EEEN 202 ELECTRICAL AND ELECTRONIC CIRCUITS II

EXPERIMENT 3: ANALYZING OPERATIONAL AMPLIFIERS OPERATING AS DIFFERENTIATOR AND INTEGRATOR

DIFFERENTIATING AMPLIFIER

Differentiator circuits are the circuits that produce the derivative of an input signal. For example, a diferentiator circuit can convert the triangular wave at the input to square wave as an output. The differentiator circuit constructed by operational amplifier is given in Figure 3.1.

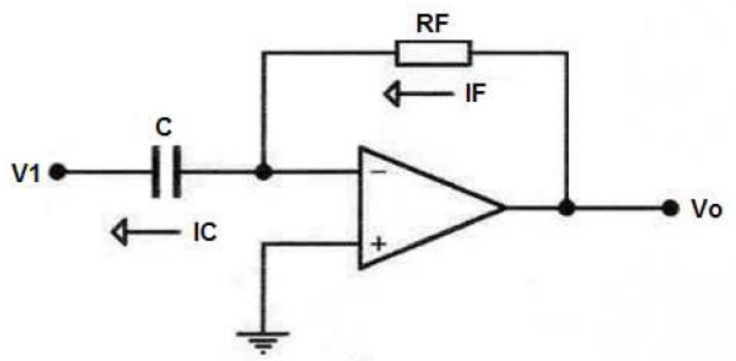


Figure 3.1

The differentiator circuit is an inverting amplifier circuit. The voltage at the inverting input of the operational amplifier is equal to zero volts due to the inverting amplifier property. The current passing through the capacitor is;

$$IC = C\frac{dV1}{dt}$$

Since the voltage at the inverting input is 0 (zero) volts, the output voltage is;

$$V0 = -(IF \cdot RF)$$

As $IF = IC$, we get

$$V0 = -C\frac{dV1}{dt} \cdot RF$$

As it is seen from the equation; the differentiator circuit differentiates the triangular wave at its input ($\frac{dV1}{dt}$), multiplies it with a time constant ($RF \cdot C$), and transfers it to the output.

The differentiation operation is performed by the capacitor "**C**" in the circuit. At high frequencies, capacitor "**C**" behaves as a short circuit. So the gain becomes very high. That high gain results in undesired oscillations. In order to prevent this situation, a resistance is connected in series with the capacitor "**C**". That resistance plays the same role with the gain limiting resistance of the inverting amplifier.

At high frequencies, the gain is $A = \frac{RF}{R1}$. The cut-off frequency of the differentiator circuit (**Fc**) is;

$$Fc = \frac{1}{2\pi \cdot R1 \cdot C}$$

The following two conditions should be satisfied in order the circuit to operate as a differentiator:

1. If the frequency of the input signal is greater than the cut-off frequency, the circuit does not perform differentiation. If we call the input frequency (**fi**); $fc > fi$ must be satisfied.
2. The time constant of the circuit is RF.C, i.e. $T = RF \cdot C$.

The period of the input signal must be at least the time constant T=RF.C or more. If triangular wave is applied to the input of a differentiator circuit, a square wave is taken from the output. If sine is applied to the input, cosine is taken from the output. If square wave is applied to the input, impulsive signals are obtained at the output.

INTEGRATING AMPLIFIER

The integrator circuits are the circuits that integrate the square wave at their inputs and transfer it to the output as a triangle wave. They can be considered as the inverse of the differentiator circuits. An integrator circuit is given in Figure 3.2. Integrator circuit is an inverting amplifier circuit. The voltage at the inverting input of the operational amplifier is equal to zero volts due to the inverting amplifier property.

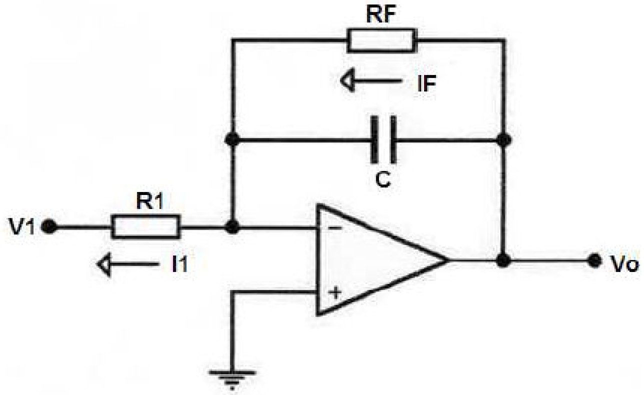


Figure 3.2

So, the current I1 is;

$$I1 = \frac{V1}{R1}$$

then we obtain

$$V0 = -\frac{1}{C}\int_0^t I1 \cdot dt$$

If we substitute the current I1 into the output equation, we get

$$V0 = -\frac{1}{C}\int_0^t \frac{V1}{R1} \cdot dt = -\frac{1}{R1 \cdot C}\int_0^t V1 \cdot dt$$

In order the operational amplifier not to be saturated by the input offset voltage, the resistance RF is connected in parallel with the capacitor C.
The cut-off frequency off the inverting amplifier is;

$$Fc = \frac{1}{2\pi \cdot RF \cdot C}$$

The following two conditions should be satisfied in order the circuit to operate as an integrator:

1. The frequency of the input signal must be greater than the cut-off frequency. If we call the input frequency (**fi**); fi>fc must be satisfied. (Note that, this condition is the inverse of the condition given for the differentiator.)
2. The period of the input signal must be approximately

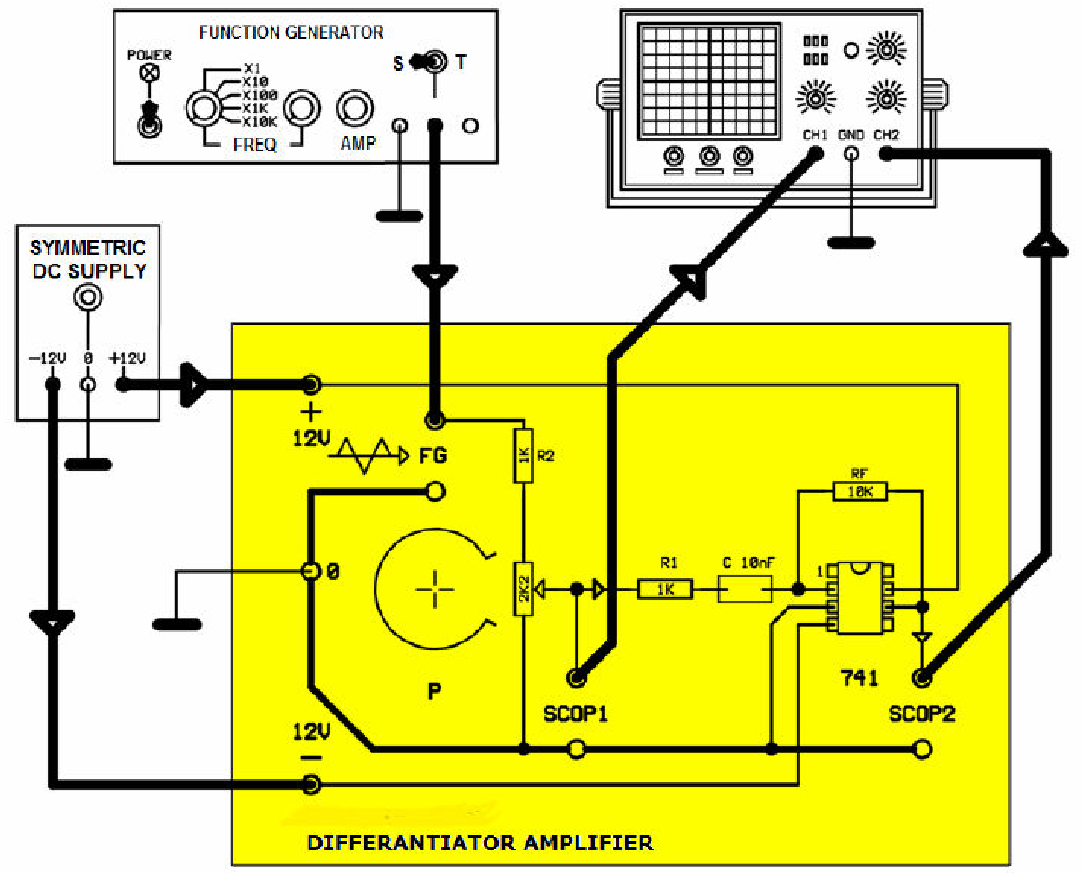
$$T = \frac{1}{R1 \cdot C}$$

If sine is applied to the input of the integrator circuit, -cosine is obtained from the output.

EXPERIMENT 3.1 ANALYZING DIFFERENTIATOR AMPLIFIER

EXPERIMENTAL PROCEDURE:

Connect the circuit as shown in the following figure.



1. Apply power to the circuit. Set the output of the function generator to triangular wave with frequency 1 KHz and amplitude 1V peak to peak by using scope 1.

2. Observe the input and output signals on the oscilloscope screen. Measure the amplitude of the output signal and write down the result.

3. How does the output signal change with the input signal? Explain it.

4. Set the frequency of the input signal to 5KHz. Measure the amplitude of the output signal. Explain the reason.

5. Calculate the cut-off frequency (**Fc**) of the circuit.

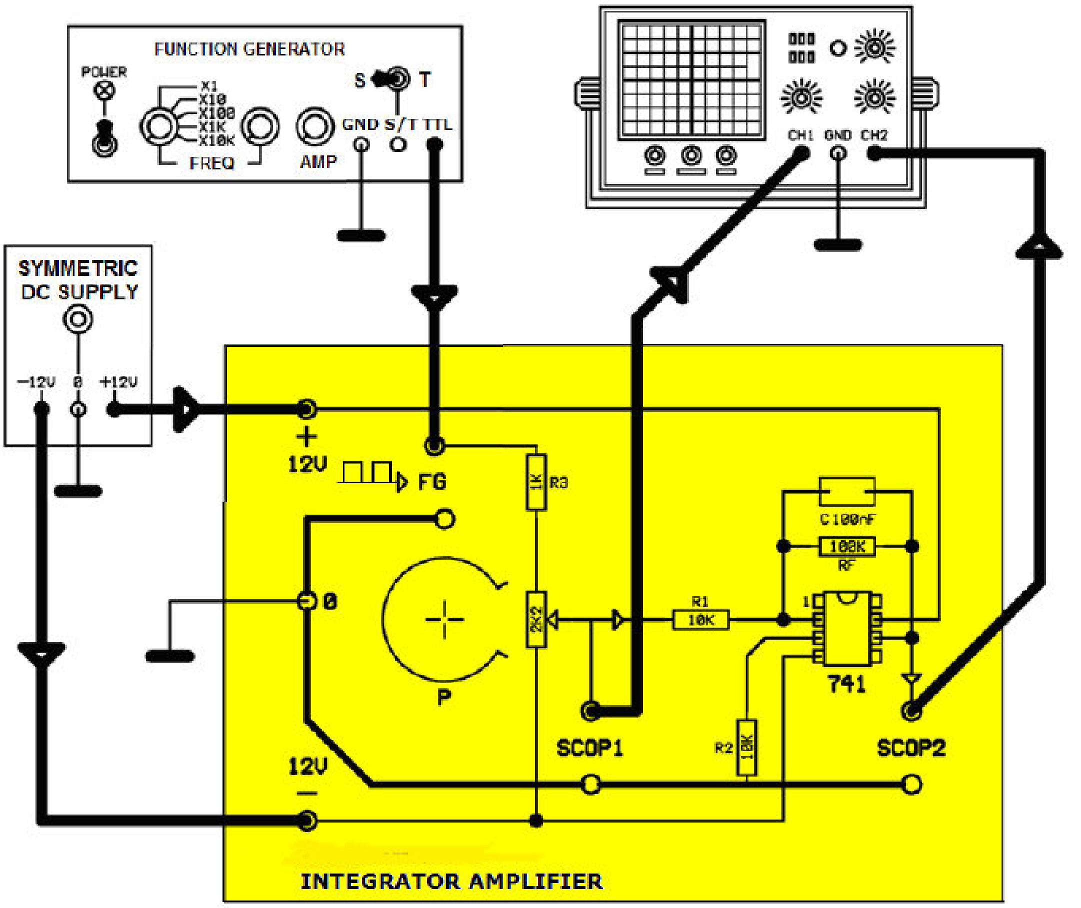
6. Apply a sinusoidal signal to the input with frequency 1 KHz and amplitude 1Vpp. Define the output signal.

EXPERIMENT 3.2 ANALYZING INTEGRATOR AMPLIFIER

The preliminary information has been given above.

EXPERIMENTAL PROCEDURE:

Connect the circuit as shown in the following figure.



1. Apply power to the circuit. Set the output of the function generator to triangular wave with frequency 1 KHz and amplitude 1V peak to peak by using scope 1.

2. Observe the input and output signals on the oscilloscope screen. Measure the amplitude of the output signal and write down the result.

3. How does the output signal change with the input signal? Explain it.

4. Set the frequency of the input signal to 5KHz. Measure the amplitude of the output signal. Explain the reason.

5. Calculate the cut-off frequency (**Fc**) of the circuit.

6. Apply a sinusoidal signal to the input with frequency 1 KHz and amplitude 1Vpp. Define the output signal.