A DIFFERENTIAL PULSE GENERATOR

MONG-KANG TS'EN (陳茂康)

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Abstract

A new method of generating electric pulses of short duration with good amplitude and steadiness is devised by superposing two similar and opposite pulses produced with two glow discharge tubes. Confirming experiments are made and fully reported. A useful formula for passing a pulse through a transformer is also derived.

1. Introduction

All electric transient prenomena involve pulse voltages or currents. At present sharp pulses of short duration find their important applications in investigation of ionospheric layers. Many methods have been used to generate them. Most of them involve some feature of degeneration. It is not difficult to produce pulses with an abrupt start, but ones with an abrupt finish are difficult to produce with a degenerative device. The difficulty lies in combining short duration with good amplitude and steadiness. Moreover there is the danger of getting a group of pulses in place of a single one, when the degenerative device obtains an oscillatory property. In the direction of overcoming these difficulties H. R. Mimmo and P. H. Wang[1] has used phase control with a thyratron and a glow discharge tube, and the present writer[2] has used a neon lamp with the peaked voltage from a transformer with a saturated iron core. However, experimental investigations show that the differential

1. Proc. I. R. E., Vol. 21, p. 529, April 1933; and Science (China) Vol. 18, p. 468, April 1934.

2. Chinese Journal of Physics Vol. 1, p. 87, Oct. 1933.

pulse generator to be described entirely removes those difficulties with simplicity and reliability.

2. The Theory

(a) *On Superposition of Pulses Produced with Glow Discharge Tubes*

When the applied voltage V_1 (See Fig. 1.) on a glow discharge tube G is increased to a certain value, the discharge suddenly takes place, and the gas in the tube becomes suddenly ionized. This causes an abrupt rise of current through the tube and the external resistance R in series with it. The voltage V_2 across R can be taken as the output, which has an abrupt rise. This phenomenon is accompanied by a glow in the tube. The applied voltage that can just start the glow is known as the striking voltage, and that just allows the glow to stop the extincting voltage. The latter is usually ten to twenty percent lower than the former. So the fall of the current through the tube and thereby the fall of the voltage across the resistance are usually not as abrupt as their rises. A continuous bias voltage E in series with an alternating voltage e can reduce the number of pulses to one per cycle instead of two per cycle, when the two electrodes of the tube are identical. When they are not, the bias voltage may be unnecessary. Thus we have a

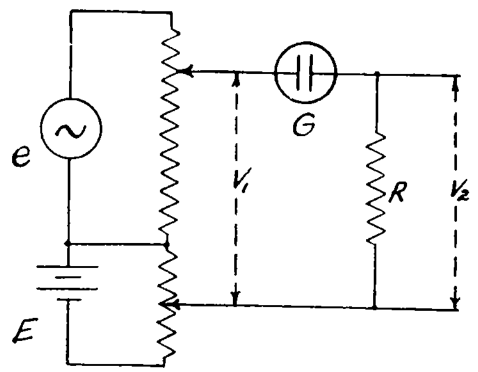


Fig. 1. Operation of Glow discharge tube.

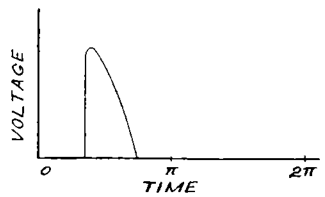


Fig. 2. Form of pulse produced with one glow discharge tube.

pulse voltage of the form as shown in Fig. 2. Now make two such pulses of nearly identical forms, one being started later than the other; and superimpose them to get their difference. The differential pulse thus obtained is just as abrupt at its fall as at its rise, the form being shown in Fig. 3.

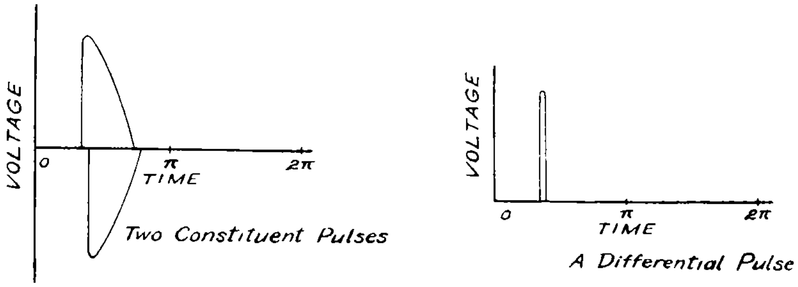


Fig. 3. Differential pulse produced with two glow discharge tubes.

(b) *On Passing a Pulse through a Transformer*

Such a good pulse can be realized only when the constituent pulses can be successfully superposed without undesirable interfering reactions or transients. Fortunately this can be satisfactorily done with transformers. The theory of applying a pulse voltage to a transformer is interesting and important. For the transformer indicated in Fig. 4, we have the equations:

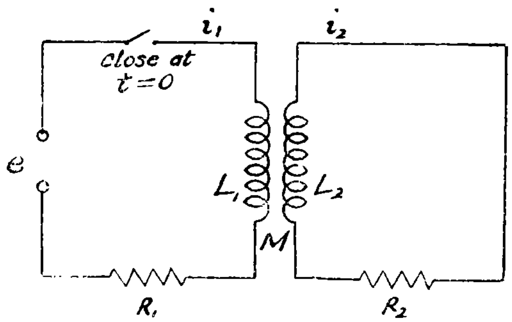


Fig. 4. Transformer under a pulse voltage.

$$(R_1+L_1p)\ i_1+Mpi_2=e,$$

and
$$Mpi_1+(R_2+L_2p)\,i_2=o,$$

where p is the differentiating symbol with respect to time. Combining them we get:

$$i_2=\frac{Mp}{M^2p^2-(R_1+L_1p)(R_2+L_2p)}\,e$$

For[3] $e=1$ after $t=o$, but $e=o$ before $t=o$,

$$i_2(t)=A_2(t)=K(\varepsilon^{m_1t}-\varepsilon^{m_2t}),$$

where m_1 or $m_2=\dfrac{-(R_1L_2+R_2L_1)\pm\sqrt{(R_1L_2-R_2L_1)^2+4R_1R_2M^2}}{2(L_1L_2-M^2)}$,

and $K=\dfrac{M}{+\sqrt{(R_1L_2-R_2L_1)^2+4R_1R_2M^2}}=\dfrac{M}{(L_1L_2-M^2)(m_1-m_2)}$.

As the value under the radical sign is always positive, the natural transient of this circuit can not be oscillatory.

A pulse can be expressed by $\Sigma E\ \varepsilon^{at}$, the E's being positive or negative real numbers, and the a's being negative real numbers. To impress the voltage $e=\Sigma E\ \varepsilon^{at}$ through the transformer, the following formula[4] derived from the superposition theorem can be applied:—

$$i_2(t)=e(o)\,A_2(t)+\int_0^t A_2(t-\lambda)\,e'(\lambda)\,d\lambda.$$

Here we have:

$$e(o)=\Sigma E,$$

$$A_2(t)=K(\varepsilon^{m_1t}-\varepsilon^{m_2t}),$$

$$A_2(t-\lambda)=K(\varepsilon^{m_1\overline{t-\lambda}}-\varepsilon^{m_2\overline{t-\lambda}}).$$

$$e'(\lambda)=\Sigma E\,a\,\varepsilon^{a\lambda}.$$

Thus we get the secondary current as below:

$$i_2(t)=m_1K\varepsilon^{m_1t}\,\Sigma\frac{E}{m_1-a}-m_2K\,\varepsilon^{m_2t}\,\Sigma\frac{E}{m_2-a}$$

$$+\frac{M}{L_1L_2-M^2}\,\Sigma\frac{Ea\,\varepsilon^{at}}{(a-m_1)(a-m_2)}.$$

3. Bush's "Operational Circuit Analysis", p. 93.
4. Bush's "Operational Circuit Analysis", p. 56.

If the values of the m's are much larger than those of the a's, that is, the transformer circuit is not too inductive, we can write:

$$i_2(t) = (\varepsilon^{m_1 t} - \varepsilon^{m_2 t})\, K\, \Sigma E + \frac{M}{(L_1 L_2 - M^2)\, m_1 m_2} \Sigma E\, a\, \varepsilon^{at}$$

As the ε^{mt} terms die out much faster than the ε^{at} terms, this can be furtherly approximated to be:

$$i_2(t) = \frac{M}{(L_1 L_2 - M^2)\, m_1 m_2} \Sigma E\, a\, \varepsilon^{at}$$

or,
$$i_2(t) = \frac{M}{R_1 R_2} \Sigma E\, a\, \varepsilon^{at},$$

Thus we see in this case, that the current in the secondary circuit consists of two new pulses, one being the pulse of the natural transients and the other being the differentiated pulse of the applied pulse. A differentiated pulse is more abrupt than its original. So a pulse, having passed through a transformer of rapid transients, will nearly preserve its original form or will become somewhat more abrupt.

When the transformer has an iron core, these formulas of course still apply, if the operation is kept below saturation. If it goes beyond saturation, the theory is still good in the main, only some distortion having been disregarded.

3. The Apparatus

This pulse generator consists essentially of two glow discharge tubes. Neon lamps are found to be very satisfactory. Other parts required are common and rugged. Wide variation in choosing the parts are permissible. As an example the parts actually used are described below:

The keynotes in Fig. 5 are:

e—220-volt 50-cycle power supply.
E—50-volt small battery.

P—Potentiometer, 1480 ohms.

P_1—and P'_1—Potentiometers, 1000 ohms each.

N and N'—R.C.A.'s standard Neontron power tubes.

R and R'—rheostats, each 18000 ohms maximum.

T and T'—American Transformer Co.'s DeLuxe audio transformers, first stage.

R_1—resistance, 75000 ohms.

P_2—potentiometer, 25000 ohms.

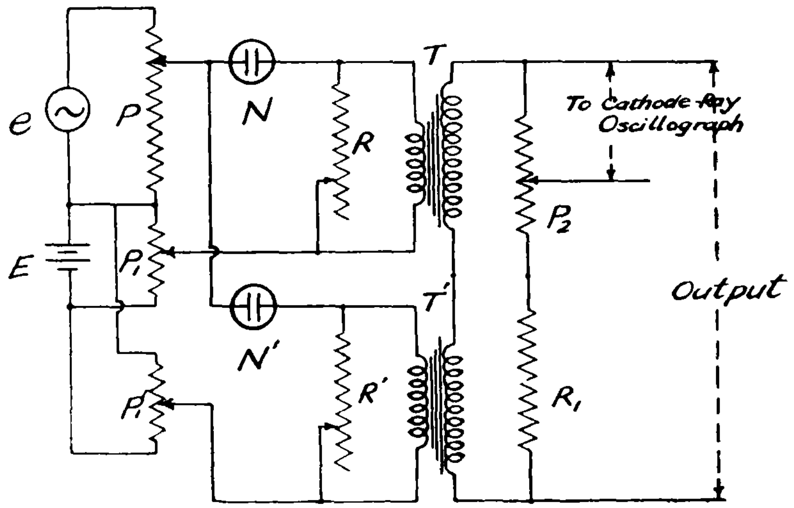


Fig. 5. Connection diagram of Differential Pulse Generator.

Fig. 6. shows the photograph of the assembled apparatus.

4. The Test

It is necessary to produce the desired form of pulse by adjustment, for calculations, can not be relied upon to be so accurate. The best indicator for the adjustment is a cathode-ray oscillograph, as it practically takes no current and introduces no transient. One of the Leybold's revised type is used, operating with a power unit to supply a 1500-volt con-

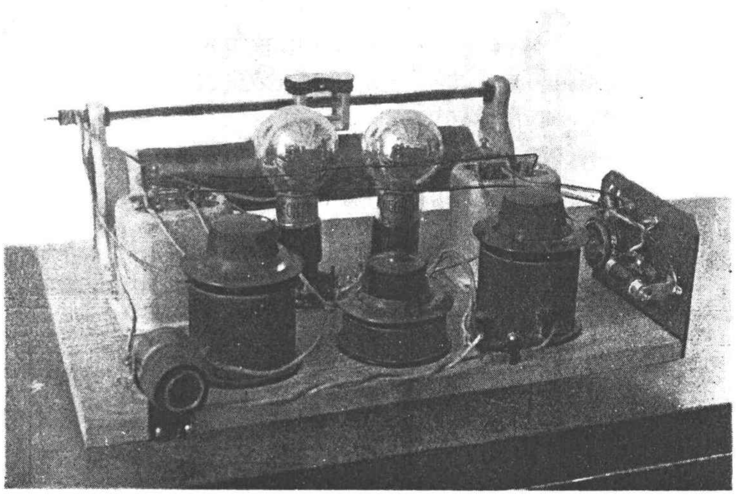


Fig. 6. Photograph of Differential Pulse Generator.

tinuous voltage on a condenser for the anode, some bias voltage on the Wehnelt cylinder and a 3.5-volt A.C. for heating the cathode filament of large heating capacity.

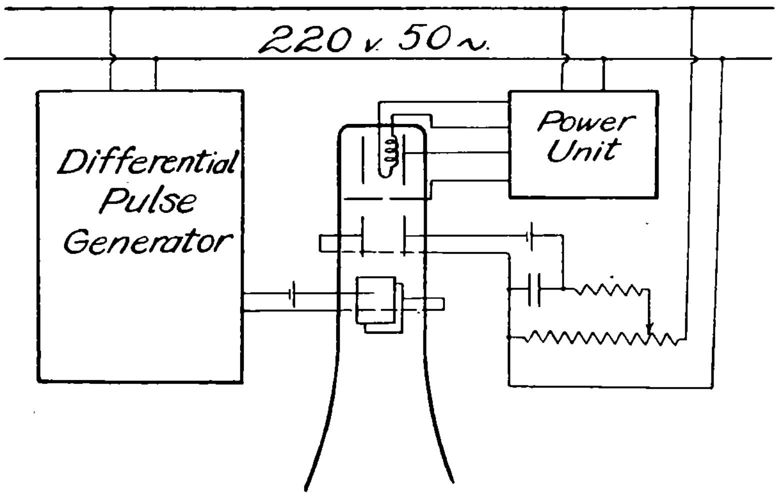


Fig. 7. Connection diagram for testing a pulse generator.

Fig. 7. shows the connection diagram used for the test. (See also Fig. 8). The time base is sinusoidal, which is provided from the same source as the e for the differential pulse generator. The voltage across the condenser as connected brings the abrupt rise of a pulse to about the middle of the base. A little stray magnetic field of the source is allowed to separate the base into a narrow loop for clearness. The batteries in the leads of the deflecting plates are used to bring the graph to about the middle of the fluorescence screen. A magnet should not be used for this purpose, as it often introduces distortion.

It is found convenient to first start one pulse and extinct it by slightly adjusting its bias voltage, and then to start and

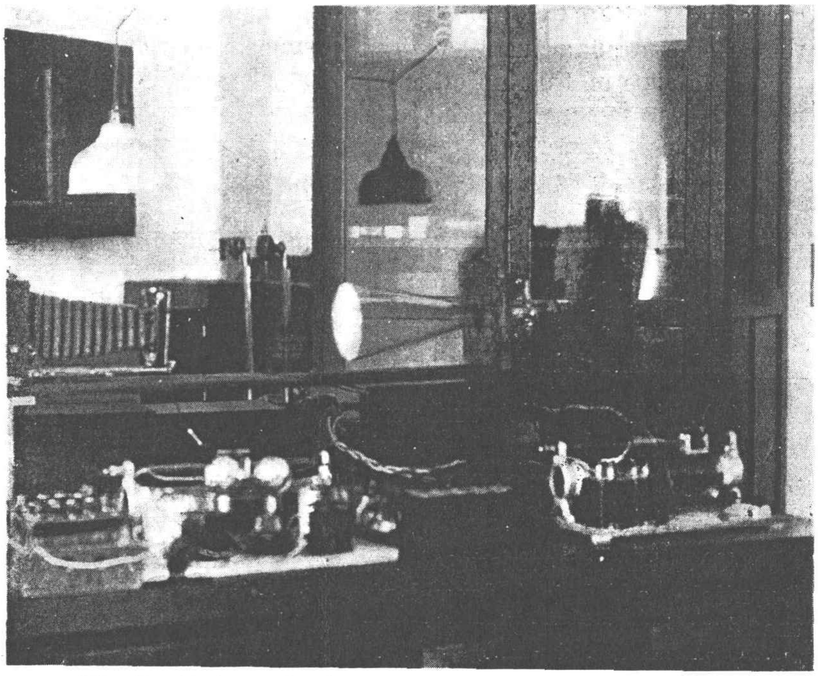


Fig. 8. Photograph showing the test of a pulse generator.

extinct the other pulse in likewise. Now start both pulses and adjust the separate amplitudes by the rheostats R and R' and the differential duration by the potentiometers P and P'.

5. The Result

The result is best shown by the photographs of the cathode-ray oscillographs. Fig. 9 gives a set of three oscillographs, showing (a) the differential pulse, (b) pulse No. 1, when the No. 2 is extincted by slightly adjusting its bias voltage, (c) pulse No. 2, when the No. 1 is similarly extincted.

The theory of superposition of pulses and that of passing a pulse through a transformer are both confirmed. The abruptness on both sides of the differential pulse and its permissible short duration and good amplitude at the same time can be seen from the photographs. It is estimated that the pulse voltage is about 200 volts across a resistance of 100,000 ohms. The duration of the differential pulse in Fig. 9 is conservatively estimated to be less than 0.00005 second. As to the easiness of adjustment and firmness of operation, the writer is sure of that no other method of pulse generation has pleased him so much as this one.

6. Conclusions

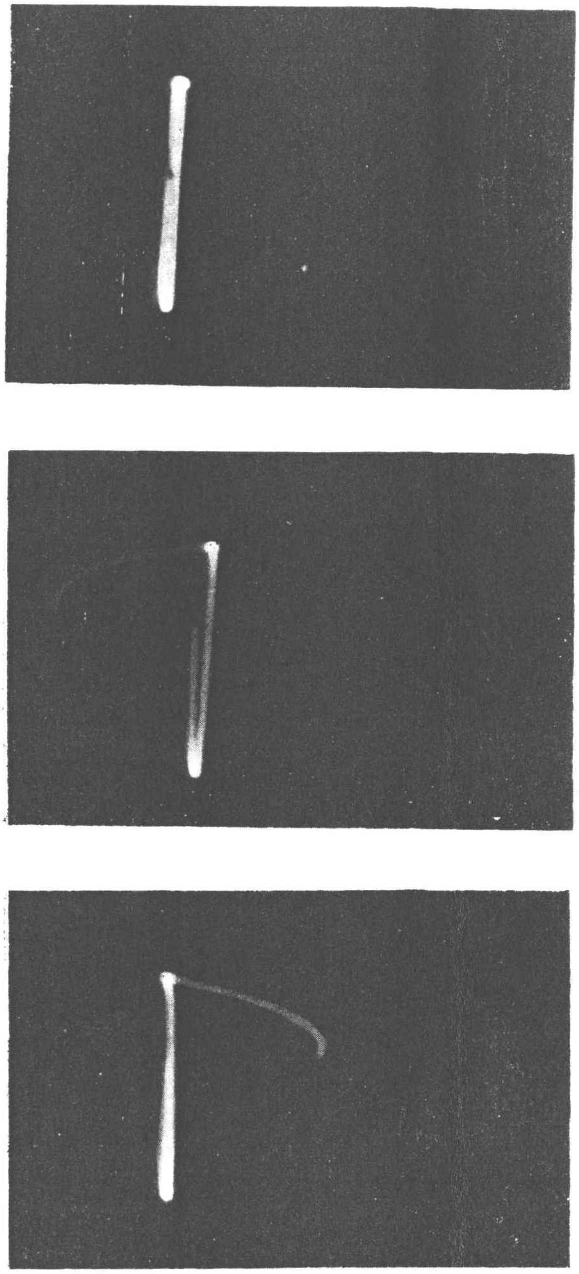
From the foregoing the following conclusions are drawn:

(1). This pulse generator has all the advantages of phase-control over amplitude control, yet the simplicity of amplitude control is preserved.

(2). The duration and amplitude of the differential pulse are separately controlled, practically not interfering one another. So pulses of very short duration can have the same amplitude as those of long-duration pulses.

(3). The steadiness of the pulse produced by this differential method is independent of the duration, even when the duration approaches its zero value. So pulses of very short duration can have the same steadiness as those of long duration pulses.

(4). The differential pulse has equal, good abruptness on both sides, that is, at its rise and at its fall.



(a) (b) (c)

Fig. 9. Photographs of Cathode-ray osillographs of differential pulse and its constituent pulses.

(5). This method of pulse generation is simple and reliable. The pulse is easily adjusted, and stays in adjustment with steadiness.

7. Acknowledgment

The writer wishes to express thanks to his assistant Mr. Ngaisi H. Chang, (張煦) who has helped him both in carrying out the test and preparing the manuscript.

費四五十小時,然後除去濾片,照以水銀光譜凡數秒,作爲决定波長之標準。

用前法所攝得之光譜大都不十分淸晰,其主要原因係由水汽管之太短。但用顯微光度計量之,各成分綫之波長不難準至1 Å範圍以內。本實驗所得各線若與五十年前 Abney 所測定太陽光譜中0.94 μ附近之吸收線相比較,可見太陽紅外光譜中許多吸收線係由大氣中水汽所產生,而證實 Abney 最初之推想。惟本實驗所測定之吸收線與 Abney 所測定太陽光譜中之對應黑綫具有一等差數約合1.5 Å。此等差數之產生想係由於波長單位之不同以及個別儀器誤差所致。

本實驗所考察之吸收帶作偶形,故從量子力學光譜强度之硏究得證水汽分子作三角形而以氧原子在一鈍角之頂點。

較差脈流發電器

陳茂康

著者新擬一法以發生强大而穩定之短時脈流。其法係用二輝光放電管所發之同樣而反向之脈流之較差;並詳述其實驗證明之結果。且對於脈流經過變壓器,推出一適用之算術方式。

窗戶紙之紫外線透射

陳尙義　孟昭英　班威廉

以水銀燈爲光源,正射於紙上,其透射部份,用分光攝影法定量。以分圓光度計 (Sectorphotometer) 及顯微光度計 (microphotometer) 量出九種窗戶紙之紫外線透射性。並實驗各種紙之抗斷强度及其纖維之構造等,俾得相當之評價。