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PROGRESS REPORT

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Contract N7onr 419 Task 6

By

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INTRODUCTION

Since the previous reports (August 28, 1953 and the report attached to our prosposal of November 18, 1953) the work has progressed along several of the lines mentioned in these reports. We have also directed our efforts towards achieving a two stage counter operating from the pulses produced by a pulse generator (see report of September 1, 1952) employing the 7-stage National Union grid-controlled multiplier tube.

Philips EFP 60 as Driving Tubes

We have obtained a number of the Philips grid-controlled one stage multiplier tubes (EFP 60) and have constructed a counting circuit using these tubes. It appears as though they are somewhat better suited for our use than are the National Union 5857 tubes. The dynamic characteristics of these tubes was measured by means of the circuit shown in Fig. 1 and the results are plotted in Fig. 2. The dynode to plate voltage one can use with these tubes is 50 volts higher than that allowed for the National Union tubes, therefore the voltage modulation of the dynode and plate will not have as large an effect on the magnitude of the output. The overall transconductance of the Philips tube seems to be about twice as great as that of the National Union tube. The one factor in favor of the National Union tube is that its output capacitance is only one third that of the Philips tube. However, this is offset, as far as our use is concerned, by the lower allowed plate dissipation, 1.5 watts as compared with 2 watts for the Philips tube.

Driving Circuit

The shortest pulse that will reliably operate a counting circuit using the National Union tubes is 10 millimicroseconds. To test the application of the Philips tubes to this type of circuit we constructed the counting circuit shown in Fig. 3. This circuit could be driven by signals as short as 7.5 millimicroseconds. No attempt was made to determine the resolving time of the circuit since we cannot, at the present, produce resolved pulses separated by less than about 15 millimicroseconds. Also, this circuit was intended only to test the operation of the Philips tubes and not to test the overall operation of a counting circuit using these tubes.

Tube diodes were used in this circuit for two reasons; first, because of the almost infinite back resistance, we could use a slave flip-flop having a small voltage difference between the steady states (the reverse current through crystal diodes makes it exceedingly difficult to design a slave flip-flop having such a low voltage swing), second, because of the higher forward impedance as compared with crystal diodes, the voltage modulation of the multiplier plate and dynode must be larger to drive the flip-flop, thus putting the multiplier tube to a more severe test. Of course part of this latter effect is offset by the lower voltage swing of the flip-flop but in turn this reduces the bias of the "off" multiplier tube so that one must apply lower input signals to the cathodes of these tubes. A short resolving time circuit would require the use of crystal diodes in place of these tube diodes.

Slave Flip-Flop

As was mentioned in our proposal we can construct slave flip-flops having voltage swings as low as 1.5 volts but as yet we have no driving circuit which can be gated by such a low voltage swing. It appears that the problem of the slave flip-flop is now resolved to searching for suitable tube types having lower than usual capacitance between the tube elements.

In this respect we have investigated a number of sub-miniature tubes but so far we have not found any having enough power output at low voltage operation to serve as flip-flop tubes. This survey is being continued, as is the survey of the available miniature types.

As a matter of record we show in Fig. 4 all of the different types of slave flip-flops that we have used or developed. It should be noted that in all of these circuits there is only a single voltage difference between the steady states. This is to be compared with the conventional triode circuit where there occurs at least two different voltage swings between the stable states; one between the plate voltages and the other between the grid voltages.

Pulse Generator

Recently we obtained two 7-stage grid-controlled National Union multiplier tubes from The Bureau of Ships. These tubes were fabricated according to the design of our experimental tubes. (See reports of June 22, 1951, May 23 and September 1, 1952.)

These tubex were used to construct a pulse generator operating on the principle of recycling one or more pulses through a delay cable connected between the output and input of the tube. (See report of September 1, 1952.) They may also be used eventually as the driving tubes in the counting circuit.

One of the tubes has been tested and the DC characteristics of the pentode section plus first dynode are shown in Fig. 5, along with the circuit arrangment used. We also made various tests to determine the effects of varying the accelerating voltage between the pentode plate and the first dynode and between the first and second dynodes.

Qualitatively it can be stated that the effect of increasing the voltage between the pentode plate and the first dynode to obtain more current through the plate window has such a small effect that it is not worthwhile to increase this voltage much beyond 50 volts. Of course, there should be enough overall accelerating voltage on the first dynode to produce some multiplication. If one increases the voltage to this dynode one should get some effect through the tube since the multiplication of this stage should rise with increasing voltage. When the multiplication of this dynode was measured there seemed to be only a small rise as compared with the multiplication of the second dynode. The absolute value was also small; 1.4 at 200 volts accelerating potential as compared with 3.7 at the same accelerating potential applied between the first and second dynode. It is quite possible that the surface of the first dynode has been spoiled somewhat during the forming of the cathode in the pentode section.

Next we measured the multiplication dynamically over five stages. The circuit used to measure this value is shown in Fig. 6. A multiplication of 374 was obtained which averages to 3.28 per stage. The voltage between stages was increased at the output end of the tube to counteract space charge effects.

After this we connected a feed back cable of 100 meters (RG 59/U) between the collector and the cathode and obtained a recycling pulse generator, using only five stages of multiplication. Next we changed the output to the 5th dynode and fed back to the grid. The oscillations were easy to start and very stable. We have operated one of the tubes in this manner for a total time of about 10 hours and have not noticed any change in overall characteristics. It should be noted that only one tube has been used so far and although this tube is promising we cannot make any general statement about the quality of the tubes until a number of them have been tested. No attempt was made to alter the shape of the pulses by stub lines, etc., so that the length of the pulses (10 millimicroseconds) was due entirely to the tube characteristics and the output impedance of the circuit. We changed to cable having 185 ohms impedance and observed no difference in the width of the pulse or its amplitude at the collector output point.

We shortened the delay cable in steps of 20 meters until we had only a total of 20 meters between the output and input, corresponding to a frequency of 10 megacycles. At this point the average current at the output was 6 milliamperes and after a few seconds of operation the collector dynode, the 6th, began to heat up and we stopped the operation. The dissipation at this point amounted to 3 watts. In the future we hope to shape the pulses so that they will be narrow and thus decrease the average current and the dissipation of the tube elements. Figure 7 shows the recycling pulse generator with the output of the dynode fed back to the control grid.

Scaling System

In order to test the idea of driving a counter circuit by means of a 7-stage grid-controlled multiplier tube we connected the pulse generator described above to a counting circuit similar to the one shown in Fig. 4. Without making any refinements to either of the circuits we could operate the counter at a continuous rate of 3.3 megacycles (60 meter delay line in the pulse generator).

Future Work

For the immediate future we plan to investigate the problem of shortening the pulses produced by the pulse generator with the idea of operating the circuit at a higher rate. At the same time we are going to build a second stage to the counting circuit so as to have a two stage counter being driven by a pulse generator. It will also be necessary to improve the counting circuit operation so that the first stage can operate at a continuous rate equal to that which can be obtained with the pulse generator.

The program for the more distant future is to devise a complete two stage counting circuit being driven by a pulse generator which can opdrate at a frequency of between 50 and 100 megacycles. There must also be some sort of circuit arrangement which will allow us to test the circuits by arbitrarily selecting a group of pulses from the output of the pulse generator and feeding these pulses to the counting circuit. This will involve a coincidence circuit having a resolving time as fast as that of the first counter circuit and it is assumed that this will necessitate the use of other of these 7-stage grid-controlled multiplier tubes.

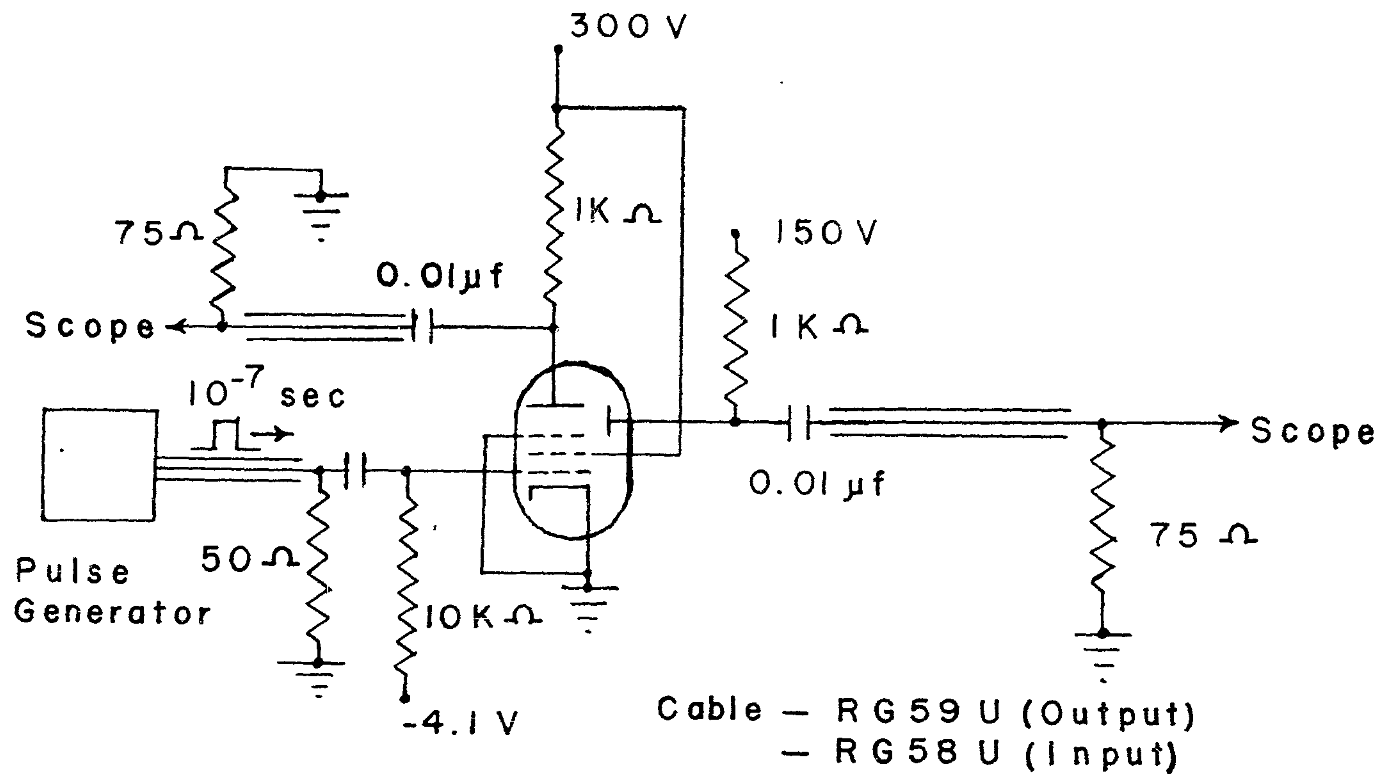


Fig.1 Circuit used to obtain dynamic characteristics of EFP-60 tube.

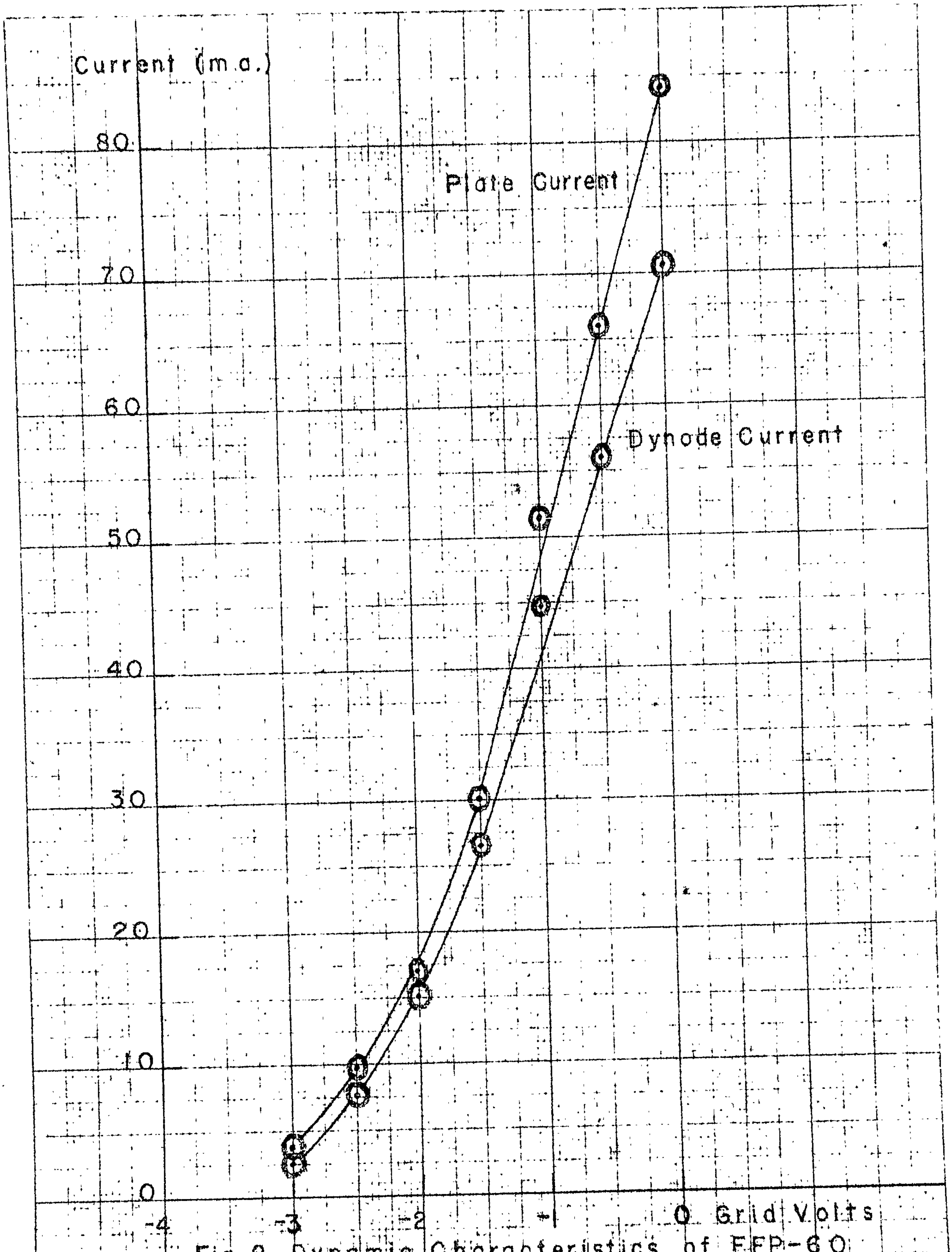


Fig. 2 Dynamic Characteristics of EFP-60

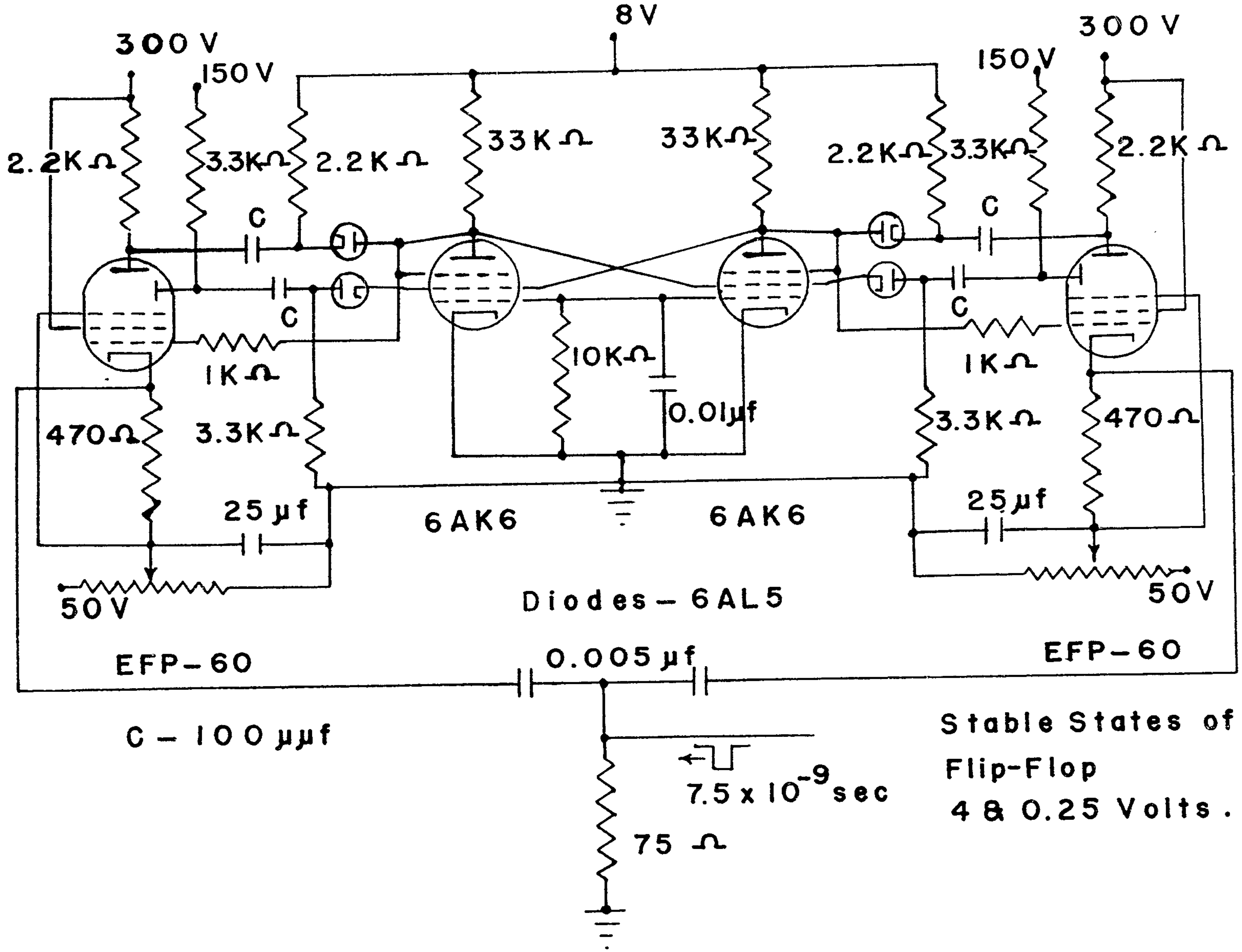


Fig. 3 Counting circuit used to test EFP-60 tubes.

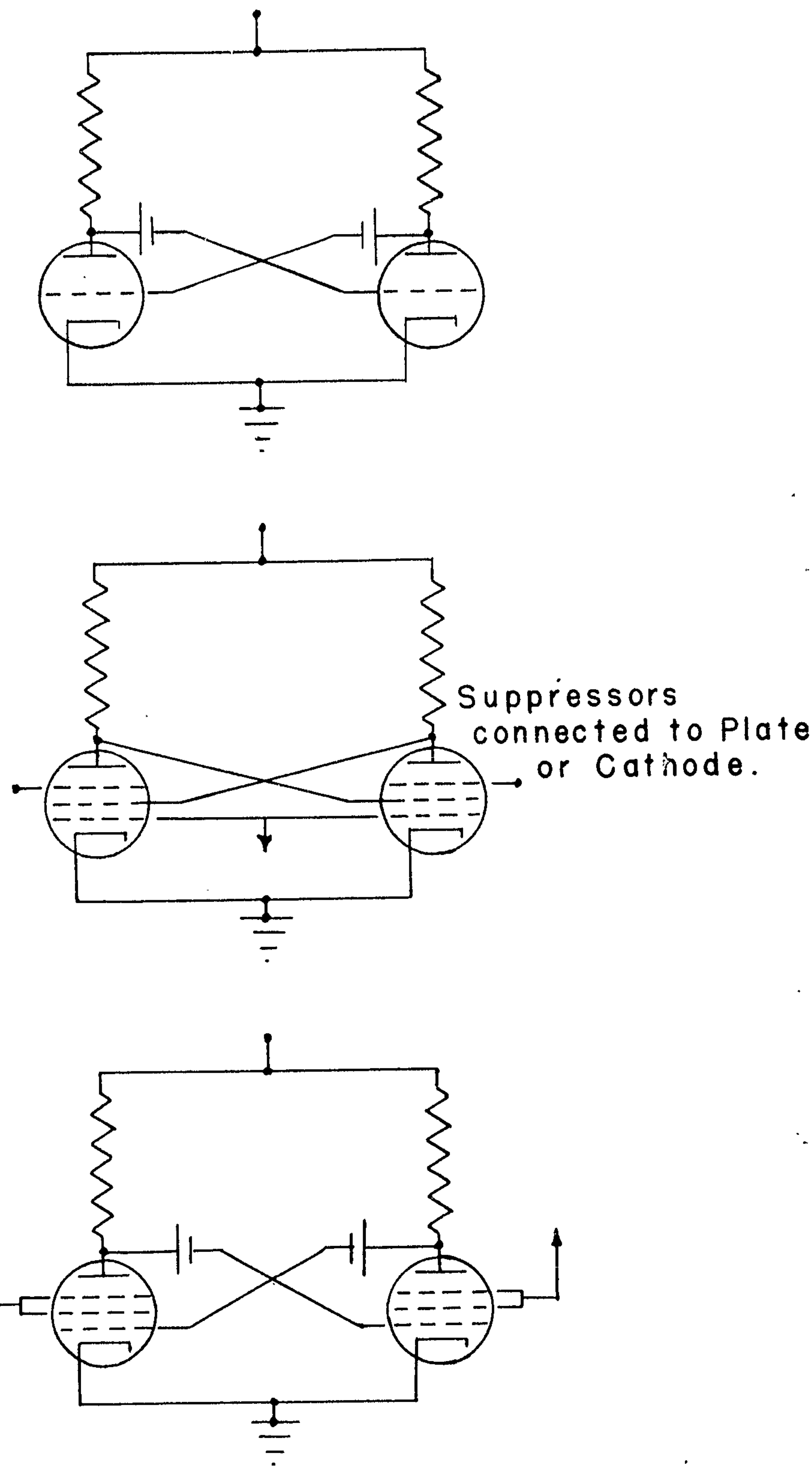


Fig. 4 Slave Flip-Flops

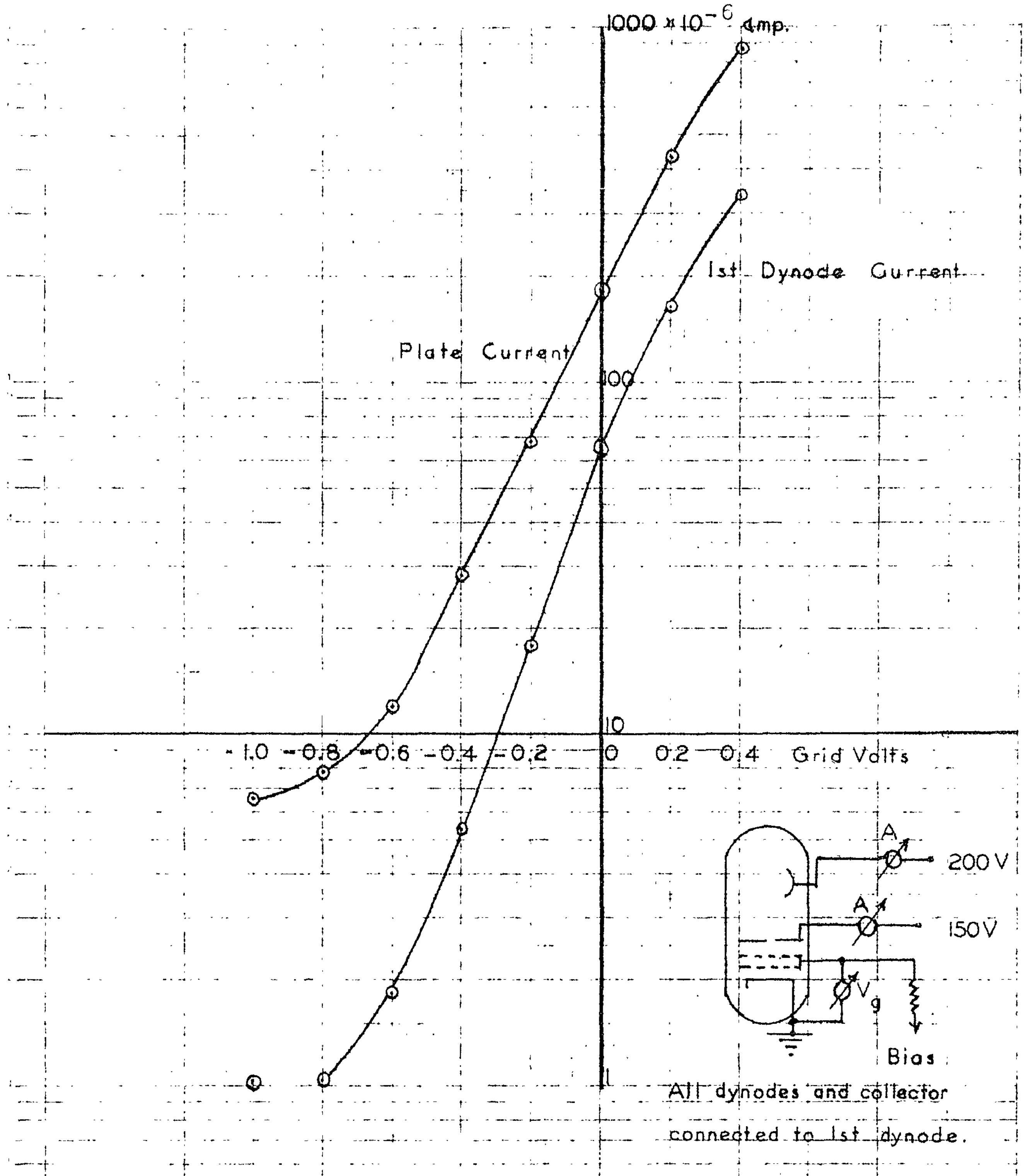
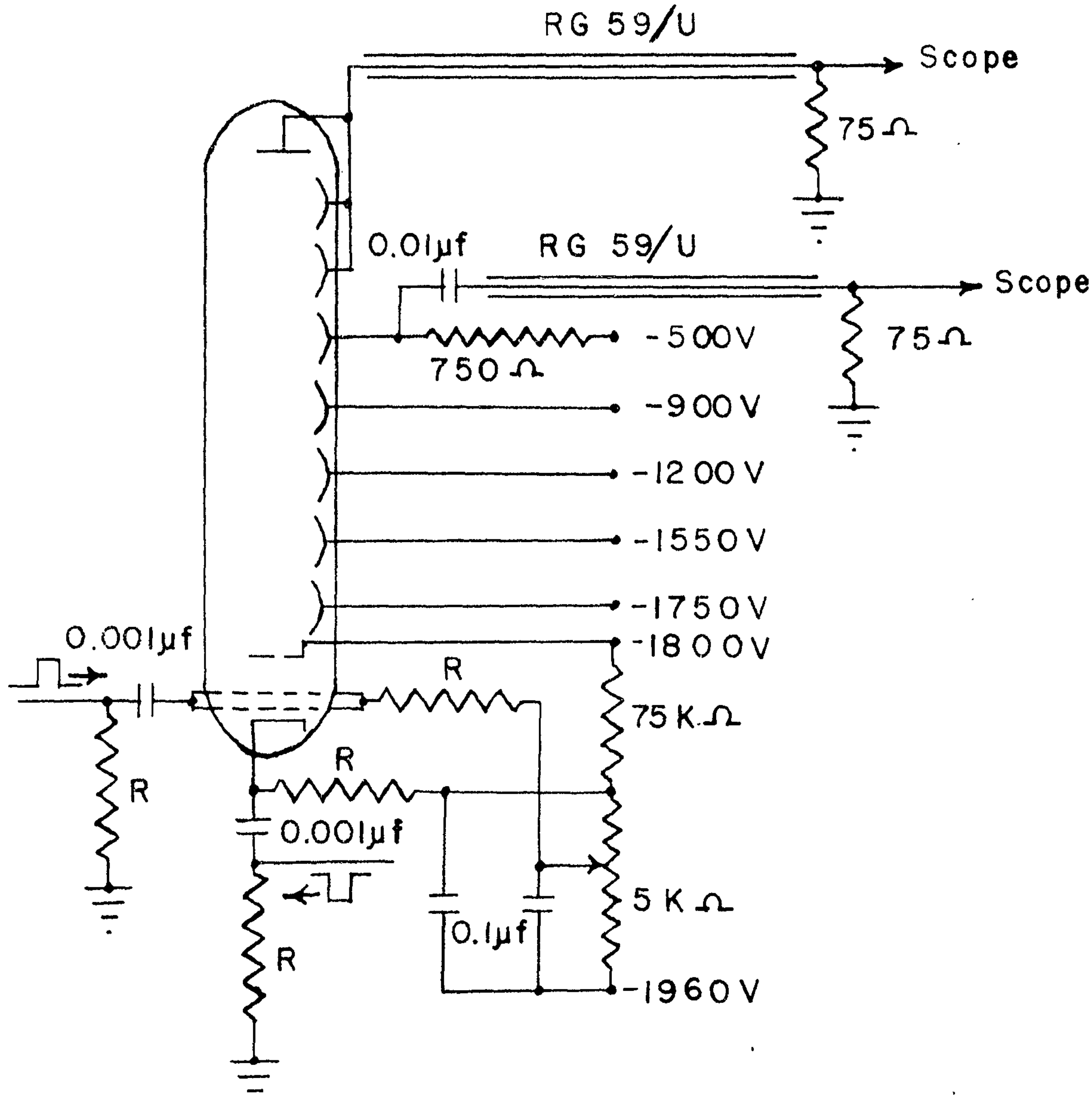


Fig. 5 DC characteristics of 7-stage grid controlled multiplier tube, HT 1D-1-2.



Modulation can be applied to either the grid or the cathode. The resistors "R" are selected to properly terminate input cables.

Fig.6 Circuit used to test grid - controlled multiplier tubes.

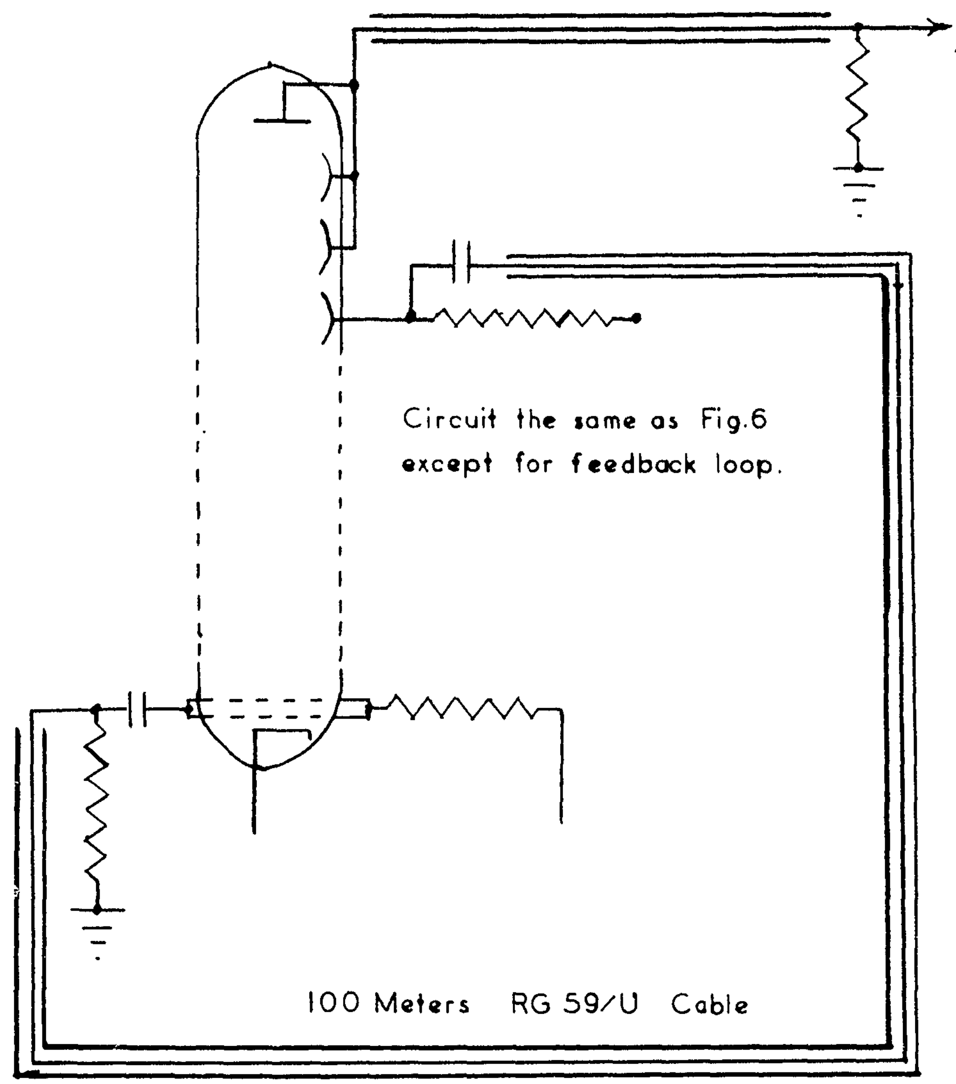


Fig. 7 Recycling pulse generator.