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| **Course Name:** | **Linear Integrated Circuits and Design** | **Semester:** | **V** |
| **Date of Performance:** |  | **Batch No:** | **B1** |
| **Faculty Name:** | **Prof.Milind Marathe** | **Roll No:** | **1912052** |
| **Faculty Sign & Date:** |  | **Grade/Marks:** | **/25** |

**Experiment No: 7**

**Title: Implementation of triangular and square wave generator circuit using**

**Opamp**

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| **Aim and Objective of the Experiment:** |
| To implement and analyze triangular and square wave generator circuit using Opamp   * To design triangular and square wave generator circuit and verify the simulated frequency of oscillation value with theoretical designed values. * To analyze sawtooth and rectangular wave generator circuit waveforms and comment about dependences of circuit parameters on amplitude and frequency. |

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| **COs to be achieved:** |
| **CO3:** Design circuits using op-amps as nonlinear applications. |

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| **Theory:** |
| **Triangular Wave Generator:**  The output waveform of the integrator is triangular if its input is a square- wave. This means that a Triangular wave generator can be formed by simply connecting an integrator to the square-wave generator. However for designing we are using Triangular wave generator, which requires fewer components. The generator consists of 1st opamp as a comparator and 2nd opamp as an integrator. The comparator compares the voltage at point P continuously with the inverting input i.e at 0V. When the voltage at P goes slightly below or above 0V, the output of 1st opamp i.e comparator is at the negative or positive saturation levels respectively. To illustrate the circuit operation, let us set the output of comparator at . This is an input of the integrator. The output of the integrator, therefore, will be a negative-going ramp. Thus one end of the voltage- divider is the positive saturation voltage and the other is the negative going ramp of integrator. When the negative going ramp attains a certain value , point P is slightly below 0V ; hence the output of comparator will switch from to . This means that the output of integrator will now stop going negatively and will begin to go positively. The output of integrator will continue to increase until it reaches . At this time the point P is slightly above 0V; therefore, the output of comparator is switched back to the level. The sequence repeats.  **Saw tooth Wave Generator:**  The difference between the triangular and sawtooth waveforms is that the rise time of the triangular wave is always equal to fall time. That is, the same amount of time is required for the triangular wave to swing from to and from to . On the other hand, sawtooth waveform has unequal rise time and fall time. The triangular waveform generator can be converted into sawtooth waveform generator by injecting a variable dc voltage into the non-inverting terminal of the integrator. This can be accomplished by using the potentiometer (pot) and connecting it to and . Depending on the pot setting, a certain dc level is inserted in the output of integrator. The duty cycle of the square-wave will be determined by the polarity and amplitude of this dc level.  A duty cycle less than 50% will then cause the output of integrator to be a sawtooth. With the wiper at the center of the pot, the output of integrator is a triangular wave. For any other position of Pot , the output is a sawtooth waveform. Specifically as the pot variable is moved towards ., the rise time of the sawtooth wave becomes longer than the fall time. On the other hand, as the pot is moved towards , the fall time becomes longer than the rise time.  **Design statement:**  Design a triangular and square waveform generator to meet the following requirements:  a) Frequency of oscillations  b) Triangular waveform amplitude of |

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| **Circuit Diagram:** |
| **1. Triangular and Square wave generator circuit using low speed Opamp OP-07** |
| **2. Triangular and Square wave generator circuit using high speed Opamp** |
| **3. Sawtooth and Rectangular wave generator circuit using high speed Opamp** |

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| **Stepwise-Procedure:** |
| 1. Design triangular and square waveform generator circuit for specifications mentioned in write-up.  2. Make the triangular and square waveform generator circuit schematic using low-speed opamp OP-07 in LTspice.  3. Plot square wave and triangular wave forms in LTspice and measure square wave peak voltage amplitude, triangular wave peak to peak amplitude and frequency of oscillations from the plots.  4. Compare the simulated values obtained from Step 3, with the theoretical values in the observation table.  5. Repeat step 2, and select LTC6244 as high speed opamp, from component library in LTspice.  6. Repeat step 3 with LTC6244 as high speed opamp.  7. Compare the simulated values obtained from Step 6, with the theoretical values in the observation table.  8. For sawtooth and rectangular waveform generator circuit, add resistors and as show in the circuit diagram.  9. Select for the case Rise time > Fall time and for the case Rise time < Fall time. Observe the sawtooth and rectangular waveforms for both the above cases. |

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| **Observation Table:** |
| **1. Triangular and Square wave generator circuit using low speed Opamp**   |  |  |  |  | | --- | --- | --- | --- | | **Sr. No.** | **Parameters** | **Theoretical values** | **Simulated Value** | | 1. | Frequency of oscillations | 2KHz | 1.3415713KHz | | 2. | Triangular wave output voltage | 7V p-p | 8.8749779V p-p | | 3. | Square wave output voltage | 13.5V peak | 14.04936V peak |   **2. Triangular and Square wave generator circuit using high speed Opamp**   |  |  |  |  | | --- | --- | --- | --- | | **Sr. No.** | **Parameters** | **Theoretical values** | **Simulated Value** | | 1. | Frequency of oscillations | 2KHz | 1.9819588KHz | | 2. | Triangular wave output voltage | 7V p-p | 7.4899463Vp-p | | 3. | Square wave output voltage | 13.5V peak | 14.980892Vpeak | |

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| **Calculations:** |
| **Peak to Peak Output amplitude of Triangular wave is**  **Frequency of oscillation is given by**  **Design Steps for Triangular wave Generator :**  **Given: , ,**  **Thus, ; Select ;**  **Also,**  **Let**  **ema_1602845504400** |

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| **Waveforms:** |
| **1: Output Triangular and square waveforms using Low-speed Opamp:** |
| **2: Output Triangular and square waveforms using High-speed Opamp:** |
| **3: Output Sawtooth and rectangular waveforms using High-speed Opamp: ( Rise time > Fall time):** |
| **4. Output Sawtooth and rectangular waveforms using High-speed Opamp: ( Rise time < Fall time):** |

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| **Post Lab Questions:** |
| 1. Why do we prefer high-speed opamp over low speed opamp in waveforms generator circuits?   Ans:- The slew rate of an op-amp or any amplifier circuit is the rate of change in the output voltage caused by a step change on the input. A typical general-purpose device may have a slew rate of 10V/ms. This means that when a large-step change is placed on the input, the electronic device would be able to provide an output 10-volt change in one ms. Hence, in order to obtain undistorted output, high speed op-amps are preferred.   1. An additional requirement in given design problem is to have square output voltage limited to . Suggest suitable modifications in the circuit and obtain the desired waveforms.        1. Build a circuit which gives only square output waveforms using opamp in LTspice. |

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| **Conclusion:** |
| In this experiment we designed triangular and square wave generator circuit and verified the simulated frequency of oscillation value with theoretical designed values and analyzed the sawtooth and rectangular wave generator circuit waveforms. |

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| **Signature of faculty in-charge with Date:** |