44.1 Problems

44.1 Calculate the output voltage waveform from the circuit in Figure 44.4 for an input triangular waveform of frequency 250 Hz and of amplitude 30 mV.

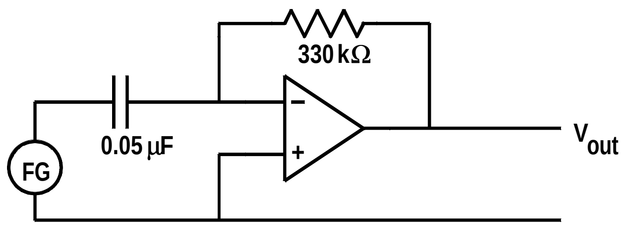

Figure 44.1: Problem 44.1.

44.2 Calculate the output voltage waveform from the circuit in Figure 44.5 when the function generator is set to give an input sinusoidal waveform of frequency 200 Hz and of amplitude 0.1 V. Sketch the traces for the input and output voltage waveforms which you would observe on a double channel oscilloscope.

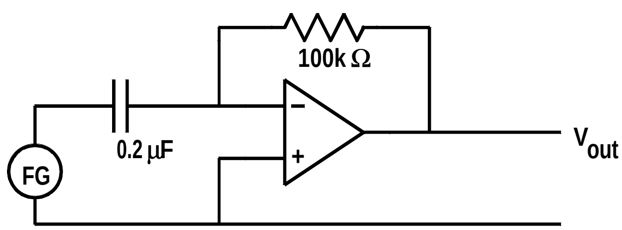

Figure 44.2: Problem 44.2.

44.3 If the signal frequency in Problem 44.2 is changed from 200 Hz to 400 Hz, what changes will occur in the output voltage waveform?

Unit 45 Integrator circuits

- The output from an integrator circuit is given by:

$$V_{out} = -\frac{1}{CR}\int V_{in}dt$$

When we feed a signal into an integrator circuit, we obtain an output voltage which is the time integral of the input voltage signal. The basic circuit used is shown in Figure 45.1.

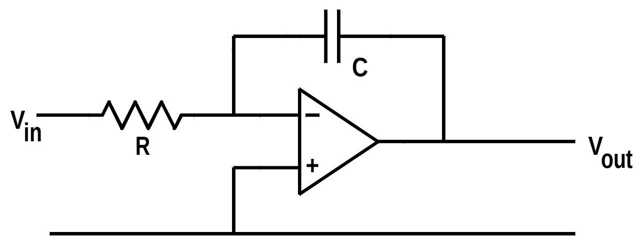

Figure 45.1: The integrator circuit.

This integrator circuit is analyzed by using the same equation for a capacitor, $Q = C \times V$, that we used in analyzing the differentiator circuit. The sequence of the argument is reversed, however.

$$\begin{aligned}
\text{We have, for the input current,}\quad I_{in} &= \frac{V_{in}}{R} \\
\text{also}\quad Q &= \int I_{in}dt \\
\text{Therefore the output voltage}\quad V_{out} &= -\frac{Q}{C} \\
&= -\frac{1}{C}\int_0^t I_{in}dt \\
&= -\frac{1}{C}\int_0^t \frac{V_{in}}{R}dt \\
&= -\frac{1}{CR}\int_0^t V_{in}dt
\end{aligned}$$

which means that the output voltage from this circuit is the time integral of the input voltage to the circuit.

45.1 Example

45.1 In the circuit in Figure 45.2 (a), the function generator, FG, is set to give an output square waveform of frequency 200 Hz and of amplitude 1 V as shown in Figure 45.2 (b).
Calculate the output voltage waveform and sketch the waveform which would be observed on a two channel oscilloscope with channel A displaying the input waveform and channel B displaying the output waveform.

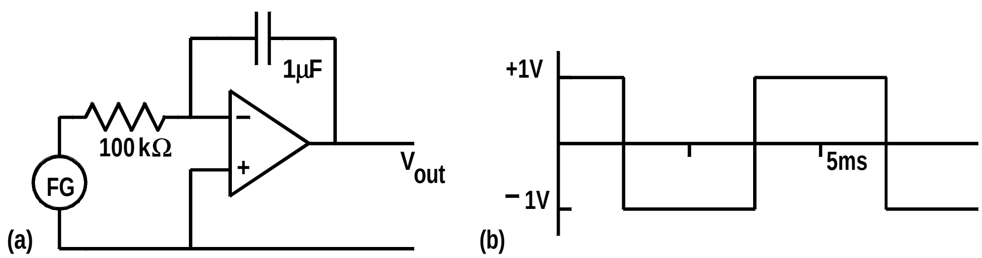

Figure 45.2: Example 45.1.

First calculate:

$$CR = 1\,\mu\text{F} \times 100\,\text{k}\Omega = 10^{-6} \times 10^{5} = 0.1\,\text{s}$$

We then use the equation for the integrator to get:

$$\begin{aligned} V_{out} &= -\frac{1}{CR}\int_0^t V_{in}dt \\ &= -\frac{1}{0.1}\int_0^t V_{in}dt \\ &= -10\int_0^t V_{in}dt \end{aligned}$$

V_{in} is constant for 1.25 ms at +1 V and then
V_{in} is constant for 2.5 ms at −1 V and then
V_{in} is constant for 2.5 ms at +1 V and then
V_{in} is constant for 2.5 ms at −1 V and then ... etc.
Also we presume that $V_{out} = 0\,\text{V}$ at the start of the time interval.

At the end of the first $\frac{1}{4}$ segment of the waveform at $t = 1.25\,\text{ms}$:
$V_{out} = -10 \times 1\,\text{V} \times 1.25 \times 10^{-3} = -12.5\,\text{mV}$
During the next 2.5 ms, the output changes by:
$\Delta V_{out} = -10 \times (-1\,\text{V}) \times 2.5 \times 10^{-3} = +25\,\text{mV}$
During the next 2.5 ms, the output changes by:
$\Delta V_{out} = -10 \times (1\,\text{V}) \times 2.5 \times 10^{-3} = -25\,\text{mV}$
which gives the waveform shown in Figure 45.3.

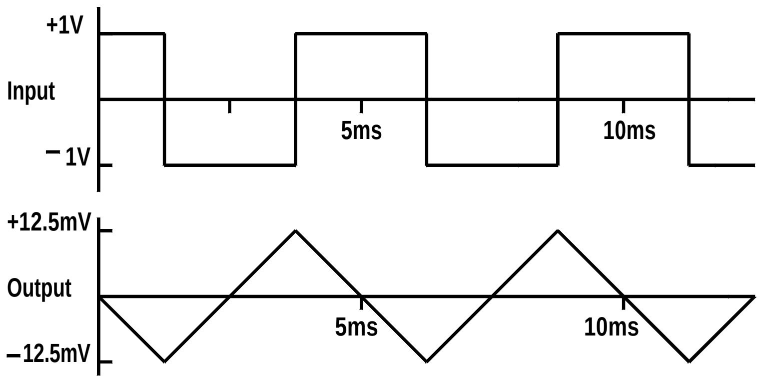

Figure 45.3: Oscilloscope trace of input and output for Example 45.1.

You should note the inversion:
when the input is greater than 0 V, the output decreases,
when the input is less than 0 V, the output increases.

45.2 Problems

45.1 The two switches in the circuit in Figure 45.4 are opened at time $t = 0\,\text{s}$. Calculate the resulting output voltage as a function of time for time from $t = 0\,\text{s}$ to $t = 30\,\text{s}$. Do the calculations accurately describe the variation of the actual output voltage? If not, why not?

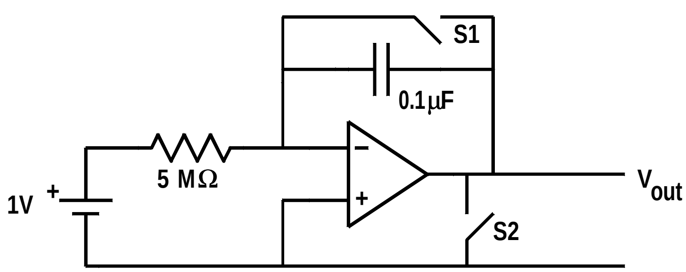

Figure 45.4: Problem 45.1.

45.2 What would be the change in the output voltage waveform in Example 45.1, if the first 1.25 ms at +1 V were omitted from the input signal?

45.3 A sinusoidal voltage waveform having an amplitude of 7.3 V and frequency 20 Hz is applied to the input of the integrator circuit shown in Figure 45.5. Calculate the output voltage waveform and sketch the input and output waveforms which you would observe on a double channel oscilloscope.

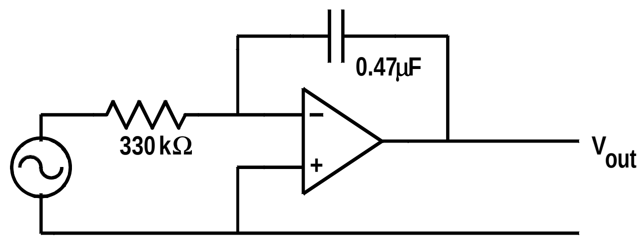

Figure 45.5: Problem 45.3.

45.4 If the frequency of the signal in Problem 45.3 is increased from 20 Hz to 500 Hz, what is the change in the amplitude of the output voltage waveform?

45.5 Does the amplitude of the output signal from an integrator increase or decrease when the input signal frequency is increased?
Two sinusoidal signals of amplitude 1.0 V and frequency 60 Hz and 2.9 V and frequency 170 Hz are applied to the inputs to the circuit shown in Figure 45.6. Use the principle of superposition to calculate the output waveform and give a sketch of the input and output waveforms.

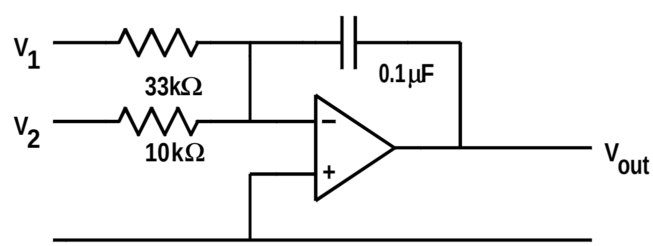

Figure 45.6: Problem 45.5.