High Voltage Generation

Purposes (Manfaat)

High DC

- Electron micro-scopes and x-ray units (high d.c. voltages ≥ 100 kV)
- Electrostatic precipitators, particle accele-rators (few kV or MV)

High AC

Testing of po-wer apparatus rated for extra high transmis-sion voltages (≥ 400 kV)

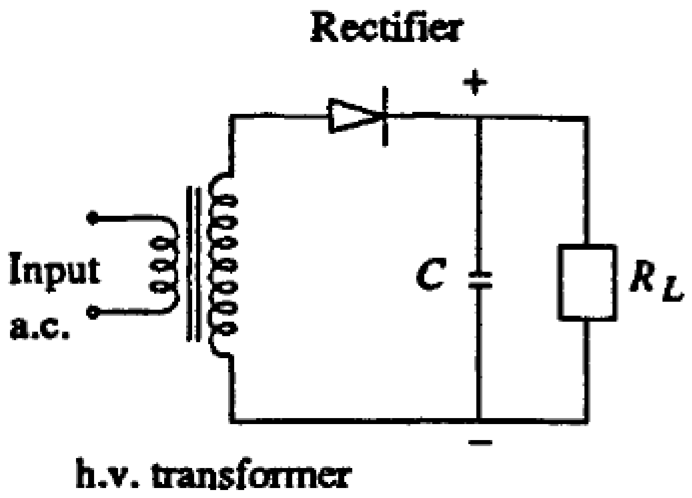
Impulse

Simulate over-voltages that occur in power systems due to lightning or switching surges

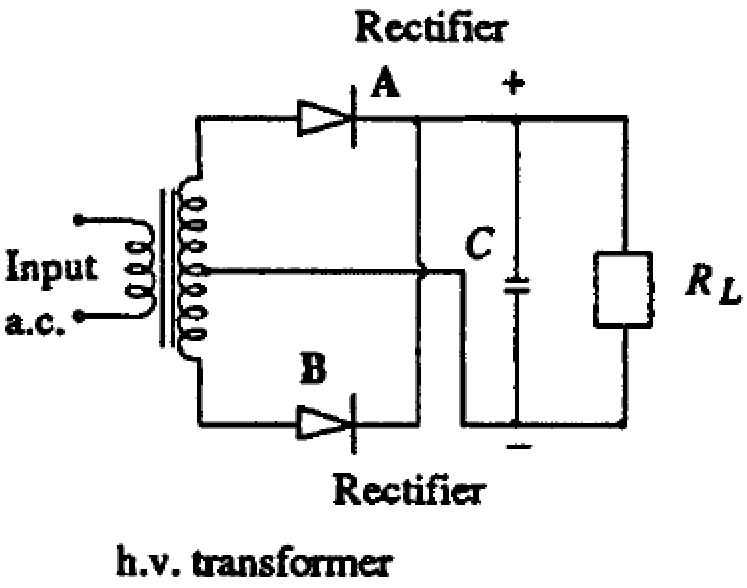
Classification

- high d.c. voltages
- high a.c. voltages of power frequency.
- high a.c. voltages of high frequency.
- high transient or impulse voltages of very short duration such as lightning overvoltages, and transient voltages of longer duration such as switching surges.

High Voltage DC Generation
By Rectifier Circuit



(a) Half wave rectifier



(b) Full wave rectifier

For applications at high voltages of 50 kV and above, the rectifier valves used are of special construction. Apart from the filament, the cathode and the anode, they contain a protective shield or grid around the filament and the cathode. The anode will be usually a circular plate. Since the electrostatic field gradients are quite large, the heater and the cathode experience large electrostatic forces during the nonconduction periods. To protect the various elements from these forces, the anode is firmly fixed to the valve cover on one side. On the other side, where the cathode and filament are located, a steel mesh structure or a protective grid kept at the cathode potential surrounds them so that the mechanical forces between the anode and the cathode £re reflected on the grid structure only.

In modern high voltage laboratories and testing installations, semiconductor rectifier stacks are commonly used for producing d.c. voltages. Semiconductor diodes are not true valves since they have finite but very small conduction in the backward direction. The more commonly preferred diodes for high voltage rectifiers are silicon diodes with peak inverse voltage (P.I.V.) of 1 kV to 2 kV. However, for laboratory applications the current requirement is small (a few milliamperes, and less than one ampere) and as such a selenium element stack with PJ.V. of up to 500 kV may be employed without the use of any voltage grading capacitors.

Voltage Doubler Circuit

Both full wave and half wave rectifier circuits produce a d.c. voltage less than the a.c. maximum voltage. When higher d.c. voltages are needed, a voltage doubler or cascaded rectifier doubler circuits are used.

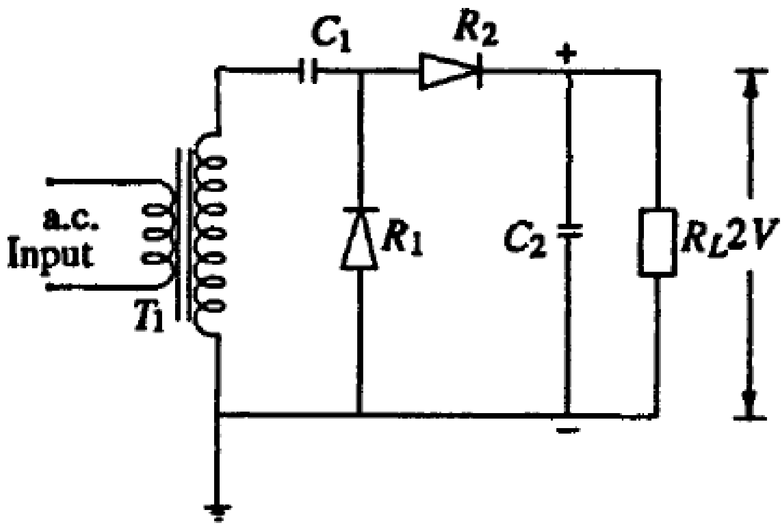


Fig. 6.3a Simple voltage doubler

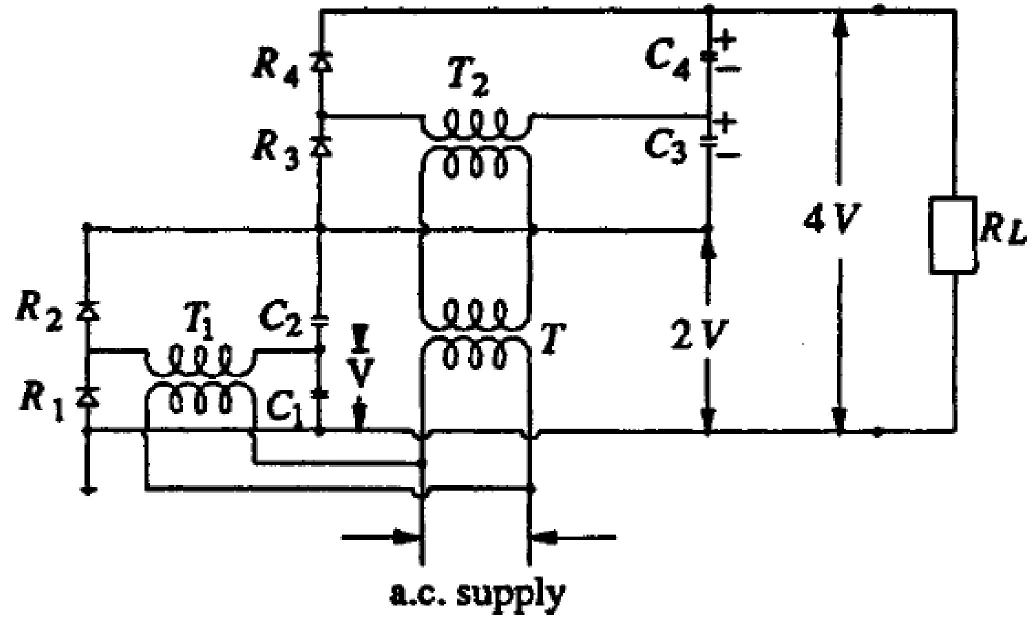
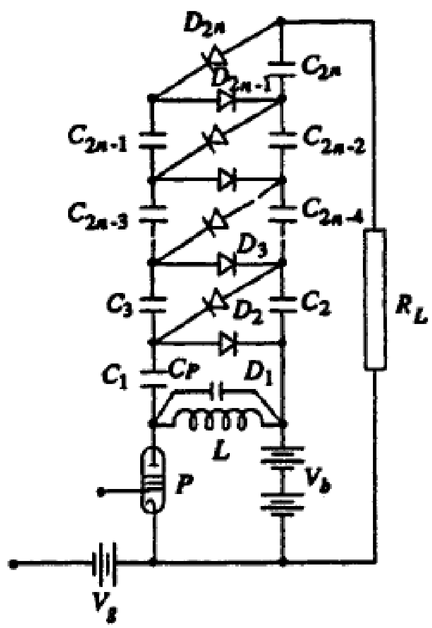
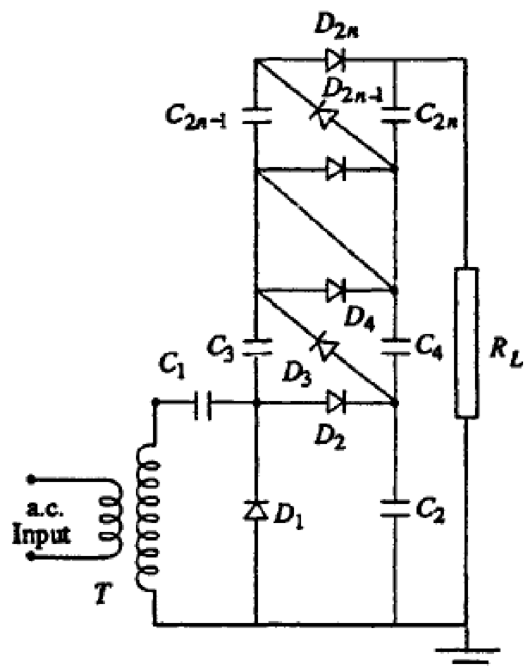


Fig. 6.3b Cascaded voltage doubler

Voltage Multiplier Circuit

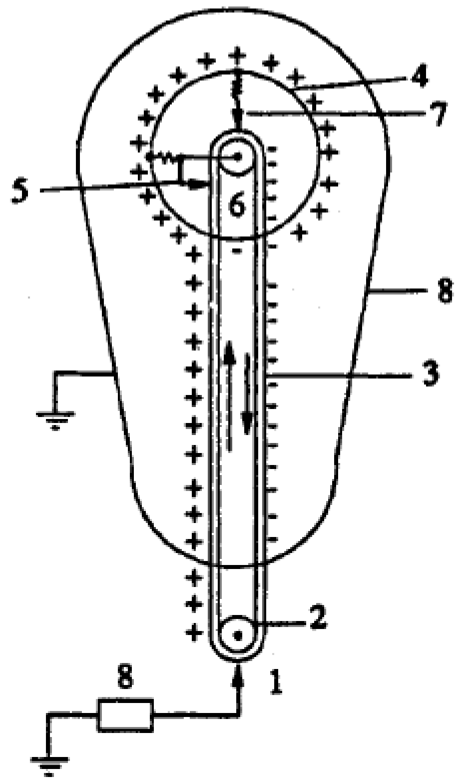
Cascaded voltage multiplier circuits for higher voltages are cumbersome and require too many supply and isolating transformers. It is possible to generate very high d.c. voltages from single supply transformers by extending the simple voltage doubler circuits. This is simple and compact when the load current requirement is less than one milliampere, such as for cathode ray tubes, etc. Valve type pulse generators may be used instead of conventional a.c. supply and the circuit becomes compact.





Cascaded rectifier unit with pulse generator & Cockcroft-Walton volt age multiplier circuit

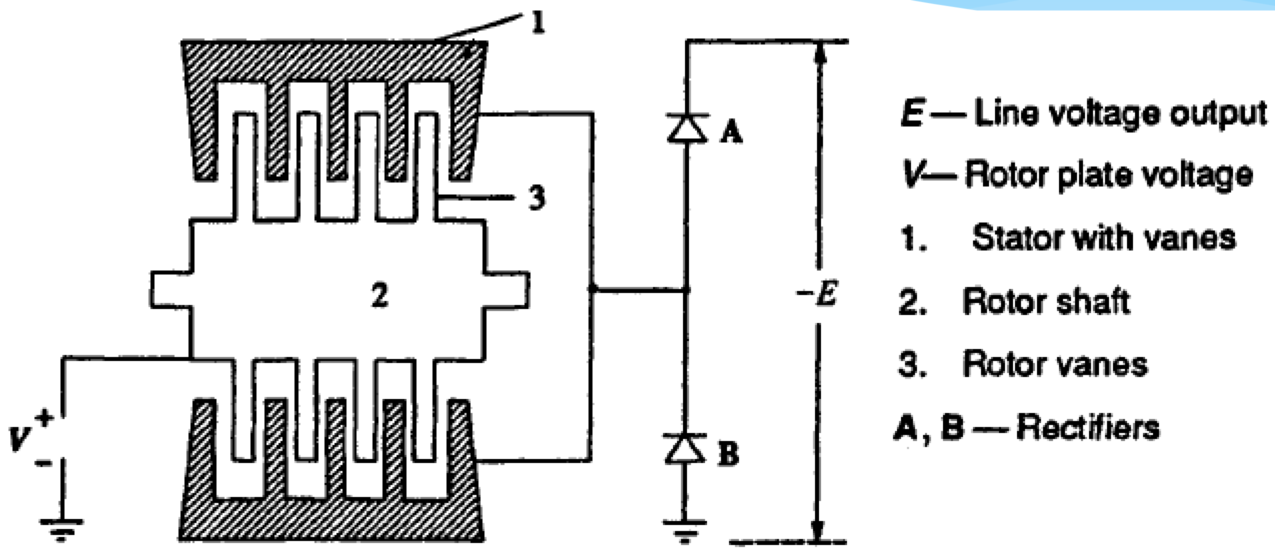
Electrostatic Machines



Van de Graaff generator

1. Lower spray point
2. Motor driven pulley
3. Insulated belt
4. High voltage terminal
5. Collector
6. Upper pulley insulated from terminal
7. Upper spray point
8. Earthed enclosure

Electrostatic Machines

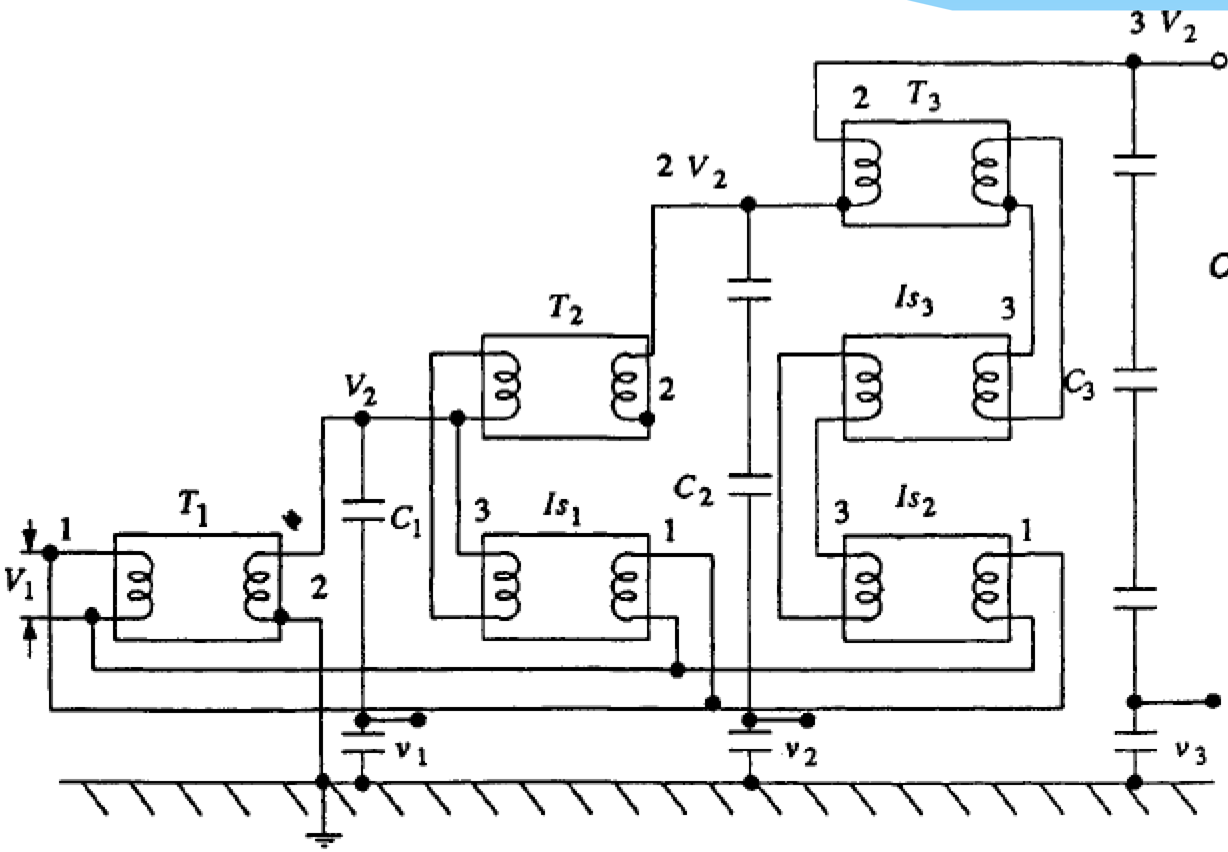


Electrostatic generator

High AC Generation

Cascade Transformer

The cascade transformer units is formed in which the first transformer is at the ground potential along with its tank. The second transformer is kept on insulators and maintained at a potential of V_2, the output voltage of the first unit above the ground. The high voltage winding of the first unit is connected to the tank of the second unit. The low voltage winding of this unit is supplied from the excitation winding of the first transformer, which is in series with the high voltage winding of the first transformer at its high voltage end. The rating of the excitation winding is almost identical to that of the primary or the low voltage winding.



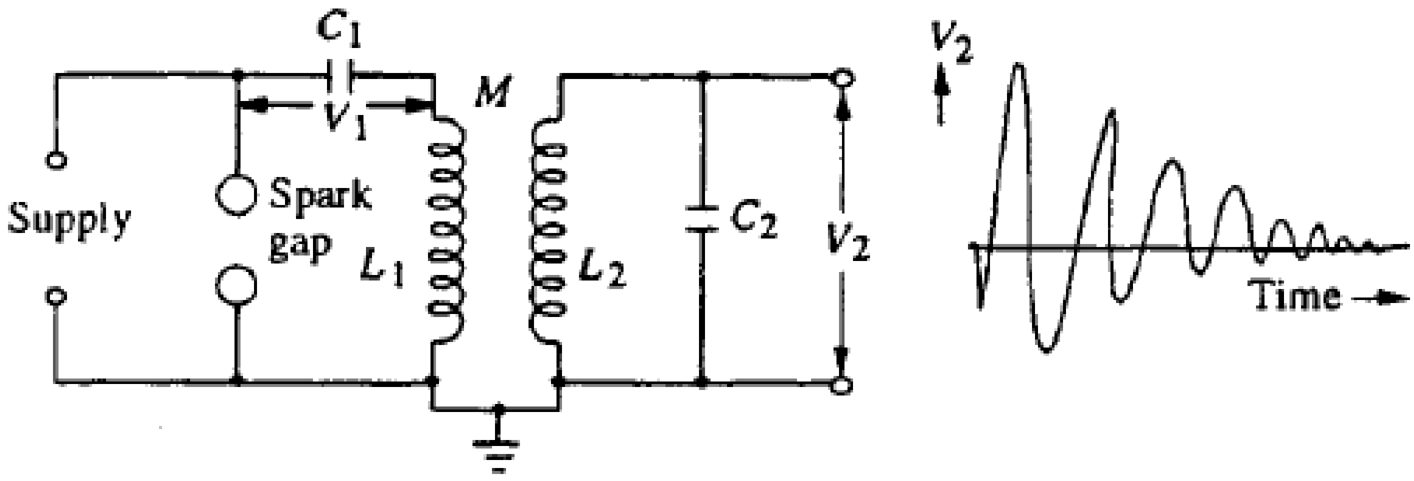
T_1, T_2, T_3 — Cascade transformer units
I_{s1}, I_{s2}, I_{s3} — Isolation transformer units
C_1, C_2, C_3 — Capacitance voltage dividers for h.v. measurement after 1st, 2nd and 3rd stages
V_1, V_2, V_3 — For metering after 1st, 2nd and 3rd stages

1. Primary (l.v. winding)
2. h.v. winding
3. Excitation winding

Cascade transformer unit with isolating transformers for excitation

High Frequency AC Generation

The commonly used high frequency resonant transformer is the Tesla coil, which is a doubly tuned resonant circuit shown schematically in Fig. 6.13a. The primary voltage rating is 10 kV and the secondary may be rated to as high as 500 to 1000 kV. The primary is fed from a d.c. or a.c. supply through the condenser C_1. A spark gap G connected across the primary is triggered at the desired voltage V_1 *which induces* a high self-excitation in the secondary. The primary and the secondary windings (L_1 and L_2) *are wound on an insulated former with no core (air-cored) and are immersed* in oil. The windings are tuned to a frequency of 10 to 100 kHz by means of the condensers C_1 *and* C_2.



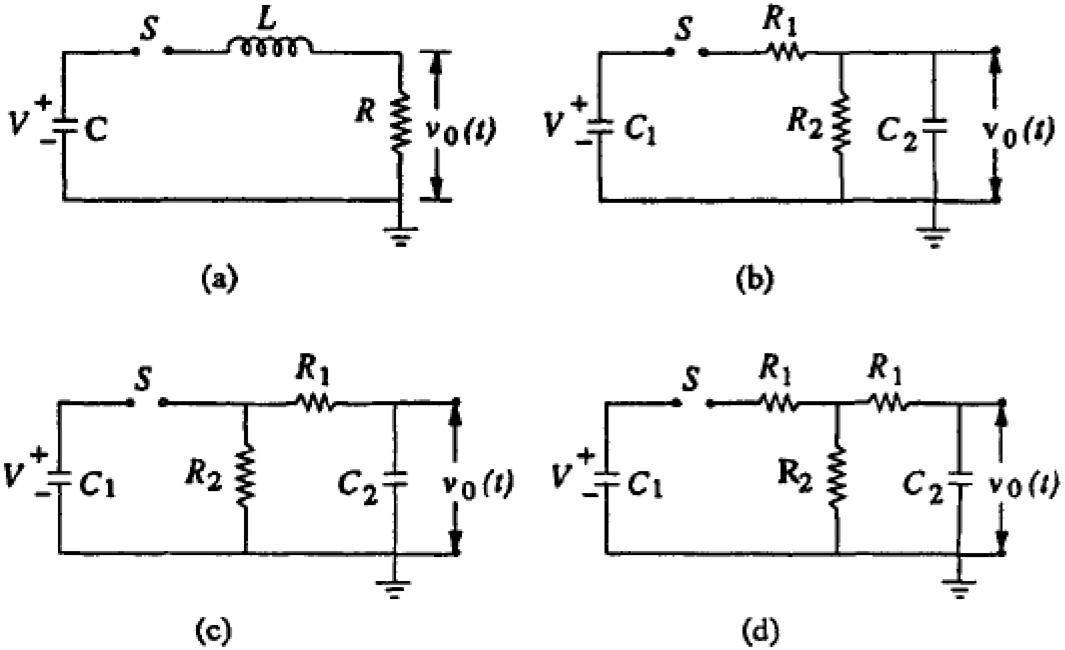
(a) Equivalent circuit

(b) Output waveform

Tesla coil equivalent circuit and its output waveform

Impulse Voltage Generation

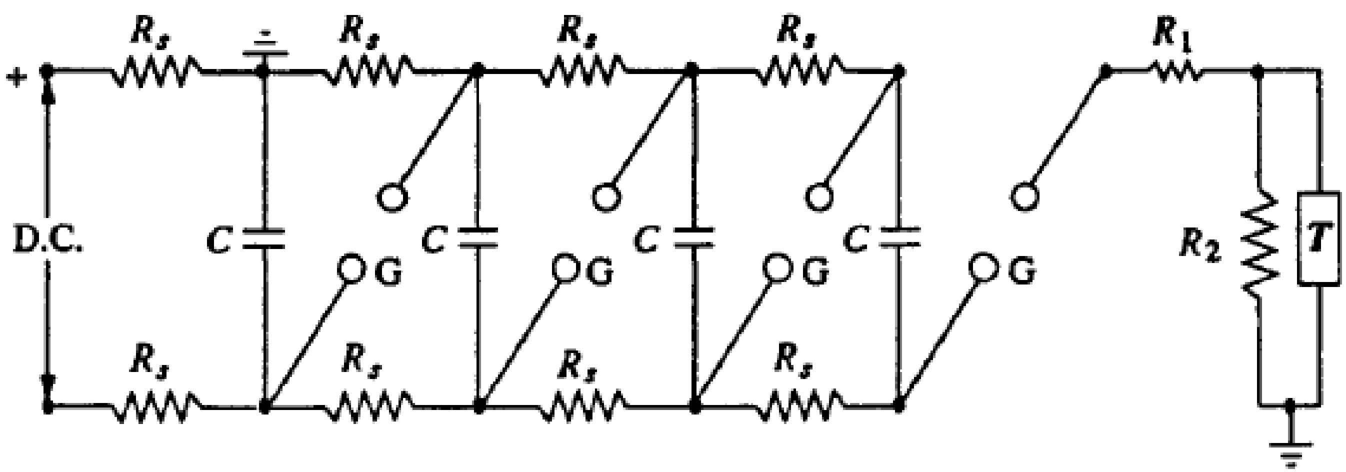
Impulse Waves may be produced in the laboratory with a combination of a series *R-L-C circuit under over damped* conditions or by the combination of two *R-C circuits.* Different equivalent circuits that produce impulse waves are given in Figs a to d. Out of these circuits, the ones shown in Figs a to d are commonly used. Circuit shown in Fig. a is limited to model generators only, and commercial generators employ circuits shown in Figs b to d.



Circuits for producing impulse waves

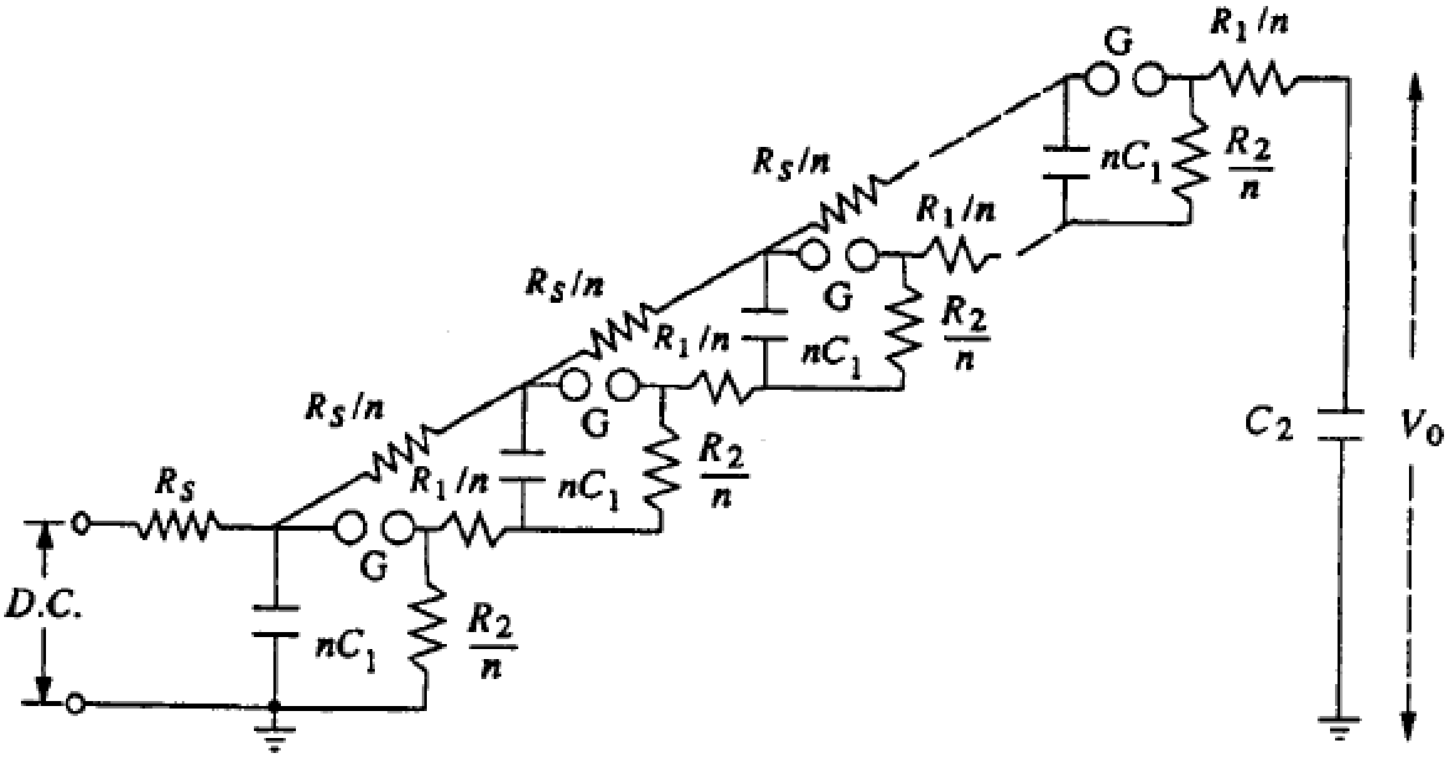
Multistage Impulse Generators—Marx Circuit

In the above discussion, the generator capacitance *C_1 is to be first charged and then* discharged into the wave shaping circuits. A single capacitor C_1 may be used for voltages up to 200 kV. Beyond this voltage, a single capacitor and its charging unit may be too costly, and the size becomes very large. The cost and size of the impulse generator increases at a rate of the square or cube of the voltage rating. Hence, for producing very high voltages, a bank of capacitors are charged in parallel and then discharged in series. The arrangement for charging the capacitors in parallel and then connecting them in series for discharging was originally proposed by Marx. Nowadays modified Marx circuits are used for the multistage impulse generators.



Schematic diagram of Marx circuit arrangement for multistage impulse generator

C — Capacitance of the generator
R_s — Charging resistors
G — Spark gap
R_1, R_2 — Wave shaping resistors
T — Test object



Multistage impulse generator incorporating the series and wave tail resistances within the generator