AN ELECTRONIC TIMER FOR
HIGH VOLTAGE PULSES

Thesis for the Degree of M. S.
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Parnell Marc
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This is to certify that the

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AN ELECTRONIC TIMER FOR HIGH VOLTAGE PULSES

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INTRODUCTION

Pulses can be defined as succession of currents varying in a very short time. It is to be pointed out that an extensive use of pulses has been made in the pioneer work in radio communications. The subsequent development of electronic tubes led to the discard of the pulses. New properties and uses have been found for them and a new field of radio engineering, radio location, is based on the production of sharp pulses by electron tubes. They also have been applied to many other electronic devices.

In the present work, a blocking oscillator is made use of in order to produce a succession of sharp pulses regularly spaced in time to control the action of a thyratron. This thyratron itself controls the discharge of a capacitor through the primary of a spark coil. Such a system is to be used in the laboratory in connection with a free fall apparatus. The old apparatus using a tuning fork gave irregular sparks. It is hoped that the electronic apparatus will give more regularly spaced sparks.

DESCRIPTION AND OPERATION OF THE APPARATUS

The different components of the apparatus are a) the spark coil; b) the thyratron circuit; c) the blocking oscillator; d) the power supply, as indicated in Figure 1.

The spark coil has the following characteristics. Its primary has an inductance of 2.56 millihenries with a Q of 9 for a frequency of 1,000 cycles. Its secondary has an inductance of 26 henries with a Q of 16.5 for a frequency of 1,000 cycles. The spark coil is energized by the discharging action of the capacitor through its primary and the thyratron, this capacitor being charged during the non-conducting time of the thyratron.

A General Electric FG 57 thyratron was used. It stands a peak plate potential of 1,000 volts with a peak plate current of 15 amperes. The filament of the tube required 4.5 amperes at 5 volts and the control grid was kept at -45 volts by means of a battery.

This high negative bias is constantly applied to the grid of the thyratron. It constitutes the fixed component of a total bias the variations of which will control the firing of the tube. The fixed bias is chosen so that the tube cannot conduct when no other potential is applied to the grid. A voltage pulse is also supplied to the grid in series with the fixed bias. This pulse is from the output of a blocking oscillator which is an important part of the circuit.

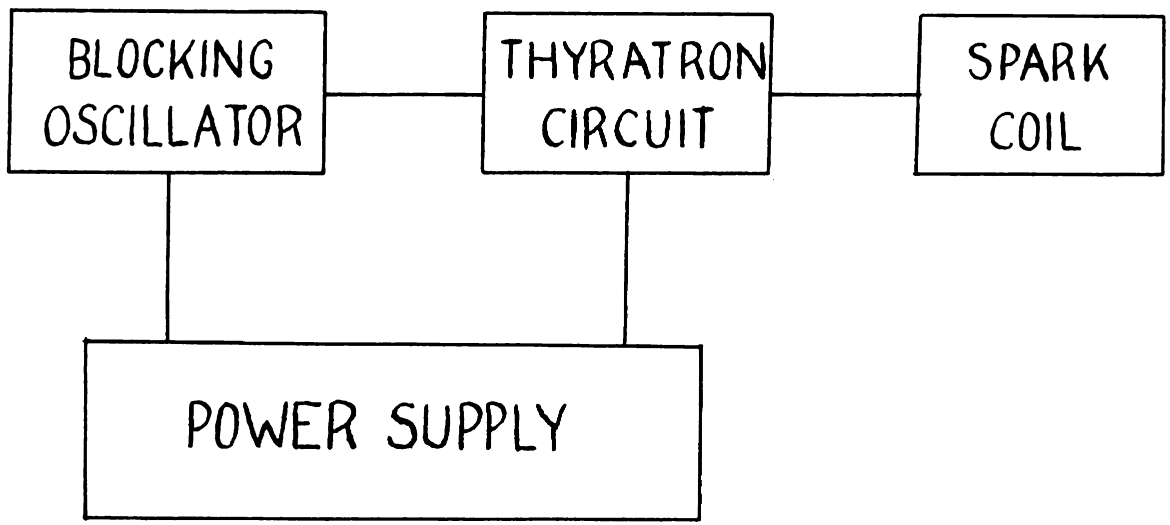

FIG. 1
BLOCK DIAGRAM

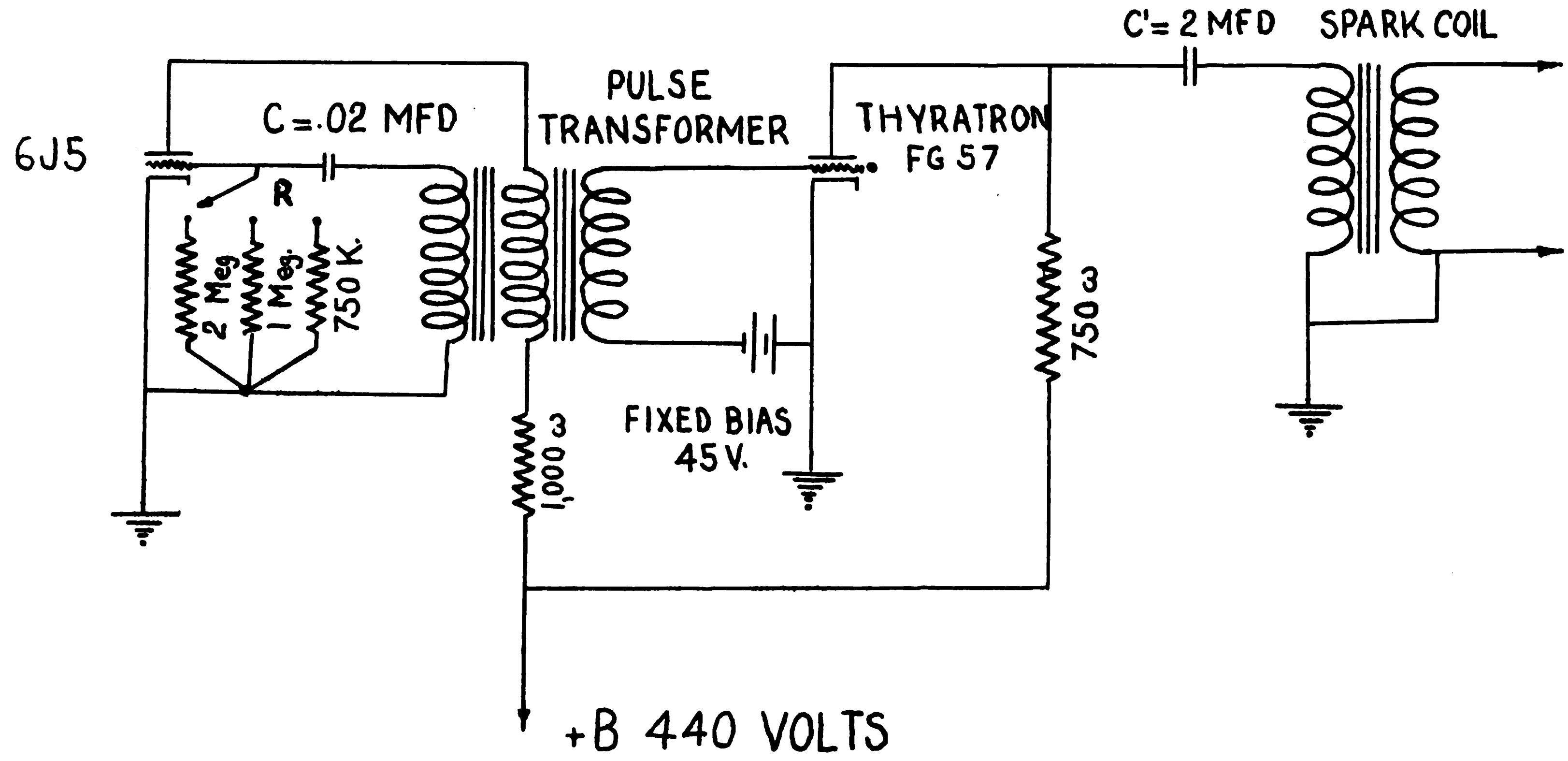

FIG. 2
WIRING DIAGRAM

When the resultant bias is above the critical firing bias voltage which is determined by the value of the plate voltage, the thyratron conducts until the plate potential falls below the value necessary for conduction.

THE BLOCKING OSCILLATOR

Since there is no grid bias, the tube begins to conduct as soon as the circuit is closed. The plate current begins to increase. At the same time, an E.M.F. will be induced in the grid coil, which coil is so arranged as to make the grid end positive. The result is that the plate current increases; E_p then increases until the saturation is reached for the plate current. Capacitor C has become charged during this time by the grid current (Figure 3 and 4 .

At this moment, since there is no more voltage induced in the grid coil, the capacitor C begins to discharge through R. The grid tends to become less and less positive. Then the plate current will begin to decrease and in the grid circuit a voltage will be impressed in the opposite direction. This means that the grid end of C tends to become more and more positive (Figure , 5, 6).

The cut off point is soon reached as C is discharging E_p will rise above E_{bb} and a slight oscillation may occur which depends chiefly on the inductance of the plate coil. One surge of I_p is attained which induces the output pulse in the third winding. A new cycle of operation is repeated as soon as the voltage across R is above cut off.

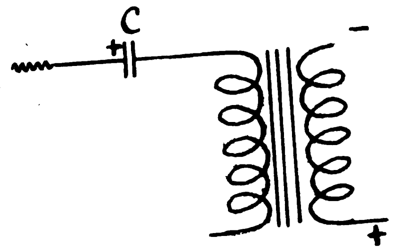

FIG. 3

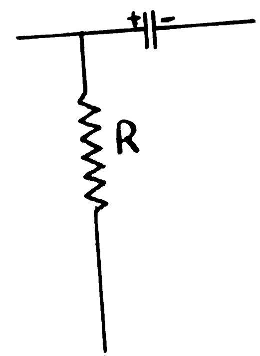

FIG. 4

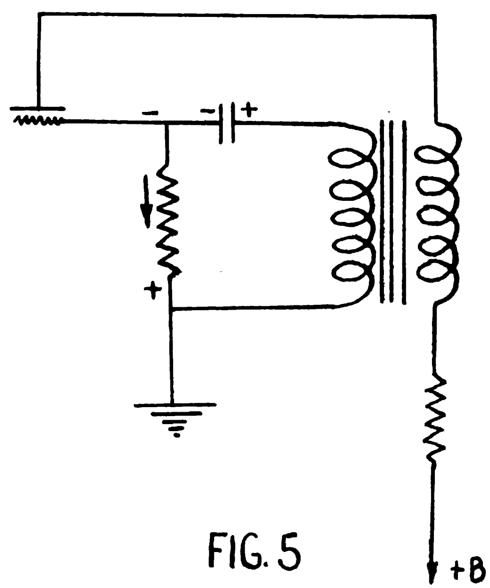

FIG. 5

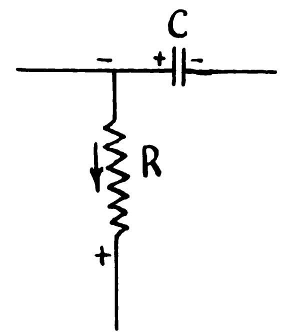

FIG. 6

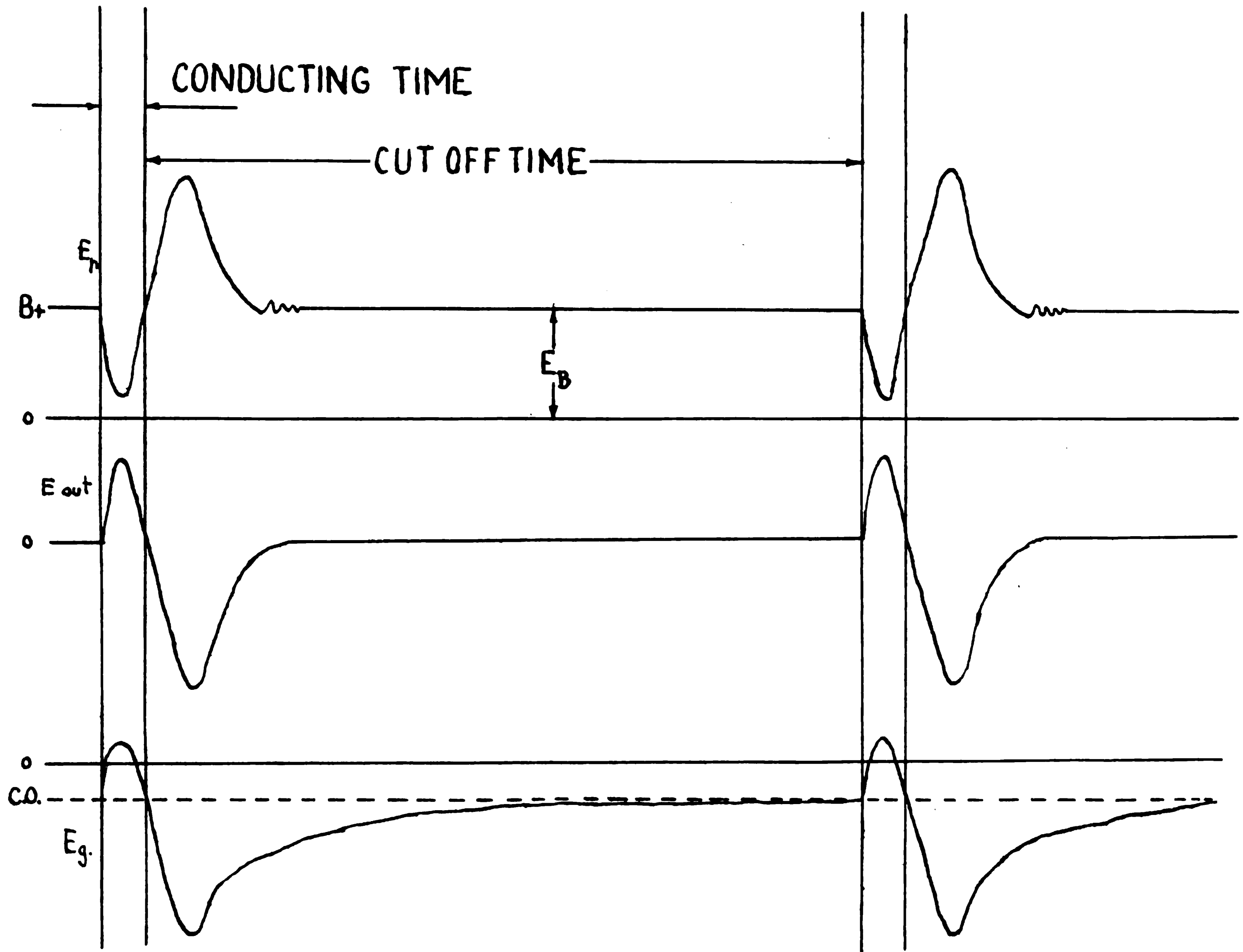

FIG. 7
VOLTAGES ACROSS L_2, L_3 AND AT THE GRID

It is then understood that the thyratron fires wherever there is a variation of magnetic field through L_1. The negative parts of the pulse occur each time the thyratron is conducting.

The interval T between successive pulses depends essentially on: 1) the cut off of the triode; 2) the voltage to which the capicator C is charged; 3) the product $T = RC$ called the time constant of the blocking oscillator.

CALCULATION OF T.

It would be very instructive to derive a formula giving the interval T between pulses according to the characteristics of the blocking oscillator. No rigorous treatment of this problem has been made. The principal difficulty lies in the fact that it is quite impossible to draw an adequate equivalent circuit for the blocking oscillator on account of the multiple reflective inductions taking place by the special three winding transformers used in the circuit.

An elementary approach to the question consists in supposing negligible the different coefficients of mutual induction and to neglect also in the series circuit made of C, R, L_1 the value of L_1 since it is found very small in comparison with the value of R which is of the order of 10^5 ohms $C = .02$ mfd. Let e_{cc} be the cut off value of the tube for the operating conditions, V_c the voltage across C when completely charged.

Then $i = \frac{V_c}{R} \epsilon^{-t/RC}$; $T = -RC \operatorname{Log}_e \frac{e_{cc}}{V_c}$

The characteristics of the 6J5 show that

$$e_{cc} = 25^{V} \text{ for } E_{bb} = 440^{V}$$

V_c probably depends upon R and is approximately equal to -60 volts.

MEASUREMENT OF T

It has not been possible to measure V_c on account of the fast successive charging and discharging of the capacitor. But a direct measurement of T has been obtained by comparison by the means of the cathode ray oscillograph of the frequency of the pulse with the frequency produced by an audio oscilator.

RESULTS OF THE MEASUREMENTS

R	T sec
2 Meg	1/23
1 Meg	1/61
750 K	1/124
500 K	1/176

THE POWER SUPPLY

The power supply presents no special features, however, a special transformer is necessary to supply the heating power to the filament of the thyratron which requires approximately a current of 5 amps, at a potential difference of 5 volts.

STABILITY OF THE APPARATUS

The principal advantage expected from this apparatus is that it will keep as constant as possible the interval between pulses during a whole laboratory period (a maximum of 2 hours).

PROBABLE CAUSES OF INSTABILITY

a) The variations of the power source

If the high voltage source of the power supply undergoes some fluctuations, a displacement of the operating conditions of the apparatus is inevitable. This can be prevented by adding a regulator to the power supply (VR - 150 for example). Occassional checks of the fixed bias of the thyratron will also be necessary.

b) Variations which may occur from the aging of the tubes.

Taking at first the case of the triode, it has been seen that the period T depends on the cut off value of the 6J5 for the operating conditions. This on the other hand, depends on the internal resistance of the tube. It is to be expected that as time goes on, this value will change and the apparatus will need appropriate adjustment. Nothing particular can be said as far as the thyratron is concerned. It can be pointed out only that as for any mercury filled tube, its operation is subject to changes depending on the temperature of the mercury. This has not a very great importance on the stability of the apparatus since the firing time has to be controlled entirely by the blocking oscillator and not by the thyratron.

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