Chapter 9

Voltage Sweep Circuits

Key Points and Formulae

- The voltage sweep waveform is a *periodic* waveform and can be generated by circuits operating in *free-running mode* as well as in *triggered-mode*.
- The most popular and important application of the voltage sweep waveform is its use in producing electrostatic deflection in a CRT. Several electronic appliances like oscilloscope, television, radar, and distance-measuring systems make use of displays based on the CRT.
- The time interval during which the sweep voltage rises from V_V to V_P is called the *sweep interval* T_s.
- The time interval T_r that is required for the voltage sweep waveform to return to its minimum value is called the *retrace time*. Other popular terms employed to describe T_r are *fly back* time, *restoration* time, *recovery* time, and *return* time.
- Three errors are commonly used to measure the departure from linearity in an ordinary voltage sweep waveform. They are slope error e_s, displacement error e_d, and transmission error e_t.
- We can mathematically show that these errors related by the following equation

$$e_d = \frac{e_s}{8} = \frac{e_t}{4} \qquad (9.5)$$

- We have to remember that keeping the slope error e_s small while generating a voltage sweep waveform would offer us maximum linearity in the sweep waveform.
- The term *relaxation circuit* is employed to any circuit in which timing intervals are determined by the exponential charging (tensing) or discharging (relaxing) of a capacitor. A charged capacitor functions like a stiff spring that has stored potential energy in it. A discharging capacitor is analogous to a relaxing spring in which stored potential energy is being converted to kinetic energy.

- The underlying philosophy in all the methods employed in the generation of voltage sweep waveform are based essentially on one principle—exponential charging and exponential discharging of the capacitor. The linearity of the sweep waveform is improved by introducing different methods, and each method is known based on the techniques it adopts for achieving better linearity.
- In the generation of voltage sweep waveform, employing exponential charging of a capacitor, linearity of the sweep waveform is improved by fulfilling the conditions $V_s \ll V$ and $T_s \ll RC$ in the circuit.
- In constant-current charging of a capacitor to obtain a voltage sweep waveform, we can identify three important functional blocks in constant-current charging approach—a capacitor, a constant-current source, and a switch.
- The Miller sweep circuit and the bootstrap sweep circuit originate from a common circuit that is essentially a series combination of a resistor and a capacitor. The linearity of the sweep waveform is improved in these circuits by introducing a fictitious voltage source included in the *RC* circuit. The current in this circuit, with the fictitious voltage, remains at a constant value $I = V/R$.
- The Miller approach produces a good voltage sweep waveform by connecting a capacitor *C* across the input and the output points of a voltage amplifier with infinite gain and infinite input resistance.
- In bootstrap approach, a good voltage sweep waveform is obtained with the fictitious voltage source realized as the output voltage of a unity gain voltage amplifier possessing infinite input resistance.
- The slope error of a voltage sweep waveform can be meaningfully expressed in the following way.

$$e_s = \frac{v_C(T_s)}{v_C(\infty)} \tag{9.16}$$

- If the voltage sweep waveform is generated in *free-running mode*, the waveform is initiated immediately and the circuit does not wait for any external trigger input to initiate the next cycle of the sweep waveform. Free-running mode operation is also described by terms such as *astable* mode and *recurrent* mode.
- In *triggered-mode operation*, the sweep waveform generator does not generate a periodic output waveform and the output waveform is present at irregular intervals. The output of a triggered-mode circuit remains at a quiescent value and the circuit waits for the arrival of an external trigger pulse. The triggered-mode operation is also known as *monostable* operation.
- The expression for *sweep-speed* in constant current charging approach would be of immense use for measuring the slope of the voltage sweep waveform. The expression for sweep-speed is given by

$$\frac{dv_C}{dt} = \frac{I}{C} \tag{9.32}$$

- The fictitious voltage source in *Miller sweep circuit* is simulated as output voltage of an amplifier with a gain of $-\infty$ and infinite input resistance. A capacitor C is connected in voltage-shunt feedback across the input and output terminals of this infinite-gain voltage amplifier.
- A capacitor that is connected across the input and output terminals of a voltage amplifier is known as a *Miller capacitor* since we come across Z_f connected in a similar way while dealing with Miller's theorem in network analysis.
- In a bootstrap sweep circuit, the input voltage and output voltage are exactly equal and of the same polarity in ideal conditions. The technique of directly connecting output terminal to the input of the circuit is termed as *bootstrapping* in electronic terminology. The input and the output of the circuit rise and fall simultaneously similar to the movement of the actual bootstraps.
- In Miller sweep waveform generation, an *initial jump* $\Delta v_o(0+)$ is observed if the output resistance R_o of the base amplifier is not zero. In the bootstrap sweep circuit we do not find any initial jump even when the output resistance R_o of the base amplifier is present.
- In Miller sweep circuit improvement in linearity is not much dependant on input resistance R_i while a large R_i is certainly desirable. The improvement of linearity in this circuit is obtained with large A.
- The performance of the bootstrap sweep circuit gets reduced to that of an ordinary exponential sweep circuit if R_i is not large enough. The gain A of the bootstrap sweep circuit has no effect on the linearity of the sweep waveform.
- It is very important to keep R/R_i small in the bootstrap circuit than in the Miller circuit in order to obtain improved linearity.