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Memorandum M-1582

Hawley K. Rising

August 6, 1952

ELECTRICAL ENGINEERING DEPARTMENT

MASTER'S THESIS PROPOSAL

TITLE: HIGH-SPEED MAGNETIC PULSE CONTROL CIRCUITS FOR COMPUTERS

BRIEF STATEMENT OF THE PROBLEM:

Present-day vacuum-tube circuits used in digital computers have been developed to the point where computer reliability is limited mainly by component reliability. Because of their ruggedness and long life, saturable transformer circuits have been investigated as possible substitutes for vacuum-tube circuits in digital computers. Considerable work has been done in the application of square-hysteresis-loop cores as elements in multi-dimensional memories for storage of information and as elements in stepping registers for control purposes. Thus far, little work has been done on magnetic-core arithmetic elements. A magnetic flip-flop and a magnetic pulse amplifier would possibly find use in the arithmetic circuits of computers. A magnetic-core flip-flop and a magnetic-core pulse amplifier will be developed in this thesis.

BRIEF HISTORY OF THE PROBLEM:

Magnetic cores have been considered for arithmetic operations by several groups.[1] Carrier-operated magnetic-core flip-flops have been developed by Engineering Research Associates[2] and the Computer Research Corporation.[3] Though the complementing rates are as high as 400 kc, the presence of the carrier complicates the circuitry and requires several diodes because two conversions to direct current are necessary for each flip-flop. The advantages of the carrier-operated flip-flop are a continuous output and power gain. An M. I. T. Master's thesis by R. J. Pfaff[4] describes a pulse-operated flip-flop with an operating speed of 50 kc. Though the circuit is simpler and no carrier is required, it has several disadvantages, such as low operating speed, inability of the circuit to complement, and the use of diodes in high-current portions of the circuit. The proposed flip-flop will attempt to combine the advantages of previously developed flip-flops without their disadvantages. It will be a pulse-operated, complementable circuit operating at greater than 500 kc with a minimum of components and no high-current diodes.

In addition to a need for high-speed flip-flops from magnetic cores, there is a need for magnetic pulse smplifiers to enable the flip-flops and other equipment to be driven from weak signals. Most of the magnetic amplifier work has been done on carrier-type amplifiers operating at power frequencies. Although the carrier-operated flip-flops have shown that carrier magnetic amplifier techniques may be scaled up to operate at carrier frequencies of a megacycle, the carrier frequencies required for amplification of pulses of the order of a half-microsecond or less would be at least 20 or 30 megacycles. It is doubtful whether magnetic amplifiers could be operated at these frequencies with present core materials, and the complications involved at such frequencies rule out any consideration of carrier-type amplifiers.

Pulsed magnetic amplifiers have been developed at the Harvard Computation Laboratory[5] for use in magnetic tape recording. These amplifiers are capable of amplifying very short pulses. Unfortunately, however, they achieve a power gain by setting a core, then driving it from a power source so that the gain is obtained at the expense of a time delay. The time delay in this type of pulsed amplifier is undesirable in many computer applications where the delays are cumulative. In order to retain the advantage of pulsed operation without the time delay, the proposed pulse amplifier will utilize the non-linearity of the core materials to provide gain. This effect was first noticed in connection with the magnetic cross valve[6], a device originally developed for frequency changing at power frequencies. The magnetic cross valve is a transformer in which the sign of the mutual inductance is determined through saturation of parts of the core by the load current. The mutual inductance is always of the correct sign to transfer energy to the load circuit regardless of the frequency of the load circuit. This idea of a variable mutual inductance produced by core saturation will be applied in the proposed pulse amplifier.

DESCRIPTION OF THE PROPOSED CIRCUITS:

Since this proposal concerns two circuits, it might be advisable to discuss each circuit separately. Basically, a flip-flop must do three things. It must remember one of two stable states; it must give an indication of its state; it must be capable of being set in one state or the other. In order to be complementable, a simultaneous attempt to set and clear must move the circuit to a third neutral state, and some element must remember from which stable state the neutral state was approached. The vacuum-tube flip-flop fulfills these conditions by coupling two tubes in a way that stable equilibrium is reached when one tube is conducting and the other non-conducting.

The complementing action is achieved by cutting both tubes off and remembering which tube was previously on by the charges on the coupling capacitors. The proposed magnetic flip-flop is analogous to the vacuum-tube flip-flop. It has two cores coupled together by a capacitor in such a way that the fluxes in the cores are always in the opposite directions. The circuit is complemented by simultaneous setting and clearing so that both core fluxes are moved into the same direction or a neutral position. The state from which the circuit approached this position is remembered by the polarity of charge on the coupling capacitor. Figure 1 shows the circuit diagram of the proposed flip-flop.

A magnetic pulse amplifier must provide a method of controlling, by means of a low-energy pulse, the transfer of a high-energy pulse from a pulse source to a load circuit with negligible time delay. To do this, the proposed amplifier will make use of the non-linear ϕ -I curve of iron core transformers. Consider two identical saturable transformers connected with primaries series-aiding and secondaries series-opposing. See Figure 2. If the transformers start out at the same points on their B-H loops, then there will be no voltage induced in the secondary circuit. If by some means the transformers are made to start at different points on their B-H loops, then because the slope and rate of change of slope are different on different portions of the B-H loop, the transformer mutual inductance will be different, and a voltage will be induced in the secondary circuit. Also, because the B-H loop is concave downward, any current flow in the secondary will tend to increase the unbalance in induced voltage and produce a regenerative build-up of secondary current. This regenerative build-up continues until both transformers are saturated. This effect will be investigated in the development of the proposed magnetic pulse amplifier in an effort to get instantaneous pulsed power gain.

PROBABLE PROCEDURE:

The test equipment shown in Figure 3 is capable of delivering four independent output pulses either from voltage sources or current sources. Any combination of pulses can be applied simultaneously in any sequence. Each circuit will be set up using several kinds of cores. All the parameters of the circuits will be varied and resulting waveforms recorded so that a design procedure may be established. On the basis of the design procedure, optimum circuits will be designed and tested for comparison with predicted performance. The experiments will be aimed toward high speed, low power consumption, and reliability.

EQUIPMENT NEEDS:

The pulse test equipment is under construction, and all additional equipment needs are available at the Digital Computer Laboratory.

ESTIMATED DIVISION OF TIME:

a.	Preparation of proposal	75 hours
b.	Experimental work and analysis	220 hours
c.	Preparation of thesis report	35 hours
d.	Total	330 hours

SIGNATURE AND DATE:

August 6, 1952

Hawley K. Rising
Hawley K. Rising

HKR/bs

References

1. M. K. Haynes, Magnetic Cores and Elements of Digital Computing Machines. Technical Report to the Office of Naval Research, Contract N6ori-71, Task Order XXII, Project ONR NR 048094, 28 August, 1950.

2. James G. Miles, Saturable Core Reactors as Digital Computer Elements. A report of Engineering Research Associates, Contract NObsr42001, 17 June, 1949.

3. Computer Research Corporation Quarterly Progress Report Number 2, (Item 18). Air Force Contract AF 19(122) - 382, Computer Research Corporation Report No. 5.

4. R. J. Pfaff, A Magnetic Flip-Flop. An M. I. T. Master's thesis submitted to the Electrical Engineering Department 16 May, 1952.

5. Harvard University Computation Laboratory, Progress Report 5, (summer of 1949), Investigations for the Design of Digital Calculating Machinery.

6. H. J. McCreary, The Magnetic Cross Valve. AIEE Transactions 1951, Vol. 70, Pages 1868-1875.

SUPERVISION AGREEMENT:

The problem described here seems adequate for a Master's research. The undersigned agrees to supervise the research and evaluate the thesis.

Approved:

Faculty Supervisor: William K. Linvill
William K. Linvill

HKR/bs

Drawings attached:

SA-52133
SA-52134
SA-52135

MAGNETIC FLIP-FLOP

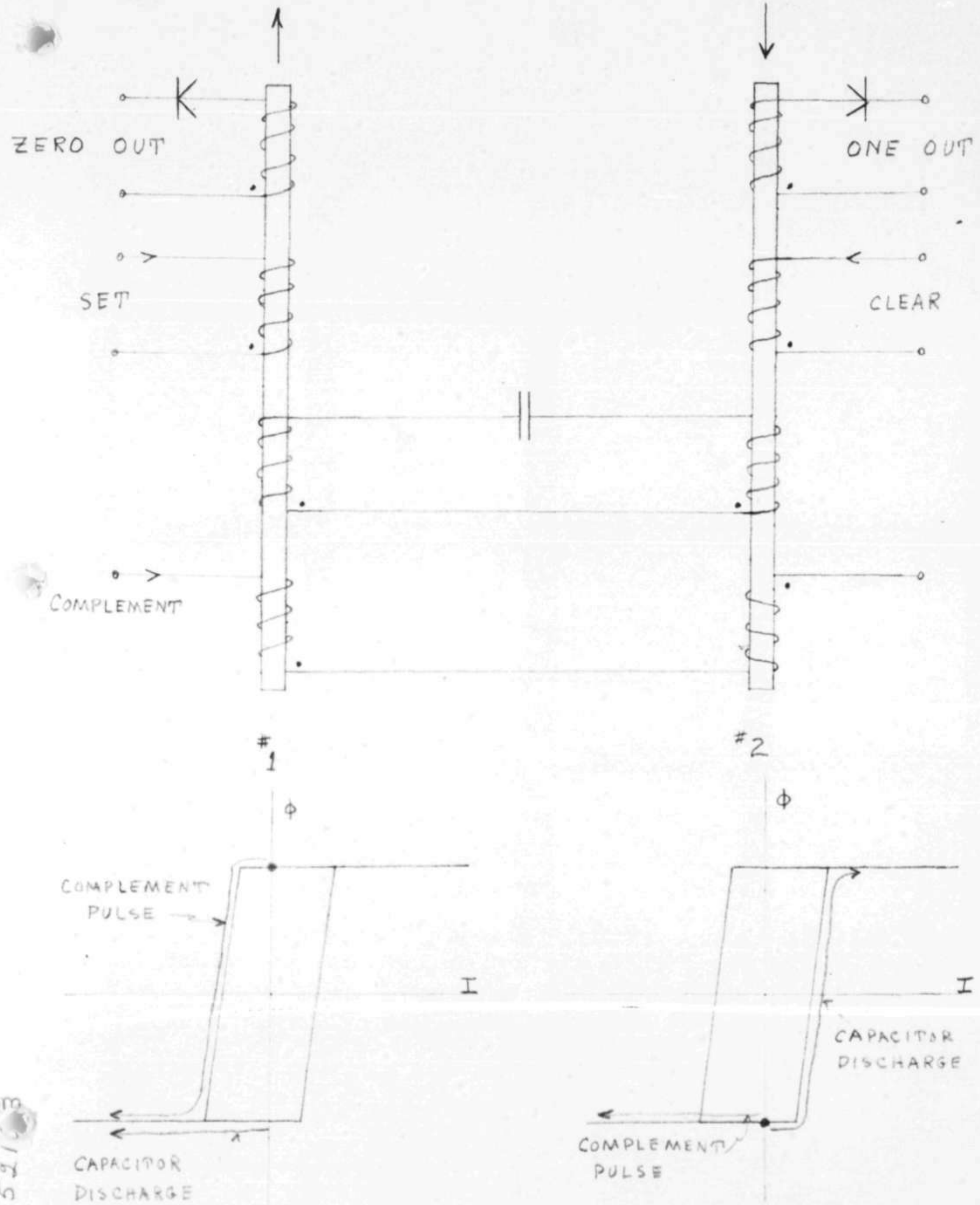

FIG. 1

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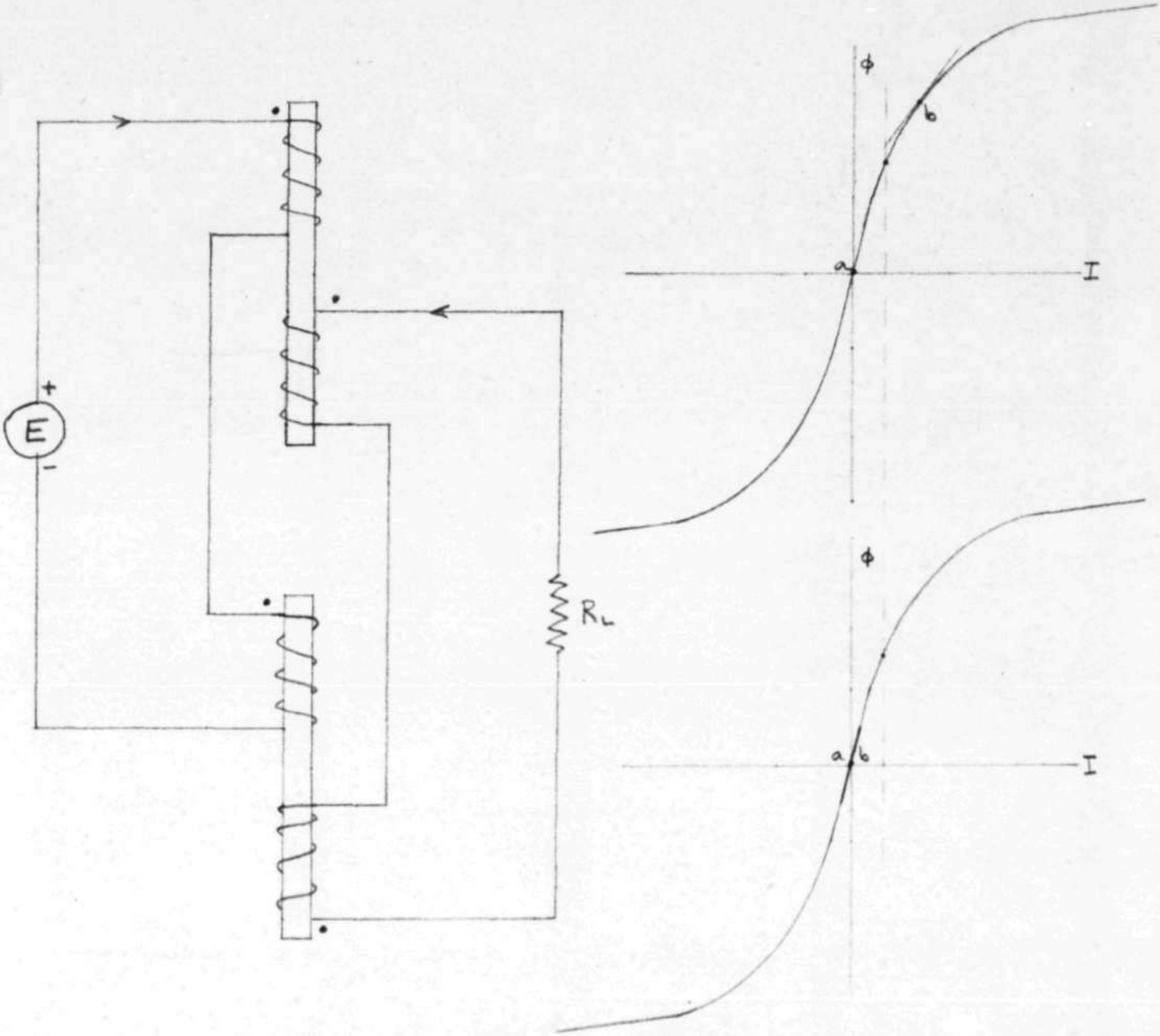
PULSE AMPLIFIER



BALANCED CONDITION: TRANSFORMERS START AT a-a. OUTPUT VOLTAGES CANCEL RESULTING IN NO LOAD CURRENT.

UNBALANCED CONDITION: TRANSFORMERS START AT b-b. DIFFERENCE IN φ-I SLOPES CAUSES NET VOLTAGE IN LOAD CIRCUIT. LOAD CURRENT FLOWS IN DIRECTION TO AID UNBALANCE

FIG. 2

SA-52/3

TEST EQUIPMENT

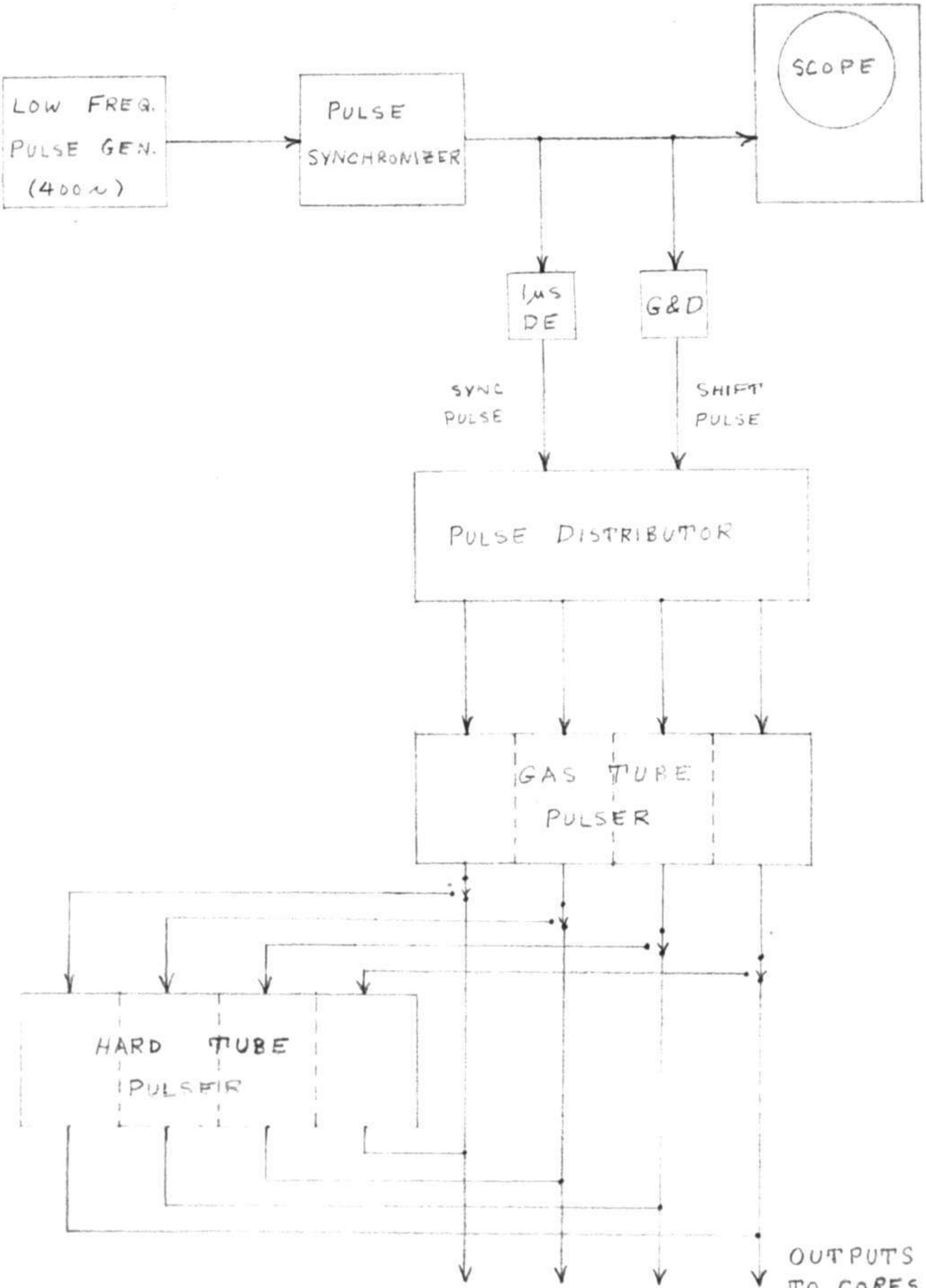


FIG. 3

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