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MASTER

Simple High-Voltage Trapezoidal Pulse Generator⁺

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Abstract-A description is given of a simple circuit used to produce negative voltage pulses up to 60 kilovolts with a portion rising with constant slope up to 10 kilovolts per microsecond.

A negative high-voltage pulse, the top rising with constant slope from V_1 to V_2 , was required for an investigation of the injection properties of a conventional electron synchrotron. In order to match possible acceptance conditions of the machine it was required that V_1 and V_2 be adjustable between 20 and 60 kilovolts while the slope of the top of the pulse, $\dot{V}$, had to be adjustable between 0 and 5 kilovolts per microsecond. The pulse source was required to deliver the injection gun current of 1 to 1.5 amperes.

A voltage pulse meeting these requirements, Fig. 1a, was produced quite simply by adding a rectangular pulse and a triangular pulse at the grid of an ML-7248 high voltage beam tetrode. The circuit is shown in Fig. 2.

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FIG. 1a — OUTPUT VOLTAGE PULSE

FIG. 1b — CURRENT PULSE IN OUTPUT TUBE

FIG. 2. SCHEMATIC DIAGRAM OF PULSE GENERATOR

The plate supply consisted of a dc x-ray power supply and the tetrode plate was coupled to the injector by a non-inductive high-voltage capacitor. A VR-22-CFRB high-voltage diode was used for dc restoration.

During the rise time the injector can be considered to be a (non-linear) resistor R_i . The equivalent output circuit of the amplifier is then simply a parallel RC circuit with C the stray capacitance to ground and R the parallel combination of R_1 , R_i , and the plate resistance of the output tube. The stray capacitance to ground was found to be about 240 μf due primarily to the gun filament transformer.

This circuit is excited with a current pulse, Fig. 1b, which can be expressed,

$$i(t) = I_1 U_1(t) + \dot{I} U_2(t-t_1)$$

where U_1 is the step function and U_2 is the ramp function. The required output voltage pulse, with constant slope from t_1 to t_2 , will be developed provided that the magnitude of the current ramp initiated at time t_1 is related to the voltage slope at time t_1 in the following way:

$$\dot{V}(t_1) = R\dot{I}.$$

If the constant current I_1 and the ramp current $\dot{I}$ are related by

$$I_1 = RC\dot{I} \exp(t_1/RC)$$

then while the current I_1 charges C at the rate $\dot{V}$ the current ramp $\dot{I}$ accounts for the voltage ramp $\dot{V}$ across R .

The magnitude of current I_1 is established, of course, by the required voltage level V_1 through the expression

$$V_1 = RI_1(1 - \exp(-t_1/RC)).$$

The trailing edge of the pulse decays with the time constant $R_1 C_c$.

If the relationship between I_1 and t_1 is not correct the slope of the voltage pulse beyond t_1 will not be constant. However, the circuit is not critical in this respect, the percentage variation of $\dot{V}$ being lower than either I_1 or t_1 . Actually the circuit has many non-linear features. The dynamic resistance of the injector gun (operating in abnormal Schottky effect conditions) may rise, e. g. from 45 to 125 kohms, between 0 and 40 kilovolts. The output tube, driven from cut-off to the positive-grid region, does not amplify in a linear way, and furthermore its grid circuit presents a non-linear load to the driver circuit, which must supply pulses of some hundred volts. It was found, however, that the over-all effect of the several non-linearities could be practically compensated over a sufficient range by a suitable mismatch of I_1 and t_1 .

The two grid voltage pulses generating the composite current pulse of Fig. 1b were added at the grid of the output tube by means of a three-winding pulse transformer. Two of the windings constituted plate loads of two 829B power tetrodes, the third being connected to the output tube grid. The signals for this drive circuit were provided by a Tektronix 545 oscilloscope. The positive gate of the delaying sweep provided a square pulse of adjustable length to the grid

of one 829B while the saw-tooth of the delayed main sweep provided a triangular pulse, adjustable in slope and delay, to the other 829B. The voltages of both pulses were adjusted by suitable attenuators.

The capabilities of the circuit were limited by the maximum cathode current of the power tube, the rise time being fast enough to avoid power limitations. The value of R_1 was determined by the maximum time constant allowable for the trailing edge.

The circuit was operated with values of V_2 up to 60 kilovolts with $V_2 - V_1$ as high as 20 kilovolts and although no negative feedback was used, the stability of the output pulse and the linearity of $\dot{V}$ were satisfactory.

With the same quality of performance, pulses with an easily adjustable linear leading edge, with $\dot{V}$ between 4 and 10 kilovolts per microsecond, were obtained by initiating the triangular pulse at or before the initiation of the rectangular pulse, thus linearizing the response to the rectangular pulse. In this case the pulse was clipped by allowing the tube to bottom at the required maximum voltage in order to establish a sharper definition of V_2 .

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FIGURE CAPTIONS

Fig. 1a. Output voltage pulse.

Fig. 1b. Current pulse in output tube.

Fig. 2. Schematic diagram of pulse generator.