RC DIFFERENTIATOR

Aim To design and set up an RC differentiator circuit and study its response to pulses and square waves.

Components and equipments required Capacitor, resistor, signal generator, bread board and CRO.

Theory A circuit is called a differentiator if its time constant is very small in comparison with the time period of the input signal. The voltage drop across R will be very small in comparison with the drop across C.

The current through the capacitor is Cdv/dt. Hence the output is proportional to the derivative of the input.

$$V_O = \text{Resistance} \times \text{current} = RC \frac{dV_i}{dt}$$

Consider a sinusoidal signal $V\text{Sin}\omega t$ is fed to the input of the differentiator. Its output will be $VRC\omega\text{Cos}\omega t$.

Response to pulse input A pulse waveform is a kind of voltage that rises to a high voltage level abruptly and remains at that level for a period of time and falls quickly to zero and remains at that level for another period of time.

Differentiated output is proportional to the rate of change of input.When input rises to maximum, differentiated output follows suit because the sudden change of voltage is transferred to the output by the capacitor. Since the rate of change of voltage is positive, differentiated output is also positive.

When input remains in maximum voltage for a period of time, the rate of change of voltage is zero. So output falls to zero. During this time input acts like a dc voltage and capacitor offers high impedance to it. So the charges in capacitor drains to earth through the resistance.

When input falls to zero, rate of change of input voltage is negative. Then the output also

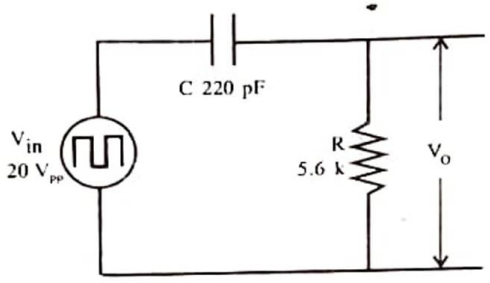
goes to negative. For perfect differentiation, it should satisfy the following criterion $RC < 0.0016T$ where $T = 1/f$, and f is the frequency of input signal.

Response to square wave input A square waveform has positive and negative excursions with respect to its reference zero. The peak of the output of the differentiator rises when the square wave is fed to the input instead of pulses.

Procedure

1. Set up the circuit after testing the components.
2. Switch ON the pulse generator and set the pulse train output at 5 V, 1 kHz.
3. Observe the input and output on two channels of the CRO.
4. Note down the output waveforms for the following conditions using a potentiometer.
   i) $RC = T$, ii) $RC << T$ and iii) $RC >> T$
5. Repeat the above steps for a square wave input of 10 V_{PP}, 1 kHz.

Circuit diagram



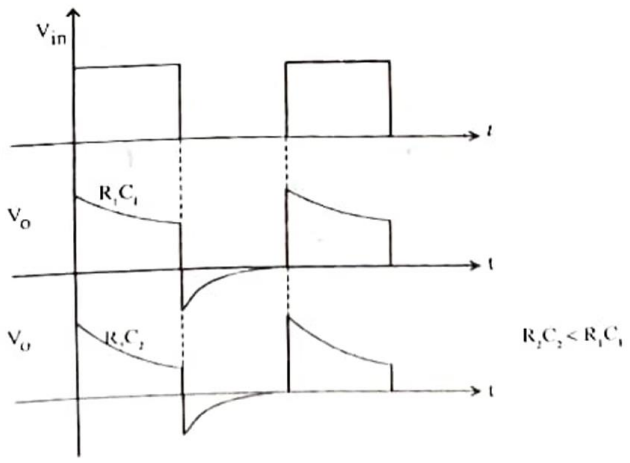
Design Let the input be a pulse train of 1 kHz. Then T = 1 ms.

For a differentiator, $RC \leq 0.0016T$

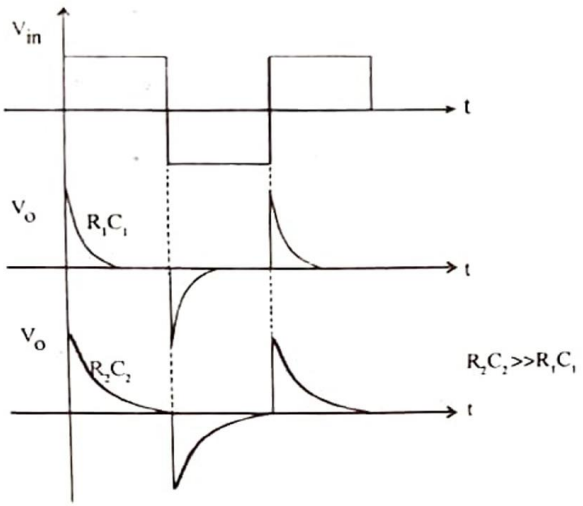
To avoid loading, as a thumb rule, select R = ten times the output impedance of the pulse generator. If the output impedance is 600 Ω then R = 6000 Ω. Use 5.6 k std.

Substituting this in the above expression we get, C = 235 pF. Use 220 pF.

Waveforms



Response of the RC differentiator to a pulse train input



Response of the RC differentiator to a square wave input

Reference

Electronics Lab Manual Volume I, K.A. Navas, **Rajath Publishers**