Chapter 13

PRODUCTION OF SHORT-DURATION PULSES

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1. INTRODUCTION

A succession of pulses is often required to initiate, at regular intervals, the operation of certain radar circuits (see Chaps. 11 and 14). Normally such pulses have a repetition period of one or two milliseconds and a duration of a few microseconds. This type of voltage variation is not conveniently obtained directly by applying a sinusoidal voltage to a limiting amplifier, for the following reasons. Firstly, there is difficulty in producing, and applying to the limiting amplifier, sinusoidal oscillations of sufficiently large amplitude and sufficiently high frequency to give rise to pulses of short duration with steep sides. Secondly, pulses produced by a limiting amplifier have usually a repetition period which is of the same order as the duration of each pulse: the smaller the mark-to-space ratio, the less truly rectangular are the output pulses (see Chapter 9 Section 6).

It is usually necessary, therefore, to apply the succession of rectangular pulses, either produced by a limiting amplifier or obtained from any other source to some pulse-shaping circuit which converts them into output pulses of sufficiently short duration for the purposes for which they are required.

Various types of pulse-shaping circuits are considered below.

2. THE USE OF A SHORT TIME-CONSTANT C-R CIRCUIT

If a succession of rectangular pulses is applied to a circuit consisting of a condenser C and resistor R in series (Fig.591), the time-constant being small in comparison with the duration of a pulse, then the voltage developed across the resistor consists of alternate positive and negative pulses, each of short duration, as shown in Fig.591 (see also Chapter 2).

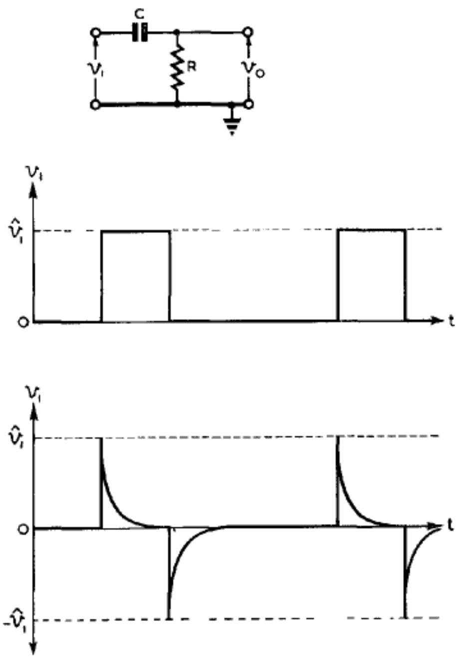

Fig.591.- Use of short time-constant C-R circuit.

This principle is utilised in the circuit of Fig. 592 . Valve 1 is a limiting amplifier which produces a rectangular output voltage from a sinusoidal input. The output voltage of valve 1 is applied to a short time-constant C-R circuit followed by a second limiting amplifier.

This second amplifier may be designed so as to discriminate between the positive-going and negative-going pulses developed across Rg, so that the final output consists of a succession of unidirectional pulses of short duration (see Chapter 9 Section 8.) In the case depicted this output consists of positive-going pulses. The repetition period of these pulses is the same as the period of the sinusoidal input voltage, as indicated in the figure.

If the voltage variation at the anode of valve 1 could be considered truly rectangular, and if various circuit components other than C and Rg could be neglected, there would be no limit to the reduction in pulse width which could be achieved by diminishing the time-constant CRg. In practice there are limits beyond which further diminution of the time-constant is not practicable. As shown in Chapter 2 Section 5 and 15, the voltage developed across Rg may be seriously affected by

(i) the input capacitance C_1 of the succeeding circuit

(ii) the output resistance of the preceding stage

(iii) the finite rate of change of the applied voltage - i.e., of the anode voltage of valve 1.

The overall effect of these unavoidable circumstances is to reduce the amplitude of the pulses developed across Rg; ultimately, if the time-constant is still further reduced. no additional decrease in the duration of the output pulses occurs.

For these reasons, and because they do not produce the rectangular shape of output pulse which is frequently required, C-R circuits usually give place to other types of pulse-shaping circuits when pulses of very short duration, of less than about 5 microseconds, are required. It should be noted that with the circuit arrangement shown in Fig. 593 the rise in the grid voltage of valve 2 at the trailing edge of a negative pulse developed across Rg tends exponentially towards the HT voltage (Fig. 594); it is therefore steeper than when the rise is exponential towards earth potential as would be the case if the circuit of Fig. 592 were used.

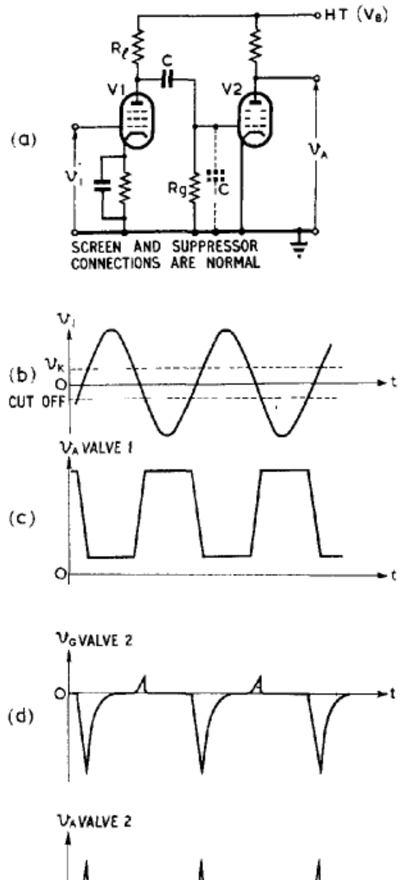

Fig. 592.- Action of limiting amplifier circuit employing short time-constant C-R network.

By this connection of the grid leak to the HT supply instead of to earth the effective pulse width can be substantially reduced without any alteration of the circuit time-constant.

3. THE USE OF A RINGING CIRCUIT

One of the factors limiting the use of a short time-constant C-R circuit for producing pulses of short duration is the input capacitance of the succeeding stage. This capacitance can be utilised in a ringing circuit, as shown in Fig. 595. The response of such a circuit to the output voltage of valve 1 is illustrated in the accompanying diagrams. The frequency of the free oscillation is given approximately by

$$f \doteq \frac{1}{2\pi\sqrt{L(C + C_i)}}$$

Some damping is provided by the output resistance of valve 1 and if this is of suitable value, the parallel damping resistor R may be dispensed with.

The positive-going change of voltage at the anode of valve 1 produces at the grid of valve 2 a damped oscillation commencing with a large positive voltage swing lasting for about a quarter of a period. The negative-going change of voltage produces a similar oscillation commencing with a large negative voltage swing.

The above considerations have neglected any effect of grid current in valve 2. However, in the circuit shown in Fig. 595, since valve 2 is not biased, the positive portions of the damped oscillations are limited. Grid current flows while the grid voltage is positive and the resulting small value of grid-cathode resistance causes considerable damping of the ringing circuit. This increases the logarithmic decrement during the flow of grid current, and reduces in size and duration the subsequent oscillation. As a result, the voltage appearing at the grid of valve 2 consists mainly of

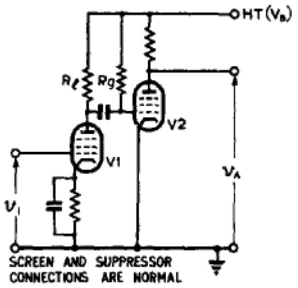

Fig.593. - Alternative arrangement of the limiting amplifier circuit of fig.592(a).

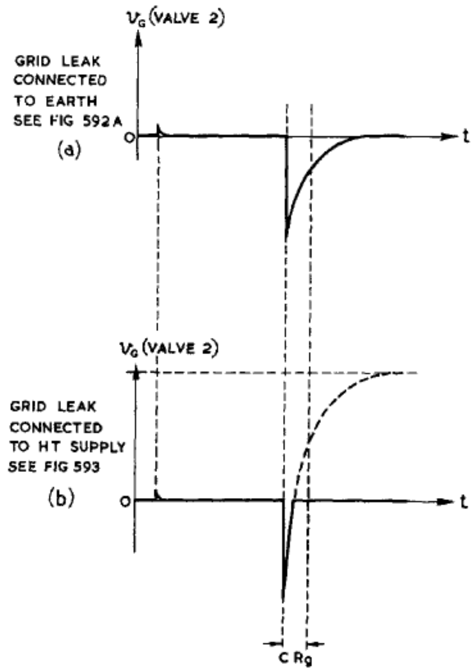

Fig.594. - Effect of connecting grid-leak to HT supply.

a negative pulse of short duration, the start of which occurs as the anode voltage of valve 1 changes in a negative-going direction.

The duration of pulses produced by this method may be of the order of 1-5 microseconds.

4. THE USE OF A PULSE-FORMING NETWORK

Pulses of short duration, considerably less than 1 microsecond, can be produced from a rectangular input by the use of a pulse-forming network. Fig. 596 shows a possible circuit arrangement. The limiting amplifier produces a rectangular voltage from a sinusoidal input. (Where the input is of too low a frequency, some degree of preliminary shaping will be needed). In the circuit considered here a short-circuited delay network is connected across the anode load. The characteristic impedance of the network is made equal to the load resistance R_ℓ. The operation of the delay line has been discussed in Chapters 2 and 4. In the present case a sudden flow of current in the limiting amplifier produces a rapid change of voltage across R which is in parallel with the input impedance of the network. This voltage is half that which would be obtained if the anode load consisted of R_ℓ alone. The voltage change developed across R_ℓ now travels along the network and after a certain time reaches the short-circuit where it suffers a reflection with a change of sign. This reversed voltage change travels back along the network and on reaching the resistor R_ℓ reduces to zero the voltage developed across it. Since the network is matched to R_ℓ there is no second reflection at this end. A voltage pulse is therefore developed across R_ℓ, as shown in Fig. 597. The duration of

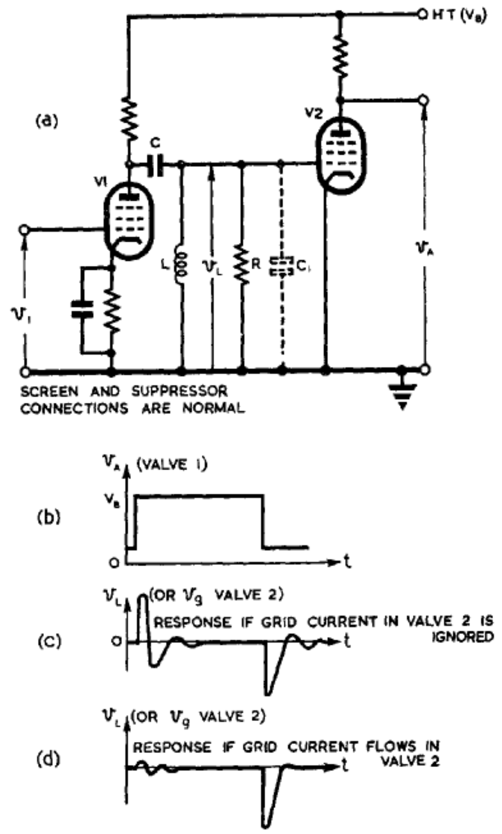

Fig.595.- Use of "ringing" circuit.

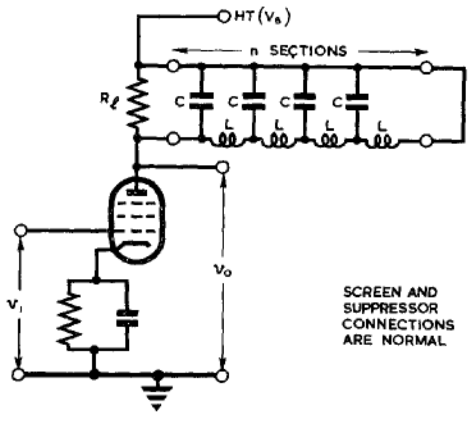

Fig.596.- Use of delay network in anode circuit.

the pulse is $2n\sqrt{LC}$ where n is the number of sections of the network and L and C are respectively the inductance of each coil and the capacitance of each condenser (see Chapter 3 Section 16). This output pulse is negative-going and its leading edge occurs at the instant at which the current begins to flow through the limiting amplifier valve. If the current through the limiting amplifier is cut off, a positive-going pulse is formed which has a duration equal to that of the negative-going pulse.

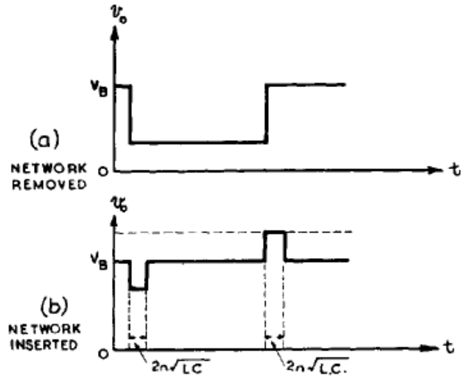

Fig.597.- Effect of network in anode circuit.

A variation of the pulse-forming circuit described above is shown in Fig. 598 . Here the network is in the cathode circuit of an amplifier, and is approximately matched at one end by the low output resistance presented by the valve to its cathode load (see Chapter 7 Section 18). The termination at the other end of the network is a resistor R_t of such a large value that this end can be considered as open-circuited. This resistor is necessary to complete the direct-current path from the cathode of the valve to earth.

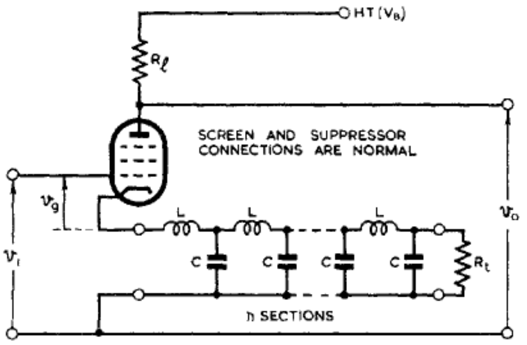

Fig.598.- Use of network in cathode circuit.

Denote by v_i the input voltage and by v_K the voltage developed between cathode and earth. The valve is assumed to be non-conducting until it is put into operation by the leading edge of a rectangular pulse applied to the grid, so that initially $v_K = 0$ and v_i is below cut-off; (Fig. 599).

As v_i rises through cut-off valve current begins to flow and the rise of v_K follows that of v_i in a manner similar to the action of a cathode follower (see Chapter 7 Section 18), the cathode load being equal to the characteristic impedance of the network. The initial rise of v_K is slightly less than the amount by which v_i rises above cut-off. The voltage change v_K travels along the network to the open-circuited end, where it is reflected, without a change of sign, to return back along the network. The returning voltage change arrives between cathode and earth an interval $2n\sqrt{LC}$ after the start of the operation, and increases the voltage of the cathode by an amount sufficient to cut off the valve current. The leading edge of the output pulse, appearing across the anode resistor R_ℓ is produced as the rise of input voltage causes the valve to conduct. The trailing edge of the output pulse is formed as the action of the network causes the valve current to be cut off. Once the valve current is cut off the cathode voltage falls slowly as the network discharges through the terminating resistor R_ℓ. The time needed for this discharge should be long enough to ensure that the valve current remains cut off until the return of the input voltage to its initial value.

High voltage pulses of about 1 microsecond duration, such as are required for the modulation of transmitters, can be obtained by first charging a delay line to a high voltage and then discharging it through a resistive load. A detailed consideration of this method of pulse production is given in Chapter 14.

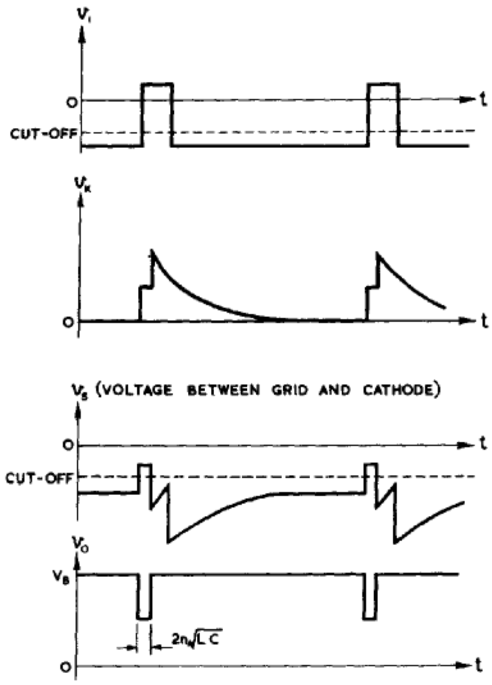

Fig.599. - Response of delay line in cathode circuit.


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