -- thanks for a difficult job well done!

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INTRODUCTION

This course is aimed at giving you a basic introduction to solid state programming equipment, with special reference to the line of units manufactured by BRS Electronics, Inc. The course's objective is to give you a working knowledge of the various types of units used in building digital logic control systems, and some idea of how they are interconnected to perform the functions required by the experimenter. You should not expect to be able to design, build, and troubleshoot a sophisticated system at the end of this course -- this will probably come only with practice. You should, however, be able to understand the functions of each unit, how relatively simple circuits operate, and develop a background which will facilitate obtaining greater proficiency with logic systems.

No prerequisites are required for this course, other than an ability to read and a motivation to learn its contents. It is especially designed for those who do not have backgrounds in electricity or electronics. A short digression on basic concepts in electricity is included following this introduction -- you are not required to read it, but you may find it helpful if you don't know a volt from an amp!

The self-teaching method used in this course requires that you carefully read each "frame" in turn and, if it is followed by a question, answer it. These answers can be made either mentally or, better yet, written down on a piece of scratch paper. You should try to give your own answer to each question before looking at the provided answer. The provided answers are separated from the questions by five asterisks, or "bullets." A card placed horizontally on the page can be used to cover the provided answers until after you have responded on your own.

Most frames require only a single word for an answer. Those that require more than one word, or a statement to be made in your own words, are marked with three asterisks. For example, the question, "What problems did you have with the course ______***______? " would require an answer in your own words.

Several short review exercises are provided to be used at the end of specific sections of the course. These are contained in the back of this booklet and you will be directed to them at appropriate points in the course. They are all of the "open book" variety.

This course is not easy, and you should expect to spend around 14 hours in its completion. It is recommended that you do not "let it go" for long periods of time. Rather some regular schedule -- say, perhaps 2 hours each day -- would insure you of the least difficulty with the course.

You can take "breaks" at any time in the program. Finishing the section you are currently working on first would probably be best, however.

A note should also be inserted concerning the "Trainer" -- that is, the standard set of units that should be available to the student for connecting his own circuits as instructed in the program. Although it is probably possible to take the program without the use of a trainer, this is not recommended. The experiences obtained from hooking-up -- and, indeed, trouble-shooting -- your own circuits will likely prove invaluable in developing proficiency in logic circuitry. The set of units used in this program are not the best possible choices for a trainer -- they are, rather, what was available to this writer at the time the program was being written. For those locations interested in setting up their own trainer, the following BRS units are recommended:

Quantity	Unit	Price
1	PS-12b Power Supply, 12VDC @ 1.4 amps	$ 140.00
1	CF-001 Table Top Rack	17.00
1	CF-201 Card File	160.00
1	CK-200 Standard Timing Capacitor Assortment	15.00
1	T-202 Taper Pin Insertion Tool	35.00
1	W-200 Taper Pin Wire Assortment	22.00
2	AG-203 AND Gate	26.00
1	AG-204 AND Gate	16.00
1	CX-205 Input Converter	20.00
6	FF-206 Flip Flop	90.00
2	ID-201 Indicator Light	32.00
1	IN-201 Inverter	10.00
1	MV-207 Multivibrator	30.00
2	OG-202 OR Gate	26.00
2	OS-202 One Shot	46.00
1	RS-201 Reset	10.00
1	RS-202 Reset	7.00
1	RY-205 Relay	42.00
	Total	$ 744.00

It should be noted that the above units, beyond being appropriate for student training, are also versatile enough to permit construction of many research control systems, e.g., various schedules of reinforcement, such as Sidman Avoidance, Fixed Interval, Escape, and so forth. As the BRS Company provides a lifetime guarantee for their logic units, the investment, relative to unit life and potential use, is minimal.

Additionally, the BRS Company does provide a complete trainer of 300 series units, the Model DA-8, which can be purchased as a unit. The 300 series differs from the 200 series, which is used in this program, in the means used in interconnecting the units. The 300 series, that is, uses front panel plug wires, while the 200 series uses rear connected taper pin wires. It is the opinion of this writer that the 200 series is the better of the two -- and on this basis it is suggested that the trainer be composed of 200 series units. In any case, the type of units should be compatible with those with which the student will be working in the future.

And now on to the program. Good luck!

BASIC ELECTRICITY

Electricity, or more precisely electric current, has to do with the movement of electrons in certain materials known as conductors. A conductor, for example copper, is a material which possesses large numbers of electrons, making it more likely that they can be easily dislodged from their atomic orbits -- that is, more easily moved.

A source of supply is essentially a combination of materials which produces high concentrations of electrons in one area (the negative pole) and a scarcity of electrons in another area (the positive pole). The battery is an example of a source of supply in which electrons are forced from one place, marked with a plus to denote the positive pole, to another, marked with a minus to denote the negative pole.

A most important factor in understanding electricity is that the positive pole has a great affinity for electrons, and that "free" electrons will be attracted to it. Likewise, the negative pole, which possesses large concentrations of electrons, repels other electrons. This can be summed up by saying that "opposites attract and likes repel."

Whenever a source of supply is connected to the two ends of an electric circuit, as shown in Figure A on the next page, the free electrons begin almost instantly to move along the wires (conductors). Their direction will be from the negative pole, which has a high concentration of electrons, toward the positive pole, which has a scarcity of electrons. The source, in this case a battery, keeps shuffling the electrons that it collects on its positive pole over to the negative pole. It will continue to do this until it becomes "dead."

The amount of current flow has, as its unit of measurement, the Amp. The amp is defined as a given number of electrons flowing past a given point in one second. More precisely, if 6.28 million, million, million electrons flow past a given point in one second, the current is one amp.

The amount of current flow is highly dependent upon both the force that is exerted by the source of supply and the resistance that the electrons encounter within the electric circuit. The force component is, of course, dependent upon the difference in the number of electrons between the positive and negative poles.

The resistance component is a function of the load in an electric circuit. It is the quality of the load to resist the movement of electrons through it.

The force component is measured in volts, and the resistance component in ohms. The relationship of volts, ohms, and amps is as follows:

> One volt is that force which will produce one amp of current in an electric circuit having a total resistance of one ohm.

This relationship is the basis for Ohm's Law, which states that voltage (E) is equal to the produce of current (I) times resistance (R), or: $E = I \times R$.

In our electric circuit (Figure A, next page) the voltage is the product of 2 amps times 30 ohms, or 60 volts. Given any two of these values, it is possible to determine the third. Notice too that as the resistance decreases, the current increases in electric circuits. In fact, as the resistance approaches zero the current approaches infinity -- hence the arcs and sparks associated with the familiar "short-circuit."

A convenient way to keep volts, ohms, and amps straight is to use the water tank analogy. In Figure B two water tanks are connected by a small pipe. There is, then, a force against the valve in the pipe that is determined by the amount of water in Tank A relative to Tank B. This force, measured in pounds per square inch, is analogous to volts. If the valve were opened, water would flow from Tank A to Tank B -- this would, of course, be analogous to electric current. The rate of flow, or amount of current, would be directly proportional to the size of the valve opening -- hence the size of the opening is analogous to electric resistance. Notice that if the opening were made as large as the tank itself, i.e, a short circuit, current flow would be maximum.

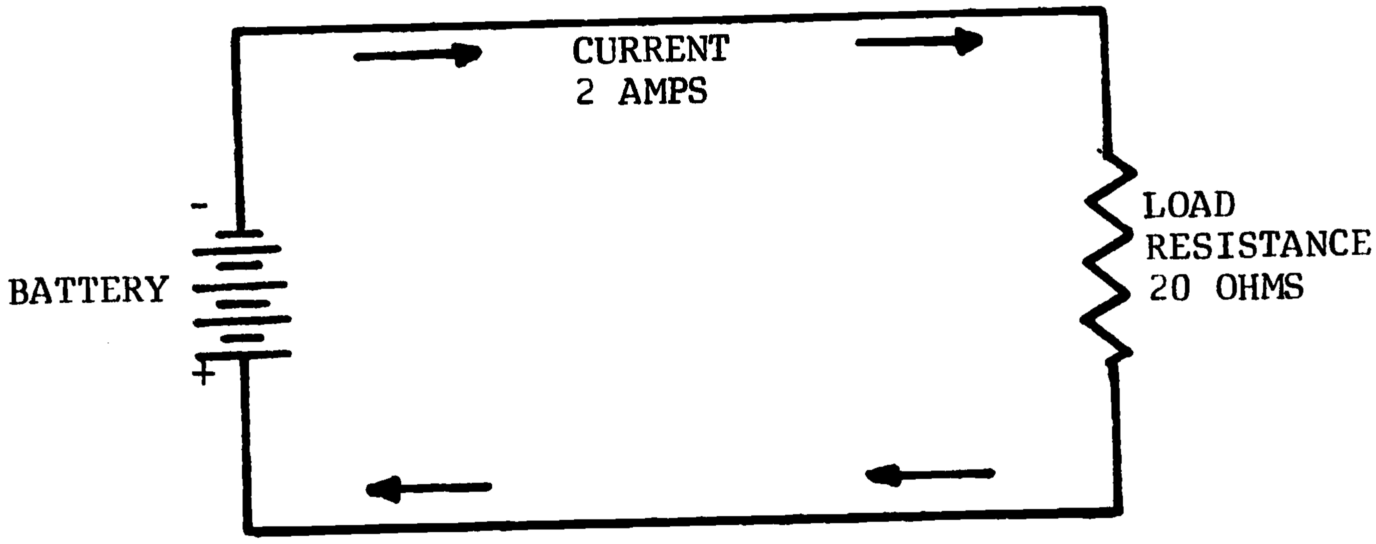


Figure A. Simple Electric Circuit

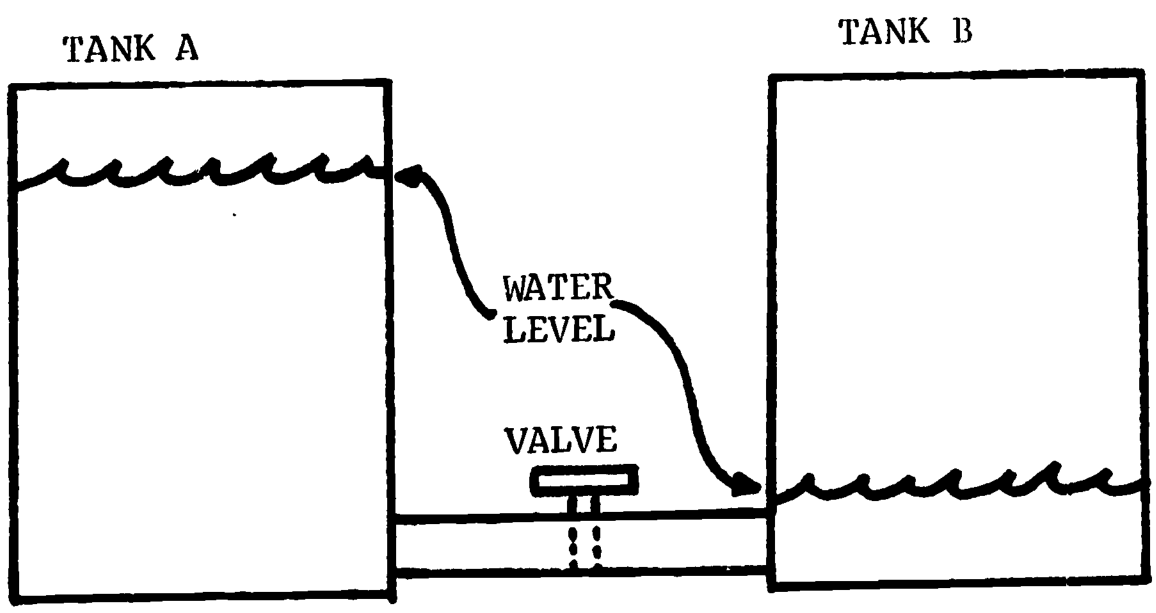


Figure B. Water Tank Analogy

PART I. INTRODUCTION TO THE RESEARCH SYSTEM

Have you read the introduction?

*****

If you have, continue to the next frame. If not, please take the time to read it before beginning.

1. The combination of a subject, his environment, and controlling devices is defined here as a <u>research system</u>. (See figure 1)

   A rat, a Skinner box, and a means for the systematic delivery of food pellets comprises a _______ _____.

*****

research system

2. (Refer to figure 1.)
   The research system is composed of two subsystems:
   (1) The Organism-Environment (O-E) Subsystem and
   (2) The Control Subsystem.
   In the skinner box example, the rat and the Skinner box together comprise the __________ Subsystem.

*****

O-E (organism-environment)

3. The behavior of the organism is a function of that particular organism in combination with his environment. If the environment were changed, then one possible effect would be a change in the organism's _______.

*****

behavior

4. The behavior of the organism always influences his environment in some way. Even minute movements influence the air surrounding him. All behavior has some effect on the ________.

*****

environment

5. In figure 1, several arrows are shown pointing away from O (the organism). These denote the effect of the organism's __________ on his environment.

*****

behavior

6. It is necessary, in systems of this type, to select certain specific responses that are easily measured and unequivocal for study. Using the Skinner box as an example, a switch closure produced by a bar pressing response is used because it is ________ __________ and __________.

*****

easily measured
unequivocal

7. Points a, b, and c in Figure 1 represent three aspects of environmental change that are produced by the organism's behavior and which are under study in this system. Points a, b, and c are __________ changes produced by the organism's __________.

*****

environmental
behavior

8. Remember that the responses to be used in any system of this type must produce easily measured and unequivocal environmental effects. Points a, b, and c, then, represent environmental changes that are both ________ ________ and __________.

*****

easily measured
unequivocal

9. Moving on now to the Control Subsystem, which accepts these environmental, behavior-produced changes as its input (see g, h, and i in Figure 1.), the switch closure in our Skinner box example would be an __________ event to the control subsystem.

*****

input

10. The function of the control subsystem is to actually alter the organism's environment in a predetermined manner. The output events (j, k, and l of Figure 1) of the control subsystem ________ the subject's environment.

*****

alter (change)

11. The influences of the environment on the organism's behavior are shown by the arrows pointed toward O and from E. Three of these points (d, e, and f) are controlled by the control subsystem. In other words, the ________ events of the control subsystem alter the environment at points d, e, and f.

*****

output

12. You may have realized by now that the control subsystem output events are determined by the input events. In other words, the subject's environment is in part determined by his __________, which is the input to the control subsystem.

*****

behavior

13. Altering a subject's environment as a function of his behavior is one basic method in psychology. The common aspect to all forms of this method is that the environment is altered on the basis of the subject's __________, and that the subject's behavior changes as a function of these environmental alterations.

*****

behavior

To review, what we have here is a closed loop. The organism's behavior, which is a function of his environment, is the input to the control subsystem. The control subsystem, in turn, alters the organism's environment as a function of this behavior

14. Research programs specify, in advance, the relationships between behavior and environmental changes. Such advance specification is termed dynamic pro_ _ _ _ _ _ _ _.

*****

programming

15. Dynamic programming refers to specified relationships between organism behavior and environmental alterations, in the special case where the environment is in part determined by behavior. If the environment were programmed, but not free to vary, it would not be dy_ _ _ _ _.

*****

dynamic.

16. In summary, dynamic programming refers to alterations made to the O-E subsystem on the basis of the organism's behavior. The environment, then, is in part a function of the subject's ________.

*****

behavior

17. Referring to Figure 1, it could also be said that dynamic programming is the advance structuring of relationships between control subsystem ________ events and __________ events.

*****

input
output

18. The control subsystem accepts subject responses and, on this basis, alters the subject's environment. It is this subsystem that forms the subject matter of this program, and it is the devices that compose this subsystem that are p_ _ _ _ _ _ _ _ _ _.

*****

programmed

19. In this first section we have used a rat, a Skinner box, and a reinforcement control mechanism as an example of a research system. Another example is the Wisconsin General Test Apparatus (WGTA)* where the subject, the WGTA, and the experimenter comprise the __________ __________.

*If you are not familiar with the WGTA please omit frames 19 through 22.

*****

research system

20. In this case the subject and the WGTA taken together comprise the ___________ subsystem.

*****

O-E

21. In the case of the WGTA, it is the experimenter that forms the control subsystem, as it is the _________ who determines what stimuli are presented, the manner in which they are presented, and the reinforcement characteristics of the situation.

*****

experimenter

22. Many WGTA programs are so devised that the behavior of the subject determines future WGTA environments. For example, as the subject solves one problem he is normally given a new, novel problem. Just as with the Skinner box, then, the subject's behavior in some measure determines his future _______.

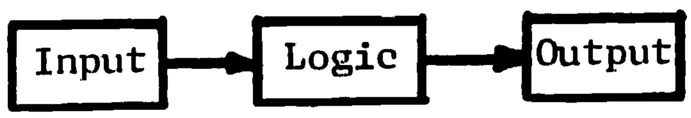
*****

environment

23. This example of the WGTA illustrates a very important fact: The control subsystem does not have to be composed of wire and metal and sophisticated looking electronic devices. The control subsystem can indeed be human. Human and non-human control subsystems each have their own advantages and disadvantages. This program, however, is concerned with non-human rather than human systems, so the latter will be omitted from future discussions.

(no answer required)

24. Most control subsystems can be broken down into three portions: input, logic, and output.



The input portion accepts subject r_ _ _ _ _ _ _ _, and the output portion alters the subject's e_ _ _ _ _ _ _ _ _ _.

*****

responses
environment

25. Taken together, the input and output portions are termed interface units. (See figure 1) The interface portions of the control subsystem mediate between the organism-environment subsystem and the lo_ _ _ portion of the control subsystem.

*****

logic

26. Because they intervene between the faces of the logic portion and the O-E subsystem, the input and output portions are termed __________ units.

*****

interface

27. The input portion of the control subsystem accepts subject responses and modifies them into a form acceptable to the logic portion. From figure 1 you can see that converting switch closures, for example, into a form acceptable to the logic portion would be a function of the __________ portion.

*****

input

28. The translation of logic portion activity into actual environmental changes is the function of the output portion. For example, if the logic portion signals that a reinforcement is to be delivered, the actual delivery would be a function of the __________ portion.

*****

output

29. Converting input events into logic activity is a function of the __________ portion, and converting logic activity into environmental change is a function of the __________ portion.

*****

input
output

30. The portion of the control subsystem that could be best described as the "brains" of the system is the _________ portion.

*****

logic

31. Taken together, the Input, Logic, and Output portions form a ______***______. (Look at figure 1)

*****

control subsystem

Perform Exercise 1 in the back of this booklet.

PART II. ANALOG AND DIGITAL CONCEPTS

32. It is apparent that most control subsystems require input events that are essentially discrete in nature. Behavior, however, rather than being discrete is cont_ _ _ _ _ _ in nature.

*****

continuous

33. Information that is continuous in form is termed analog information. A motion picture of a behaving organism yields __________ information (as perceived by the viewer).

*****

analog

34. Analog information that has been sampled often and quantified into discrete numbers is called digital information. Recording the rate of a specified response while watching a motion picture yields __________ information.

*****

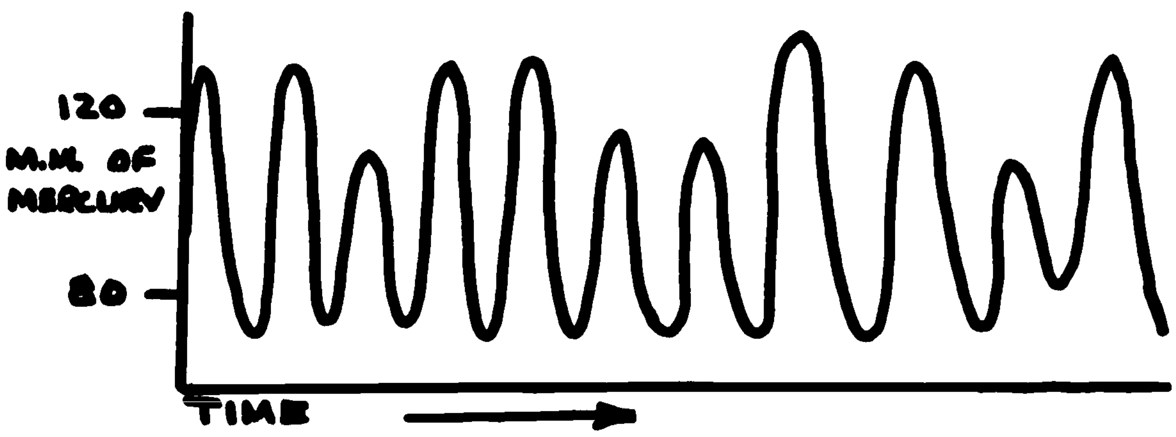
digital

35. Analog is to continuous, as __________ is to discrete.

*****

digital

36. A graphic representation of a subject's blood pressure is also an example of __________ information. It may look like this:



*****

analog

37. To meaningfully describe the above blood pressure record requires, however, that it first be converted into some form of _________ information.

*****

digital

38. We could, for example, record the number of times that the pressure goes over a specific value, such as 120 mm. of mercury. In so doing we have converted from _________ information (pressure) to _________ information (frequency count per unit time).

*****

analog
digital

39. But, more precision would be obtained, wouldn't it, if we set two or more values, and recorded the number of times that the pressure went over each?

*****

Question is rhetorical, and requires no answer.

40. We could, for example, record the number of times that the pressure exceeded 115 mm, 120 mm, and 125 mm of mercury. This would more accurately describe the "true" state of affairs regarding the subject's blood pressure.

41. This illustrates a basic fact about analog to digital conversion. In sampling analog information, discontinuity is introduced as a function of the rate at which the data are sampled. If the time interval between samples is reduced, this discontinuity will also be _______.

*****

reduced

42. If the sampling interval is reduced to zero, _________ information will be retained intact, as we would then record continuous behavior intact.

*****

analog

43. To summarize, the organism, in the research system, continuously generates _________ information.

*****

analog

44. Whenever analog information is converted into digital form, some information is necessarily lost. The researcher must choose, then, between large amounts of unwieldly _________ information and, by necessity, incomplete _________ information.

*****

analog
digital

45. The experimenter can either record, to the best of his ability, this analog data intact, or he can select out certain portions of it, with reference to a time base, thereby obtaining _________ information.

*****

digital

46. A rat in a Skinner box is continuously generating _________ information, as he is continuously behaving.

*****

analog

47. When we specify a given response to use as an input to the control subsystem, for example a switch closure produced by a physical force of specified magnitude, we have sampled this analog information in a _________ manner.

*****

digital (discrete)

PART III. THE BINARY NUMBER SYSTEM

48. Early number systems were unwieldly and awkward to use. One of the simplest, a mark for each unit, cannot be used to express large quantities. A later improvement, Roman Numerals, overcame this disadvantage, but was not amenable the operations of simple arith _ _ _ _.

*****

arithmetic

49. With the Arabic, or decimal, number system common arithmetic operations can be easily defined and used. An advantage of the decimal system, then, is the ease with which __________ operations can be performed.

*****

arithmetic

50. A basic featu e of the Arabic system is that the operations correspond to true life operations. Just as the input portion codes events into logic activity, so the Arabic system __________ real life operations into arithmetic operations.

*****

codes

51. The decimal system uses ten symbols representing the quantities 0 through ___.

*****

9

52. Other numbers are constructed by assigning different values or weights to the postion of the symbol relative to the decimal point. The value of a number, then, is dependent upon its __________ relative to the decimal point.

*****

position

53. The quantity represented by a decimal number, then depends upon its __________ relative to the decimal point.

*****

position

54. For example, the number 008. represents the quantity eight units, while the number 080. represents the quantity eighty units. The quantity represented, therefore, depends on the __________ of the number relative to the decimal point.

*****

position

55. From this we can see that each position in a decimal number has a value which is ten times that of the next position to the right. Thus, the value of 080. is ___ times that of 008.

*****

10

56. Moving a number one position closer to the decimal point is the same as __________ that number by 10. Thus 080. divided by ten equals 008.

*****

dividing

57. In sum, each <u>position</u> relative to the decimal point has a weight. This <u>positional</u> <u>weight</u> is determined by the <u>number of</u> <u>symbols</u> used in the number system. Because the decimal system uses 10 symbols, each position has a weight that is some multiple of ____.

*****

10

58. In the decimal system, the positional weights are determined by the fact that ten __________ are used in the system.

*****

symbols

59. In the decimal system every positional weight is a multiple of ten and can be expressed by ten raised to some power.

The ones position is 10^0
The tens position is 10^1
The hundreds position is 10^2
The thousands position is ___

*****

10^3

60. The progression of increasing exponents can be continued as far as desired to the left of the decimal point. Each position to the left increases the value of the <u>exponent</u> by ___, which increases the <u>weights</u> in multiples of ___.

*****

1
10

61. The same progression can be extended to the right of the decimal point, but here the exponents will be _________ instead of positive.

*****

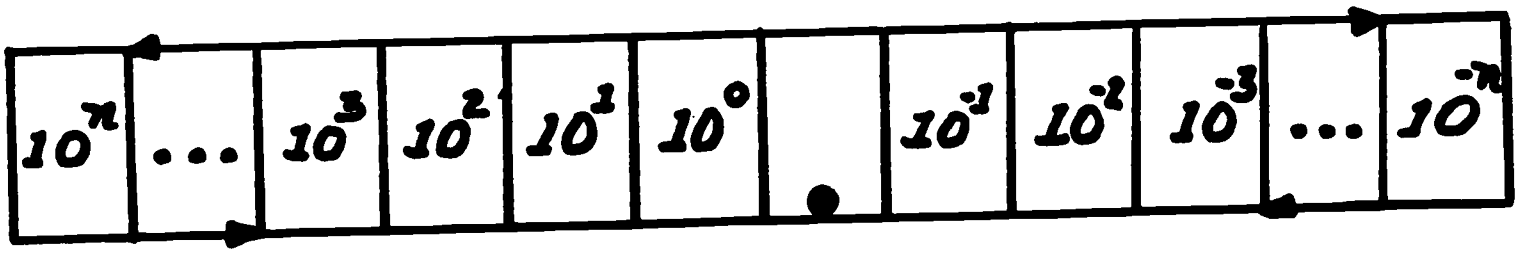
negative

62. For example, the first position to the right of the decimal point is the tenths position. It has a weight, on the basis of its _________, of 10^{-1}

*****

position

63. The following diagram represents the general solution for any decimal number:



Powers of ten are used as positional weights because there are ___ symbols in the decimal system.

*****

ten

64. To review, the number of symbols in any number system determines the value of the weights assigned to the positions relative to the decimal point.

65. Two advantages accrue to number systems having a fixed number of symbols: (1) There is only one way that any given number can be written, and (2) there is only one value that can be assigned to any given number. For example, given a quantity of XXXXXX units, with each X representing one unit, the <u>only</u> way that this can be written in the decimal system is with the symbol __.

*****

6

66. Likewise, the only value in terms of units that can be ascribed to the symbol "5" is XXXXX units. Given any symbol, there is only one ______ that can be assigned to it, and given a quantity of units, there is only one _______ that can represent that quantity.

*****

value
symbol

67. We have said that the weights assigned to the positions are determined by the number of symbols in any given number system. If the number of symbols were changed, then these _______ would also have to be changed.

*****

weights

68. A general rule of any number system that provides only one way to write a number and only one value for any number is that the weights of the positions are equal to powers of the ______ of symbols in that system.

*****

number

69. The number of symbols used in any number system is called the radix of that system. The decimal system has a radix of ____.

*****

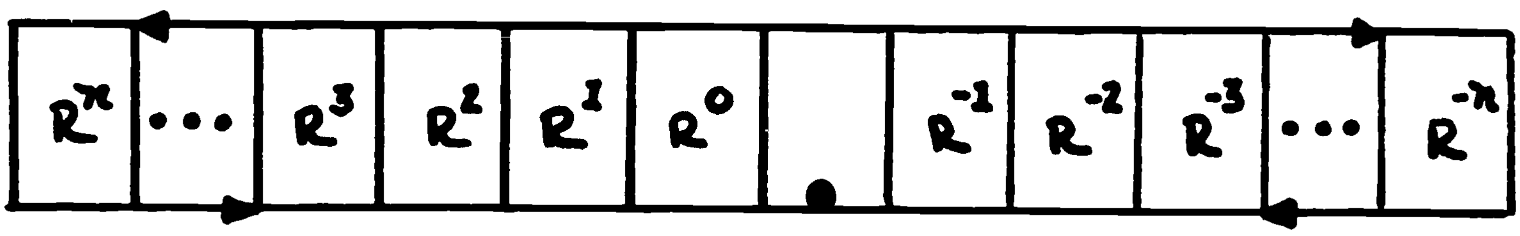
ten

70. Ten is not a magical number; there is no reason why the number of symbols could not be more than or fewer than ten. It is by convention that the __________ system uses 10 symbols.

*****

decimal (arabic)

71. The diagram below represents the skeleton of a general number system with a radix of R.



The value of R, the radix, corresponds to ______***______ in the system.

*****

the number of symbols

72. The binary number system is most often used in logic and computer applications. Since it has only two symbols, 0 and 1, it has a radix of ___ and the positional weights are powers of ___.

*****

2
2

73. Following the skeleton of the general number system, the positional weight of the first position to the left of the decimal is equal to 2^0, or one.* Therefore the quantity represented by the binary number 001. is ___, just as it is in the decimal system.

*Any number raised to the zero power equals one.

*****

1

74. Taking the second position to the left of the decimal is another case however. Here the positional weight would be 2^1 or ___. Therefore, the decimal equivalent of the binary number 10. would be ___. In words, this could be stated as "one 2 plus zero 1's," reading the number from left to right.

*****

2
2

75. As was stated earlier, the binary number system has only two symbols, 0 and 1. Each 1 in a binary number represents some value that has a decimal equivalent, the value of this decimal number being determined by the ________ of the 1 relative to the decimal.

*****

position

76. The third position to the left of the decimal has a positional weight of 2^2, or 4. The symbol 1 in this position has a decimal equivalent of ___.

*****

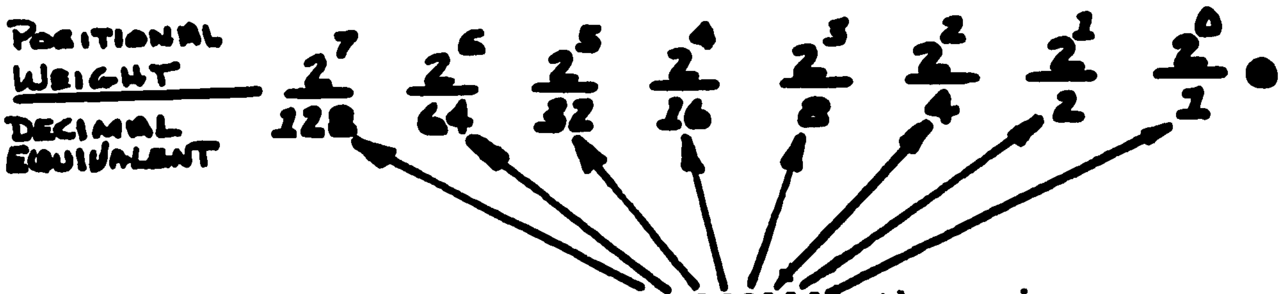
4

77. Taking the binary number 111., then, we can see that the decimal equivalent of the whole number would be equal to the sum of ___, ___, and ___, or 7.

*****

4
2
1

78. The following skeleton facilitates determining the decimal equivalent of binary numbers:



The value of the binary 00100111. then, is ____.

*****

39

79. The easiest way to convert a binary number to its decimal equivalent is to first lay out a table using the binary positional weights:

32	16	8	4	2	1
1	0	1	1	0	1

Then insert the binary number below the positional weights, and simply add up those columns having a 1 in them. The number above, then, has a decimal equivalent of 32 + 8 + 4 + 1 = 45.

Convert the following binary numbers to their decimal equivalents: 1 0 1 0 = ___
1 0 1 1 1 = ___

*****

10
23

80. To convert from a decimal to a binary number, first subtract the largest power of 2 which will go into the number being converted. For example, to convert 45 to the binary system, we would first subtract from 45 the value 32 (or 2^5), leaving 13. Then lay out a table:

64	32	16	8	4	2	1
0	1					

and put a 1 in the 32 column. (A 0 can be placed in all columns to the left of the 32 column, as it is obvious that these will never be used for this particular number.)

Then subtract from the remainder (13), the largest power of 2 that will go into that remainder, and again place a 1 in the appropriate column. Fill zeros in to the left as required.

64	32	16	8	4	2	1
0	1	0	1			

The remainder now is 5, from which we obviously subtract ___, as this is the largest power of 2 that will go into 5.

*****

4

81. We now have

64	32	16	8	4	2	1
0	1	0	1	1		

with a remainder of 1. Obviously, a 0 should be placed in the ___ column and a ___ in the 1 column, completing our conversion.

*****

2
1

82. Convert the number 78 to binary form, showing your subtraction and tally columns.

*****

64	32	16	8	4	2	1
1			1	1	1	

Then:

$$\begin{array}{r} 78 \\ \underline{-64} \\ 14 \\ \underline{-\ 8} \\ 6 \\ \underline{-\ 4} \\ 2 \\ \underline{-\ 2} \\ 0 \end{array}$$

Finally, fill in all zeros, giving 100110 = 78

83. In the same fashion the binary number 10101. has a decimal equivalent of ___.

*****

21

84. How about the numbers 11111? 10111? 110000?

*****

31
23
48

85. As with the decimal system, simple arithmetic operations can be performed with binary numbers. First, we will consider binary addition.

The first Rule of binary addition is:

$$\begin{array}{r} 0 \\ \underline{+0} \\ 0 \end{array}$$

Or, just as in the decimal system, zero added to zero equals ___.

*****

0

86. Now, consider the addition of zero and one:

$$\begin{array}{r} 1. \\ +0. \\ \hline 1. \end{array}$$

Again, this is equivalent to the decimal system, where 1 plus 0 equals 1. This Rule holds for other positions relative to the decimal as well. Solve:

$$\begin{array}{r} 101. \\ +010. \\ \hline \end{array}$$

Answer _____ (in binary form)

*****

111.

87. It is always possible to check computations of this sort by converting the binary values into their decimal equivalents. Write, in decimal numbers, the following problem and its solution:

$$\begin{array}{r} 100011. \\ +010100. \\ \hline \end{array}$$

*****

$$\begin{array}{r} 35 \\ +20 \\ \hline 55 \end{array}$$

88. We now have two Rules of binary addition:

0 + 0 = _____

1 + 0 = _____

*****

0
1

89. The next step is the case where we must add two 1's together:

$$\begin{array}{r} 1. \\ +1. \\ \hline ?. \end{array}$$

(Continued on next page)

To aid the solution, first convert these numbers into decimal equivalents, where they both equal one. The answer, then, must be equal to the decimal value of two, which is the binary number ___.

*****

10.

90. We have found, then that

```
  1.
 +1.
 ---
 10.
```

The third Rule, then, is that 1. + 1. = 0 and one to carry. Apply this rule to the following problem, giving the answer in binary form:

```
  101.
 +101.
```

Answer _____.

*****

1010.

91. A more difficult problem is:

```
  101.
 +111.
```

What do you get for an answer? _____

*****

1100.

92. If you didn't get 1100. as an answer you did something wrong. Working it out:

Column	a	b	c
	1	0	1.
	+1	1	1.

Adding the two 1's in Column C gives 0 + 1 to carry to column b. We now have ???0. in the answer
Adding the two 1's that are now in column b also gives 0 0 + 1 to carry to column a. We now have ??00. in the answer.
Adding, finally, the three 1's in column a yields 1 + 1 to carry. This gives the answer of 1100.

93. The fourth Rule of addition, then, is

$$1 + 1 + 1 = 1 + 1 \text{ to carry.}$$

This makes sense, as 1+1+1 in the decimal system equals 3, which is written binarily as ____.

*****

11.

94. Try this one for practice:

```
 101101
+ 1010
```

Which equals the binary ________, having a decimal equivalent of ___.

*****

110111
55

95. We will now consider binary subtraction. The first Rule is 0 - 0 = 0, which again is the same as in the decimal system. Therefore

```
 0000.
-0000.
```

equals _____.

*****

0

96. Next consider the problem:

```
 1.
-0.
```

Again, we are the same as the decimal system, where one minus zero equals one, so the answer here is _____.

*****

1.

97. The second Rule of subtraction, then, is:

1. - 0. = 1.

On this basis, solve:

```
 110011.
-000000.
--------
```

Give binary and decimal equivalents again.

*****

110011
51

98. The next step is to look at 1 - 1 = ?

As you might expect, the answer is o. So our third rule is:

1 - 1 = 0

Solve, giving both binary and decimal equivalents:

```
 11110.
-10100.
-------
```

*****

01010.
10

99. Only one more rule for subtraction remains:

0 - 1 = 1 and 1 to borrow

In the problem

Column	a	b	c
	1	0	0.
	-0	1	0.
	0	1	0

subtracting in row b requires that we borrow the 1 from column a, leaving a 0 in the answer of column a. Now solve the following, again giving binary and decimal equivalents:

```
 101101.
-011001.
--------
```

*****

10100
20

100. For more practice, solve the following, giving both binary and decimal answers:

```
 110101.
-011111.
```

Remember the rules:

0 - 0 = 0
1 - 0 = 1
1 - 1 = 0
0 - 1 = 1 + 1 to borrow

*****

010110.
22

101. Perform Exercise 2 in the back of this booklet.

PART IV. THE LOGIC SIGNAL

102. Within the control subsystem, electrical signals are generated that correspond to input and output events. The subject's responses, then, are first translated into __________ __________.

*****

electrical signals

103. The Logic Signal, then, is elec_ _ _ _ _ _ in nature, and is defined in terms of electrical values.

*****

electrical

104. A Logic Signal consists of four possible conditions. Two of these, ON and OFF, are termed continuous states. When the Logic Signal is either ON or OFF, it is said to be in a __________ ______.

******

continuous state

105. Refer to figure 2. The ON and OFF continuous states are defined logically by a voltage differential. For our purposes we will define the ON state as the absence of voltage (zero volts, or ground potential). Zero volts, then, indicates that the Logic Signal is ____.

*****

on

106. It is very important to remember that ON is defined by NO voltage (spell ON backwards and you have NO). Admittedly, this is the reverse of common sense, but that's just the way it is.

107. The OFF state of a Logic Signal is defined here as the presence of a negative twelve volts DC*, (-12 VDC). When a -12VDC is present, the Logic Signal is ____.

*Direct Current

*****

OFF

108. The specific voltages used to define ON and OFF are referred to as Logic Levels* In our case, the Logic Levels are _____ volts for OFF and ____ volts for ON.

*Logic levels vary with the manufacturer of logic equipment

*****

-12
zero

109. The logical ON is often referred to as the "1" state. The absence of voltage, or ground potential, indicates that the Logic Signal is in the ____ state.

*****

"1"

110. Just as "1" refers to the logic function of ON, so "O" refers to the logic function of ____.

*****

OFF

111. Ground, or zero volts, is to "1" as -12 VDC is to ____.

*****

"O"

112. Referring to Figure 2, which graphically shows a logic signal: The logic function of OFF is represented in the figure by the letters __ & __, as these points are at a -12 VDC.

*****

a, c

113. In Figure 2, the logic function of ON, or the "1" state, is represented by the letter ___, as this point is at zero VDC, or ground.

*****

c

114. The "O" and "1" states are, however, only two of the four possible conditions of the Logic Signal. It is apparent that if the Logic Signal is neither ON or OFF, it must be somewhere in between. That is, it must be either positive-going (OFF to ON), or ________ ______ (ON to OFF).

*****

negative going

115. The positive-going and negative-going states are termed <u>transition</u> states. Whenever the Logic Signal is neither ON or OFF, it is in a __________ _____.

*****

transition state

116. If the Logic Signal is going from ON (zero volts) to OFF (-12VDC), it is said to be in a negative going ________ state.

*****

transition

117. If the Logic Signal is negative-going, it is moving from the ____ state to the ____ state.

*****

"1" (ON, ground)
"0" (OFF, -12 VDC)

118. The occurrence of a subject response will, generally speaking, be represented by the logic function of ON, or _____ VDC, signal.

*****

zero

119. Whenever the Logic Signal is moving from the "0" state to the "1" state, it is said to be in a ________ ______ transition.

*****

positive going

120. In Figure 2, the positive-going transiton is indicated by the letter ___, while the negative-going transition is indicated by the letter ___.

*****

b
d

121. To review: "0" state = OFF = -12 VDC
"1" state = ON = 0 volts = Ground Potential

It is helpful if you keep these straight!

122. A second type of electrical signal used in digital logic control subsystems is the <u>Special</u> <u>Reset</u> <u>Signal</u> (see Figure 3). As can be seen, the Special Reset Signal consists of instantaneous ________ going transition followed by a trailing off to the OFF voltage.

*****

positive

123. The functions of the Special Reset Signal will be discussed later. Briefly, it is used to "clear" data from logic units at appropriate points in time, e.g., when a new subject enters the experimental environment. Whenever a "clear line" is desired, a _______ _____ ______ would likely perform this function.

*****

special reset signal

124. Perform Exercise 3 in the back of this booklet.

PART V. DIGITAL LOGIC SUBSYSTEM -- INPUT PORTION

125. The basic function of the input portion is to convert subject behavior into logic level signals. The input to the input portion is subject behavior, and the output is in the form of _____ _____ signals.

*****

logic level

126. Usually a unit called an Input Modifier, Input Converter, or CX Package performs this conversion function* We will use the term Input Converter, symbolized "CX", in this program. The _____ ________ converts subject behavior into _____ _____ signals.

*Terminology varies with manufacturer.

*****

Input Converter
logic level

127. The function of converting subject behavior into logic signals is performed by an _____ ________ unit.

*****

Input Converter (CX)

128. The major function of the Input Converter, or CX, is to convert, or code, input events into _____ _____ signals.

*****

logic level

129. Refer to Figure 4, which shows a basic circuit using a CX unit. The CX requires a switch closure at the input jack to generate an output. In Figure 4, this is shown by the two wires from the telegraph key connected to the input jack, labeled "External Contacts, N.O." N.O. means "normally open," i.e., the contacts of the telegraph key are ____ until it is depressed.

*****

open

130. In Figure 4, then, the input to be coded is in the form of a ______ closure at the CX unit input jack. Notice that this switch can be physically separate from the CX unit, and connected to the unit through wires.

*****

switch (telegraph key)

131. Whenever a "short" circuit is connected across the input jack terminals of a CX unit, an output is present at the output pin. If a switch connected to the input is closed, the output will go from OFF to ___. This is shown in the lower portion of Figure 4.

*****

ON

132. See Figure 4. The CX unit also has two pushbuttons on the front of the unit. One of these, labeled "Manual Operate", functions in parallel with the input jack. Therefore, pushing the "Manual Operate" pushbutton results in a change from ____ to ON at the output pin.

*****

OFF

133. The other pushbutton, labeled "Reset," provides for a reset function, Depressing this button results in a Special ______ Signal at the Reset Output pin (see Figure 4).

*****

Reset

134. As can be seen in Figure 4, the closing of the telegraph key (shaded portions of the graph) is coded into the logic function of ON, while the periods that the key is open are represented logically by ___.

*****

OFF

135. To review: "0" state = OFF = OPEN = -12 VDC.

When the key is Open, the output of the Input Converter will be _____.

*****

OFF (at - 12VDC) (in 0 state)

136. Whenever the telegraph key is depressed, however, the output of the Input Converter will be at the _____ volt level.

*****

zero

137. Using the "0" state - "1" state terminology, the closing of the telegraph key is coded into the ____ state, while the periods that it is open are represented by the ____ state.

*****

"1"
"0"

138. A switch closure, or more precisely a physical force translated into a switch closure, is the most common input event used in control subsystems. The telegraph key is an example of the translation of an organism's behavior into a ______ closure.

*****

switch

139. One of the major problems encountered in using switch closures as input events is that most switches have a characteristic known as "contact bounce." (See Figure 4) Simply enough, this is because the switch contacts b_ _ _ _ _ between the open and closed positions.

*****

bounce

140. This bouncing (rapid opening and closing of the switch contacts) may repeat several times in rapid succession. If the CX is fast enough, it can be expected that each switch closure during the bounce period will result in an ______ from the CX unit.

*****

output

141. Most Input Converters eliminate the bounce by rejecting signals faster than 40 per second. Contact bounce, as might be expected, is at a higher rate than __ *** ______.

*****

40 per second

142. A second function of the CX unit, then, is to eliminate ______ ______ from the input events to be coded.

*****

contact bounce

PART VI. DIGITAL LOGIC SUBSYSTEM - OUTPUT PORTION

143. Just as coding refers to the translation of external events into logic level signals, so de_ _ _ _ _ _ refers to the conversion of logic level signals into electrical impulses acceptable to associated external devices.

*****

decoding

144. The decoding function is performed by the output portion of the Control subsystem. In the output portion, logic level signals are ________ into signals used to control other, external devices.

*****

decoded

145. Three broad classes of output devices can be identified:

(1) Those which indicate the current status of the research system, or Indicators.
(2) Those which record the events occurring within the research system, or Recorders.
(3) Those which actually effect the environmental changes associated with the output of the control subsystem, or Converters.

146. Conditions currently in effect within the research system are indicated by Ind_ _ _ _ _ _ output devices.

*****

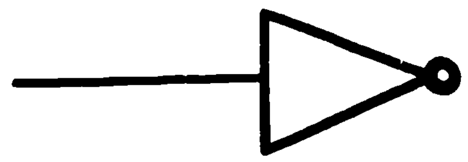
Indicator (Indicating)

147. An indicator light, indicating to the experimenter that a signal light (S^D) is being presented to the subject, at that moment, is an example of an __________ output device.

*****

indicating

148. Indicator lights, symbolized ID, are very useful aids to the experimenter. Generally they are used to indicate the ______ ______ of the research system. Schematically, they are represented by the diagram:



*****

current status

149. Indicator lights respond to logic level signals. If a logic ON (ground) is applied to the input pin of an indicator light, the light will also be ___.

*****

ON

150. In terms of voltages, a -12 VDC signal applied to the input of an ID means that the light will be _____.

*****

OFF

151. Another type of output device records occurrences within the O-E subsystem, preserving them for later analysis. A cumulative recorder, which records subject responses over time, is an example of a ________ output device.

*****

recording

152. Another type of recording output device is the digital counter. Like the ID, these counters also respond to ________ level signals.

*****

logic

153. Each positive going transition applied to the input pin of a digital counter results in the stepping of the counter to the next highest digit. If six positive going transitions have been received, the counter will read ___.

*****

6

154. Finally, some output devices are associated with changing the organism's environment in accordance with the predetermined program. Included in this category are reinforcement dispensers, stimulus presentation devices, and all other programmed environmental events. All of these units have the common feature of __________ the organism's environment.

*****

changing

155. The output devices which actually change the subject's environment are called converters, because they __________ logic level signals into conditions suitable for external equipment.

156. Various types of output interface units are used in conjunction with each of these three basic categories of output devices. They will be discussed in more detail following an introduction to the logic portion of the control subsystem.

157. Perform Exercise 4 in the back of this booklet.

PART VII. DIGITAL LOGIC SYSTEM: LOGIC PORTION

Section 7.1--Physical Characteristics and Interconnections.

158. Before proceeding, it is necessary to discuss the physical makeup of the control subsystem, and the means used in interconnecting the individual units of the control subsystem together. First, inspect the equipment included in the "trainer."

159. It can be seen that a frame, or "card file," containing 40 receptacles, is used to hold the individual units. Each logic unit plugs into one of the receptacles. Using the card extractor (attached to the right side of the file) remove one of the units, remembering which slot you took it from.

160. Each unit, as you can see, consists of a front panel, which contains any pushbuttons, jacks, etc., used in the unit, a card made of fiberboard on which the circuitry is mounted, and a series of metal contacts which mate with similar contacts inside the receptacle.

161. The rear of each receptacle (on the back of the card file) consists of 15 pairs of small holes, which are made to accept taper pin wires. The taper pin wires are used to interconnect the individual units.

162. Replace the unit you have removed.

163. The holes on the back of the receptacles are lettered a through s, skipping, g, i, o, and q. Each letter is associated with two holes, which are electrically common. That is, connecting a wire to the left hole of a pair is the same as connecting it to the right hole. (This is a versatility feature, allowing the researcher to easily connect two wires to the same point.)

164. Refer to Figure 30. Figure 30 contains schematic diagrams of all of the units in the BRS 200 series. Generally, each unit has at least one input and one output. The letters that identify connection points in Figure 30 correspond to the letters on the back of the receptacles on the card file. Note also that many of the units are composed of more than one sub-unit. Locate the AG-203 unit. As you can see, there are actually two separate AG units mounted on a single card.

165. Locate the CX-205 unit in Figure 30 and the actual unit in the card file. You can see that the face of the unit has a jack for the input and two push-buttons -- Manual Operate and Reset. The normal output will be at pins F and H, which means that the output will be present simultaneously at 4 pins -- the two associated with F and the two associated with H.

166. As noted earlier, the CX unit also performs a reset function. The reset output is at pins J and K, and will be present at these points whenever the reset button is depressed.

167. Pin S is connected to ground and pin A to a -12 VDC power supply. Verify this by tracing the output of the power supply to its points of connection on the card file.

168. Now locate the Indicator, or ID-201, unit on Figure 30 and in the card file. Notice that the unit contains four separate units, which are associated with the four input pins, C, F, J, and M. Applying a logic ON to any one of these four pins will light the ID lamp associated with that pin.

169. Refer to Figure 31, which represents the rear view of the card file. The 40 boxes represent the 40 receptacles, each of which accepts one logic unit.

170. In Figure 31, two units are shown plugged into the card file -- a CX-205 and an ID-201. Pins A and S are shown connected to the power supply. A telegraph key (we will use a micro switch) is shown connected to the N.O. jack on the CX. At this point, perform the following operations: (Refer to Figure 31, which shows these interconnections.)

171. (1) Plug the micro switch into the CX unit, N.O. input jack (plug is already attached).

(2) Connect a taper-pin wire from the output of the CX unit (Pin F) to the input of the top ID light (Pin C). (A tool is provided for inserting and removing taper pin wires -- if you don't know how to use it, just push the wires in with your hands and ask later how the tool works.)

(3) Turn the power supply switch to ON.

172. You now have a working circuit, consisting of a switch-closure input to the CX unit, and the output of the CX unit connected to an ID unit. When the switch is closed, the output of the CX will be ON at Pins ___ and ___. (See Figure 30)

*****

F
H

173. Pin F of the CX is connected to Pin C of the ID. When the CX output is ON, the top ID will be ___. (Depress the switch to see what happens.)

*****

ON

174. Therefore, whenever the telegraph key is depressed, the top ID will be ___.

*****

ON

175. We also know that the output of the CX will be ON if the "Manual Operate" pushbutton is depressed. Therefore, the ID can be turned ON by either depressing the telegraph key or by ___________***___________. Depress the Manual Operate button to check your answer.

*****

pressing "manual operate"

176. Turn power supply OFF and remove the wire connected earlier.

177. At this point it is necessary to introduce three simple rules for properly wiring logic equipment:
   1. Keep the wires as short as possible.*
   2. Never wire with the power ON.
   3. Never connect two logic unit "outputs" together.

We will have reason to review these rules later in the program.

*This is often done by proper placement of units in the card file -- which will be impossible here as unit positions are "fixed" for this program.

Section 7.2 - The Flip Flop

178. The logic signal, as noted earlier, is defined as a voltage differential between the "0" and "1" states. The "0" state is defined as ____ VDC and the "1" state as ____ VDC.

*****

-12
zero

179. There are 4 possible conditions of the logic signal: ON, OFF, Positive-going, and Negative-going. A positive-going signal is one that is in the process of changing from a -12 VDC to ____ VDC, while a negative-going signal is one that is changing from 0 VDC to ______.

*****

0
-12 VDC

180. There are, generally speaking, two broad classes of logic units that are used in the control subsystem: (1) Units responding to continuous states and (2) Units responding to trans_ _ _ _ _ states.

*****

transition

181. The class of units that respond to transition states respond only to positive going, or ________ to ________, transitions. These are:
   (1) Flip Flop
   (2) One Shot
   (3) Reset
   (4) Inverter

*****

negative to positive
or
(-12V to 0V)
("0" to "1")

182. The flip flop (FF), or bistable multivibrator, is basically a <u>storage</u> unit. Input events can be ______ with the use of a flip flop.

*****

stored

183. Refer to Figure 5. Basically, the flip flop responds to input signals by changing its state from "0" to "1" or vice-versa. If the flip flop is in the "0" state, an input signal can be used to change it to the ______ state.

*****

"1"

184. Conversely, if the flip flop is in the "1" state, an input signal can change it to the ____ state.

*****

"0"

185. Referring to Figure 5, changing the state of the flip flop is accomplished by applying a pos_ _ _ _ _ going transition signal to the appropriate <u>data</u> <u>input</u> pin.

*****

positive going

186. The positive-going transition signal must be applied to the pin associated with the state that the flip flop <u>is</u> <u>currently</u> <u>in</u> to accomplish the change of state. From Figure 5 it can be seen that if the flip flop is in the "0" state, a positive-going signal must be applied to the <u>set</u> input pin.

187. If the flip flop is in the "0" state, a positive-going transition applied to the set input pin will change it to the ____ state.

*****

"1"

188. Conversely, a positive-going signal applied to the reset input pin will, if the flip flop is in the "1" state, change it to the ____ state.

*****

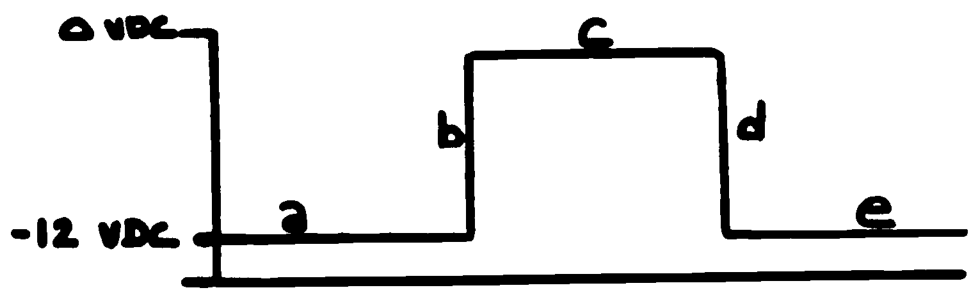
"0"

189. In order for a positive-going transition applied to the reset input pin to change the state of a flip flop, it is necessary that the flip flop be in the ____ state.

*****

"1"

190. The data input set and reset pins respond to positive-going transitions. They respond to which portion(s) of the following logic signal? ______



*****

b

191. The output of a flip flop is a continuous signal. If the flip flop is in the "1" state, the "1" output pin will be at a continuous _____ volt level, or ON.

*****

zero

192. If the flip flop is in the "0" state, the "0" output pin will be at a continuous ____ volt level.

*****

zero

193. If the "1" output is ON, then the "0" output will be OFF, or at a ____ volt level.

*****

-12VDC

194. A flip flop is always in either the "0" or the "1" state. If one of the output pins is ON, then the other must be ____.

*****

OFF

195. Refer to Figure 5. The selectable output pin is used to select, by means of a switch, either output "0" or output "1" for use in the circuit. If the switch is in the "1" position, the selectable output pin will be ON only if the flip flop is in the ____ state.

*****

"1"

196. The "Diode Reset," "Direct Reset," and "Direct Set" pins all require the Special Reset Signal to operate.

A Special Reset Signal applied to the "Diode Reset" pin always results in a "clear line." That is, if the flip flop is in the "1" state, a reset signal will always change it to the ______ state.

*****

0

197. If the flip flop is already in the "0" state, the Special Reset Signal applied to the "Diode Reset" pin will ***__________.

*****

do nothing (or some such)

198. The Direct Reset and Direct Set pins perform the same function as do the reset and set input pins, except that they require the Special Reset Signal instead of a ___***___.

*****

positive going transition

199. If the flip flop is in the "O" state, a Special Reset Signal applied to the Direct Set pin will put the flip flop into the ____ state.

*****

"1"

200. The Indicator Light (which is usually optional, depending upon the manufacturer) connected to the "1" output pin indicates the current status of the flip flop. If the flip flop is ON, the lamp will also be ____.

*****

ON

201. In "T" operation a jumper wire is connected between the set and reset input pins. This causes the flip flop to change states on every positive going transition, irrespective of its current state. In "T" operation a jumper is connected between the ____ and ______ input pins.

*****

set
reset

202. If a flip flop is connected for "T" operation, and if it is in the "O" state, a single positive-going transition applied to the"T" will change the flip flop to the _____ state.

*****

"1"

Section 7.3 - Storage, or Memory

203. One of the basic uses of the flip flop is for storage, or memory. Figure 6 shows a single flip flop and two ID lights connected in a memory circuit.

204. Figure 32 shows the way in which the Figure 6 circuit is interconnected at the rear of the card file. The actual pins used can be determined by reference to Figures 30 and 6.

205. Referring to Figures 6 and 32, the wire connecting Pin F of the CX-205 to Pin F of the FF-206 is used to connect the CX Output to the _____ input pin of the flip flop.

*****

set

206. Confirm that reset output of the CX is connected to the Diode Reset of the flip flop on Figure 32. If the Reset pushbutton on the CX is pressed, the FF will always wind up in the _____ state.

*****

0, or OFF

207. The FF "1" output pin is connected to the top ID-201 light at Pin ____. (See Figures 6 and 32).

*****

C

208. The top ID unit will be ON whenever the FF is in the _____ state.

*****

"1"

209. The FF "0" output is connected to the second ID light. This ID will be ON only when the FF is in the _____ state.

*****

"0"

210. Now return to Figure 6:
A signal from the CX takes the form of a positive going transition at the set input pin of the FF, changing the FF from the "0" state to the ____ state.

*****

"1"

211. As the flip flop changes from "0" to "1", the "0" indicator light will ___***___ and the "1" indicator light will ___***___.

*****

go out
come on

212. Any further output signals from the Input Converter will not affect the flip flop. That is, the flip flop will "remember" this first event until it is instructed to "forget." As might be expected, the "forget" signal here is the Special Reset Signal applied to the "Diode _____" pin of the flip flop.

*****

reset

213. Using Figure 32 as a guide, connect the memory circuit shown in Figure 6. Remember to first turn the power supply to ____, if it is ON.

*****

OFF

214. When you have the circuit connected, turn the power supply to ON, and momentarily depress the CX-205 "Reset" button. This insures that the flip flop will begin in the "0" state, as indicated by the lower ID light being ON.

215. If the micro switch is not already plugged into the CX-205 unit, connect it now. Then momentarily depress the micro switch button. This puts the flip flop into the _____ state, as ID-1 (top light) is now ON and ID-2 (second light from top) is now OFF.

*****

"1"

216. A note on terminology should be inserted here. Reference to unit types will always be made using the full name of the unit, e.g., CX-205, FF-206. If a circuit contains more than one of one type of unit, these will be distinguished by a single digit, e.g., ID-1, ID-2.

217. Now operate the micro switch again. ID-1 is still ____ and ID-2 ____.

*****

ON
OFF

218. Now operate the CX's reset again. ID-1 is now ____ and ID-2 ____.

Repeat this procedure until you are familiar with the sequence of events.

*****

OFF
ON

219. The function of this simple circuit is to demonstrate that the flip flop can "remember" events. When it began in the "O" state, one input pulse was sufficient to change it to the "1" state, an event that it __________ until you reset it back to "O".

*****

"remembered"

220. Turn power OFF and remove all connecting wires.

Section 7.4 - Division

221. A second basic function of the flip flop is that of division by two. Here the flip flop is connected for T operation. As was noted earlier* a T is formed by connecting the set and reset input pins together. (See Figure 5) When the set and reset input pins are tied together, the flip flop is connected for ___ operation.

*Refer to Frames 201 and 202, if required

*****

T

222. In T operation the flip flop will change states on every input pulse. If the flip flop begins in the "0" state, a positive going transition applied to the T will leave it in the ____ state.

*****

"1"

223. Refer to Figure 7, which shows a flip flop connected for division by two, i.e., it is connected for T operation. Each time the key is depressed a positive going transition will be present at the output of the ______ __________.

*****

Input Converter (CX)

224. If the flip flop begins in the "1" state, momentarily depressing the key will deliver a positive transition to the T of the flip flop, causing it to go to the ____ state.

*****

"0"

225. The next time the key is depressed, the flip flop will go to the ____ state.

*****

"1"

2

226. In Figure 7 indicator lights are connected to the "1" and "0" output pins. The top light, the "1" indicator will be ON whenever the flip flop is in the ____ state.

*****

"1"

227. The flip flop will be in the "1" state once for every two key closures, that is, it "flip-flops" back and forth between the "0" and the "1" states each time the key is closed. If the flip flop starts in the "0" state, and if 6 input pulses are received, then the indicator light associated with the "1" output will be lit ___ times.

*****

3

228. Figure 33 shows the interconnection for the "division by two" circuit of Figure 7. Do the following:
   (1) Make sure power is OFF.
   (2) Connect the circuit as shown in Figure 33. Notice the short jumper wire between Pins F and J of the flip flop - this is the T interconnection.
   (3) Turn power ON.
   (4) Reset the circuit by depressing the "reset" button on the CX-205. This insures that you are starting in the "0" state, with the top ID OFF and the bottom ID ON.

229. Momentarily depress the micro switch. The top ID is now ___ and the bottom one is ____.

*****

ON
OFF

230. Again depress and release the micro switch. ID-1 is now ____ and ID-2 is ____.

*****

OFF
ON

231. As you can see, ID-1 will be ON once every ____ input pulses, hence this is a division by ____ circuit.

Repeat depressing the micro switch until you are familiar with the sequence of events.

*****

two
two

232. Turn power OFF and remove all connecting wires.

Section 7.5 - Binary Counter

233. This divison by two function permits counting with logic units. For this we must use the base 2, or binary, number system. Figure 8 shows a counter using 5 flip flops, which can therefore count to a maximum of 31 (1 plus 2 plus 4 plus 8 plus 16). Before beginning our analysis of the circuit assume that the "Reset" button has just been depressed -- this would insure that all Flip Flops would start in the ____ state.

*****

"O"

234. The first positive-going pulse from the Input Converter is received at the "T" of the first flip flop. This changes the state of the first flip flop from "O" to ____.

*****

"1"

235. At this point we have a count of 1-0-0-0-0, or 1, indicating that we have received ____ input pulse. The second incoming pulse will change the first flip flop from "1" back to ____.

*****

1
"O"

236. But notice what happens as FF-1 goes from "1" to "0" in terms of the connecting wire from the "0" output to the "T" of the second flip flop: As might be expected, a ________ ______ transition signal is applied to the "T" of FF-2. This changes the state of FF-2 from "0" to "1", giving us a total count of 0-1-0-0-0, or two.

*****

positive going

237. The third input pulse is then received. Quite obviously, it immediately changes the state of FF-1 from ____ to ____. It cannot alter the state of FF-2, however, because no positive-going transition is applied to FF-2's "T". This leave us, then with a count of ____ or three.

*****

"0"
"1"
11000

238. Additional flip flops can be added to the basic binary counter as are necessary for any application. Adding two more flip flops would yield a capability of counting up to ____ input events.

*****

127

239. Figure 34 shows the interconnections for the binary counter shown in Figure 8. Connect the circuit as shown. Then turn the power ON and depress the CX's "Reset" button. All flip flops are now _____.

*****

OFF ("0" state)

240. Now depress the micro switch momentarily. Looking at the indicator lights built into the flip flop units, which flip flop(s) are ON now? _____.

*****

FF#1

241. Depress the micro switch 7 more times. Now which flip flops are ON? ______

*****

FF#4

242. Depress the micro switch 7 more times. Now which flip flops are ON? ______

*****

FF#1, 2, 3, 4

243. Notice how we count here:

Decimal	FF-1	FF-2	FF-3	FF-4	FF-5
1	1	0	0	0	0
2	0	1	0	0	0
3	1	1	0	0	0
4	0	0	1	0	0
5	1	0	1	0	0
6	0	1	1	0	0
7	1	1	1	0	0
8	0	0	0	1	0
9	1	0	0	1	0
10	0	1	0	1	0

How about 15? ___ ___ ___ ___ ___

*****

FF1	2	3	4	5
1	1	1	1	0

244. Depress the reset button on the CX-205 and repeat counting with the counter until you are familiar with its operation.

245. Turn the power OFF and remove all connecting wires.

Section 7.6 - AND Gate

246. Unlike the flip flop, which responds to positive-going transition states, the AND Gate responds to cont- - - - states. (See Figure 9)

*****

continuous

247. The AND Gate permits specifying which input events are necessary for the generation of an output event. In a 2-legged AND Gate (Figure 9a), output event C will occur only if both input A and input B are simultaneously present. If either A or B is not present, output event C will ____ occur.

*****

not

248. On Figure 9A:

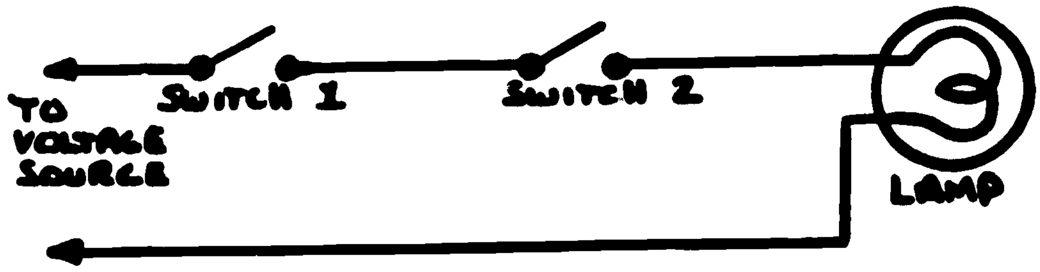
Let A be the presence of a green S^D light in a Skinner box.
Let B be a bar pressing response.
Let C be the delivery of a food pellet.

Then C will occur ONLY IF a bar pressing response (B) is made in the presence of ___***___ ______.

*****

a green S^D light

249. The function of the AND Gate can be illustrated by two switches connected in series. In the following diagram, in which a light and two switches are connected in series, it can readily be seen that the light will be ON, only if both switches are closed.



250. In the same manner, an output will not occur from the AND Gate unless all of its used inputs are _____.

*****

ON

251. The AND Gate is ON at its output when all used inputs are ___; it is OFF at its output when any used input is ____.

*****

ON
OFF

252. Notice the use of the word "used" in the preceeding frames. Remembering that ON is defined by 0 volts, if an input is not used (nothing connected to it), this will be the same as having an ON signal applied to it (no voltage will be present).

253. Therefore, if an input is not used, it will always be ON - this way a 5-legged AND Gate can be used as a 2, 3, or 4-legged Gate with no problems. (Do you see now why they use the presence of voltage to define OFF, and no voltage to define ON?)

254. Figure 9b shows the construction of a 5-legged AND Gate using two 3-legged AND Gates. In this case an output will be present at h, only if inputs__, __, __, __, and __ are also present.

*****

a, b, c, f, g

Section 7.7 - Logic Determination of a Predetermined Count

255. Adding an AND Gate to our Binary Counter permits the "Logic Determination of a Pre-determined Count." That is, we can operate other logic or interface units on the basis of a predetermined number of input events. For example: "Deliver a reinforcement after every 15 bar-press responses." Here a predetermined number of _____ _______ (15) will result in the delivery of a reinforcement.

*****

input events (bar presses)

256. Figure 10 shows the construction of a predetermining counter. It can be seen that an output will be generated by the AND Gate only when ___***___ flip flops are in the "1" state.

*****

the first four

257. Figure 10 is, of course, a binary counter exactly like Figure 8. After the first input from the CX, the count will be 1-0-0-0-0, indicating that only FF-1 is in the "1" state. After the second count we will have 0-1-0-0-0, with FF-2 in the "1" state. After the third input, which FF(s) will be in the "1" state? ________

*****

FF#1 & FF#2

258. When the AND Gate output is ON, the ID will also be ON. This will occur only if _____ input events have already occurred.

*****

15

259. Figure 35 shows the interconnections required for the predetermining counter shown in Figure 10. Connect the circuit. Then turn the power ON and depress the CX's "Reset" button. All flip flops are now in the ____ state.

*****

"0"

260. After one response (press the micro switch momentarily) only FF #__ is ON.

*****

1

261. After five responses flip flops ___ and ___ are ON.

*****

1 and 3

262. The first four flip flops are ON after ___ responses.

*****

15

263. Turn power OFF and remove all connecting wires.

264. By using the selectable outputs of the flip flops, as is shown in Figure 11, it is possible to instruct the counter to deliver an output event after from 1 to 31 input events. That is, we can select any number between 1 and 31. Does this sound like something familiar? Like maybe an FR schedule? In Figure 11 all switches are shown in the "1" position except for FF-1 and FF-5, which are in the "O" position. Here an output event will occur after 14 input events.

265. Using a blank layout sheet* (By this time you should be familiar with laying out and connecting circuits), show how you would connect the circuit shown in Figure 11. Label this sheet "Selectable Predetermining Counter" and save it. Wire the equipment, turn the power ON, and depress the "reset" button. Set the flip flop selectable output switches as follows: FF-1 and FF-5 to "O" and FF-2 thru FF-4 to "1". Then depress the micro switch until the ID light comes ON, counting the responses as you do so. How many input events were required? _______

*Blank sheets are provided in the back of the illustrations booklet.

*****

14

266. Which flip flop switches would be in the "1" position to deliver an output event after 12 input events? ***

(Check your answer by trying it on the trainer)

*****

3 and 4

267. Turn the power OFF and remove all interconnecting wires.

Section 7.8 - One Shot

268. Refer to Figure 12. The basic One Shot consists of a single input and output. When a positive-going transition is applied to the input, the One Shot is triggered into operation at its output. Like the flip flop, the One Shot operates on a positive-going ________ signal.

*****

transition

269. When a positive-going transition triggers a One Shot, the output will be ON for a fixed length of time ("t"). A momentary input pulse gives an output pulse of duration ____

*****

"t"

270. When the One Shot output is ON, further input signals will HAVE NO EFFECT. Looking at Figure 12, the telegraph key closure occurring between 3 and 4 seconds does not effect the One Shot output because ______***______.

*****

it is already ON

271. More sophisticated One Shots provide for adjustable ON times, "t." Coarse timing adjustments are accomplished by changing the value of the External Capacitor (see Figure 12). As might be expected, increasing the value of the capacitor also ________ "t."

*****

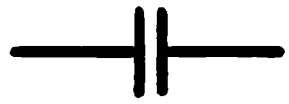
increases

272. Locate the OS-202 unit in Figure 30. As you can see, the capacitor is connected between pins __ and __.

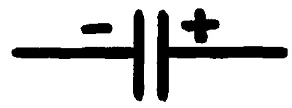
*****

C, L

273. A digression on capacitors:
The symbol for a capacitor, or condenser, is:



If the capacitor is polarized, it will be shown as:



Most of the capacitors used with BRS equipment are polarized, and you must observe their polarity when connecting them in the equipment. Notice in Figure 30 that the OS-202 unit requires that the positive end of the capacitor be inserted into the E pin, and the negative end into the L pin.

274. You can determine the polarity of capacitors in several ways:

(1) Some have a black band encircling the positive end.
(2) Some have a plus sign at or near the position end.
(3) On tubular metal capacitors, one of the wires is connected to the tube, or metal case, itself. This is the negative end.

275. If there is no marking, you do not have to observe polarity.

Inspect the capacitors provided with the trainer to see the ways in which polarity is indicated.

276. Capacitance is measured in farads, or more usually in microfarads (MF, MFD) or micromicrofarads (MMF,MMFD). Values are usually written on capacitors in terms of MFD units. With BRS equipment we use capacitors for timing purposes that range from .047 MFD to 150 MFD.

277. A band on one end of a capacitor indicates that this is the ________ end.

*****

positive

278. Fine timing adjustments are accomplished with the potentiometer (variable resistor) marked "t" in Figure 12. Changing the value of "t" (usually a screwdriver adjustment) changes the time that the output will be ___.

*****

ON

279. The external capacitor provides coarse time adjustment of the One Shot unit's ON time ("t"), while the potentiometer on the front of the unit provides _____ time adjustment.

*****

fine

280. The following table lists the output ranges of the OS-202 unit for various values of the external capacitor:

Cap. (MFD)	Range
None	30-800 microseconds
.047	.3-8 milliseconds
.47	3-80 milliseconds
4.7	30-800 milliseconds
47.	.15-10 seconds
150.	.5-30 seconds

281. From the preceeding table you can see that with an external capacitor of 47.MFD, it would be possible to adjust the potentiometer for ON times ranging from ___ to ___ seconds

*****

.15, 10

282. Figure 36 shows the connections for Figure 12.

(1) Connect the circuit
(2) Insert a 20 MF capacitor as shown, making sure that you observe polarity.
(3) Turn the front panel "t" potentiometer on the OS-2 unit fully clockwise.
(4) Turn power ON
(5) Momentarily depress the micro switch, watching the ID light as you do so.

The ID light stays ON for approximately ___ second(s)*.

*If the light does not go out, turn power OFF and reverse capacitor leads. You may have it in backwards.

*****

5

283. Now turn "t" fully counterclockwise and depress the micro switch momentarily, observing the ID light as you do so. Now the ID light stays ON for approximately ____ seconds.

*****

.01 (approximate) (Very short!)

284. As you can see, increasing the time of the OS unit is accomplished by turning "t" in a ________________ direction.

*****

clockwise

285. Turn power OFF and replace the 20 MFD capacitor with a 50 MFD capacitor. Turn "t" fully clockwise, turn power ON, and initiate a response. The ID stays ON for approximately ____ seconds.

*****

10

286. Now turn "t" fully counterclockwise and initiate another response. This time the output event is of approximately ____ seconds duration.

*****

.15 sec. (approximate)

287. In other words, increasing the value of the capacitor (from 20 to 50 MFD) results in a(n) ______ OS output time.

*****

longer (increased)

288. Turn the power OFF and clear all connecting wires.

Section 7.9 - Reset

289. Reset is accomplished either manually (reset button on Input Converter) or electronically with a Reset unit. A Reset unit delivers a Special Reset Signal whenever a positive-going trans_ _ _ _ _ is applied to its input (See lower portion of Figure 13.)

*****

transition

290. The output of a Reset unit is a S_ _ _ _ _ R_ _ _ _ S_ _ _ _ _. Its shape and duration are independent of the duration of the input pulse.

*****

Special Reset Signal

291. Applying a positive-going transition to the input of a Reset unit results in a _______ _____ ______ at its output.

*****

Special Reset Signal

292. A Special Reset Signal can also be obtained from the reset output on the CX unit. Locate the CX-205 unit on Figure 30. Depressing the Reset pushbutton on the front panel of the unit results in a Special Reset Signal at pins __ and __.

*****

J, K

Section 7.10 - Inverter

293. The Inverter unit has one input and one output. When the input is ON, the output is OFF; and when the input is OFF, the output is ___.

*****

ON

294. If the input to an inverter is at zero volt potential, the output will be at _____ volt potential.

*****

-12V

295. If the input to an inverter is at -12VDC, then the output will be at _____ VDC.

*****

zero

Section 7.11 - Selectable Predetermining Counter with Automatic Reset and One Shot Output

296. In Figure 13 a One Shot, an Inverter, and a Reset unit have been added to the Selectable Predetermining Counter. The flip flop selectable output switches have been set for a predetermining count of _____.

*****

21

297. When 21 input events have been received, the output of the AND gate will be turned ___.

(See lower portion of Figure 13.)

*****

ON

298. If the output of the AND Gate is at zero volts, or ON, then the input of the One Shot is likewise ___.

*****

ON

299. Assuming that the One Shot "t" has been set for one second, then the Indicator Light will be lit for a period of ___ ______ when the AND Gate output is ON.

*****

one second

300. During the period of time "t" that the One Shot is ON, the input of the Inverter will also be ___.

*****

ON

301. If the input of the Inverter is ON for one second, then during that second its output will be ____.

*****

OFF

302. Because the Reset unit responds only to positive-going transitions, no output will be generated from it until the Inverter output is also positive going. This will not occur until the ___ of time "t".

*****

end

303. The Inverter output will be positive-going only when its input is ________ _____. This will occur only at the end of time "t".

(See lower portion of Figure 13.)

*****

negative going

304. At the end of time "t", then, a Special Reset Signal will be generated by the _____ unit.

*****

Reset

305. This Special Reset Signal will be applied to the D_ _ _ _ R_ _ _ _ pins of the flip flops, and will give them a "clear line," i.e., will return any that are in the "1" state to the "0" state.

*****

Diode reset

306. Figure 37 shows the interconnections for Figure 13. Connect the circuit as shown, using a 50 MFD capacitor in the One Shot and turning "t" to near its middle range.

Set the counter for 21 -- to do this flip flops ____, ____, and ____ should be in the "1" position and all others in the "0" position. (Check your answer by giving 21 input events and checking for an output from the ID light.)

*****

1, 3, and 5

307. Set the counter for 10 -- which flip flops are now in the "1" position? ________

(Check your answer by trying it.)

*****

2 - 4

308. As you can see the One Shot unit has allowed us to:

(1) Obtain an output pulse of variable, and precise, duration.
(2) Automatically reset our counter to zero at the end of a predetermined number of input events.

You will see later in the program how these functions greatly facilitate certain types of research.

309. Turn the power OFF and remove all connecting wires.

310. Perform Exercise 5 in the back of this booklet.

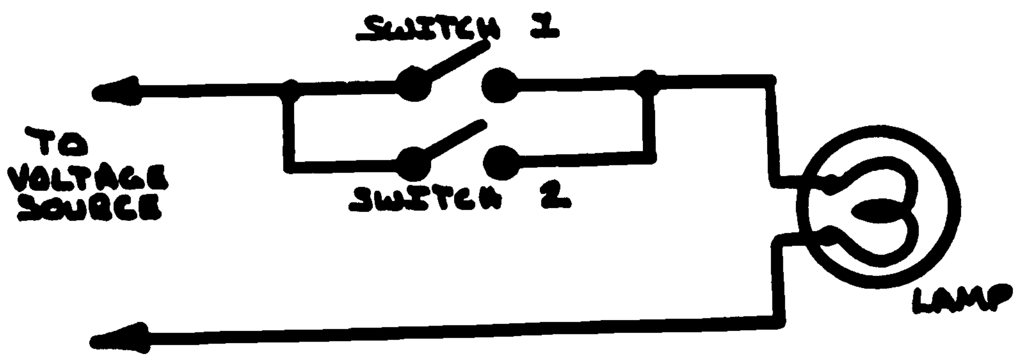
Section 7.12 - OR Gate

311. Refer to Figure 14.
The next unit we will deal with is the OR Gate. Figure 14a shows a 2-legged OR Gate, with inputs a and b, and output c. As its name implies, the output of an OR Gate will be on if either a __ b is ON.

*****

OR

312. Remember that we illustrated the function of the AND Gate with two switches connected in series. The OR Gate can be illustrated by the same two switches connected in parallel:



313. From this diagram it is easily seen that the lamp will be lit if either S-1 or S-2 is closed. Will the light be lit if both S-1 and S-2 are closed? ____

*****

Yes

314. An OR Gate will also be ON if <u>both</u> a and b are ON. The only time that an OR Gate will be OFF is when ____ used inputs are OFF.

*****

All

315. Figure 14b shows that OR Gates can be combined to gain as many input positions as are desired. There will be an output at k if there is an output from either OG-1 ___ OG-2.

*****

OR

316. In Figure 14c, an OR Gate has been used in one of its basic functions: combining 2 or more independent inputs when they are desired to produce an equivalent event. ID-2 will be ON if either AG-1 or AG-2 is ___.

*****

ON

317. AG-1 will be ON if FF-1 is in the "1" state AND FF-2 is in the __ state AND FF-3 is in the __ state.

*****

"O"
"O"

318. Therefore AG-1 will be ON after ____ input pulse(s) has(have) been received from the CX.

*****

one

319. By the same reasoning, AG-2 will be ON after ___ pulses from the CX.

*****

6

320. Therefore ID-2 will be ON after either ___ or ___ pulses from the CX.

*****

1, 6

321. Remove a blank layout sheet and show how you would connect the circuit shown in Figure 14c, referring to Figure 30 as necessary. Label your sheet "OR Gate" and save it.

Connect the circuit. Turn power ON and Reset the system. Initiate responses until ID-1 comes ON. How many did it take? _____

*****

one

322. Reset the system and initiate responses until ID-3 comes ON. How many did it take? _____

*****

6

323. After how many responses was ID-2 ON? _____ *** _____

*****

after 1 and after 6

324. Turn power OFF and remove all interconnecting wires.

Section 7.13 - Multivibrator

325. The Multivibrator (MV), or Clock, is a source of accurate pulses for use in the control and timing of digital circuits. If we wanted to control an intertrial interval, for example, we would use a(n) __________ unit.

*****

MV

326. Basically, the MV generates a continuous series of pulses equally spaced in time. Whenever the MV is ON, a _____ __ _____ are generated at its output.

*****

series of pulses

327. The basic MV can be easily understood by reference to Figures 15a and b. Here two One Shot (OS) units and two Inverters are connected to form an MV. It can be seen that the output of OS-1 (Fig. 15b) is a series of _____.

*****

pulses

328. At time "a" in Figure 15 both OS units are OFF. OS-1 is triggered into operation at time "b". While OS-1 is ON, the output of IN-1 is ____.

*****

OFF

329. At the end of the OS-1 pulse (time "c"), the IN-1 output is a ________-_____ transition. Because OS units operate on transitions, this triggers OS-2 into operation.

*****

positive-going

330. As OS-2 fires, the output of IN-2 goes to ____.

*****

OFF (-12 VDC)

331. At the end of the OS-2 pulse, the output of IN-2 becomes a ________-_____ __________, which triggers _____ into operation.

*****

Positive-going transition
OS-1

332. This cycle is repeated over and over, the result being a continuous train of pulses at a frequency determined by the OS pulse lengths. To obtain pulses equally spaced in time, it is obvious that the pulse lengths of the two OS units must be _____.

*****

equal.

333. Figure 16a shows a basic MV unit, the MV-207. It has an "enable" input which may also be called "allow" or "sync". As might be expected, the pulses will be present at the MV output only when the "enable" input is ___.

*****

ON

334. Most MV units have an adjustable frequency. Coarse adjustment is accomplished by connecting an external capacitor to the appropriate MV pins, just as was done with the OS unit. Increasing the size of the capacitor also __________ the length of the MV pulses.

*****

increases

335. Figure 16a shows an MV-207, which provides for a choice of two ranges of repetition rates, selected by the front panel switch. The switch actually selects between two different capacitor-potentiometer combinations, allowing the experimenter to easily change frequencies.

*****

336. As the MV pulse length is increased, fewer pulses will occur per unit time. In terms of frequency, then, increasing the size of the external capacitor __________ frequency.

*****

decreases

337. For finer frequency control most MV units provide a potentiometer, marked "t" in figure 16a. Notice that separate "t's" are provided for the A and B positions. By adjusting this potentiometer (usually with a front panel knob or screwdriver adjustment) the MV _________ can be changed in small increments.

*****

frequency

338. If the MV "enable" input were connected directly to ground, its output would be __________.

*****

continuous

339. Figure 16b shows an MV-207 connected to an ID light. A CX is connected to the MV input. The MV will deliver a train of pulses to the ID whenever the CX output is ___.

*****

ON

340. The following chart gives the output ranges in pulses per second (pps) or pulses per minute (ppm) that can be obtained with various external capacitor values:

Ext. Cap. (MF)	Range
None	2000 - 40,000 pps
.047	125 - 3,000 pps
.47	12 - 300 pps
4.7	2 - 30 pps
47.	6 - 300 ppm
150.	2 - 120 ppm

341. Remove a blank layout sheet, label it MV, and show how you would connect Figure 16b. Then:

(1) Connect the circuit, putting a 20 MF capacitor in for the "A" capacitor, and a 150 MF capacitor in for the "B" capacitor
(2) Turn the front panel "t" for the "A" position (upper "t") fully clockwise, and the "B" position "t" fully counterclockwise.
(3) Put the front panel switch into the "A" position.
(4) Turn the power ON
(5) Depress and hold the micro switch. The ID light should indicate that the MV is delivering approximately 10 pulses per minute.

342. Depress and hold the micro switch again, and then slowly turn the "A" position "t" in a counterclockwise direction. This ________ the number of pulses per minute delivered.

*****

increases

343. Now turn the "A" position "t" fully counterclockwise, and again hold the micro switch closed. Then flip the MV front panel switch from "A" to "B". This __________ the number of pulses per minute delivered.

*****

decreases (reduces)

344. Thus you can see that the larger the capacitor connected to an MV unit, the ______ the rate of pulses delivered.

*****

slower

345. Turn Power OFF and remove all connecting wires

346. Perform Exercise 6 in the back of the booklet.

Section 7.14 - Time Determination by Predetermined Count

347. The addition of an MV to our basic binary counter allows us to build a "time determination by predetermined count" circuit, as shown in Figure 17. The input pulses to the binary counter are from the ____, instead of an Input Converter as before.

*****

348. Notice that the OS used in Figure 17 has both normal and inverted outputs. Most OS units are equipped with both, which allows use of the inverted output without a separate IN unit.

Assume that the OS has just finished firing, which has triggered the RS unit and reset all FF's to the ____ state.

*****

"0"

349. When the OS normal output is OFF, its inverted output will be ___.

*****

ON

350. Whenever the inverted output of the OS is ON, the "enable" input of the MV will be ____. (Trace it out on Figure 17.)

*****

ON

351. The output of the MV is connected to the T input of FF-1. When the "enable" input of the MV is ON, a series of positive going transitions will be applied to the ___***___.

*****

T of FF-1

352. On the second output pulse of the MV, FF-1 will go to ___ and FF-2 will go to ___, giving a count of 01000, or 2.

*****

OFF, ON

353. AG-1 and AG-2 are connected to form a 5-legged AND Gate. The output of AG-2 will be ON after ____ pulses have been delivered from the MV.

*****

25

354. As the output of AG-2 goes to ON, a positive-going transition will be applied to ***__________.

*****

The OS input

355. This will give a pulse at the normal output of the OS for duration "t". The ID light will be ___ during this time interval.

*****

ON

356. Therefore the ID will be ON for a duration of time ("t") after every ____ MV pulses.

*****

25

357. During time "t" the inverted output of the OS will be ____.

*****

OFF

358. The ID light will be ___ during time "t".

*****

ON

359. When the inverted output of the OS is OFF, the enable input of the MV will be ___, which results in no output pulses from the MV

*****

OFF

360. At the end of time "t" the inverted output of the OS will be in a ___***___ transition state. This will be applied to the RS unit, which will give a ___***___ at its output.

*****

positive-going
special reset signal

361. This special reset signal will reset all FF units to the ____ state, preparing them for the next series of MV pulses.

*****

"0"

362. Assuming that the MV pulse frequency has been set for 1/second, this cycle will be repeated every ___ seconds.

*****

25

363. If the selectable output switch on FF-3 were changed from "0" to "1", the cycle would be repeated every ___ seconds.

*****

29

364. By increasing the size of the MV external capacitor, the length of time for each cycle would be _________. This is the same as _________ its frequency.

*****

increased
decreasing

365. 1. Using a blank layout sheet, label it "Time Determination."
2. Show how you would connect the circuit shown in Figure 17.
3. Connect the circuit, using a 50 MF capacitor with the MV unit's "A" position (set front switch to "A" as well) and a 150 MF capacitor with the OS unit.
4. Set the OS "t" to full counterclockwise position.
5. Set the MV "t" to approximately mid-range.
6. Set the flip flops for a count of 10. This is done by putting the switches on FF __ and FF __ into the "1" position.
7. Turn the power ON and wait for the ID to come ON.
8. Adjust the "t" of the OS to obtain a relatively short but easily seen flash on the ID. This will occur after every ___ pulses from the MV.
9. Adjust the "t" of the MV unit so that the ID unit flashes occur at 10 second intervals. If this is so, how many pulses per second is the MV unit delivering? ____.

*****

2, 4
10
one

366. Set different combinations of FF switches and OS and MV "t" settings until you are familiar with the operation of this circuit.

367. Turn off the power and remove all connecting wires.

368. Perform Exercise 7 in the back of this booklet.

Section 7.15 - Ring Counter

369. A Ring Counter, constructed with 3 FF's and a CX, is shown in Figure 18. To understand how it works, assume that FF-1 is in the "1" state and FF-2 and FF-3 are both in the "0" state.

The first output pulse from the CX will be delivered to the "1" input pins of all 3 FF's simultaneously. The effect of this first output will be to put FF-1 into the ____ state.

*****

"0"

370. FF-2 and FF-3 will not initially be affected by this first pulse, as ___***___.

*****

they are already in the "O" state.

371. But, as FF-1 goes from 1 to O, a positive transition will be present at its ___ output pin.

*****

"O"

372. The positive transition at the "O" output of FF-1 will be delivered to the set input of ____.

*****

FF-2

373. Remember that FF's change state very fast*. The conditions of FF-2's input pins, then, are positive transitions at both the 1 and O input pins. The O pin gets its input from FF-1, and the 1 pin gets its input from ___***___.

*They can switch back and forth at any speed up to 40,000 times per second!

*****

the CX (Input Converter)

374. We are now dealing with something familiar. Applying a positive transition to both input pins simultaneously is exactly the same as "T" operation. If a positive transition is applied to the "T" of a FF, the FF will always ___***___.

*****

change its state

375. The effect of the first input pulse, then, is to put FF-1 into the __ state and FF-2 into the __ state.

*****

0, 1

376. At the end of the first input pulse, then what states are the FF's in?

FF-1 is in the _____ state
FF-2 is in the _____ state
FF-3 is in the _____ state

*****

0, 1, 0

377. A second input pulse is now delivered to the 3 set input pins. FF-2 immediately changes to the _____ state.

*****

0

378. As FF-2 goes from "1" to "0", a positive transition will be coupled to the _____ input pin of FF-3.

*****

set

379. Again, simultaneous transitions will be present at FF-3's ____ and ____ input pins. This changes FF-3 to the ____ state.

*****

set, reset, "1"

380. Therefore, at the end of the second input pulse, the FF's will be in the following states:

FF-1 is in the _____ state
FF-2 is in the _____ state
FF-3 is in the _____ state

*****

0, 0, 1

381. It should now be apparent why this circuit is called a Ring Counter. At any given point in time only ___ FF is ON, and each FF is ON in sequence following a train of input pulses.

*****

one

382. The wire connected from the "O" output of FF-3 to the set input of FF-1 insures that ____ will come on after the 3rd input, as FF-3 goes OFF.

*****

FF-1

383. If a third input pulse were delivered from the CX, the following conditions would result:

FF-1 in the _____ state
FF-2 in the _____ state
FF-3 in the _____ state

*****

"1", "0", "0"

384. Notice however that here we must insure that one, and only one, FF in the "1" state. If all FF's were OFF at the beginning, the first input pulse would ___ ________.

*****

do nothing

385. Figure 19 shows a 6 stage Ring Counter connected to insure that FF-1 will always start in the "1" state and that all other FF's will start in the "0" state. Depressing the Reset (RS) button on the Input Connector resets FF-2 thru FF-6 to the ____ state, irrespective of their current status.

*****

"0"

386. The RS signal is also connected to the input of an additional reset unit, the output of which is connected to the "Direct Set" of FF-1. This arrangement insures that FF-1 will go to the ____ state when the RS is depressed.

*****

1

387. After the RS button has been pressed, then the FF states will be:

FF-1 in the ____ state
FF-2 in the ____ state
FF-3 in the ____ state
FF-4 in the ____ state
FF-5 in the ____ state
FF-6 in the ____ state

*****

"1", "0", "0", "0", "0", "0"

388. After the first input pulse from the CX, FF-1 will be in the ____ state and FF-2 in the ____ state, and FF's 3-6 in the ____ state.

*****

"0", "1", "0"

389. After the second input pulse, <u>only</u> FF-__ will be ON.

*****

3

390. The line from the "O" output of FF-6 to the "O" input of FF-1 is necessary to have FF-1 come ON when FF-6 goes ____. If this line were not added, all FF's would be ____ after the 6th input pulse.

*****

OFF, OFF

391. Now look at the line going to the reset input of FF-6. Assume that only FF-5 is ON, and that an input pulse is being received. This pulse would immediately change FF-5 from the "1" state to the ____ state.

*****

"O"

392. As FF-5 goes from "1" to "O", a positive transition is coupled to the ____ pin of FF-6.

*****

set

393. This positive transition at the set input of FF-6 puts FF-6 into the ___ state.

*****

"1"

394. We now have only FF-6 ON. If the line to the reset input of FF-6 were removed, the next incoming pulse would not change the state of FF-6. In other words, if this line were removed, FF-6 would always stay ____, irrespective of future inputs.

*****

ON

395. 1. Remove a blank layout sheet and label it "Ring Counter."
2. Show how you would connect the circuit in Figure 19.
3. Connect the circuit.
4. Turn the power ON and reset the system.
5. Begin pressing the micro switch. How many input events are required before FF-6 comes ON? ____

*****

five

396. The 6th input pulse leaves which FF ON? ____.

*****

FF-1

397. Practice with the circuit until you are familiar with its operation.

398. Turn power OFF and remove all connecting wires.

Section 7.16 - Decade Counter

399. The most efficient way of counting with flip flops is in the Base 2, or Binary, system. Often, however, the experimenter requires counting in the more familiar decimal mode. We will now consider a way in which flip flops can be used to count decimally.

400. Figure 20 shows a Decade Counter (DC)*. It delivers an output after 10 input pulses have been received. If the monitor OS and ID have been connected, the ID will be ON for a period of time ("t") following the ____ input pulse.

*The DC is available as a self-contained unit, although it can be constructed as shown in Figure 20. See DC-201 in Figure 30.

*****

10th

401. To understand how it works, begin with all FF's in the "0" state. The first input pulse from the CX will put FF-1 into the _____ state. This gives a count of 1000, or 1.

*****

"1"

402. The second input pulse delivered to the "T" of FF-1 puts FF-1 back into the _____ state. At the same time a positive transition is applied to the "T" of _____.

*****

0, FF2

403. FF-2 now goes to the "1" state, giving a count of 0100, or 2. The next input pulse will ___***___, giving a total count of 1100, or 3.

*****

turn FF-1 ON

404. Consider that we have now received 8 input pulses. Which FF's are ON now? _____

*****

only FF-4

405. If FF-4 is the only FF ON after 8 inputs, the ninth pulse will simply turn ____ ON.

*****

FF-1

406. The next, or tenth, pulse will turn FF-1 ____ and FF-2 ____.

*****

OFF, ON

407. As FF-2 goes to ON, a positive going transition is coupled from its "1" output to the _____ input of FF-4.

*****

reset

408. Remember that FF-4 has been ON ever since the 8th input pulse, and that this is the first time since we started that we are turning it OFF. As FF-4 goes to OFF, a positive transition is coupled to the input of the RS unit and to the "10 transfer" line. The output of the RS unit is applied to all FF's, and it ___***___.

*****

resets all FF's to 0

409. The positive transition is also applied to the OS, which is connected to the ID. Therefore, after the ____ input pulse the ID will be ON for a period of time "t".

*****

10th

410. The decade counter, then, gives a logic level output for every ____ input pulses.

*****

10

411 Section 7.17 - 0.99 Predetermining Counter

411. Figure 21 shows a 0 to 99 count predeterming counter composed of two Decade Counter (DC-201) units, two Binary to Decimal Decoder (BD-201) units, and 4 AND Gates.* The DC units are both the same as the DC unit we just dealt with in Figure 20, consisting of four FF units and an RS unit connected internally. After 10 input pulses, a logic level output will be present at the __________ output pin. (See Figure 21)

*See DC-201 and BD-201 in Figure 30.

*****

÷ TEN TRANSFER

412.412. The BD unit provides a 0 to 9 decimal output on the basis of a 1-$\overline{1}$-2-$\overline{2}$-4-$\overline{4}$-8-$\overline{8}$ binary input. If no input pulses have been received by the DC, the $\overline{1}$, $\overline{2}$, $\overline{4}$, and __ input pins to the BD will be ON.

*****

$\overline{8}$

413. If all of the "not" pins, i.e., $\overline{1}$, $\overline{2}$, $\overline{4}$, and $\overline{8}$, are ON, and none of the other pins are ON, i.e, 1, 2, 4, and 8, then the 0 output pin of the BD will also be ______.

*****

ON

414. Beginning, then, with the BD 1, 2, 4, and 8 pins OFF, and all of the "not" pins ON, we receive our first pulse into DC-1. This simply turns the $\overline{1}$ pin to OFF, and the 1 pin to ON. As might be expected, the 0 output of BD-1 then goes to OFF, and the 1 output of the BD goes to ____.

*****

ON

415. Notice that the DC is simply a binary counter of four FF stages, with the "1" and "0" pins of each FF brought out as a separate output. The BD accepts these FF outputs as its inputs and, on this basis delivers a 0 to 9 decimal output. After 6 input pulses, for example, the only DC output pins at ON* would be pins ___ and ___, and the only BD output pin at ON would be pin ____.

*Ignore, from here on, the "not" pins. As they are simple complements of the 1-2-4-8 pins, we do not have to specify their state for any count determination. Whenever one of the 1-2-4-8 pins is ON, its complementary "not" pin will be OFF, and vice versa.

*****

2, 4, 6

416. When the 10th input is received by the DC-1 unit, it will reset automatically to 0, and send a pulse on the "divide by 10 transfer" line to the input of DC-2. This will turn the 10 output pin of DC-2 to ON, and likewise the 10 output pin of BD-2 to _____.

*****

ON

417. After 30 input pulses to DC-1, the ____ and ____ output pins of DC-2 will be ON, and the ____ output pin of BD-2 will also be ON.

*****

10, 20, 30

418. After 46 input pulses to DC-1, the ____ output pin of DC-2 will be ON, the ____ output pin of BD-2 will be ON, and the ____ and ____ output pins of DC-1 will be ON.

*****

40, 40, 2, 4

419. The predetermining count function of this circuit is determined by the connections at the output of the BD unit. The output of AG-1 will be ON if _____ input pulses have been received.

*****

25

420. Likewise, if 94 input pulses have been received, the output of AG-__ will be ON.

*****

AG-4

Section 7.18 - Comparator

421. We now turn to the Comparator function. The Comparator is a logic network which receives inputs from 2 sources and delivers an output only when both inputs are in identical states. In Figure 22a, output C will be ON only if inputs A and B are either both ____ or both ____.

*****

ON, OFF

422. In Figure 22a, if input A is ON and input B is OFF, then output C will be ____.

*****

OFF

423. Considering Figure 22a in more detail: If input A is ON, the top input to OG-1 will be ____ and the top input to OG-2 (the output of IN-2) will be ____.

*****

ON, OFF

424. Therefore, if A is ON, OG-1's output will be ____, and the top input to AG-1 will be ____.

*****

ON, ON

425. To allow AG-1's output to be ON requires that the other, lower, AG-1 input must also be ON. This can happen only if the output of OG-2 is ____.

*****

ON

426. We already know that the top input to OG-2 is OFF because A is ON, as the top input to OG-2 is simply an inversion of A through IN-2. Therefore, the output of OG-2 will be ON only if input B is ____.

*****

ON

427. Reversing the procedure, we can show that it is not possible to get an output at C if A is OFF and B is ON. Solve this problem by writing in "ON" or "OFF" for the following points, given that A is OFF and B is ON:

IN-1 input _____
IN-1 output _____
OG-1 output _____

*****

ON, OFF, OFF

428. This is enough to show that C cannot be ON if A is OFF and B is ON, as OG-1 must be ____ as a prerequisite to an output from AG-1.

*****

ON

429. The comparators in Figures 22a, 22b, and 22d are all very similar, and illustrate different ways to accomplish the same logic function. The comparator in 22c is somewhat different, however. In 22c, if A is ON and B is OFF:

(a) OG-1 output will be ____.
(b) OG-2 output will be ____.
(c) Therefore C will be ____.

******

ON, ON, ON

430. The comparator in Figure 22c, then demands that the two inputs A and B be _________ before an output can be generated at C.

*****

different

Section 7.19 - Comparator Control

431. Figure 23 shows a Comparator Control circuit, which delivers an output if and only if identical conditions exist in two binary counters.

In Figure 23, the top three FF units form a "Control Binary Counter," which serves as a "model" for the lower, or "Count Binary Counter" FF's. If the Control BC is preset for 6, then an output will be delivered if ____ input events are received by the Count BC.

*****

6

432. The top three FF's are connected in a 3-bit binary counter (Control BC) with one modification: FF-1 is connected to reset to the "1" state instead of the "0" state. If the "Control" BC has just been reset, the first incoming pulse will change FF-1 to ____ and FF-2 to ____, giving a count of 010.

*****

0, 1

433. The second input pulse from the CX will change FF-1 to "1", giving a total count of ____.

*****

110 (3)

434. If we started with the three FF's in 1-0-0 states, we would have a 1-1-1 condition after _____ input pulses from the CX.

*****

6

435. So six input pulses will put FF's 1, 2, and 3 all in the "1" state. In terms of AG's 1, 3, and 5, the top inputs to these AND Gates will all be ____. (Trace it out on Figure 23)

*****

OFF

436. At the same time the top inputs of AND Gates 2, 4, and 6 will all be ___.

*****

ON

437. Now look at FF's 4 through 6: On the first positive transition from the MV, FF-4 will go from "0" to ___. (Assume FF-4, FF-5, and FF-6 begin in the "0" state)

*****

1

438. When FF-4 is in the "1" state, the bottom input of AG-1 will be ___, and the bottom input of AG-2 will be ___. (Trace it out.)

*****

OFF, ON

439. This means that the two inputs to AG-1 will be both OFF, and the two inputs to AG-2 will be both ON. Therefore the output of OG-1 will be ____.

*****

ON

440. We have seen that if FF-1 thru FF-3 are ON, and if FF-4 is ON, then the output of Comparator One will also be ____. In the same way the output of Comparator Two will be ON when FF-5 matches with FF-2.

*****

ON

441. The output of FF-3 is compared to the output of FF-6 in Comparator Three. An output will be present from Comparator Three when FF-3 and ______ are in identical states.

*****

FF-6

442. Therefore, if the Control BC is preset for 6, there will be outputs from all three comparators after ____ input pulses have been received by the Count BC.

*****

6

443. Therefore, an output, as indicated by the ID, will be generated from the entire circuit only when the two BC's have received an equal number of input events, with the _______ BC serving as the "model" for the _______ BC.

*****

control, count

444. Note also that the enable input of the MV is connected to the inverted output of the OS. Therefore the MV will be _____ whenever the OS is ON, i.e., during the time that an output is being delivered.

*****

OFF

445. The diode (D-1) connected to the output of RS-2 should be explained. A diode is specially constructed so that current can flow in only one-direction, i.e, with the arrow in the symbol.

In Figure 23, the diode allows us to reset all 6 FF's with the Input Converter reset output. It allows us to reset only the lower 3 FF's automatically after an output is delivered from OS-1, meanwhile leaving the top 3 FF's in their preset condition. In Figure 23 the reset current can flow "downward" from the CX to the Count BC, but cannot flow "upward" from RS-2 to the Control BC.

Section 7.20 - Comparator and Exclusive OR Gate

446. Providing an output only when two input events are the same is the function of the _________.

*****

Comparator

447. We will deal next with the Comparator and its complement, the Exclusive OR-Gate.

As noted earlier, the Comparator delivers an output only if its inputs are identical. In Figure 24a, an output will be delivered from the OG only if FF-1 and FF-2 are both ____ or if they are both ____.

*****

ON, OFF

448. The Exclusive OR Gate, on the other hand, delivers an output <u>only if the two inputs are in different states</u>. In Figure 24b, there will be an output from the AG only if FF-1 <u>or</u> FF-2 is ON. If both FF's are in the SAME state, the output of the AG will be ____.

*****

OFF

449. The Comparator function can be represented symbolically as: $C = (A.B) + (\overline{A} . \overline{B})$

That is, an output will be present if A and B are both ON, or if A and B are both OFF. (In this notation system the . refers to "and" and the plus sign to OR.)

If we have either $(\overline{A}.B)$ or $(A.\overline{B})$ the output of the comparator will be ____.

*****

OFF

450. The Exclusive OR function can be symbolized as:

$$C = (A.\overline{B}) + (\overline{A}.B)$$

That is, an output will be generated only if conditions A and B are different, and no output will be present if A and B are the same. If we have either ________ or ________ the output of the Exclusive OR will be OFF. (Use symbols as above in answer to this frame.)

*****

$(A.B)$, $(\overline{A}.\overline{B})$

451. It can now be seen that inverting the Comparator output gives an Exclusive OR function, and inverting the Exclusive OR output gives the Comparator function.

In the case of the inverted Comparator output, the output of IN-1 will be ON if FF-1 and FF-2 are ___***___.

*****

in different states

452. By the same reasoning, the inverted output of the Exclusive OR will be ON when FF-1 and FF-2 are ___***___.

*****

in the same state

453. To review: Providing an output only when two inputs are different is the function of the ___***___, while providing an output when two inputs are the same is the function of the ______.

*****

Exclusive OR-Gate
Comparator

Section 7.21 - Random Generation

454. We now turn to the random generation of events using logic apparatus. Figure 25a shows an electronic "coin," which randomly chooses between two events, i.e., "heads" and "tails."

In Figure 25a, when the CX is operated, the MV will be ______.

*****

ON

455. Each time the MV delivers a pulse, the FF will ___***___.

*****

change states

456. When the CX is no longer operated, the MV will stop delivering pulses and the FF will stop changing states. The FF will end up in either the ___ or the ___ state.

*****

"1", "0"

457. Now, adjust the MV to a very fast frequency, i.e., 40 KC (40,000 pulses per second). Can you predict which state the FF will end up in, if the CX is operated for variable periods of time? __________.

*****

No. At least you shouldn't be able to!

458. If you answered "no" to the preceding frame, you are entirely correct. In fact, the operate time of the CX would have to be precise to 1/40,000 of a second for the FF to systematically change states. This is, then ______ generation.

*****

random

459. Figure 25b contains a highly similar circuit in the construction of an electronic "die," having random probabilities of 6 events (sides of die). Figure 25b consists of a 6-stage ring counter connected in "looped" fashion. Remember that in a ring counter only ____ FF is on at any given time, and that each FF comes on in sequence.

(NOTE: Don't let the abbreviated diagram of the ring counter throw you. This is just a short-hand diagram of the complete counter.)

*****

one

460. Again, if the MV is set for an extremely fast frequency, and if the CX operate time is not extremely accurate, the single FF that is ON when the CX goes to OFF will be determined ran_ _ _ _ _.

*****

randomly

461. Figure 25c shows a random probability gate. Depressing the RS button on the CX will start the two lower One Shot units (OS-4 and OS-3). These two OS units function as a single MV unit, and deliver a train of ______ as their output.

*****

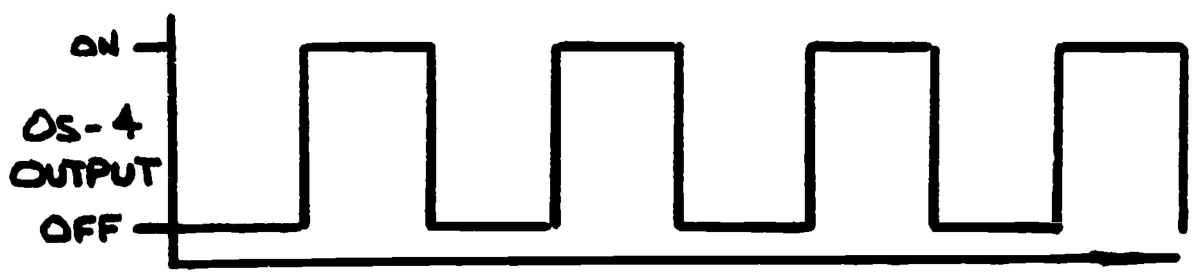
pulses

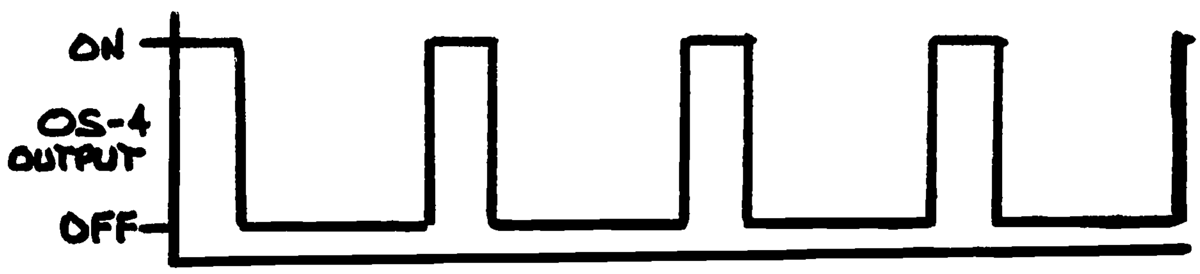
462. Notice that when OS-3 is ON, OS-4 is OFF, and when OS-3 is OFF, OS-4 is __.

*****

ON

463. Notice too that the ON duration times of the two OS units are independently variable. This allows us to determine the ON and OFF portions of the pulse train independently. Two examples of possible pulse trains are:





In other words, we can have unequal ON and OFF times at the output of ____.

*****

OS-4

464. The output of OS-4 is one of the inputs to the AG unit. The other input is from the CX unit normal output. Operating the CX delivers a brief, and adjustable by means of OS-1, pulse to the AG. The probability of this pulse producing an output is equal to the proportion of time that the second AG leg is ON. Therefore, the probability of an output is determined by the proportion of time that ____ is ON.

*****

OS-4

465. As the proportion of time that OS-4 is ON is increased, the probability of an output occurring when the CX is operated ________.

*****

increases

466. If the duration of the output pulse of OS-4 is shortened, then the probability of an output when the CX is operated is ________.

*****

decreased.

467. Increasing the time that OS-3 is ON is the same as __________ the probability that an output will be produced by depressing the CX operate button.

*****

decreasing.

PART VIII. PROGRAMMING STRATAGEMS

468. This section will deal with the instrumentation of six stratagems:

1. Fixed ratio
2. Fixed interval
3. Differential reinforcement for low rates
4. Sidman avoidance
5. Escape
6. Escape avoidance

Section 8.1 - Fixed Ratio

469. The Fixed Ratio schedule of reinforcement has as its function the delivery of reinforcement on the basis of a fixed (but selectable) number of input events (responses). Delivering a reinforcement after every 10 responses would be a function of a _____ _____ schedule.

*****

fixed ratio

470. Figure 26 shows a fixed ratio circuit. Little need be said about it as it is, simply enough, a binary counter using four flip flops. With this circuit it would be possible to have schedules ranging from a 1:1 to a __:1.

*****

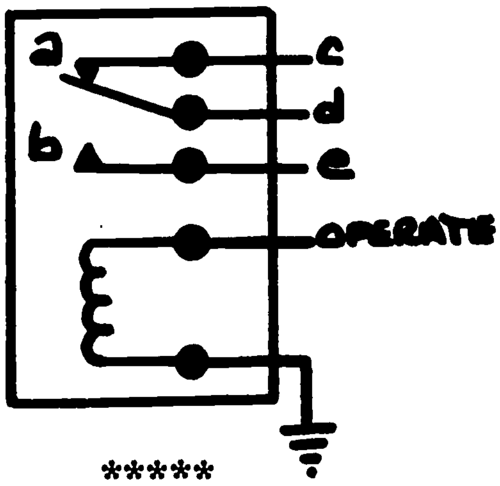
15

471. The unit marked "RY-1" in Figure 26 needs explanation, however. The RELAY (RY) is an output converter that accepts a logic level signal as an input, and has a contact closure as its ______.

*****

output

472. Whenever a logic ON is applied at the relay's input, the moveable contact moves from the upper contact (point "a" below) to the lower contact (point "b" below). This gives a short circuit between output pins d and __.



*****

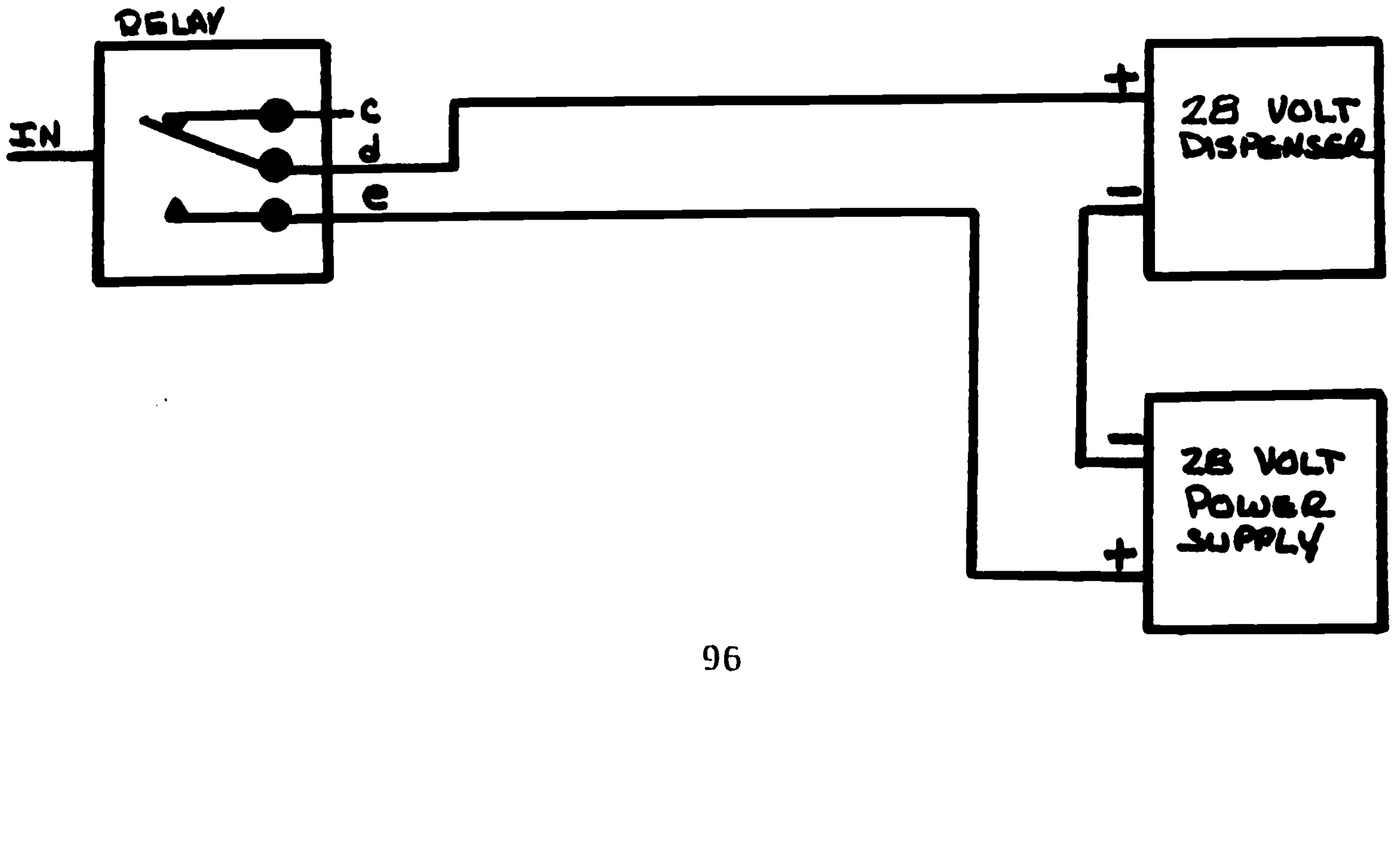
e

473. The relay, then, is much like a switch, the difference being that it opens and closes on the basis of electrical rather than manual inputs. Whenever a logic ON is applied at the input, the "normally open" circuit will be ______.

*****

closed

474. The relay can be used to convert logic level signals into electrical signals appropriate for driving other external devices, e.g., dispensers. The following diagram illustrates how this can be accomplished:



475. Whenever a logic ON is applied to the RY input, a switch closure will result between pins ____ and ____.

*****

d, e

476. The positive side of the external power supply is connected to Pin e of the relay. Whenever the relay is operated, the positive 28 volts will be applied to the ________ side of the dispenser as well.

*****

positive

477. Locate the RY-204 and RY-205 units in Figure 30. As you can see, the RY-205 units have both normally-open and normally-closed contacts, while the RY-204 has only normally _____ contacts.

*****

open

478. You can also see that there are two separate relays mounted on each of the RY-204 and RY-205 packages.

*****

479. The only other difference between the RY-204 and RY-205 is that of current rating. The RY-204 is capable of passing only low currents through its contacts, while the RY-205 has a higher _______ rating.

current

480. In Figure 26, then a given number of responses will light the ID-1 indicator, and will operate the ______.

*****

relay

481. The relay will remain operated for a period determined by the _____ unit.

*****

OS-1

482. The function of connecting the OS-1 output into the actual dispensing of reinforcement is performed by the _____ unit.

*****

relay (RY-1)

482a. Perform Exercise 8 in the back of this booklet.

Section 8.2 - Fixed Interval

483. We will now turn to the Fixed Interval schedule, as shown in Figure 27. The Fixed Interval Schedule is one in which the 1st response after a predetermined period of time will deliver a ____________.

*****

reinforcement

484. Delivering a reinforcement after the 1st response following set 10 second intervals is a function of the _____ ________ schedule.

*****

fixed interval

485. The following frames refer to Figure 27:

A response is converted by the Input Converter into a logic level signal. Responses are then connected to the top input of ____.

*****

AG-2

486. For AG-2 to give an output, the output of ____ must first be ON.

*****

AG-1

487. AG-1 will be ON only when the binary counter has completed its count. In Figure 27, assuming that MV-1 is set for 1 PPS, this will occur after ___ seconds. (Assume all FF's start in "O" state)

*****

27

488. At the end of 27 seconds, then, AG-1 will be ON. This ON signal is inverted by IN-1 and coupled to MV-1, which turns MV-1 ____.

*****

OFF

489. With AG-1 ON and MV-1 OFF, assume that a response is made. This turns AG-2 ON at it's output, which in turn, triggers ____ into operation.

*****

OS-2

490. OS-2's function is to deliver reinfrocement through ____.

*****

RY-1

491. The delivery of reinforcement is signaled by the lighting of ____.

*****

ID-1

492. The output of AG-2 is inverted by IN-2, and operates RS-2, RS-2, then ___________***___________.

*****

resets all flip flops to "O"

493. When the counter resets to "0," the output of AG-1 goes to ____.

*****

OFF

494. When AG-1 is OFF, MV-1 goes to ___.

*****

ON

495. Make Certain that you understand the operation of the Fixed Interval Circuit before proceeding to the next frame.

Section 8.3 - Differential Reinforcement for Low Rates

496. The addition of the circuitry drawn in heavy lines easily turns the FI schedule into a DRL schedule or "Differential Reinforcement for Low Rates of Responding."

497. The contingency in DRL is, again, time -- but here responses made prior to the passage of some preset minimum time will reset the accumulated time to zero.

498. That is, in DRL, the reinforced response must be made after a minimum period of time in which __ responses were made.

*****

No

499. In Figure 27, if AG-1 is OFF, the lower input to AG-3 will be __.

*****

ON

500. When AG-1 is OFF, then, a response will, through the Input Converter, trigger the ____ unit.

*****

RS-1

501. RS-1, as you can see, resets the counter to ____.

*****

zero

502. Thus, the addition of the solid lines makes this a DRL circuit - any response occurring before the binary counter has completed its count will reset the counter

503. Maximum reinforcement, then, is obtained by ____ rates of responding.

*****

low (slow)

505. Using a blank layout sheet, show how you would interconnect the FI circuit. Hook it up, turn the power ON, and test it for proper operation. (Don't forget the timing capacitors in MV and OS units)

506. Do not remove your interconnecting wires

507. Add the DRL portion of the circuit, and test it for proper operation.

508. Remove all interconnecting wires

<u>Section 8.4 - Sidman Avoidance</u>

509. Figure 28 shows a Sidman Avoidance Circuit. Its definition is that <u>negative</u> reinforcement, e.g., shock will be applied if a given behavior does <u>not</u> occur during a specified period of time.

510. For example, if Johnny's father tells him to "mow the lawn by 5 p.m. or be grounded for a week," he has set up a ______ _________ schedule.

*****

Sidman Avoidance

511. Looking at Figure 28, negative reinforcement will be delivered by RY-1, which is, in turn, operated by the _____ unit.

*****

OS-2

512. OS-2 can be triggered by either input to the ____ unit.

*****

OG-1

513. The two inputs to OG-1 are from AG-1 and AG-2. Thus, negative reinforcement will be delivered whenever all inputs to either of these AND Gates are ___.

*****

ON

514. AG-2, the S-S AND Gate, will be ON after each ___ second interval (assuming MV-1 is set for 1 pps and the counter is never reset).

*****

15

515. The SS interval, then, is the interval between negative reinforcements, given that the counter is never _____.

*****

reset

516. Notice, too, that the S-S AND Gate will not fire unless FF-5, the CONTROL Flip Flop is in the ____ state.

*****

"O"

517. The responses are connected via the OS-1 unit to the ____ input pin of the CONTROL Flip Flop.

*****

set

518. Responses are also connected, via OG-2 and IN-2 to the RS-1 unit. The RS-1, in turn, ___***___.

*****

resets the counter to zero

519. Thus, by responding, the subject can put FF-5 to "1" and reset the counter, and by so doing can avoid all negative reinforcements from the ____ AND Gate.

*****

S-S

520. A second time, the R-S interval, is included in the circuit. This is the time between the last response and the first reinforcement, after which the reinforcement will be delivered at the _____ interval.

*****

S-S

521. In Figure 28, if the CONTROL Flip Flop is in the "1" state, a reinforcement will be delivered ___ seconds after the last response.

*****

5

522. If this has happened, e.g., a reinforcement was delivered after 5 seconds of non-response time, the output of OG-1 would, through IN-1, put the CONTROL Flip Flop into the ____ state.

*****

"O"

523. The next reinforcement, then, will be delivered after 15 additional seconds, provided that ______***______.

*****

no responses are made

524. Notice that there are 3 ways that the counter can be reset. These are ______***______, ______***______, and ______***______.

*****

delivery of reinforcement
occurrence of a response
depressing reset on Input Converter

525. The diode, D-1, prevents two of these reset commands from resetting the CONTROL Flip Flop. These are ______***______ and ______***______.

*****

delivery of reinforcement
occurrence of a response

526. Finally, note that MV-1 is OFF during the ON time of ____.

*****

OS-2

527. This insures that the R-S and S-S times occur at the termination of the reinforcement, rather than at its _____.

*****

onset (start)

528. Be sure that you are familiar with this circuit before continuing.

529. Using a blank layout sheet show how you would connect the Sidman Avoidance Circuit. Connect it and test it for proper operation.

530. Remove all interconnecting wires.

Section 8.5 - Escape

531. The next circuit we will consider is the Escape stratagem. Escape is defined as the termination of negative reinforcement, which was started after a predetermined period of time, on the basis of a response.

532. In the Escape paradigm, the subject ______ (can/cannot) get by with no negative reinforcement.

*****

cannot

533. In other words, negative reinforcement is always delivered after a set period of time, and it can be terminated only by a ________.

*****

response

534. Figure 29 shows the interconnections for the Escape circuit. In Figure 29, ID-1 signals the presentation of "unlimited reinforcement," i.e., it will be ON until a ________ is made.

*****

response

535. The portion of the circuit enclosed by dotted lines can be added to limit the ON times of the reinforcement. If this is used, the length of the reinforcement will be determined by the ____ unit.

*****

OS-1

536. Reinforcement will be delivered whenever _____ is in the "1" state.

*****

FF-6

537. FF-6 is turned ON by the output of AG-1. AG-1 will be ON, if MV-1 is set for 1 pps, after ___ seconds.

*****

25

538. When AG-1 is ON, MV-1 will be OFF through the ____ unit.

*****

IN-1

539. Assuming that the counter has counted 25 seconds, putting FF-6 into the "1" state, and stopping MV-1, ID-1 will be ON until ______***______, which returns FF-6 to the _____ state.

*****

the next response
"0"

540. The output of the input converter is also connected to the reset input of OS-1. As might be expected, an ON signal at this point will ______***______ .

*****

turn the output of OS-1 to OFF.

541. Thus, if the limited reinforcement option is used, reinforcement can be terminated by either ___***___ or ___***___.

*****

the occurrence of a response
OS-1 reaching the end of its time

542. The counter is reset by either RS-1 or RS-2. RS-1 is triggered when FF-6 goes to the "0" state, which occurs on any response after ___________ has been initiated.

*****

reinforcement

543. Use a blank layout sheet and show how you would connect the circuit. Hook it up and test it.

544. Do not remove your interconnecting wires.

Section 8.6 - Escape Avoidance

545. The addition of RS-3 in Figure 29 makes this into an Escape-Avoidance circuit. That is, the subject can _____ negative reinforcement by making a response during the inter-reinforcement periods.

*****

avoid

546. As you can see, RS-3 simply resets the binary counter on _____ response.

*****

every

547. As reinforcement will not be delivered until the counter has reached the end of its count, the subject can, by responding, _____ all reinforcement.

*****

avoid

548. Add RS-3 to your circuit, and test it for Escape-Avoidance Operation.

549. Remove all interconnecting wires.

PART IX. OTHER LOGIC UNITS

550. This section deals with various logic units not previously discussed in preceeding frames. We will take each in turn, point out functions, inputs, and outputs. Turn to Figure 30, which shows unit interconnections. Additional information concerning these units can be obtained by reference to the BRS Catalog.

Section 9.1 - Reset Units (RS)

551. Reset units have already been discussed, but a few points should be made concerning differences in the various types of RS units. The RS-201 (Figure 30) has two inputs for each of the four separate RS sections. The lower inputs (pins C, H, K, and P) are for use with high-frequency circuits (10KC-40KC), and can reset up to 5 flip flops per output.

The lower inputs are for ____ frequency applications.

*****

high

552. The upper inputs (pins B, F, L, and R) are for frequencies up to 10KC, and can reset up to 20 flip flops. By comparison, then, the upper inputs are for use with ______ (higher/lower) frequencies, and can reset _____ (more/fewer) flip flops.

*****

lower
more

553. The RS-202 unit has two Reset Circuits. You must connect pins D and N to ground for proper operation. The inputs are at pins __ and __.

*****

C, P

554. Pins F and H and L and K allow the use of the diodes alone. Earlier in this program, if you remember, we had reason to use diodes to allow reset pulses to operate in one direction only. The RS-202 diodes can be used for these purposes.

*****

555. The RS-203 unit can reset up to 20 flip flops, on either logic signal command or by depressing a "Reset" button on the front of the unit. Closing the pushbutton or a ground level on pin F will result in a reset signal at pin __.

*****

L

556. The RS-203 also contains an auxiliary pushbutton. Pushbuttons will be discussed later in this section, so no explanation is given here.

557. The RS-204, is just like the RS-202, except that it has ____, rather than 2, separate reset circuits.

*****

4

558. <u>Section 9.2</u> - <u>One Shot Units (OS)</u>

558. The One Shot has also been discussed previously. Here it should be pointed out, however, that there are two types of OS units. The OS-202 (current versions of this unit are labeled OS-204) provides for both coarse and _____ time adjustments.

*****

fine

559. The OS-203, on the other hand, allows <u>only</u> _____ time adjustment, by way of external capacitors (See Figure 30).

*****

coarse

560. Note also that the OS-202 is a single unit, while the OS-203 has __ separate circuits in the same package.

*****

2

Section 9.3 - AC Switch (AS)

561. The AS-201 is a solid state AC switch that can be used to operate external AC equipment, such as tape recorders, carousel projectors, and so forth.

562. Applying a logic ON at pin __ results in a 115 volt AC output at the AC output socket (not shown in Figure 30).

*****

E

563. Note also that the AS-201 takes up two card file spaces.

Section 9.4 - Binary Counter (BC)

564. The BC-201 is highly similar to the DC-201, which we have dealt with earlier. The BC, however, does not automatically reset and deliver an output after ___ input pulses, as does the DC.

*****

10

565. A reset signal applied to pin N will reset the BC to __.

*****

0

Section 9.5 - Comparator (CP)

566. The CP-202 is a comparator circuit much like we dealt with earlier, mounted on a single card. As you can see, it is composed of 2 AND Gates and one __ ____.

*****

OR Gate

567. The comparator function is to compare two inputs and deliver an output when they are ___***___.

*****

both the same, or identical

568. Section 9.6 - Decimal Counters (CT)

568. The CT-202 is a decimal counter, which counts one digit for every logic input pulse. As you can see, there are two separate counters mounted on the same card.

*****

569. The upper counter is activated by input pulses at either pin C or D. The lower counter's input is at pin __.

*****

P

570. Note also that the CT-202 requires an external 28 VDC to operate, the positive side of which is connected to pin __, __, or __.

*****

H, J, K

Section 9.7 - Flip Flop (FF)

571. There are several different flip flop units, as shown in Figure 30. To begin with, the FF-207, FF-208, and ______ all contain two separate FF circuits on the same card.

*****

FF-209

572. The FF-208 and FF-209 units are identical, except that the FF-209 has a "1" state indicator, while the ______ does not.

*****

FF-208

573. Some FF units have "1" indicator lights, while some do not. Those with indicator lights are FF-209, FF-206, and ______.

*****

FF-204

574. Another difference in flip flops is the presence or absence of a selectable output pin. The only units with selectable outputs are the ______ and ______ units.

*****

FF-206, FF-210

Section 9.8 - Amplifier (HA)

575. The HA units are amplifiers which allow the researcher to "boost" a logic signal to a level where it can drive many more units than could otherwise be driven. It will be discussed more fully in Part X of this program.

Section 9.9 - Lamp Driver (LD)

576. The LD, or Lamp Driver, units are constructed to drive external 12 VDC or 28 VDC lamps. The external lamp will be ON when a logic ON is applied to the input pins of the LD unit.

577. The LD-201 and LD-202 are for 12 VDC lamps, while the LD-203 is for use with ______ lamps.

*****

28 VDC

Section 9.10 - Pushbutton (PB)

578. The PB-201 consists of two normally open pushbutton switches, mounted on a single card. Depressing the top PB results in a switch closure (short circuit between pins __ and __.

*****

F, H

Section 9.11 - Relay Driver (RD)

579. RD units are specially constructed solid state switches which are used to operate external 28 VDC relays, solenoids, etc.

580. The RD unit requires care in its interconnections - hence the "consult catalog" note on Figure 30. You can see, however, that a logic ON at pin C of the RD-202 will result in an output at pin __.

*****

E

581. One of the advantages to the RD unit is that it has no moving contacts, as does the RY unit. That is, it is a _____ state switch.

*****

solid

Section 9.12 - Divide by Ten Counter (SD)

582. The Divide by Ten Counter, or SD-201, could better be termed a Divide by X Counter, with X a variable from one to ten.

*****

583. The SD-201 delivers an output for X number of inputs, with X selectable from one to ten by means of a front-panel,ten-position switch. If the switch were set to 5, an output would be delivered on the _____ input event.

*****

fifth

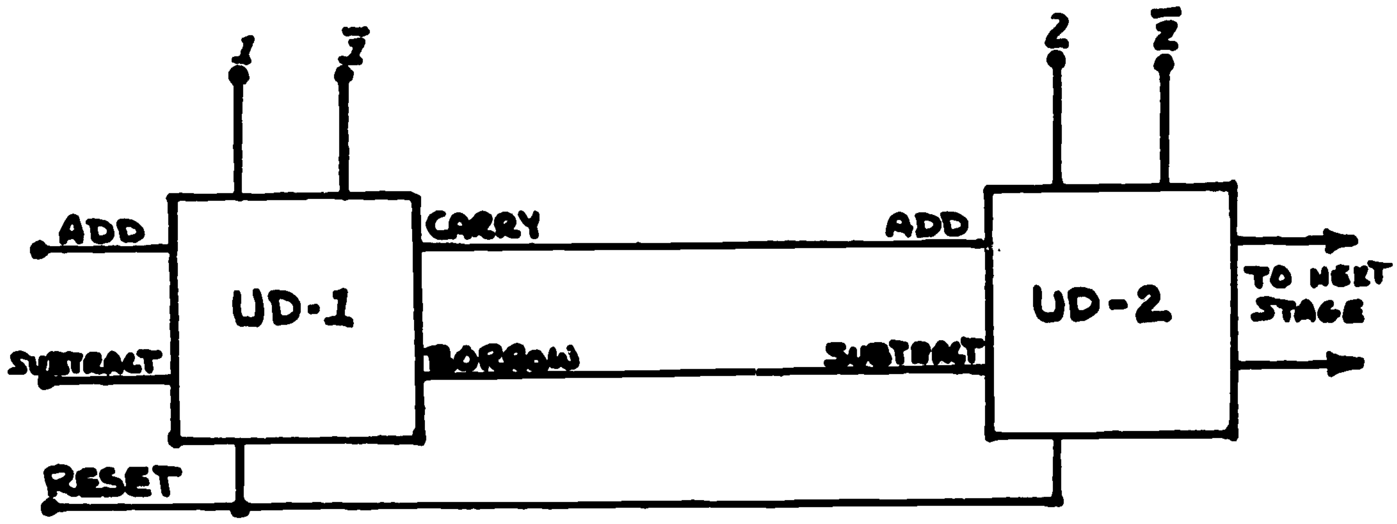
Section 9.13 - Up-Down Counter (UD)

584. The UD is a useful device in applications requiring a bi-directional binary counter. That is, the UD unit can both add and ________.

*****

subtract

585. The following diagram shows two UD units connected in an add-subtract binary counter.



Note that there are two input lines here - one for adding and one for subtracting. Assume that both UD's are in the "0" state, i.e., their "not" pins are ON. The first input pulse on the "add" input will change UD-1 from "not one" to _____.

*****

"one"

586. The second input will change UD-2 from "not two" to "two," and UD-1 from "one" to "___ one."

*****

"not one"

587. After the third "add" input, both UD's will be in the ___ state.

*****

"1", or on

588. As you can see, the add function here is the same as in any binary counter. An input to the "subtract" pin, however, will ________ one from the total count.

*****

subtract

589. Thus, if we started with both UD's in the "1" state, one "subtract" input would leave them in which state?

UD-1 ____
UD-2 ____

*****

"0", "1"

Section 9.14 - Switch (SW)

590. There are two basic kinds of switches, both of which are shown in Figure 30. The SW-201 is a slide switch, just as is used on the FF-206 units. When the button is pushed up, a switch closure is obtained between pins D or E and ___.

*****

H

591. Figure 30A contains diagrams of six recent additions to the BRS line. We will now consider each in turn.

Section 9.15 - Pulse OR Gate (OG-206)

592. The OG-206, the Pulse OR Gate, provides for either pulse or indefinite ON outputs. An input at the pins marked with a dot in Figure 30A result in pulse outputs.

593. Thus, any logic ON at pin C of the OG-206 will result in a short _____ ______ at pin F or H, irrespective of the condition at pins D or E.

*****

pulse output

594. Pins D and E function in normal OR Gate fashion, i.e., a logic ON at either will produce an output ON at pin ___.

*****

F or H

595. The lower OR Gate is the same as the upper, except that it has an additional pulse input pin.

Section 9.16 - Selectable AND Gate (AG-208)

596. The AG-208 is a normal AND Gate, except that each input is selectable between two independent pins. Thus the top input can be obtained from either pin ___ or ___.

*****

C, D

597. The AG-208 also provides an inverted output at pin ___.

*****

P

Section 9.17 - CX with One Shot Output (CX-207)

598. The CX-207 is an Input Converter highly similar to the familiar CX-205, The major difference is the addition of a One Shot output, available at pin ___.

*****

E

599. Depressing the pushbutton, or a short across the "Input N.O." pair results in a One Shot output pulse at pin E, and an indefinite, or normal, output at pin __ or __.

*****

F, H

600. Notice that the One Shot duration time is only coarsely adjustable with an external capacitor between pins ___, ___ and ___, ___.

*****

J, K; L, M

Section 9.18 - Sonalert (SA)

601. The SA-201 Sonalert is an Audio-Visual Indicator unit. It delivers a visual lamp ON whenever a logic ON is applied to input pin ___.

*****

E, F

602. It also delivers a 2.5 KC tone from the front speaker whenever pin L or M is ___.

*****

ON

603. The front panel "Enable" switch is used to disable the tone circuit when its function is not required.

*****

Section 9.19 - Exclusive OR Gate (OG-207)

604. The OG-207 is an Exclusive OR-Gate. That is, it delivers an output when one and only one of the ______ is ON.

*****

inputs

605. If pin D is ON and pin C is OFF, pins F and H will be ___.

*****

ON

606. If pin D is ON and pin C is ON, pins F and H will be ___.

*****

OFF

Section 9.20 - Switch (SW-203)

607. The SW-203 is a two-pole, five-position rotary switch. The common contact on the upper pole is connected to pin ___.

*****

H

608. Both Common Contacts "sweep" around the rotary contacts simultaneously. If the switch were set for "3," short circuits would be obtainable between pins H and __, and between pins P and __.

*****

D, L

609. Perform Exercise 9 in the back of the book.

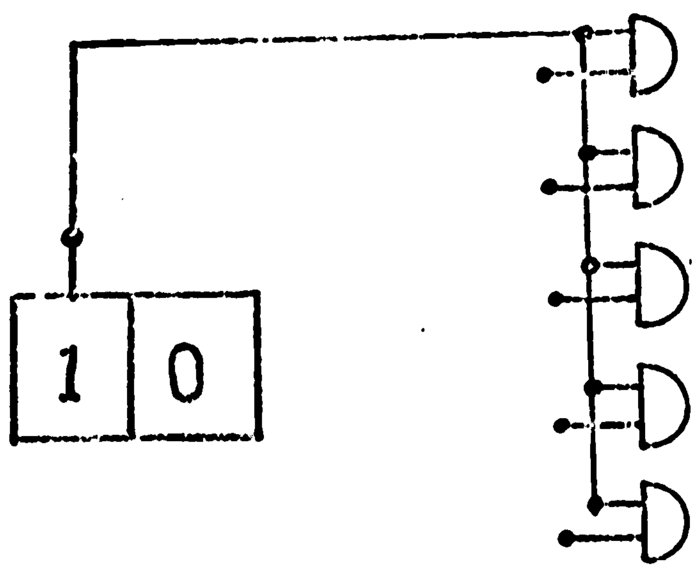
PART X. DESIGN AND THE SOLUTION OF DESIGN PROBLEMS

The final part of this program deals with several aspects of logic circuitry that are important to the researcher interested in designing and constructing his own logic circuits. The programmed format will be foregone here, as the material is more amenable to prose explanation.

Section 10.1 - Loading

Loading refers, as you might expect, to the attachment of units or devices that draw electrical power to a voltage source. The "load" of an electric circuit refers, then, to the amount of power that all of the attached units or devices must have in order to function properly.

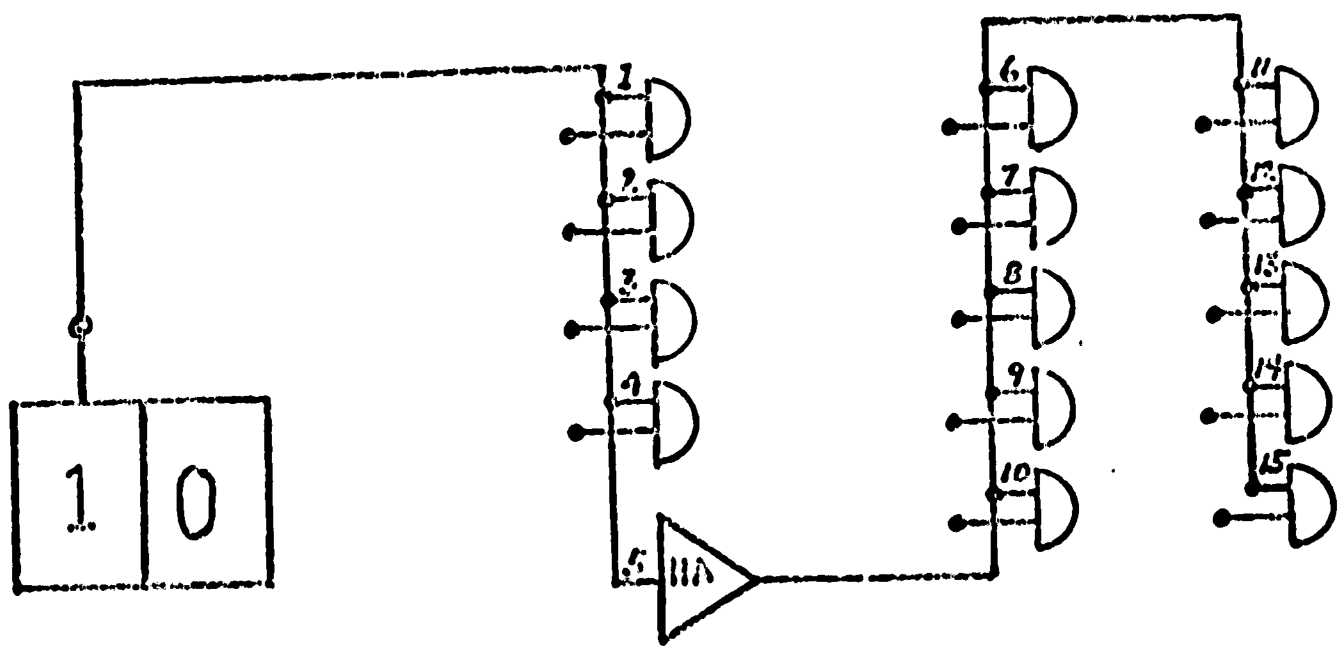
In the case of logic units, the load of any unit consists in the total number of other units connected to its output. Thus, the load of the Flip Flop "1" output below consists of five AND Gate inputs:



The BRS line of units uses the term "standard load" to refer to the amount of power required to drive any logic unit. All BRS units, that is, place one standard load upon the output of the unit to which they are connected. Thus, in the drawing above, five standard loads are connected to the Flip Flop's "1" output.

Most of the logic units manufactured by BRS are capable of driving from four to five standard loads.* As the Flip Flop can drive only five standard loads, adding an additional AND Gate -- or any other unit for that matter -- to the "1" output in the drawing above would overload the circuit. In this case there would be a good chance of either non-operation or inconsistent operation.

At times it is necessary to drive more than five inputs with the output of a single unit. This can be accomplished in the following manner:



*Consult the BRS Catalog for the driving capabilities of each unit.

In the circuit above, the Flip Flop output is directly connected to five standard loads, one of these being the Amplifier, or HA, unit, which likewise requires only one standard load for its input. The output of the HA is capable of driving up to ten other units -- i.e., it has an output capacity of ten standard loads. We have, then increased the driving capacity of the flip flop "1" output by nine, and we can now drive 14 standard loads (5 - 1 + 10 = 14), excluding the HA unit.

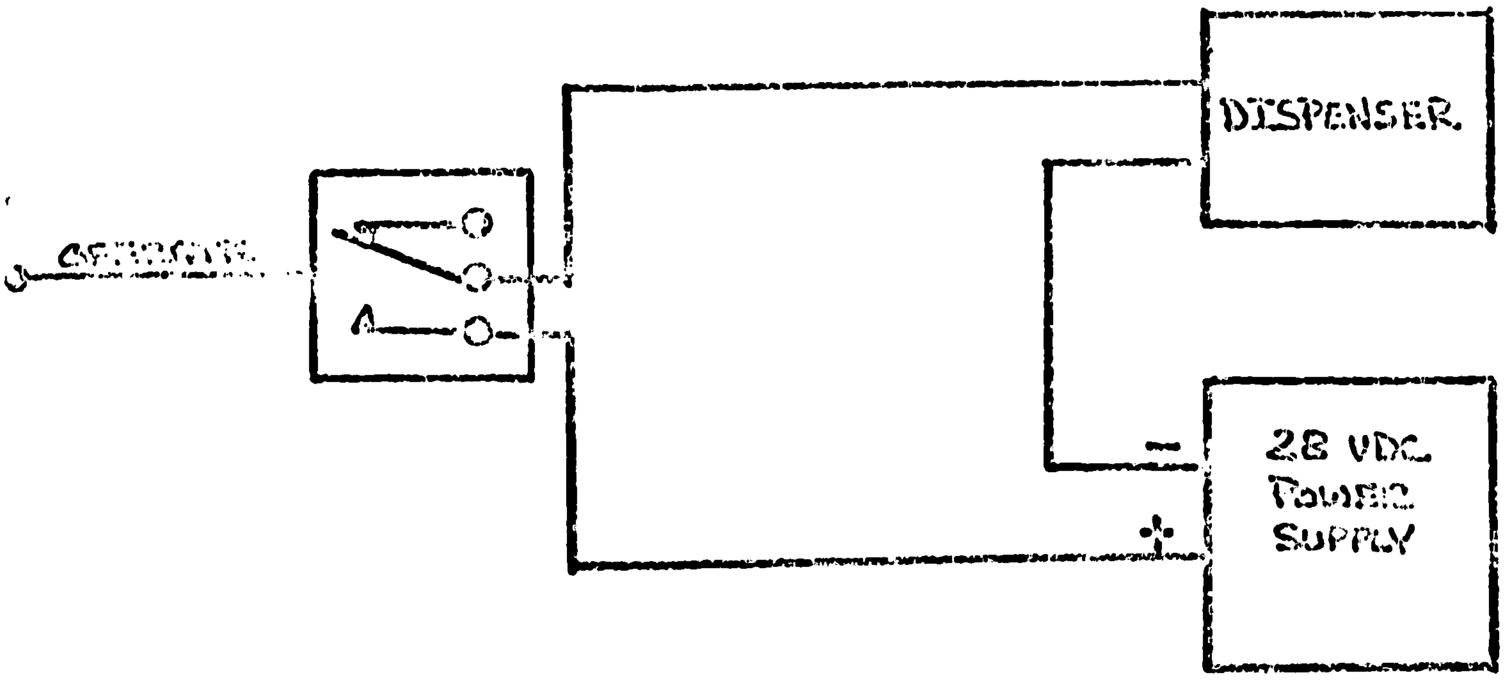
Loading must be taken into account in any circuit design. Some practice will familiarize you with the drive capabilities of the various units.

Section 10.2 - Noise Suppression

The term "noise rejection" refers to the capability of logic units to reject, i.e., remain uninfluenced by, external sources of electrical power. Several of the units, remember, operate on the positive-going transitions and/or special reset signals. These units are especially susceptible to influence from external electrical noise.

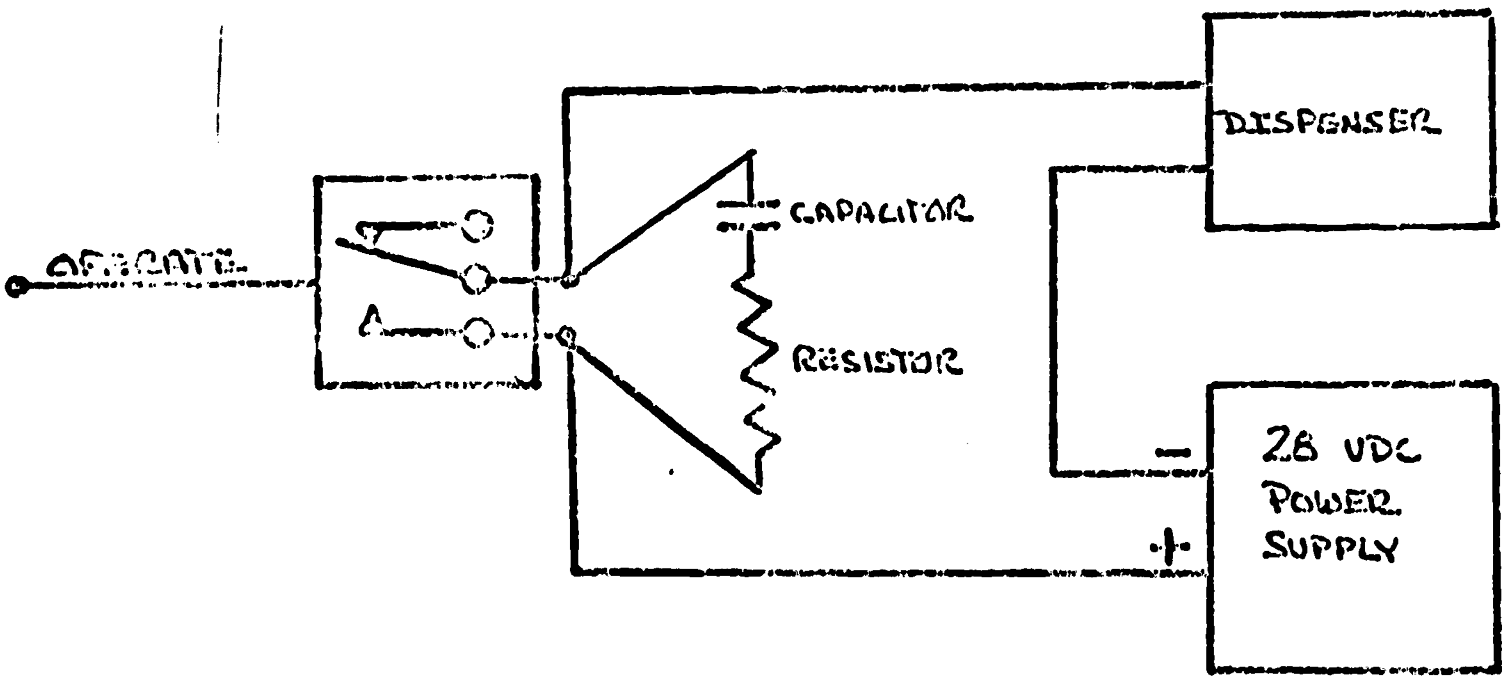
Sources of noise in the immediate environment, e.g., electric motors, electric fans, fluorescent lights, etc., are rarely a problem, as logic units usually reject this type of noise. The major problem, rather, lies within the equipment itself, particularly at those points in the circuit where logic signals are converted to other levels to drive external devices.

In the diagram below a Relay (RY) is connected to drive an external 28 Volt M&M dispenser:



The noise of concern here is generated within the Relay. The dispenser is a fairly high current device, with the result that arcing and sparking occurs at its contacts each time the Relay is operated or released. This noise, if coupled to the inputs of other units, can substitute for positive transitions and/or reset signals, causing them to operate spuriously.

The most efficient way of eliminating this source of trouble is through the use of <u>spark suppressors</u> connected across the relay contacts. The drawing below shows the same circuit with a spark suppressor added:

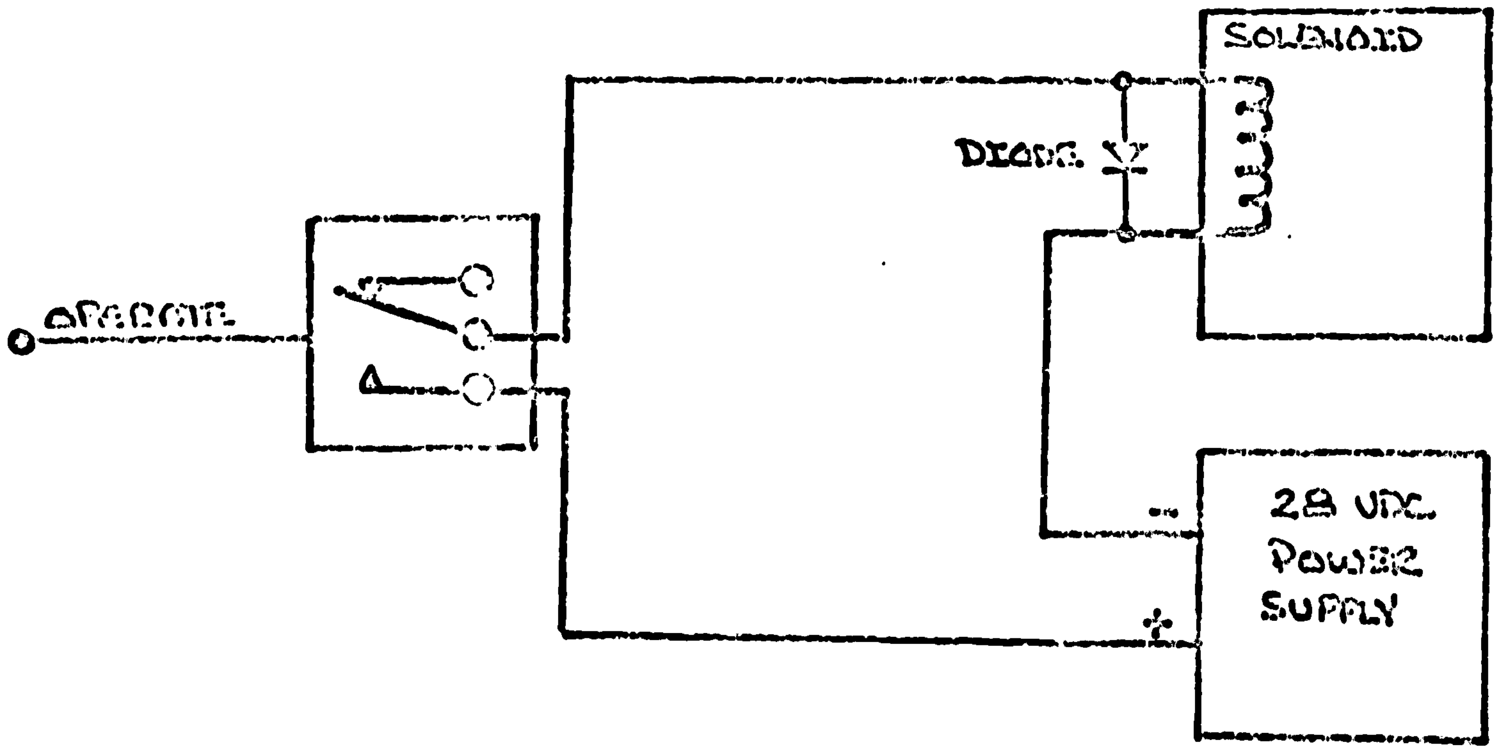


The spark suppressor, as you can see, is simply a capacitor (.47 MF, 100 WVDC) and a resistor (2 ohm, 1/2 watt) connected in series. The suppressor can be easily connected to taper pins, and inserted at the rear of the card file.

The effects of noise can also be minimized by following the rule of always keeping interconnecting wires as short as possible. This requires, of course, proper placement of units in the card file, as you construct the circuit.

Additionally, making sure that the rack holding the card file and power supply is well grounded will also serve to reduce noise problems.

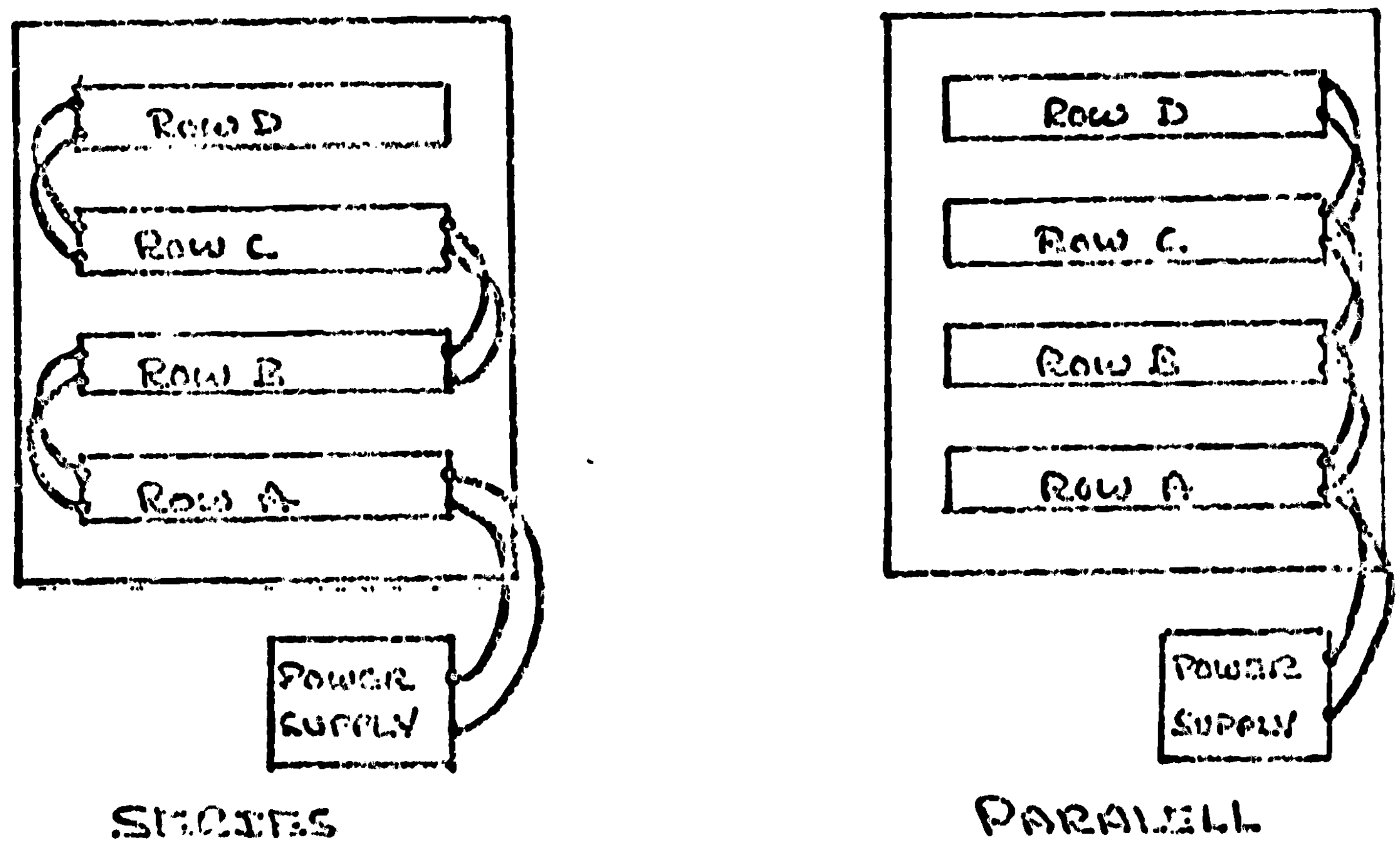
Finally, if the external device is of an inductive type, i.e., it has a coil, such as a relay or solenoid, the use of a diode connected across the load will reduce noise generation. In the diagram below a Relay is shown driving an external solenoid, and a diode is shown connected across the solenoid coil:



You must remember, however, to connect the diode in the manner shown. If its polarity is reversed, a high current will flow through it all of the time, shorting out the external device. The result will usually be a burned diode or blown fuse.

Section 10.3 - Power Distribution

As you will remember, a 12 VDC power supply must be connected to each row of units in the card file. If several rows are used, it becomes important to connect the rows in parallel, rather than series, fashion. The drawing below schematically represents these alternative methods:



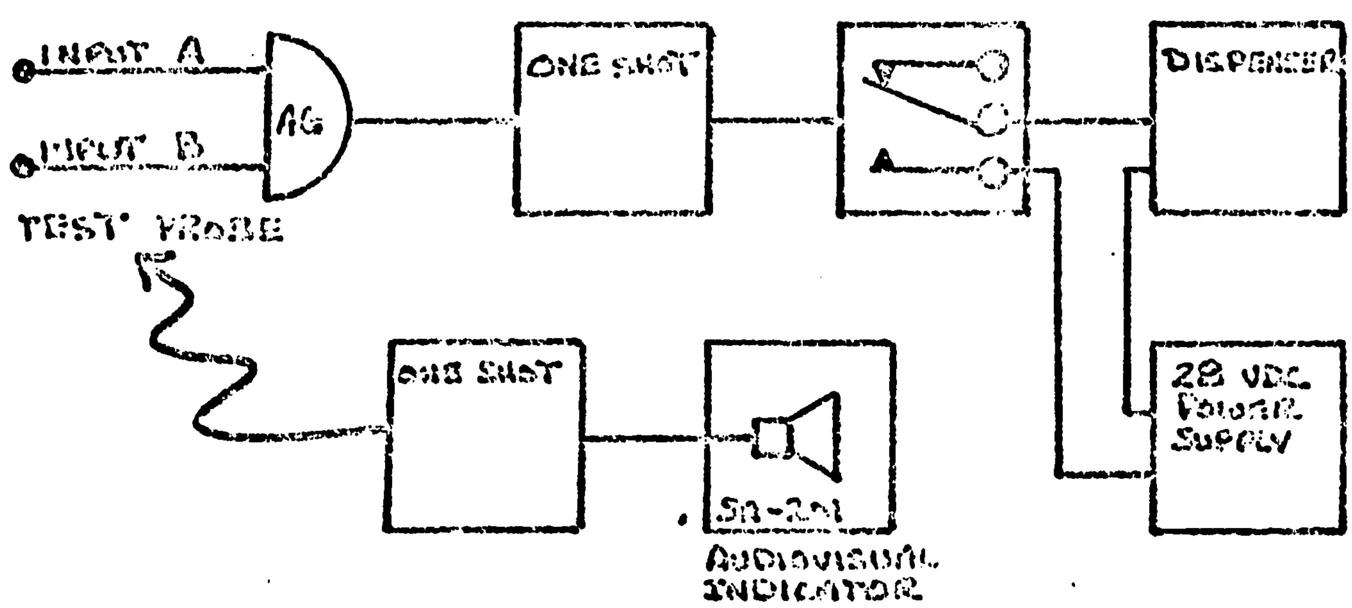
The problem here is one of voltage drop. If the series method is used, the source voltage must pass through all of the wires that interconnect each unit in each row, in order to reach the uppermost row. When this is the case, and if several rows are used, the voltage will be significantly lower than 12 volts at the top row, which will likely result in improper operation of the top row units. The parallel method of interconnection is facilitated by the fact that both the R and S Pins of most units are connected to ground, and both the A and B pins are connected to -12 VDC.

Section 10.4 - Troubleshooting

The problems associated with troubleshooting in logic apparatus are complicated by the speed with which the units operate. After all, it is pretty difficult to run down the absence of a signal that should have been present for only 1/40,000 of a second!

A helpful device that you can construct is, simply, a One Shot unit, with its output connected to the input of the audio portion of the Audiovisual Indicator. Using a wire connected to the One Shot input as a probe, then, will permit you to detect the presence of a logic signal, irrespective of its duration (or lack of it).

Consider the following simple circuit, for example:

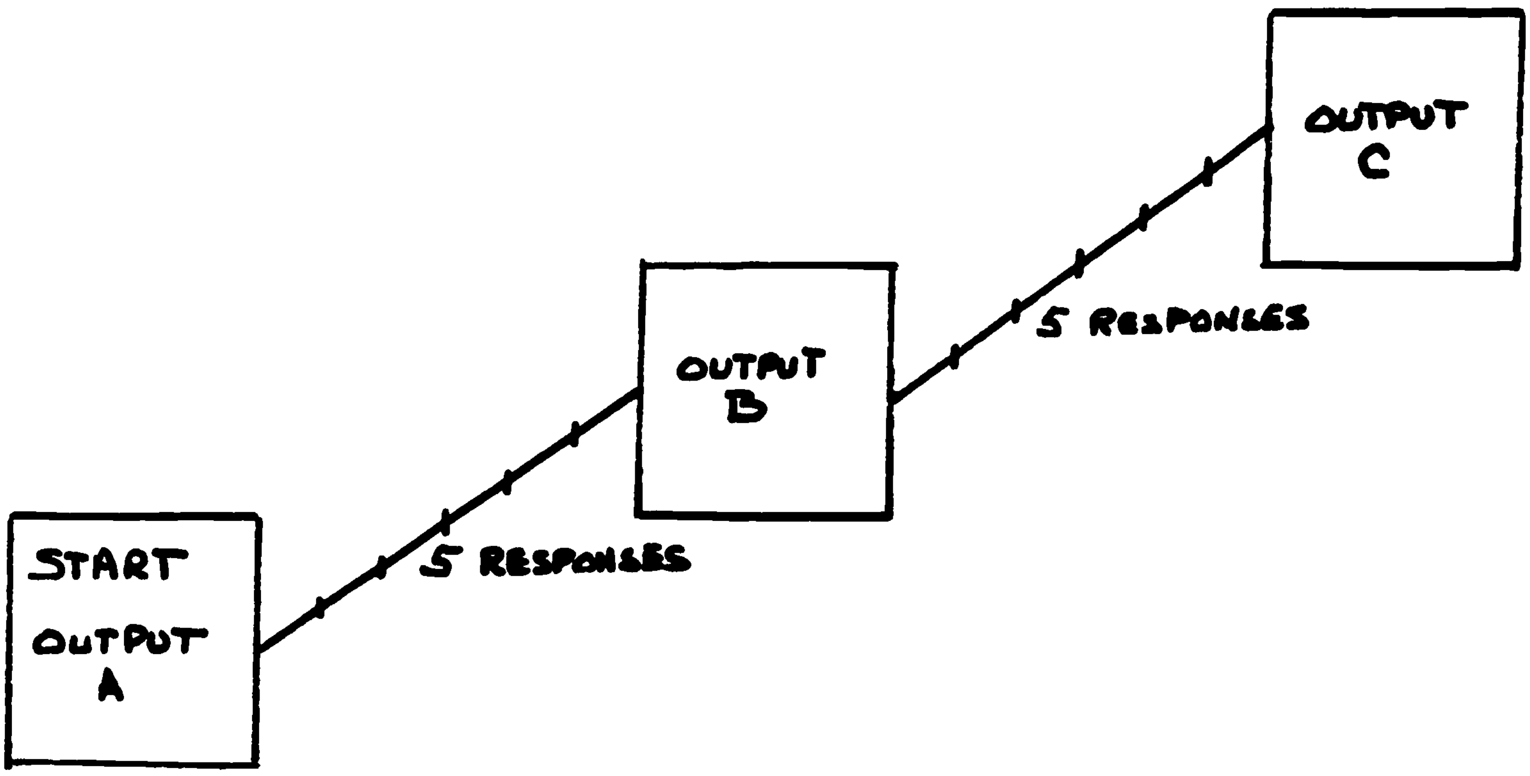


If the dispenser were supposed to operate when event A and event B were simultaneously present, and if it did not, the trouble could be (a) an absence of event A, (b) an absence of event B, (c) a faulty One Shot unit, or (d) a faulty Relay unit. Connecting the input of the One Shot-Audiovisual Indicator combination to each of these points in turn should quickly determine which of these possibilities is indeed true.

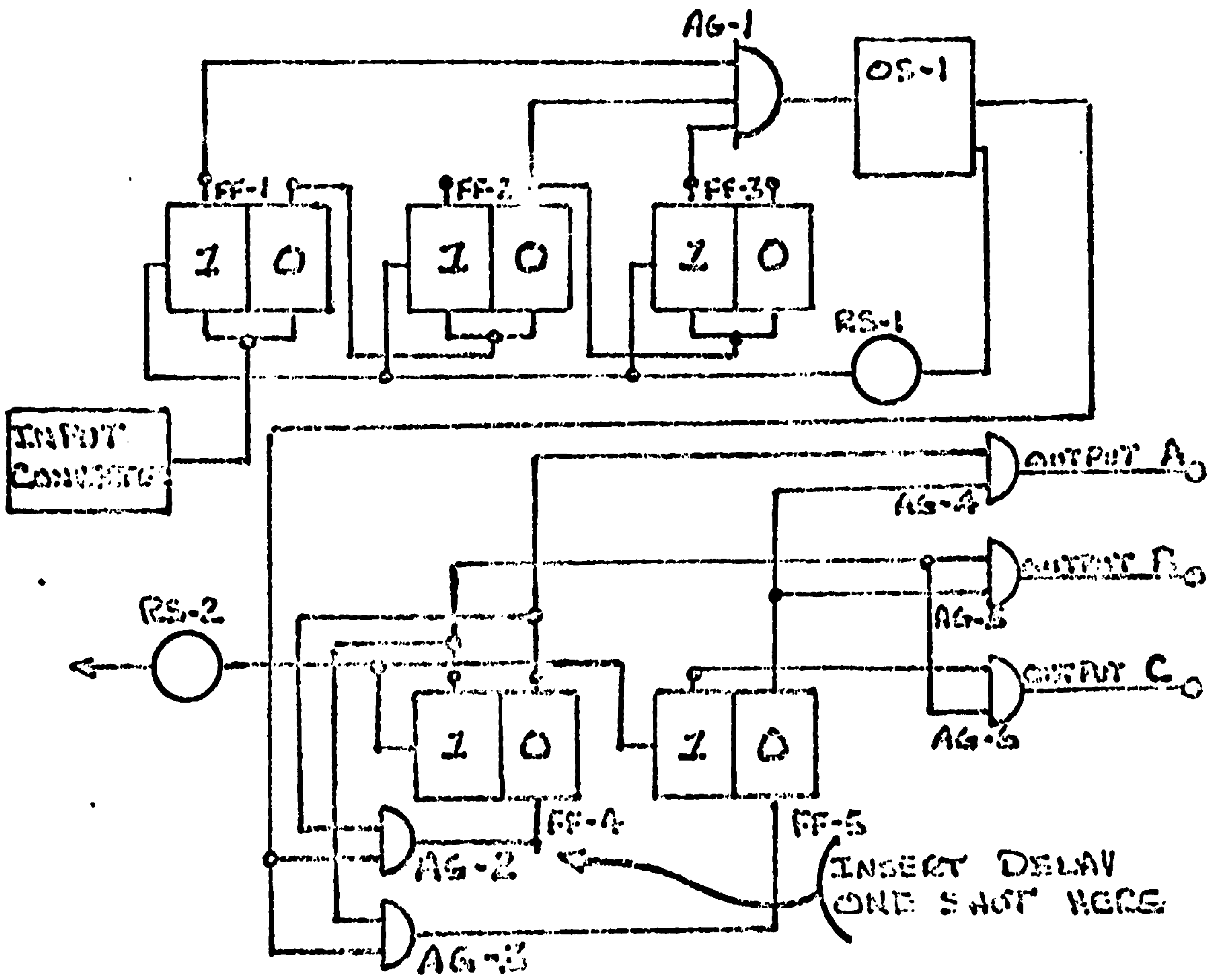
Section 10.5 - Timing

The problem of timing is often one of the hardest to surmount in designing logic circuits. The problem here is generated by the speed with which logic units operate -- sometimes their speed seems to work against the researcher.

Consider, for example, the following problem. An experimenter wants a circuit that will give an output of A at the beginning of a subject session, shift to an output B at the end of the first five responses, and finally to output C at the end of the next five responses.



The initial step is, of course, to build a counter that will count five responses, and then automatically reset. We can then define our three conditions in terms of the states of two Flip Flops. In the diagram below, A is defined as both Flip Flops in the "0" state, B as FF-4 in "1" and FF-5 in "0," and C as both FF-4 and FF-5 in "1."



Assume that the response counter begins with all Flip Flops in the "0" state, and that both FF-4 and FF-5 are in the "0" state as well. This means that the A output is ON.

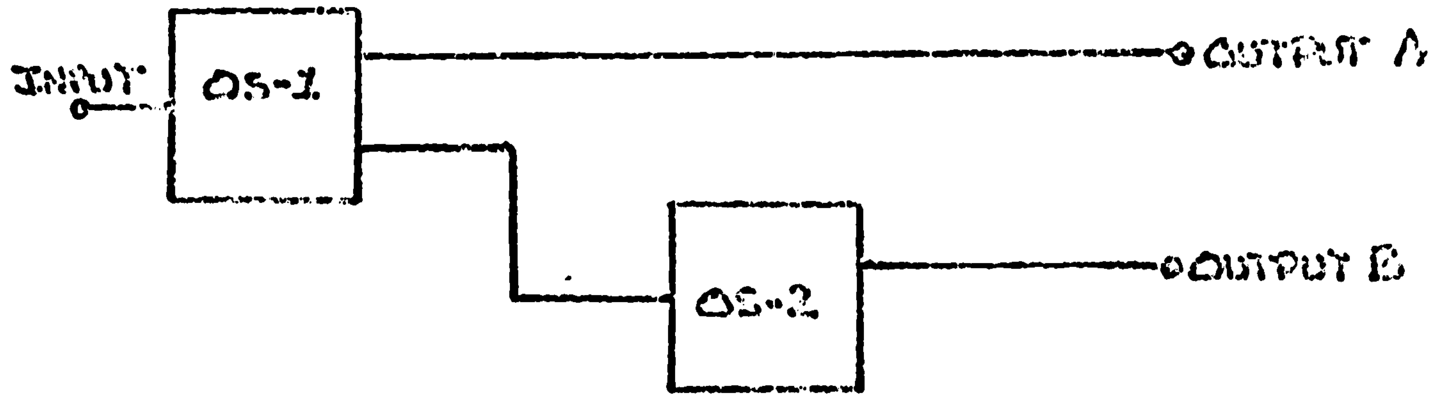
After five responses OS-1 will trigger which, if FF-4 is in the "0" state will, by way of AG-2, change FF-4 to the "1" state. This turns output A to OFF, and output B to ON.

The next series of five responses will, by way of AG-3, put FF-5 into the "1" state, giving us output C in place of B. A reset signal via RS-2 would return the circuit to the A condition.

The only problem with the above circuit is that it won't work. The symptom, to the trouble-shooter, is that it will never go to the B condition -- it jumps, rather, directly from A to C. The reason for this should be clear -- as FF-4 goes to "1," the output of OS-1 is still ON -- and this output, via AG-3, quickly shifts FF-5 to "1."

Although there are several ways in which this problem could be solved, one of the simplest is the insertion of a One Shot between the output of AG-2 and the set input of FF-4, with the inverted output of the OS going to the FF input. In this case FF-4 will <u>not</u> go to "1" until OS-1 has <u>finished</u> firing, providing that the duration of the added OS unit is <u>longer</u> than the duration of OS-1. Therefore, the OS-1 input to AG-3 will not be ON when FF-4 changes to "1," and FF-5 will not change states until OS-1 refires -- which will not occur until after the next series of five responses.

The use of One Shot inverted pulses is one of the easiest ways to perform timing functions of this type. Consider the following circuit:



Here it is possible to generate an output (B) of adjustable duration beginning at the precise end of another output (A) of adjustable duration. The reason for this is, of course, that OS-2 will not fire until it receives a positive transition -- an event that will not occur until OS-1 has finished its ON time.

The use of the above circuit is straightforward. For example, consider the case where the researcher was using a print out counter, such as the Datatrol supplied by BRS, or the Presin Moduprint. In this case, the series One Shots could be used to provide for print-reset operation. That is, output A could serve to operate a Relay, causing the counter to print. Output B could then operate a second Relay, causing the printer data wheels to reset to zero. By using series One Shots like this, the two functions can be kept sequential, with a minimum of time intervening between the two events.

Concluding Comment

This concludes the program. The writer sincerely hopes that it will be of some value to you in your research endeavors. Remember, too, that in case of problems the BRS-Foringer Company, of 5451 Holland Drive, Beltsville, Maryland, 20705, is always ready -- and, more importantly, able -- to aid you in their solution.

Completing the "reader comment form" on the next page would be helpful in any decisions regarding future revisions of this program. Please complete it and mail it to the address given.

COMMENT FORM

Now that you have completed the program, your critical comments on its method and content would be appreciated by the author. If your answer is "No" to any of the below questions, or if any of your answers require qualification, please comment in the space provided below, continuing on the reverse side of the page, if necessary.

	Yes	No
Did this program meet your needs?	____	____
Was it easy to read and understand?	____	____
Was it well organized?	____	____
Was it complete?	____	____
Was it in keeping with your technical abilities?	____	____
Did you have any major difficulties in its completion?	____	____

COMMENTS

(Please give specific page or frame reference when appropriate.)

Thank you for your help. You can mail this form to:

Larry Larsen
Peabody College, Box 196
Nashville, Tennessee 37203

EXERCISES

Although the following exercises are "open book," you are urged to complete as much of them as possible without referring to the program. The answers to the exercises can be found in the rear of this booklet.

Exercise 1.

1.1 Define dynamic programming.

1.2 Define interface unit, differentiating between input and output interface units.

Exercise 2.

2.1 Convert the following numbers from binary to decimal notation:

2.1a 11011. __________

2.1b 1000110. __________

2.1c 1110101. __________

2.2 Convert the following numbers from decimal to binary notation:

2.2a 63. __________

2.2b 39. __________

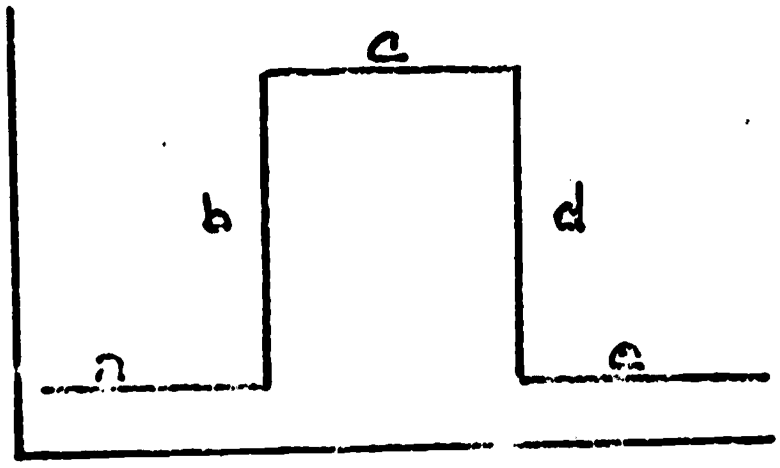
2.2c 1127. __________

2.3 The weights assigned to the symbol positions (with reference to the decimal point) in both the decimal and binary number systems are determined by __________________________.

2.4 We have dealt with both the binary and decimal number systems. The octal system, on the other hand, has a radix of 8. Can you convert the octal number 13724. to its decimal equivalent? (Hint: lay out a table as shown in frame 79, making the necessary corrections for base 8. And remember -- the octal system has eight symbols.)

Exercise 3.

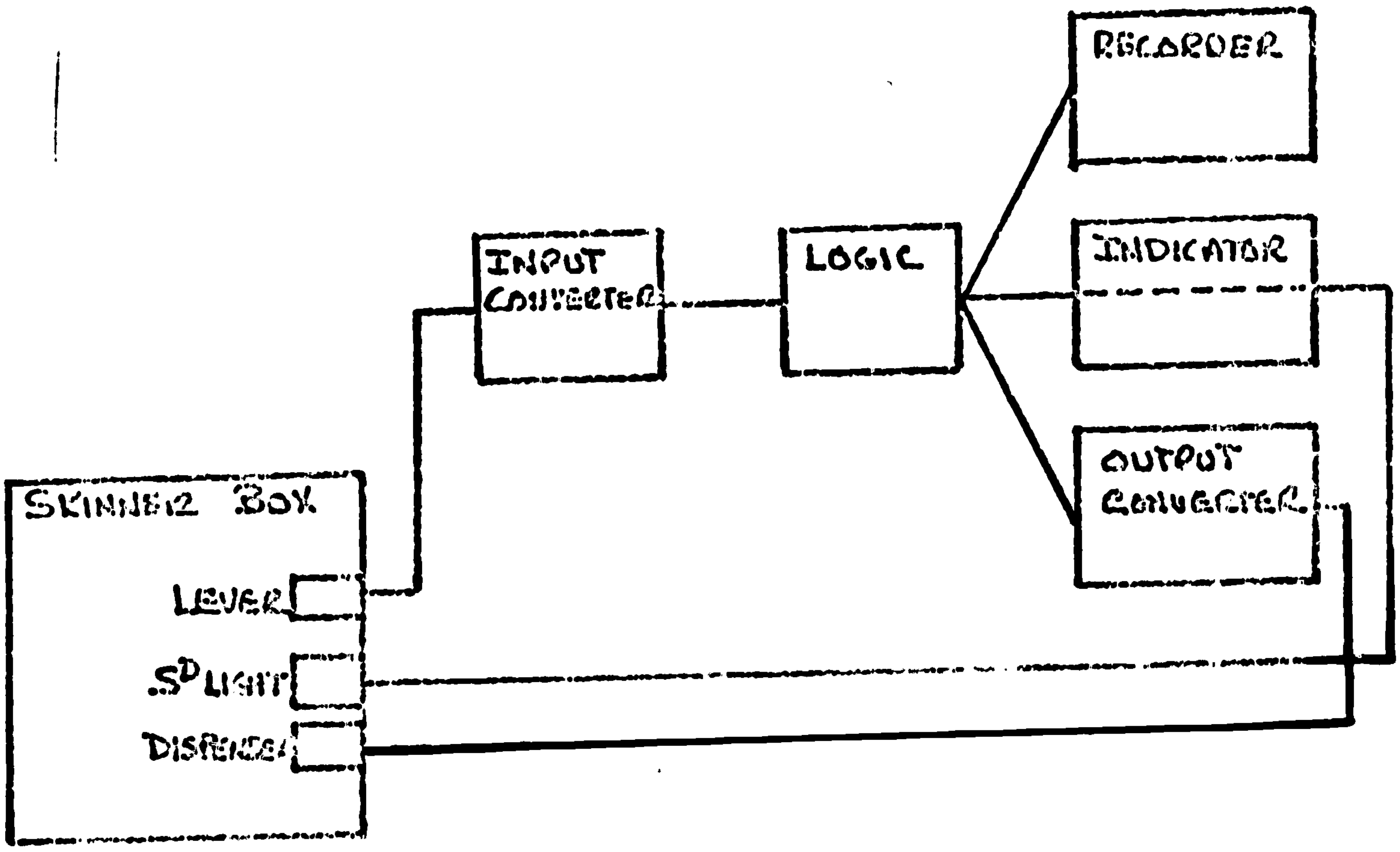
3.1 Given the following logic signal, place the letters a through 3 in the appropriate spaces. You may use more than one letter per space.



3.1a ______ ON
3.1b ______ "1" State
3.1c ______ Zero Volts
3.1d ______ Transition
3.1e ______ Ground
3.1f ______ Positive-going transition
3.1g ______ OFF
3.1H ______ Negative-going transition
3.1i ______ "0" State
3.1j ______ -12 VDC

Exercise 4.

4.1 The following illustration shows, in block diagram form, a research system consisting of a Skinner box, input and output interface sections, and a logic section.



Using the above illustration as a guide, what are the functions of the following:

4.1a Input Converter

4.1b Logic Section

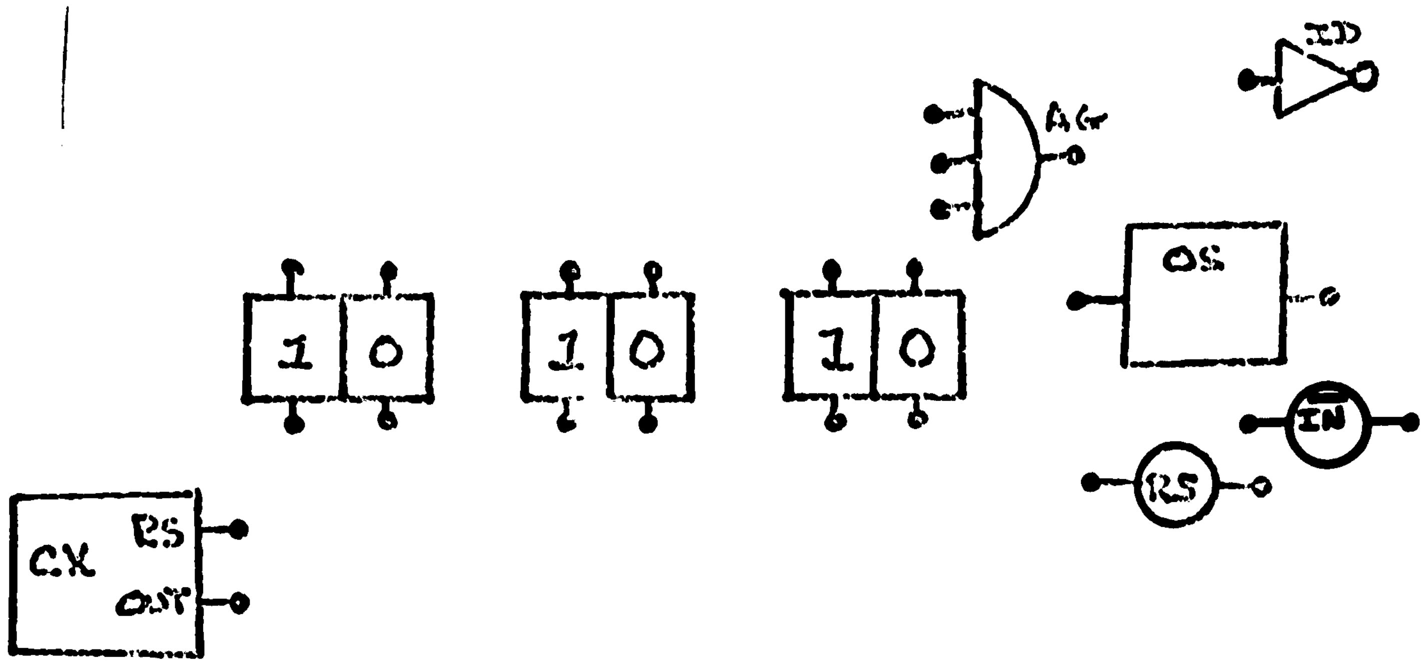
4.1c Output Converter

4.1d Recorder

4.1e Indicator

Exercise 5.

5.1 Given the following units, draw in the interconnecting wires that will form a three-stage binary counter, with a CX unit input, a One Shot output, and automatic reset.



Exercise 6.

6.1 Briefly describe the function of the following logic units, with particular reference to inputs and outputs.

6.1a Flip Flop

6.1b Multivibrator

6.1c Reset

6.1d Inverter

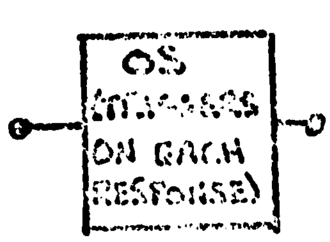
6.1e AND Gate

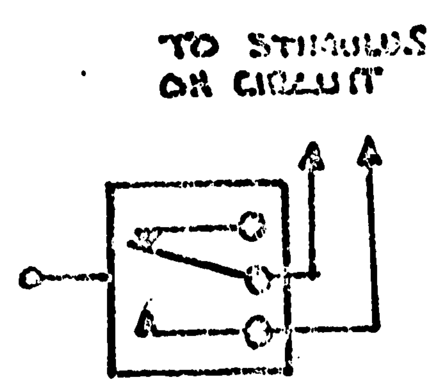
6.1f OR Gate

6.1g One Shot

Exercise 7.

7.1 Given the following units, and that you have additionally, 4 Flip Flops, 1 Multivibrator, 1 3-legged AND Gate, 1 One Shot, and one Reset unit to work with, show how you would construct an intertrial timer with which it is possible to adjust the length of time intervening between the last response of the subject and the onset of the next stimulus presentation. Note that the One Shot below fires on each response and that the stimulus will be presented whenever the Relay is operated. Hint -- use 3 FF's as a binary counter, and the other as a control FF.





Exercise 8.

8.1 Given that you have a Skinner box equipped with a response lever and two lights (one S^D and one S^{DELTA}), construct a circuit that will perform the following functions:

a. Present, in alternate periods, the S^D and S^{DELTA} lights, with the time that each is ON independently adjustable, i.e., S^D ON for 30 sec., followed by 15 sec. of S^{DELTA}, followed by 30 sec. of S^D and so forth.

b. Allow the subject to obtain reinforcement on a selectable FR schedule only during S^D time.

c. Reset, and thereby prolong the S^{DELTA} time for any response occurring in the presence of the S^{DELTA} light.

d. Count S^D and S^{DELTA} responses on a digital counter (see CT-202 on Figure 30).

Hint -- use two binary counters, of 5 stages each.

Exercise 9.

9.1 Given the following units, and that you have, additionally, one BC-201, one RS-203, one OG-203, and one AC-208, devise a circuit that will deliver reinforcement on a selectable (from 1:1 to 1:15) Fixed Ratio schedule for consecutive correct responses, automatically resetting after each reinforcement.

EXERCISE ANSWERS

Exercise 1.

1.1 Dynamic programming is the advance structuring of relationships between input events (subject behavior) and output events (environmental changes) in the research system.

1.2 Interface units mediate between the O-E subsystem and the logic portion of the control subsystem. Input interface units convert subject behavior into logic level signals, while output interface units convert logic level signals into signals appropriate for controlling, recording, or indicating research system events.

Exercise 2.

2.1a 27
2.1b 70
2.1c 117

2.2a 111111.
2.2b 100111.
2.2c 10001100111.

2.3 the number of symbols in the system.

2.4 6090

The solution is:

Weight	8^4	8^3	8^2	8^1	8^0
Octal Digits	1	3	7	2	4

Decimal Equivalent $1x8^4 + 3x8^3 + 7x8^2 + 2x8^1 + 4x8^0 = 6090$

Exercise 3.

3.1a c
3.1b c
3.1c c
3.1d b,d
3.1e c
3.1f b
3.1g a,e
3.1h d
3.1i a,e
3.1j a,e

Exercise 4.

4.1a Converts behavior (bar presses) into logic level signals.

4.1b Determines the times for reinforcement delivery on the basis of organism behavior.

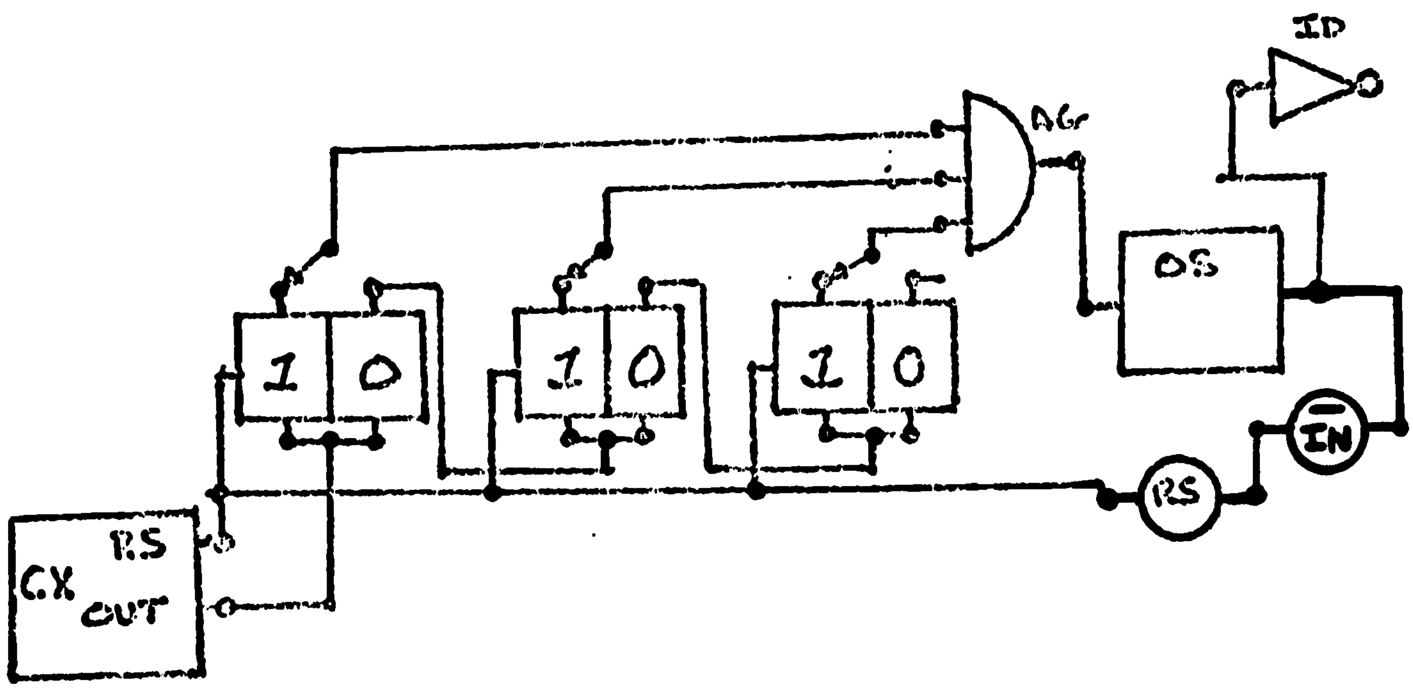
4.1c Converts logic level signals into events appropriate for delivering reinforcement.

4.1d Records subject behavior.

4.1e Indicates to the researcher when the S^D light is being presented.

Exercise 5.

5.1 Your interconnections should look like this:



Exercise 6.

6.1 Bistable multivibrator that changes states on the basis of appropriate logic level input signals. It is always either ON or OFF.

6.2 Delivers a train of logic level ON-OFF signals, when its enable input is ON.

6.3 Delivers a special reset signal when a logic ON is applied at its input.

6.4 Inverts logic level signals, i.e., when it is ON at its input, it is OFF at its output, and vice versa.

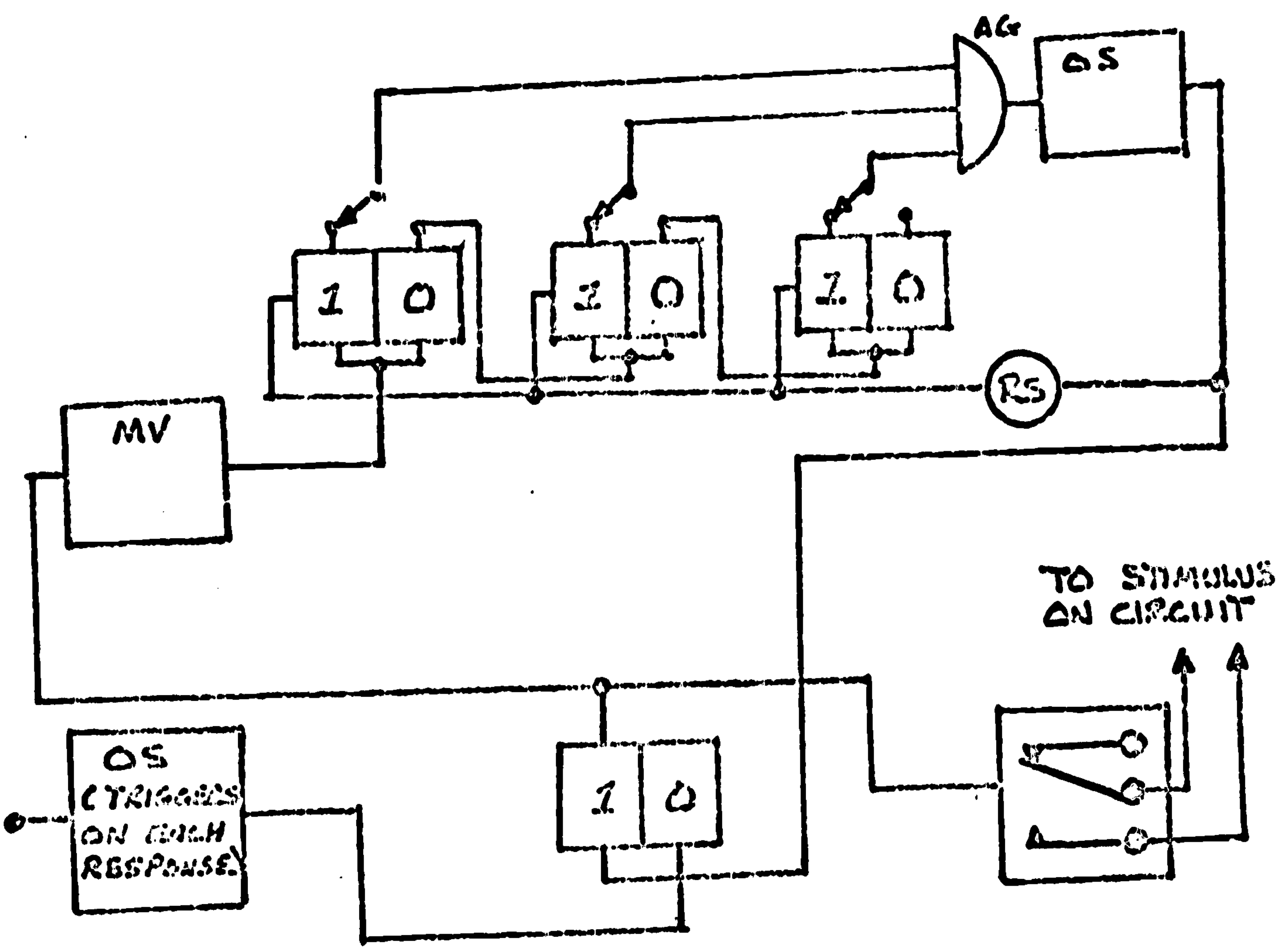
6.5 A logic ON is present at its output, when all used inputs are simultaneously ON.

6.6 A logic ON is present at its output, when any of its inputs are ON.

6.7 Delivers a logic ON pulse of adjustable duration, beginning at that point in time when a logic ON is received at its input.

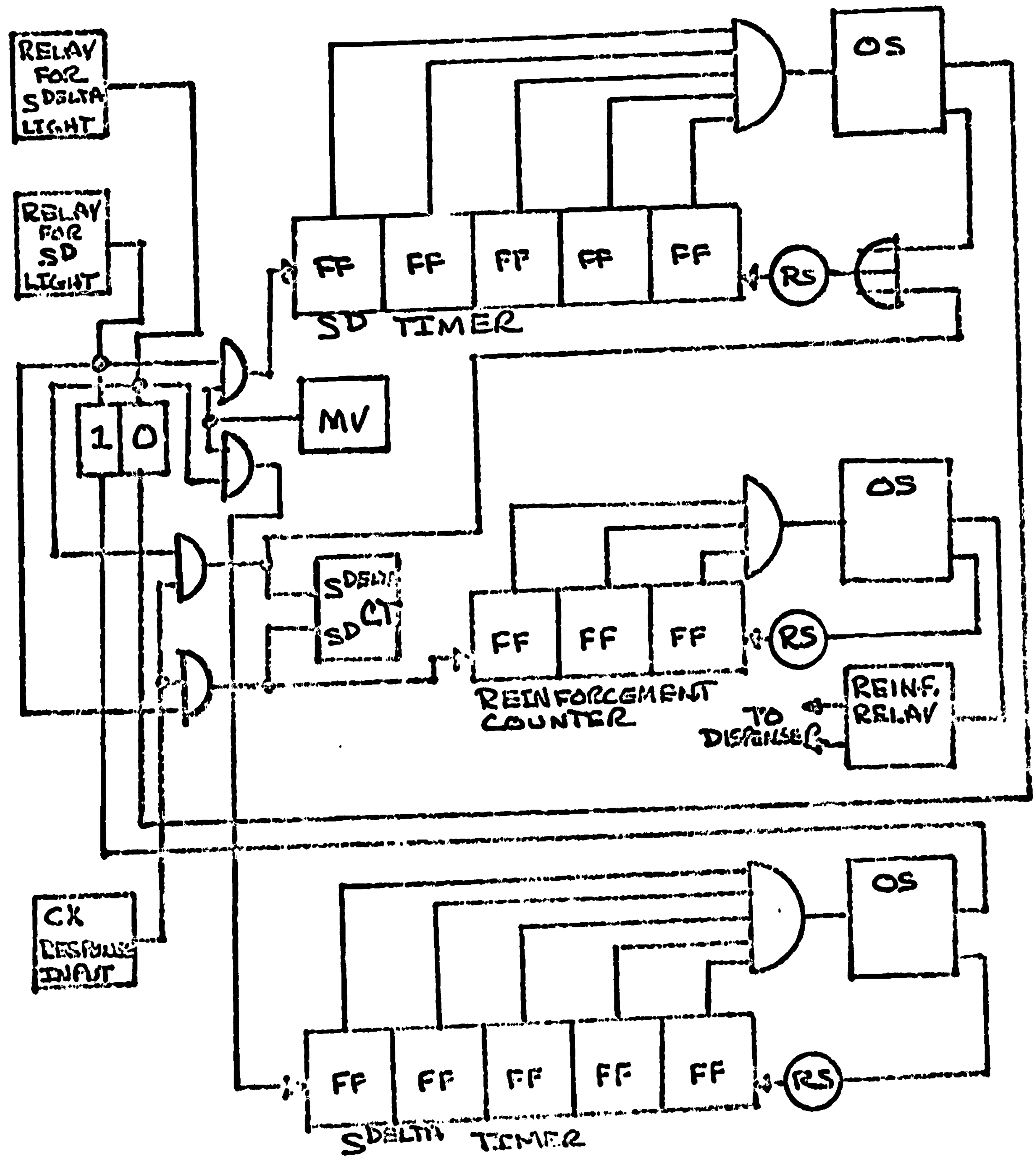
Exercise 7.

7.1 Your circuit should look something like this:



Exercise 8.

8.1 A circuit similar to this one would perform the required functions. (Note that the binary counters are drawn in abbreviated form for reasons of space limitations):



Exercise 9.

9.1 One way to accomplish this function is as follows: