STUDY OF IMPULSE WAVE GENERATOR CIRCUITS & WAVE SHAPING

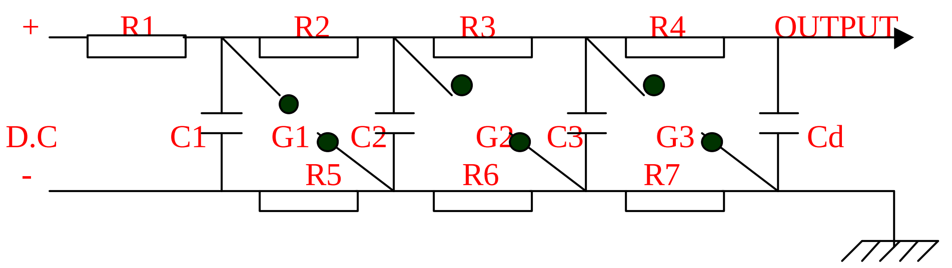
Objective:

To study the effect of series resistance (Rs), divider resistance (Rd) and the load capacitance on the impulse wave-shape.

Theory:

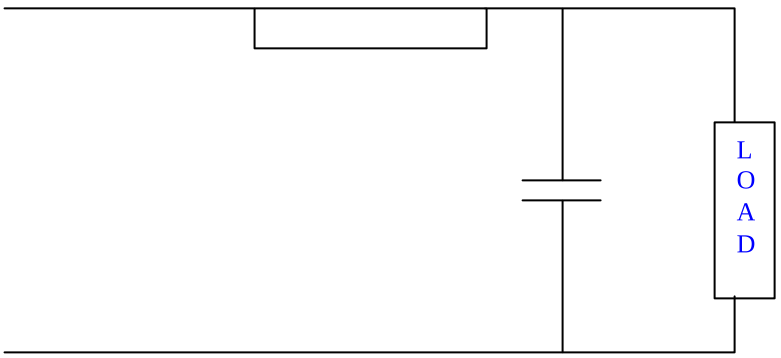
An impulse voltage is an uni-directional voltage that rises from zero to a maximum value in a very short time and dies away more or less to zero in a comparatively greater time. An impulse wave is specified by its peak value, front time (t_f) and tail time (t_t). For the definition of tf and t_t, see Indian Standards Specification No: IS-2071-1962.
The impulse voltage wave is basically generated from the Marx's circuit as shown in Fig. 1.

FIG.1



Capacitors C1, C2, C3 etc. are charges in parallel from a high voltage D.C. source through charging resistors R1, R2, R3 etc. When the capacitors are fully charged, the trigger-gaps G1, G2, G3 etc. breakdown and connect the capacitors in series instantaneously, bringing the magnitude of the output voltage approximately equal to the sum of the voltages to which he capacitor are charged. The output from the last capacitor is given to a wave shaping circuit as shown in FIG.2.The wave shaping network together with the capacitance of the generator and load produces an impulse voltage of the desired wave-shape (1/50 µs) across the load.

FIG.2

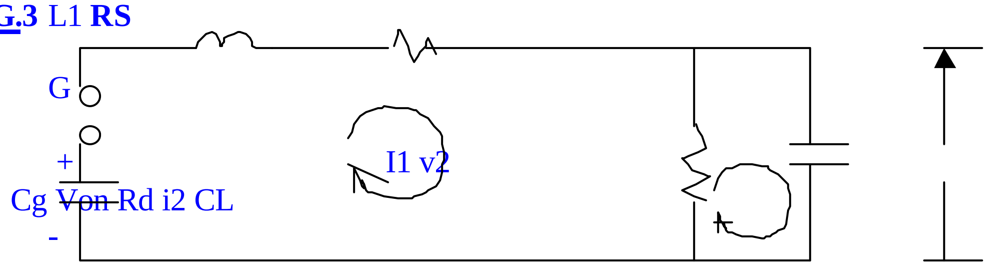


The actual surge- voltage generator (impulse generator) with its charging resistors and discharging spark-gaps is one of considerable complexity, but for approximate calculation of the waveform delivered on discharge, these internal complications can be neglected and the generator approximated by a single lumped capacitance in series with inductance and resistance. The series circuit is completed through an external discharge resistor, which in turn is paralleled by the apparatus under test. The load on a surge generator usually influences the waveform of the surge to which this load is subjected, so considerable calculation is necessary in the application of such generators.

The discharging gap is a non-linear element in the network, but the varying voltage drop that it introduces is taken as negligible compared with the other voltage drops of the network. The gap is accordingly treated as a switch.

The equivalent network of a surge-voltage generator serving to test the insulation properties of an open-circuited transformer is shown in FIG.3

FIG.3 L1 **RS**



For effects during the first few hundred microseconds, the transformer is represented approximately by its equivalent lumped capacitance to ground. The initial voltage across the generator equivalent capacitance Cg is Vo. The initial voltage across C_L and the initial current in L_1 are zero. The Laplace transform equations are:

$$(L_1 s + Rs + Rd + 1/ Cg .s) I_1 (s) - Rd. I_2(s) = Vo/s$$

$$-Rd\, I_1(s) + (Rd + 1/C_L\, s)\, I_2(s) = 0$$

Solution of these two equations gives
$I_2(s) =$

$$\frac{Vo\,.Rd.s}{L_1\, Rd\, s^3 + \left(\frac{L_1}{C_L} + Rd\, Rs\right) s^2 + \left(\frac{Rd + Rs}{C_L}\right) s + \frac{Rd}{Cg} + \frac{1}{Cg\, C_L}}$$

From this, since the initial voltage across C_L is zero,

$$Vs(s) = I_2(s)/\, s\, C_L$$

$$= ao/(s^3 + b_2 s^2 + b_1 s + bo)$$

where

$ao = Vo/(L1\, C_L)$

$bo = 1/(L_1 Rs\, Rd\, C_L)$

$b_1 = (1 / L_1\, Rd) * \left(\frac{Rs + Rd}{C_L} + \frac{Rd}{Cg}\right)$

$b_2 = (1 / L_1\, Rd) * \left(\frac{L1}{C_L} + RsRd\right)$

The three roots of the characteristic equation are s1, s2 and s3. One of the roots is real, and the remaining two form a complex conjugate pair. The inverse transformation of $V_2(s)$ gives

$$V_2(t) = L^{-1}\left[\frac{ao}{(s-s1)(s-s2)(s-s3)}\right]$$

$$= K_1 e^{s1t} + \mathrm{Re}\left[2 K_2 e^{s2t}\right]$$

where

$$K_1 = \left[\frac{ao}{(s-s2)(s-s3)}\right]_{s= s1}$$

$$K_2 = \left[\frac{ao}{(s-s1)(s-s3)} \right]_{s=s2}$$

V_2 (t) is of the form:

$$V_2 (t) = A\, e^{-\alpha_2 t} + B\, e^{-\alpha_1 t} \operatorname{Cos} (\omega o t + \theta)$$

The solution shows that V_2 (t) is composed of a decreeing exponential and a damped oscillation. These have the following characteristics:

Time constant of the exponential = $1/ \alpha_1$

Time constant of the damped oscillation = $1/\alpha_2$

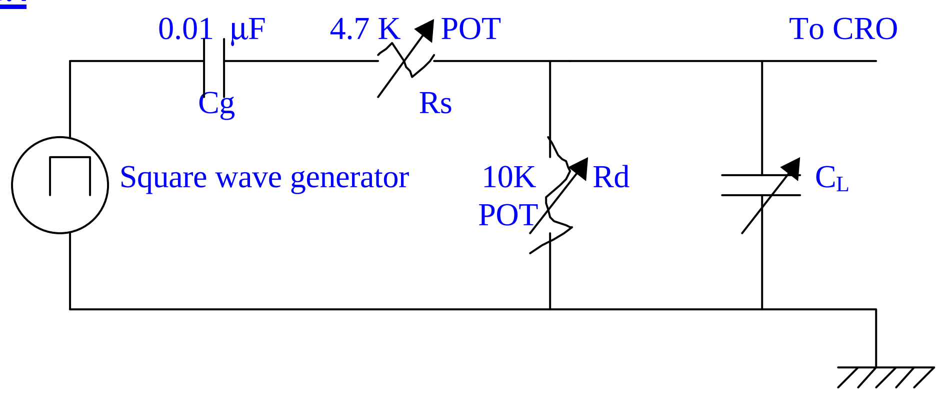
Period of the oscillation = $2\pi / \omega o$

The process of solution can be simplified considerably if L1 is neglected. One then has to solve a quadratic equation rather than a cubic.

Procedure

The circuit shown in Fig.4 may be used in the laboratory to produce an impulse wave.

FIG.4



Cg represents the generator capacitance and C_L the load capacitance. Rs and Rd are the series and divider resistances respectively of the wave shaping circuit.

For a given set of values of Rs (= 2K), Rd (=3K) and C_L (= 300pF), trace two osillograms, one of he front and the other of the tail of the wave. Note the time scale of he oscilloscope. Repeat this process for:

a. Keep Rs and Rd constant, vary C_L and trace the waveforms for 3 different values of C_L.

b. Keep Rs and C_L constant, vary Rd and trace the waveforms for 3 different values of Rd.
c. Keep C_L and Rd constant, vary Rs and trace the waveforms for 3 different values of Rs.

From the oscillograms,

t_f = 1.67 * (the interval between 30% and 90 % of the portion of the peak value)

t_t = time corresponding to 50 % of the peak value on the tail of the wave.

The value of t_f and t_t can be calculated theoretically from the expressions

$$t_f = 3 * Rs \left[\frac{Cg\ C_L}{Cg + C_L} \right]$$

$$t_t = 0.7 * (Rs - Rd)(Cg + C_L)$$

Observations:

S.No.	Rs	Rd	C_L	Time scale	Time to front, t_f		Time to tail, t_t	
					Expt.	Cal.	Expt.	Cal.

Report:

a. Compare the theoretical and experimental values of t_f and t_t and discuss the reasons for the differences (if any).
b. Calculate the output voltage waveform as a function of time for one set of values of Rd, Rs, Cg and C_L. Compare with the oscillogram.
c. Why do we subject high -voltage apparatus to impulse testing? Explain in brief.