STAGE

MNQ

A WORKING PAPER DRAFT

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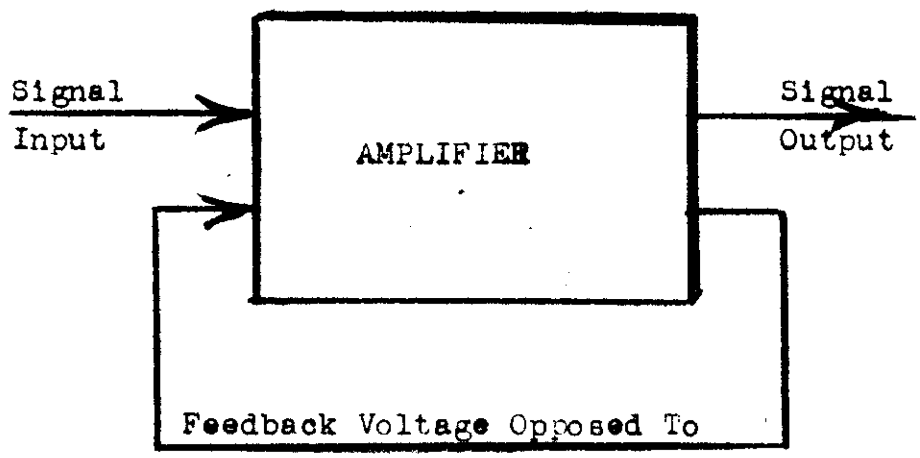
SOCIO-ENGINEERING PROBLEMS

FEEDBACK CIRCUITS IN COMPUTERS AND SOCIETY.



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SOCIO-ENGINEERING PROBLEMS

A series of working paper drafts on the subject of the social relations of engineering. This series of reports on ideas developed in the pursuit of my hobby of considering the potential analogies of various engineering concepts in the social sciences as a way of establishing a technique for engineers to discharge their responsibility for the social use of their ideas and inventions. The function of this newsletter is to provide a limited distribution of some preliminary ideas for discussion prior to editing for submission to established journals and engineering societies. In some cases no formal publication is planned, since this medium of communication will be used to suggest ideas to universities and research institutes who are better prepared to develop the ideas.

Frederick B Ward

Engineers' Council for Professional Development:

> "The engineer may be regarded, therefore, as an interpreter of science in terms of human needs and a manager of men, money, and materials in satisfying these needs."

This series deals with the function of the engineer as an "interpreter" on the assumption that other people are dealing with the management functions which many engineers acquire.

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SCIENCE AND HYPOTHESES

In this whole development of the study of "socio-engineering problems" it is important that it is understood that many scientific laws are not "proved", but that these so-called "laws" are really the hypotheses which have been successful in making theoretical predictions consistent with known facts and experiments. For example it has not been possible to derive completely from more fundamental laws the laws of electricity and magnetism known as Maxwell's Equations.

An excellent example of the status of a scientific theory (the special theory of relativity) is given by Panofsky (a). In this example a matrix is shown in which the rows are theories and the columns are experiments. In each position of the matrix appears an appropriate symbol indicating whether the results predicted by the theory agrees, contradicts, or does not apply with (to) the experiment.

a. Wolfgang K. H. Panofsky Classical Electricity and Magnetism Physics 210B, Univ. of Calif. Syllabus UG, March 1949, pp. 249-51.

WHY A WORKING PAPER DRAFT?

The reason for the existence of this "working paper draft" is that preliminary work in the area of social responsibility of engineers has to be done by conference or correspondence between individuals who are interested in the subject. Engineers with ideas on the social relations of their engineering work are not likely to be available at the same place for round table discussions like some social scientists have reported in Behavioral Science (b). After some correspondence and exchange of notes, the material may be referred to some one in the social sciences who may be better prepared to continue the investigation of the problem or it may be revised for submission to one of the engineering or scientific journals.

Where articles may be at different stages of development, we have to pay more attention to the process of solving problems including the statement of the problem, forming and testing hypotheses in the process of scientific research. An investigation of the social consequences of some invention might go through the following stages:

- A: Searching for background reference material,
- B: Brief reading of background material,
- C: Study of background material,
- D: Summarizing of previous research worker's results,
- E: Definition of the immediate problem,
- F: Tabulation of references for the specific problem,
- G: Brief study of the specific problem,
- H: Formulation of preliminary hypotheses,
- I: Checking of preliminary hypotheses for agreement with known data,
- J: Collection of new data or setting up experiments,
- K: Checking of hypotheses with cultural values in art, music, poetry, etc.,
- L: Critical testing and revision of hypotheses,
- M: Preliminary report writing,
- N: Circulation of preliminary reports to others for critidsm,
- O: Revision of reports,
- P: Publication of articles,
- Q: Experimental use of ideas with small groups of specialists and/or laymen,
- R: Review of the value of hypotheses as tried in practice,
- S: Preparation of popularized versions for public use,
- T: Preparation of more technical versions for social science research.

b. Behavioral Science vol. 1, no. 1, p. 69.

These working paper drafts are more likely to be at stages D, E, F, H, N, O, R, or S since it may be more efficient to exchange ideas at an early stage to determine whether the problems are being adequately investigated. This particular issue is identified as stage "MNQ," because it is a preliminary report, is being circulated to other engineers and social scientists for criticism, and is organized with slides for trial use with group discussion.

PROFESSIONAL ENGINEERING POLICIES

I have prepared this material as an individual professional engineer. First I aim to follow the limitations accepted under the California Board of Registration for Civil and Professional Engineers, namely that I state positive conclusions only in the branch of engineering in which I am registered, i.e., electrical engineering (EE reg. no. 2966). The way I deal with subjects which cross over into other specialized fields of science or engineering is to state the problems, ask questions, and to propose working hypotheses. The determination of definitive answers is left to the appropriate specialists such as mechanical engineers, physicists, sociologists, psychologists, anthropologists, political scientists, lawyers, etc.

Second, I aim to follow the rules of ethics established by the National Society of Professional Engineers and affiliated state societies (c). I interpret my hobby of preparing this series of socio-engineering problems notes as a "professional" activity as defined under the division of engineering activities proposed by the American Institute of Electrical Engineers and summarized in NSPE Professional Policies (d).

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c. National Society of Professional Engineers <u>Ethics for Engineers</u> (Canons of Ethics, Creed, and Rules of Professional Conduct.)
d. National Society of Professional Engineers <u>Professional Policies</u> Revised as of July 1, 1958. pp. 42-43.

My use of initials "P.E." after my name on the title page of this series is the abbreviation for "Professional Engineer" in accordance with the policies of the N.S.P.E.

SOCIO-ENGINEERING PROBLEMS

The part of the number ahead of the decimal point indicates the issue number of <u>Socio-Engineering Problems</u> in which the problem is discussed.

Problem 1.1: How can engineers develop some kind of perspective to give them a synthesis of the specialized fields of science needed for them to fulfil their function as an interpreter of science in terms of human needs?

Problem 1.2: What is the nature of the social responsibility of engineers?

Problem 1.3: How can engineers help make the results of their work be utilized in tune with mankind's highest aspirations as stated by the major religious faiths?

Problem 2.1: What distribution of structures in a large city best meets the human needs of the people?

(a) Does a mesa type concentration of skyscrapers in the center best serve the needs of the people?

(b) Does a central cultural area (heart) surrounded by logarithmically rising building heights provide better communication between the people working and living in a large city?

(c) Does a special distribution of buildings around parks using natural stream beds, canyons, hills, etc., better meet human needs?

The page and figure numbers following the next problems refer to the location of working hypotheses in this issue:

Problem 3.1: How can engineers explain their work to the educated layman in a way that is general, but is still specific/enough to be of value?

Hypothesis: Negative feedback circuits as discussed by Norbert Wiener (e, f, g) may be useful to show the common form of phenomena in related fields and for conveying basic ideas to the educated layman. pp. 1-2 F. 1-2.

Problem 3.2: Can we develop a feeling of relatedness of phenomena in different fields by use of negative feedback circuits?

Some hypotheses are developed in relation to the following fields or phenomena:

Basic Form	pp. 1-2, 9-10.	F. 3.
Electronic Circuits	pp. 2-3.	F. 3-5.
Computer Logic	pp. 3-4.	R. 6-7.
Computer Programming	pp. 4-5.	F. 8
Computer Memory, Mechanical Access	pp. 5-7.	F. 9-13.
Business Organization	pp. 7-8.	F. 14-16.
Capitalist Economic System	pp. 8-9.	F. 17-19.

Problem 3.3: To what extent do proceedings of earlier cybernetics conferences satisfy the above problems?

This requires a study of the proceedings of the Macy Foundation reports and others to determine the extent of coverage.

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e. Norbert Wiener <u>Cybernetics</u> (1948)

f. NOrbert Wiener <u>The Human Use of Human Beings - Cybernetics and Society</u> N.Y.: Hoghton Mifflin Co. (1950). Also Second Edition Revised. Garden City, N.Y.: Doubleday Anchor Books (Reprinted 1956)

g. Norbert Wiener "Eight Years of Cybernetics and the Electronic Brain" <u>Pocket Book Magazine</u>, No. 2. (1955) pp. 45-60, esp. 56-60.

SUPPLEMENTARY REFERENCES

h. Shannon and Weaver <u>A Mathematical Theory of Communication</u>

i. Editors of the Scientific American <u>Automatic Control</u> N.Y.: Simon and Schuster (1955)

j. W. Sluckin <u>Minds and Machines</u> Pelican Books, A308 (1954)

k. C. Wright Mills <u>The Causes of World War Three</u> N.Y.: Simon and Schuster (1958)

l. John Mills <u>The Engineer in Society</u> N.Y.: Van Nostrand (1946)

SOME HYPOTHESES ON FEEDBACK CIRCUITS IN COMPUTERS AND SOCIETY.

Abstract

The concept of inverse feedback circuits is discussed in a descriptive, non-technical manner to show the usefulness of the concept in a series of levels of organization in the design and use of computers in society. Elementary open and closed-loop temperature control systems, mechanical feedback governors, electronic amplifiers, cathode followers, and electromechanical servomechanisms are discussed. Feedback loops in computer logic and programming are briefly discussed. Feedback loops in business organization are discussed with a description of how "inline" processing moves some human feedback links with long time constants into the accounting machine logic and programming. Feedback loops in the economic system and analog computer systems for representing them are discussed.

Note

This material is based upon two informal talks given to electronics and mathematics students on January 23, 1957, at California State Polytechnic College, San Luis Obispo, California.

Introduction

This report deals with principles which are common to the design of computers and to the use of computers in society. Selected components are discussed which illustrate philosophical abstractions that are held in common to the system in which computers are used. These common elements consist of negative feedback circuits which provide for stabilization of electronic circuits, mechanical systems, heating systems, business operations, and segments of the economic system.

SLIDE ONE

Basic Feedback Circuits

To illustrate what a feedback circuit is we will compare the two control systems in this slide. The upper system we call an open loop system. T_o is the outside temperature, T_h the thermostat, F the furnace, and T the room temperature. This open cycle control system may work under standard conditions. The thermostat which measures the outside temperature is calibrated to turn the furnace on sufficiently to keep the room warm, provided all the doors and windows are kept closed. If the windows and doors are left open, the calibration of the thermostat will not be correct and the room temperature will fall below the desired level.

Let us look at the closed-loop in the lower diagram. The thermostat turns the furnace on and off and, in turn, controls the temperature. Here we have a closed-loop control system which will control the furnace to maintain the desired room temperature. This self-regulating feature of this closed-loop system is a primary example of the feedback principle.

SLIDE TWO

Here we have a flyball governor of the form that was used with the early steam engines. As the speed of the steam engine increases the balls on the governor have a greater velocity and a greater centrifugal force outward. The rising of the flyballs move the lever that closes the valve so that less steam can come to the engine, reducing its speed. And, as the speed is reduced the balls will drop reopening the valve. This governor is a mechanical inverse feedback system.

SLIDE THREE

Here we have made a more general representation of the closed-loop thermal control system and the mechanical feedback system in the form of an electrical negative feedback amplifier. The amplifier, could be an ordinary triode with part of the output signal connected back to the input grid one hundred and eighty degrees out of phase with the input signal. This makes the gain of the negative feedback amplifier less than one. The output signal still varies proportionally to the input. The negative feedback permits the maintaining of the output voltage near a stable value.

SLIDE FOUR

Three kinds of feedback circuits are illustrated. In a servomechanism we have a varying input and we want to make the output follow the input either identical to it or with a fixed ratio to the input. So we feed back a signal from the output as an error signal so that this amplifier or control system will keep the system moving as long as there is a difference between the input signal and the output signals. The negative feedback principle can also be used as a regulator circuit. Here we have a fixed reference voltage and we want the output to be the same as the fixed voltage. If a variation occurs in this system such as an increase in load which changes the voltage, the difference between the controlled variable and the reference voltage gives an error signal which causes the control amplifier to correct for the disturbance.

Now that we have briefly examined general classes of feedback circuits, now we must examine how we are going to use these feedback circuits in the design of computers. A common feedback circuit in a computer is the cathode follower.

SLIDE FIVE

Electronic Negative Feedback Circuits

Here we show an ordinary triode. Instead of placing the limiting resistor in the plate circuit, it has been put in the cathode circuit. A tap off this resistor is coupled to the control grid. This connects part of the output voltage into the input grid circuit such that it opposes the input signal. The results of this cathode follower are that we get an output characteristic of voltage versus the input voltage that is independent of the variations of the different individual tubes we may put in the circuit. The use of negative feedback in the cathode follower circuit provides an impedance transformation from a high impedance to a low impedance.

SLIDE SIX

Here we have a photograph of a type of pluggable unit and the circuit diagram for a type of cathode follower circuit used in IBM computers. Here we see that for any given computer system electronics engineers will design the kinds of circuit needed and will design electronic circuits such as cathode followers for different conditions. These different circuits are then manufactured as pluggable units. Then another group of engineers, who are more mathematicians than electronics engineers, design the logic of the computer system. The engineers in the applied logic area will represent these pluggable unit electronic circuits with block symbols in their logic diagrams so they don't have to worry about the details of designing the individual electronic circuits. They will specify how many blocks of logic transformer, flip-flop, and pulse generating pluggable units are needed, and how they are to be logically connected. This shows there is cooperation between the different types of engineers in the design of computers. On the left we have a sample circuit diagram of what is contained in this pluggable unit such as a cathode follower. In the center is the logical symbol which is used by the men who design the logic of the system. On the right a photograph of a typical pluggable unit.

SLIDE SEVEN

Feedback Loops in Computer Logic

Here we have a block diagram of an IBM 650 magnetic drum computer. We see that here we get another type of feedback circuit on another higher but more general level of organization. Here we receive information from a card which is then read on a card reader, and translated into computer code and stored on the drum. Then, in accordance with the program, we pick information off certain cells on the drum and transfer them to the arithmetic unit. After the calculation is made the result goes back onto a suitable place on the drum and another item is read out. We have feedback loops in the computer logic where branching is made following a test for certain conditions. To eliminate errors due to incorrect characters validity checks are inserted at certain points where we check the number of bits in each digit for validity. The 650 computer uses the biquinary code and in other computers we use other types of code. In these validity checks each character is checked for the correct number of bits. They can be used in two ways: (1) If an error is determined it can just stop the computer, or (2) The previous program sub-cycle can be repeated. The computer stops when a human feedback link is required to find out what the trouble is, and to correct it, and then start the computer back on its way. So here we find that the engineers, mathematicians working on the logic computer can deal with another type of feedback circuit which is not as easily specified in terms of electric circuits, but never-the-less represents a transmission of information from the output back to control the input.

SLIDE EIGHT

Feedback Loops in Programming

Now we have moved from feedback circuits within the logic system more specifically to feedback circuits which can be added to the computer by the programmers. Here we see we can utilize the program instructions to calculate certain check numbers. For example, if the sum of each of the separate accounts equals the total of all the numbers entered into the system, and if these get out of balance and we didn't get an error signal, something is wrong and we try human intervention to check the calculation over again.

Mechanical Access Mechanism Feedback Circuit

Now, let us consider another type of feedback, that comes in the mechanical design of a computer. For this example, consider the Random access Memory in the IBM RAMAC 650.

SLIDE NINE

Here we have an array of 50 disks which are rotating at constant velocity, and we have a set of arms with two magnetic heads that can be moved radially across 100 tracks, and can be shifted up and down to any one of the 50 disks. We have a feedback system in the control system of moving these heads into the right place. Actually, there are two feedback systems, one to move the arms to the selected disk and the other to move the head to the selected track.

SLIDE TEN

Here is a diagram showing the features of the access mechanism. We have a motor driven shaft with two clutches, so that one clutch moves the access arm up, the other drives it down. The potentiometer is set to provide a reference voltage corresponding to the desired disk. There is an error signal generated proportional to the difference between the position of the access arm and where it should be. If we were to just have this simple feedback loop system, the head would go past the desired place and oscillate back and forth and it would take a long time to get the access arm to the right place, and would slow down the access time to get to the desired place in the memory. To slow down the movement before it gets to the zero point, we provide an additional feedback loop. We have a tachometer on this drive which generates a voltage proportional to the speed at which the capstan is moving, which also feeds into the amplifier and provides a feedback, such that advance information or anticipation of the null position is provided so that it can come to rest at the desired place without going past it.

SLIDE ELEVEN

Here we have a block diagram showing an equivalent circuit of this mechanism and the control circuits that control the movement of the access arm in the RAMAC disk file. Starting from the left the desired angle R is set by the control logic by setting the desired tap on the potentiometer. This results in an error voltage into the amplifier. This applies a voltage V to the clutch which develops a torque T which rotates the capstan through the angle C toward the desired angle R. We have represented the two feedback loops together in one feedback loop here. The K_3P term represents the tachometer voltage and K_4 is derived from the potentiometer voltage.

SLIDE TWELVE

We can analyze the circuit operation by what is called a root locus plot of this feedback circuit. The equation in the upper lefthand corner C(P)/R gives us the ratio of the actual angle of the capstan to the desired value as a function of these time constants. In the lower lefthand corner we have transformed this equation to represent the locus of the roots of the differential equation which this transfer function represents. The curves in this character are shown for particular values of the time constants. The curve on the complex frequency plane represents the locus of roots of the equation for the negative feedback loop as a function of the amplifier gain. The arrows on the curves represent the direction the roots move with increasing amplifier gain. These roots are used to construct the response curve C(T) as is shown in the next slide.

SLIDE THIRTEEN

For a step input, the output C(t) is constructed from the roots obtained from the root locus equation or from solution of differential equation. Now if we vary the gain of the amplifier we can get different types of response. If we take $(1/T = 40)$ we get the curve which oscillates about the desired position. If we decrease the gain to make the time constant a little longer, we can make C(t) approach the desired value a little more slowly and with less oscillation.

SLIDE FOURTEEN

Feedback Circuits in Business Organization

The next question is how do these feedback circuits enter into business management. Here we have a typical batch processing of information in a business. We see that there exists a type of feedback circuit which is not necessarily efficient. It may involve people carrying punched cards from one machine to another, and after they are sorted carrying them back to file. For economical operation several days work is accumulated, because they have to move the whole batch of cards through all the machines. This means there is usually a time delay of a few days before specified information can be obtained from the system.

SLIDE FIFTEEN - A

Here is an external view of the 305 RAMAC machine.

SLIDE FIFTEEN - B

Here we have the logic diagram of the RAMAC Random Access Memory Accounting Machine, IBM 305A. We'll not go into detail of the logic of this machine, but point out what effect it will have on business. This machine has a Random Access stack of disks with a logic control circuit input and output system which will enable one to process the record without having to wait till a batch of records are included, because we can find any record in this disk without having to sort a whole batch of cards. This enables us to find out the status of one customer's account immediately without waiting till all his transactions from similar batches of quantities have accumulated. We call this in-line processing. Now we shall see what changes in the circulation of information in a business when we change to in-line processing.

SLIDE SIXTEEN

Let's look at this slide. Now let's go two slides back to slide fourteen and take a look at this. We see all these loops representing the cards being moved and sorted, and so on and taken back to the file. Now let's go two slides ahead to slide sixteen. We'll see that the external feedback loops have disappeared. We have made these calculations on each item as it happened in the line of business and we'll automatically accumulate data in the memory for tying on the summary reports, so that what happens externally to the machine requires much less human intervention. The executive can inquire into the machine to find the status of an account without having to wait for batch processing. So we have moved these feedback loops that consist of people carrying batches of cards around from machine to machine, and put feedback loops in the machine program to do this work. We see that this shortens the time delay in getting essential information of a business back to the management so that management can more easily make decisions in time to correct any difficulties in the operation of business. This, in a way, represents the kind of feedback system between management making decisions resulting in production and sales and the consumer reaction coming back reflecting the operation so that there is a feedback in time for the managers to make revisions in their decisions, to fit the operating conditions in business.

SLIDE SEVENTEEN

Feedback Loops in the Economic System

Here we have what we call a unilateral production analog. It's called unilateral because information that only travels in one way around the various loops. A bilateral one would be one in which opposing voltages could cancel each other so that the one voltage that was higher would determine the direction of flow. We could set potentiometers and supply voltages in an analog computer to represent these, or we could collect the data from an actual business and use the data in a digital computer with a program to compute what is going on and to compare different points here with theoretical systems to see whether we should change or lower the interest rate or change our business policies to make the system more stable.

SLIDE EIGHTEEN

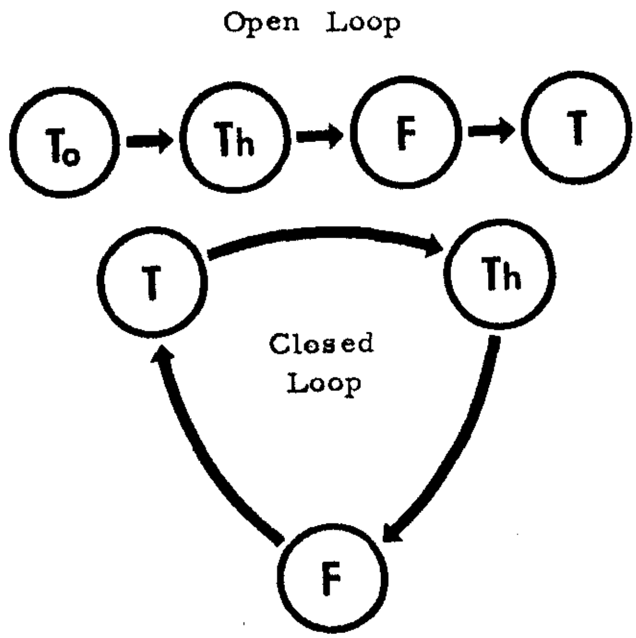
This capital production analog is a simplified description of the economic system. Here we have a negative feedback loop and a positive feedback loop which are tied together. This analog representing capital production consists of attenuators, amplifiers, integrators, and adders. This analog is of the form proposed by Kalecki in 1933, enlarged upon by Keynes in 1935, and experimentally constructed by O. J. M. Smith in 1952. When the attenuator and gain settings were scaled to represent the parameters of the real economic system, the analog circuits went into oscillation with a period of approximately ten years.

SLIDE NINETEEN

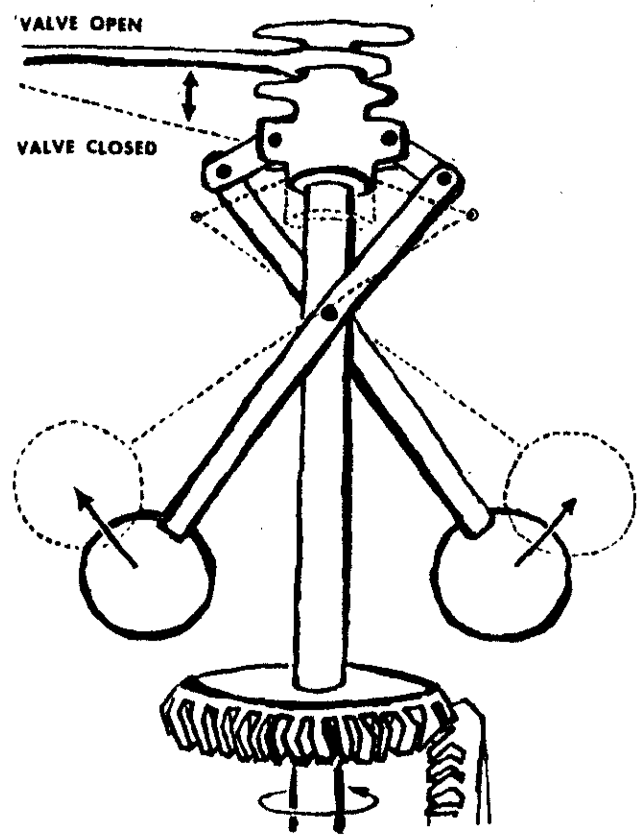
Comparing the ten year period scaled from the economic analog with world power production between 1900 and 1940 shows that major minima occurred in 1908, 1921, and 1932 which gives periods of thirteen and eleven. This indicates that the period of ten years is of the right order of magnitude.

Conclusions

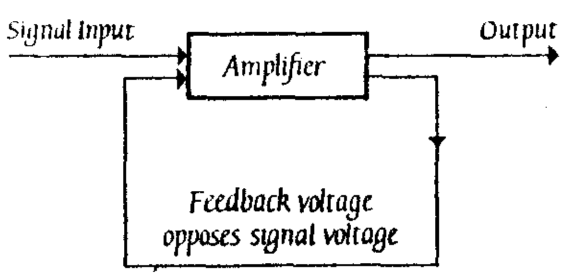
We have now seen a bird's eye view of feedback circuits as they exist in elementary mechanisms, heat systems, electronic circuits, computer circuits, how they are used in computer logic, computer programming, and in the mechanical access units of a computer. We have then gone on to see how we have feedback circuits to provide error checking in computers. We have then seen how a computer system with random access to its memory provides greatly shortened time delay in the feedback circuits within an individual business so that management can get the information it needs to make evaluations of its decisions and to make new decisions much more simply and quickly so that business can be operated on a much more stable basis. We have obtained a glimpse of how the whole economic system may be represented as a more complex set of feedback networks. Digital computers can be used to collect the data for individual sectors of the economic system to contribute to stability. We may develop an understanding of how the economic system works by using an analog computer in which we use typical values of the data that we have been able to collect and evaluate on digital computer systems. Thus, we obtain some idea of the relationship of the different fields of engineering, mathematics, logic, business management, administration and economic theory that are tied together in the application of computers to the development of our present day civilization.



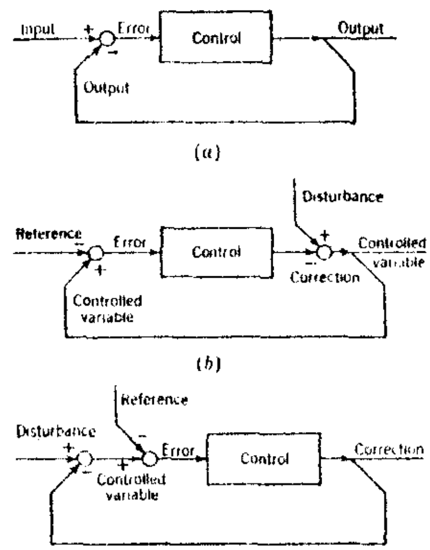
Slide 1 - Open and Closed Loop Temperature Regulating Systems



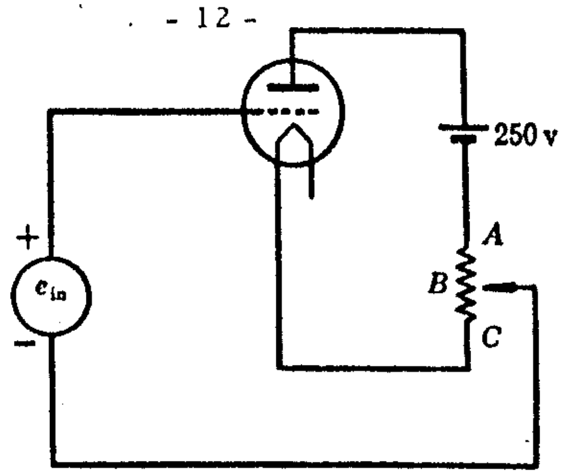
Slide 2 - Steam Governor



Slide 3 - *Schematic Representation of the Negative Feedback Amplifier*

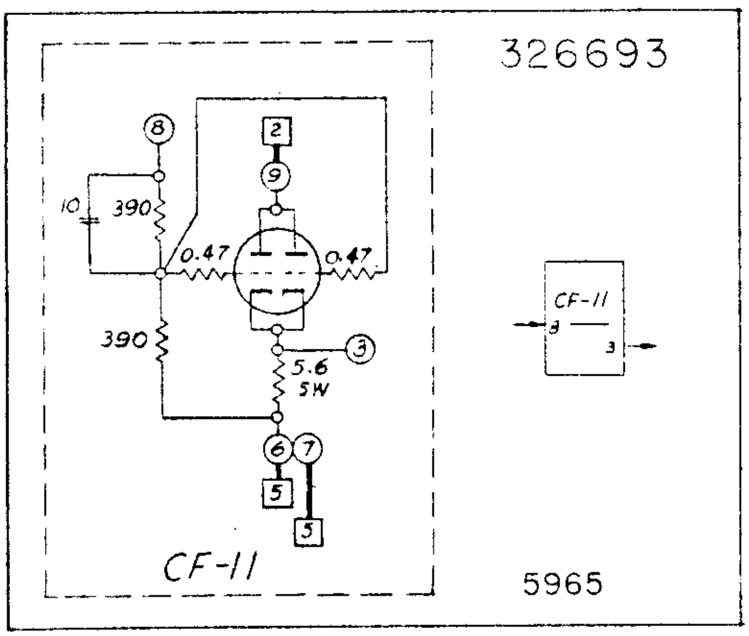


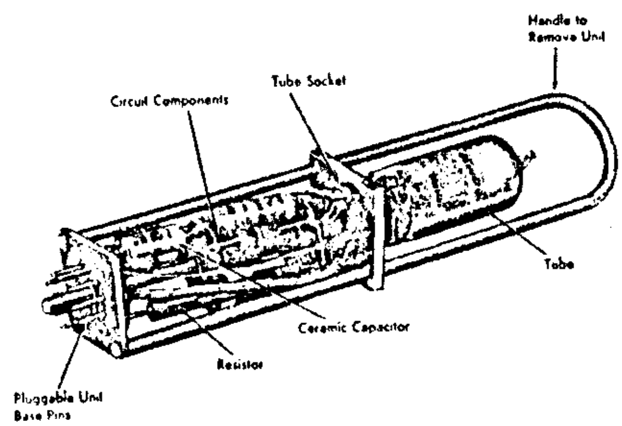
Slide 4 - Control systems: (*a*) servomechanism, (*b*) regulator, (*c*) regulator treated as servomechanism.



A portion of the output voltage is connected in series with the input to provide *inverse feedback.*

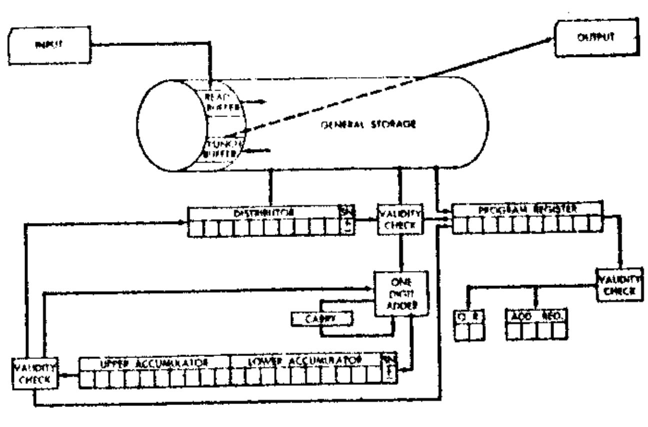
Slide 5 - Cathode Follower Circuit





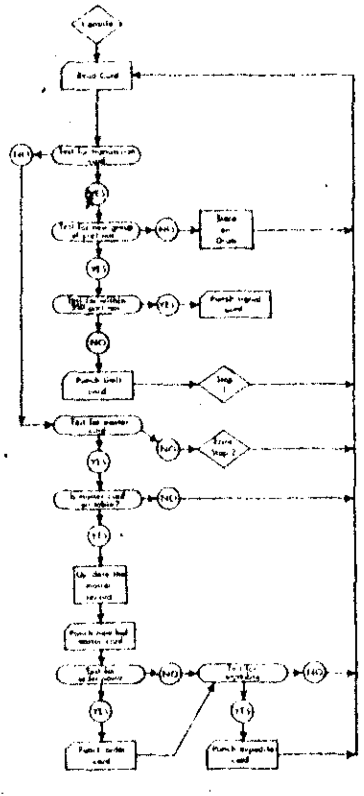
Pluggable Unit (Text p. 61D)

Slide 6 - Example of Cathode Follower Pluggable Unit



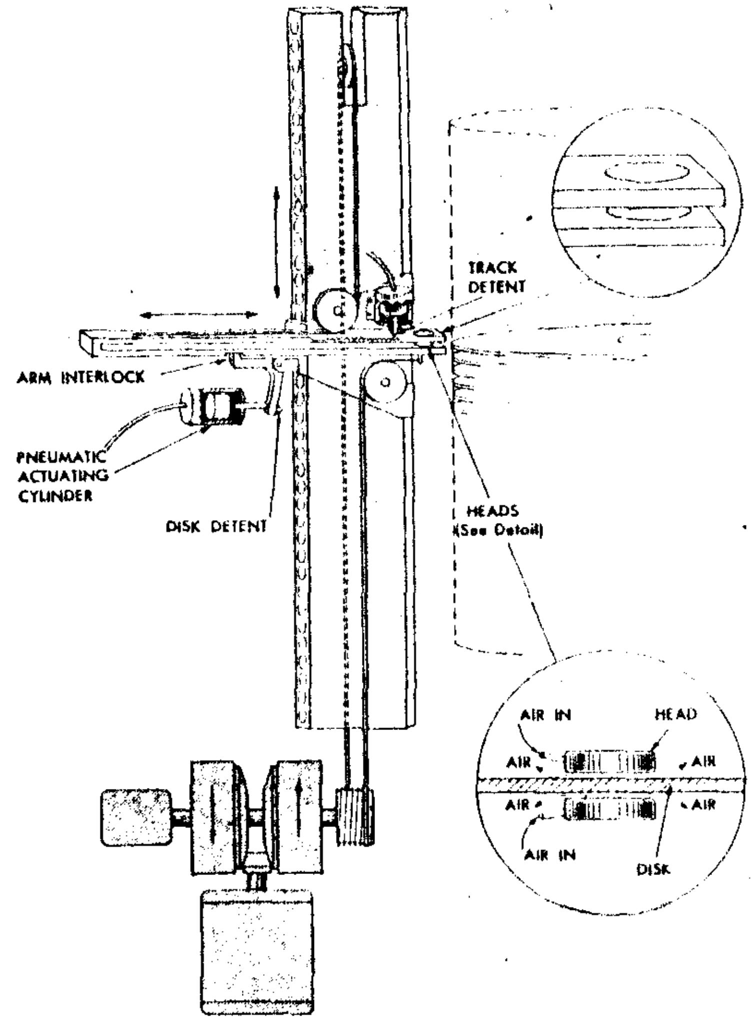
Validity Check Points

Slide 7 - Validity Checking in 650 Machine Logic

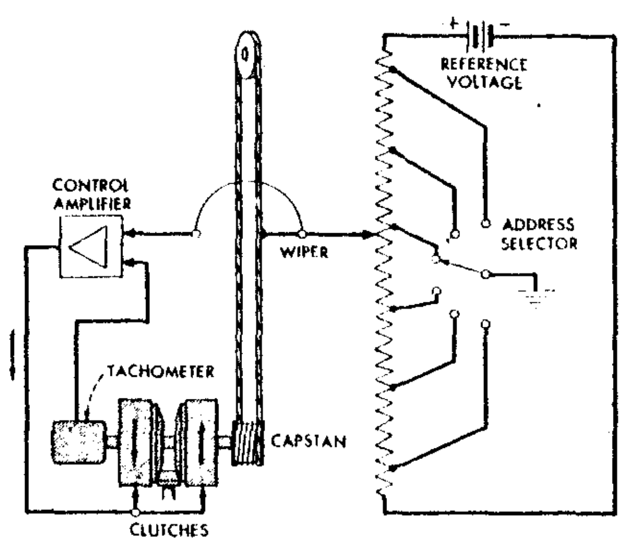


Block Diagram

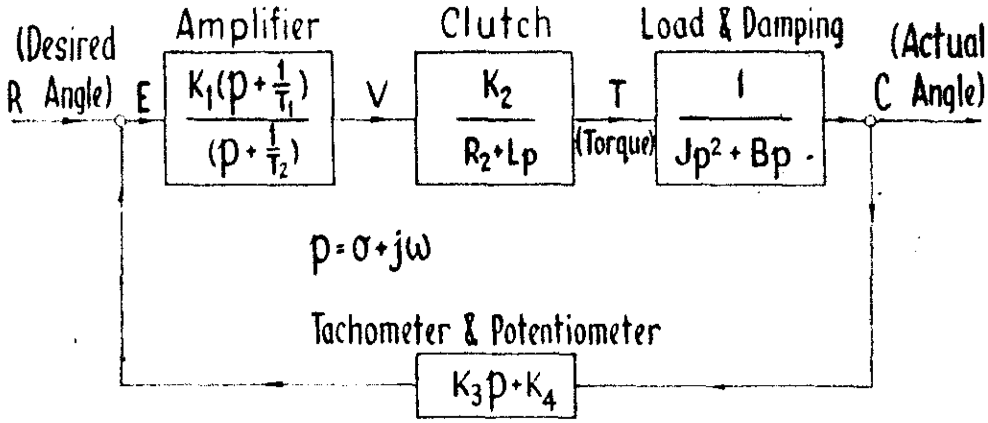
Slide 8 - Punched Card Accounting System



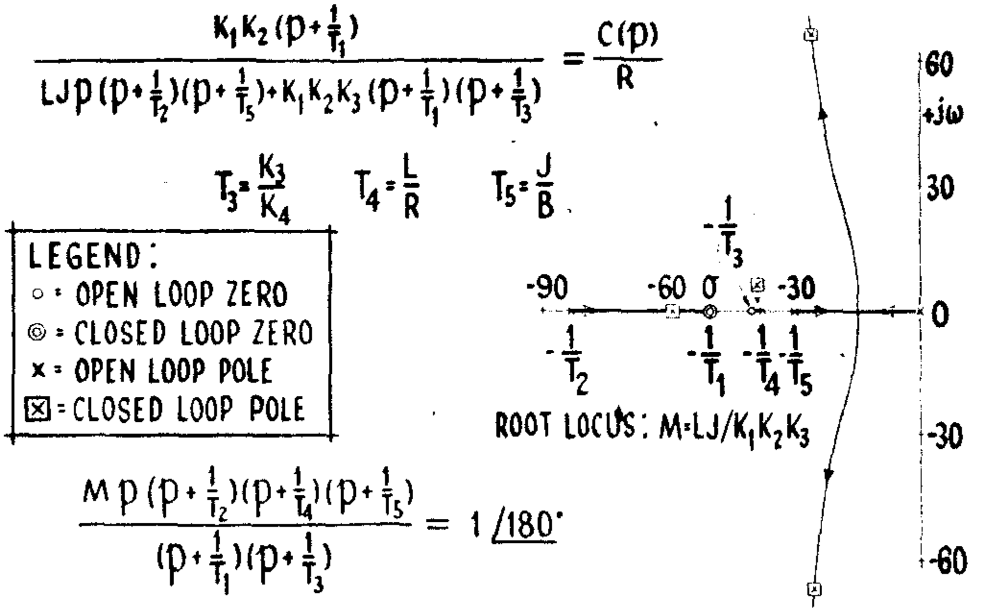
Slide 9 - **Functional diagram of access mechanism showing general scheme of vertical and horizontal positioning, interlock and actuator group.**



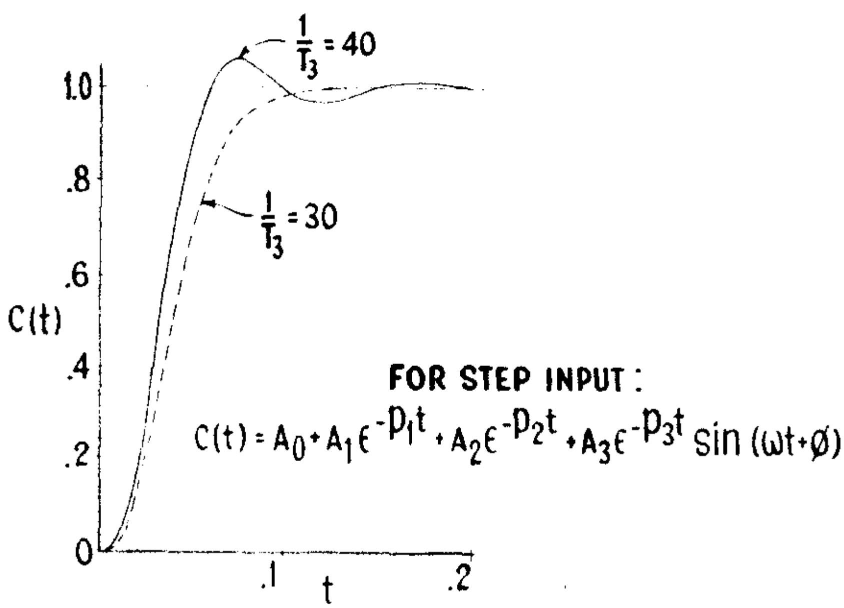
Slide 10 - **Functional schematic for either horizontal or vertical positioning by access mechanism.**



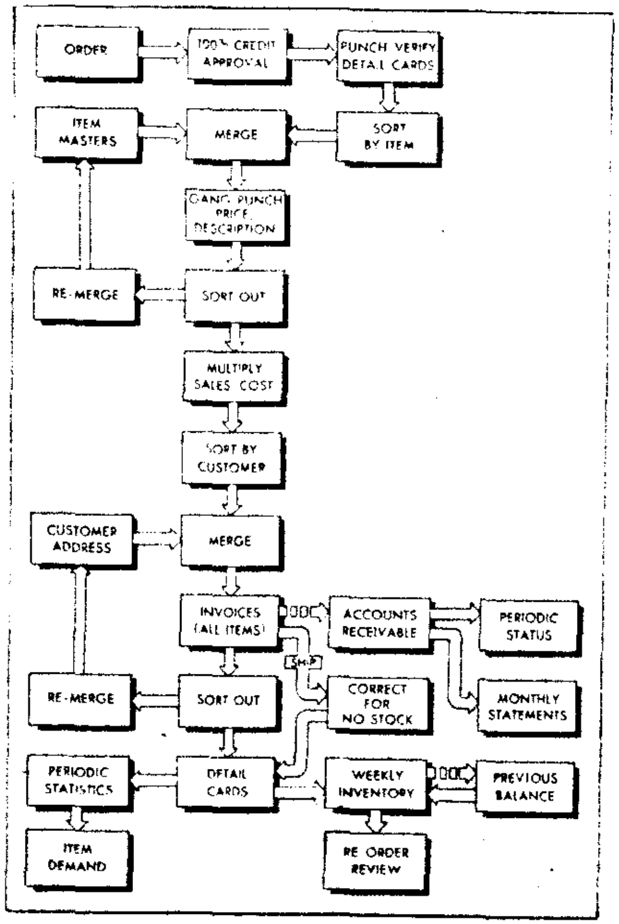
Slide 11 - BLOCK DIAGRAM of RANDOM ACCESS MECHANISM



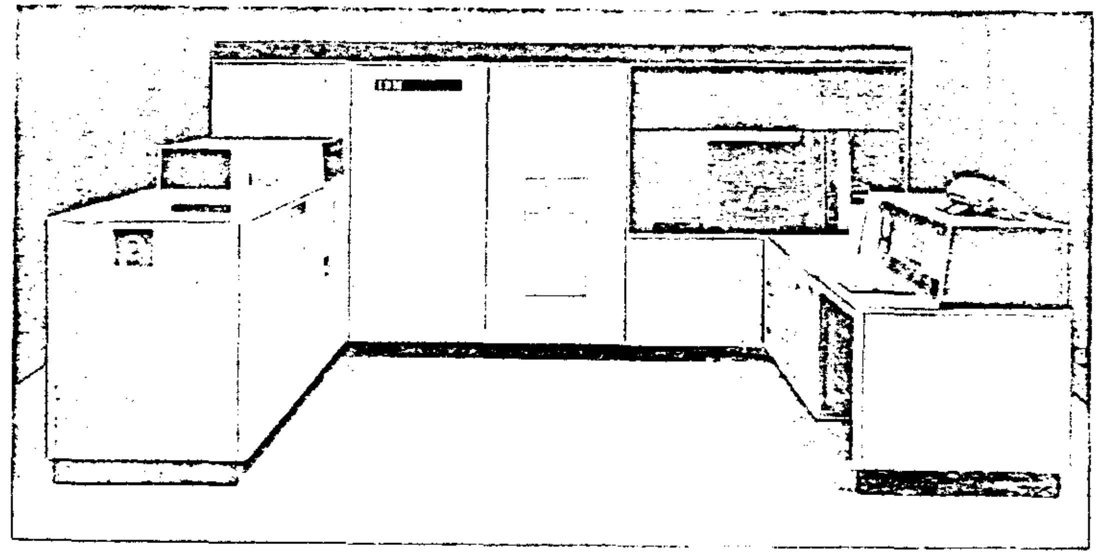
Slide 12 - Root Locus Analysis of Feedback Loop of Access Mechanism



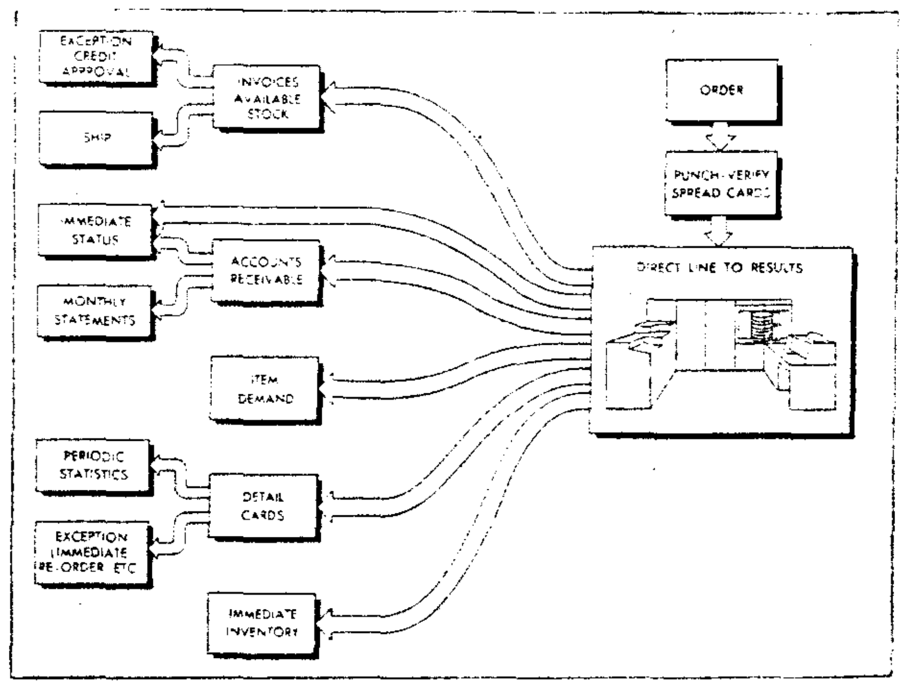
Slide 13 - Transient Response of Access Mechanism



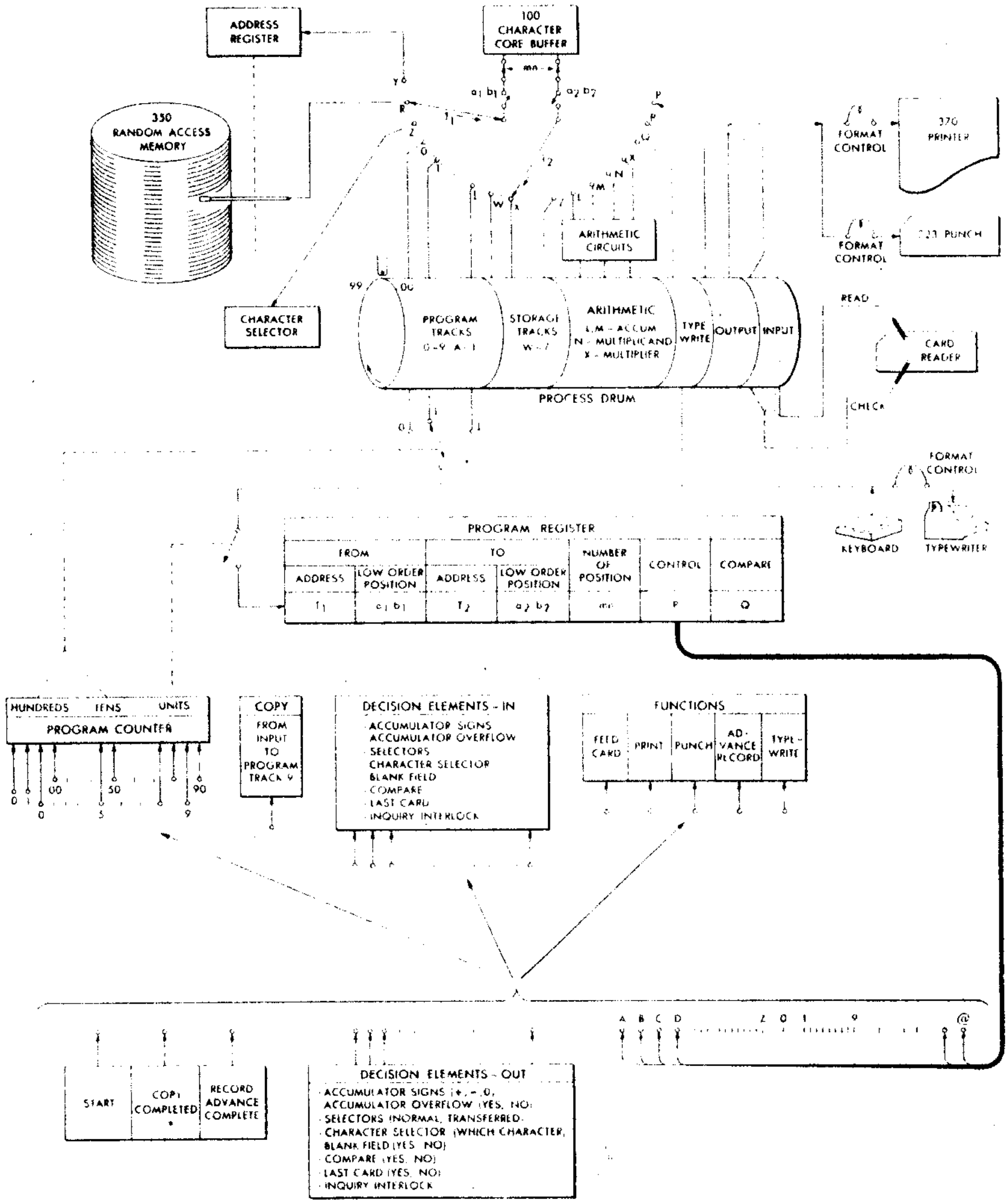
Typical IBM batch processing. Slide 14



The IBM 305 Random-Access Memory Accounting Machine. - Slide 15 - A



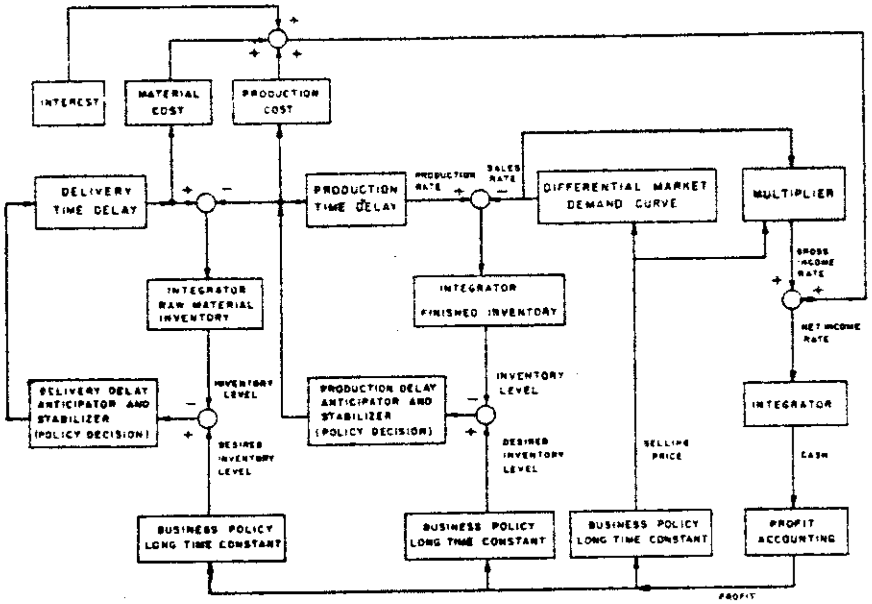
Typical IBM in-line processing. Slide 16



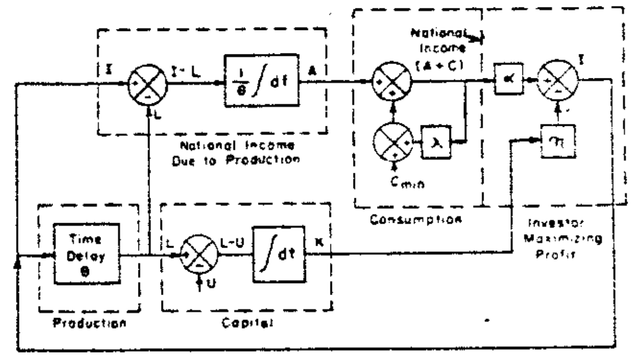
Slide 15 - B

Logic diagram for the Random-Access Memory Accounting Machine.

Note: Control circuits indicated are completed by control panel wiring from exit hubs below to entry hubs above. Decision elements may be used in any desired sequence. Control is returned to stored program by picking appropriate level of program counter.

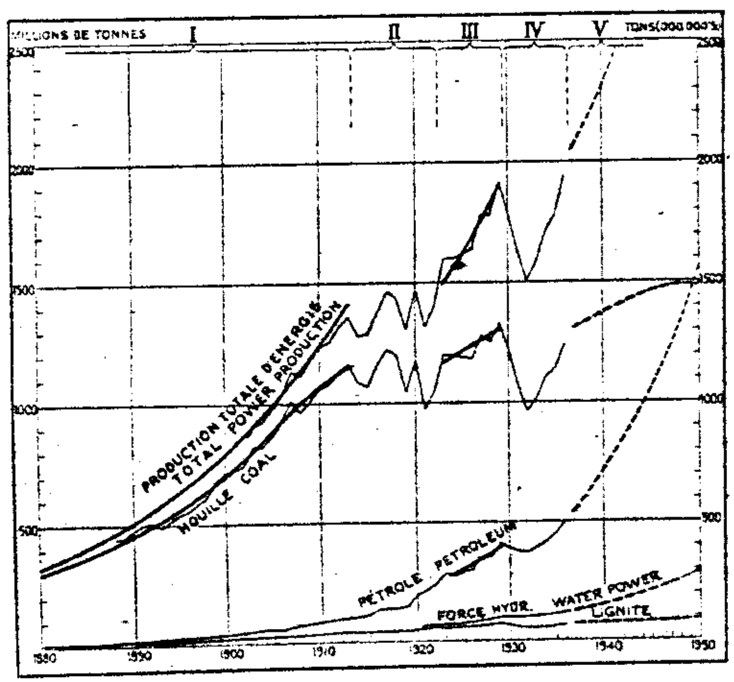


Slide 17—Unilateral production analog.



Slide 18 —Macrodynamic capital production analog.

Slide 19 - Trends of Power Production (in Terms of Coal)



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