

GUJARAT TECHNOLOGICAL UNIVERSITY

BE-4 SEMESTER – OLD PAPER – S22 TO W25 – QUESTION BANK ANSWER

Subject Name & Code:

ANALOG CIRCUIT DESIGN (3141002)

(Disclaimer: The purpose of these AI-generated responses is just education and reference. Utilise them to grasp topics and structure, but always rewrite in your own words and double-check)

Waveform Generators using Op-Amp

Q.1 – Explain square wave generator using op-amp.

(7 marks)

Ans:

A square wave generator (astable multivibrator) using op-amp produces a non-sinusoidal square wave output without any external trigger.

Circuit:

- Op-amp in inverting configuration with positive feedback (Schmitt trigger).
- Timing capacitor C and resistor R (or R_C) connected from output to inverting input.
- Feedback resistors R_1 and R_2 from output to non-inverting input to set hysteresis.

Diagram prompt:

[DG PROMPT]

Title: Square wave generator using op-amp (astable multivibrator)

Description: Draw op-amp. Non-inverting input connected to voltage divider:

resistor R_2 from output to (+), resistor R_1 from (+) to ground. Inverting input connected to capacitor C (other side to ground) and also to output through resistor R (or R_f). Output is square wave. Label R_1, R_2, R, C . Show output waveform: square wave with amplitude $\pm V_{sat}$, and capacitor voltage exponential charging/discharging between thresholds.

Working:

- Initially assume output = $+V_{sat}$. Then voltage at non-inverting terminal = $V_{ref+} = V_{sat} \times \frac{R_1}{R_1+R_2}$.
- Capacitor C charges through R toward $+V_{sat}$.
- When capacitor voltage reaches V_{ref+} , op-amp switches to $-V_{sat}$.
- Now non-inverting terminal becomes $V_{ref-} = -V_{sat} \times \frac{R_1}{R_1+R_2}$.
- Capacitor discharges toward $-V_{sat}$ through R .
- When capacitor voltage reaches V_{ref-} , op-amp switches back to $+V_{sat}$. Cycle repeats.

Time period and frequency:

$$T = 2RC \ln \left(1 + \frac{2R_1}{R_2} \right)$$

If $R_1 = R_2$, then $T = 2RC \ln(3) \approx 2.2RC$.

$$f = \frac{1}{2RC \ln \left(1 + \frac{2R_1}{R_2} \right)}$$

Advantages: Simple, wide frequency range (Hz to kHz).

Applications: Clock generator, function generator (as core of square wave section).

Q.2 – Explain triangular wave generator using op-amp.

(7 marks)

Ans:

A triangular wave generator produces a linear ramp (triangular) waveform. It typically uses a square wave generator followed by an integrator.

Circuit (two op-amps):

- First op-amp: square wave generator (Schmitt trigger).
- Second op-amp: integrator (inverting integrator) driven by the square wave output.

Diagram prompt:

[DG PROMPT]

Title: Triangular wave generator using two op-amps

Description: Draw first op-amp as square wave generator (with R_1, R_2, R, C). Its output goes to second op-amp via resistor R_3 . Second op-amp as integrator: inverting input via R_3 , feedback capacitor C_i , non-inverting input grounded. Output of integrator is triangular wave. Optionally add potentiometer to adjust symmetry. Show waveforms: square wave (top) and triangular wave (bottom).

Working:

- Square wave generator outputs $\pm V_{sat}$ with period T .
- Integrator converts each half-cycle into a linear ramp (positive slope for positive input, negative slope for negative input).
- Output of integrator rises linearly during $+V_{sat}$ and falls linearly during $-V_{sat}$, producing a triangular wave.

Frequency and amplitude:

Let square wave amplitude = V_{sat} , integrator time constant $\tau = R_3 C_i$.

Slope = $\pm V_{sat}/\tau$.

Peak-to-peak output $V_{pp} = \frac{V_{sat}T}{2\tau} = \frac{V_{sat}}{2f\tau}$.

Advantages: Linear ramp, low distortion.

Applications: Sweep generator, PWM modulator, function generators.

Q.3 – Draw and explain sawtooth wave generator using op-amp.

(7 marks)

Ans:

A sawtooth wave generator produces a waveform that rises linearly (or falls) and then quickly resets. It can be derived from a triangular wave by controlling charging/discharging asymmetry.

Circuit (using op-amp and transistor reset):

- Integrator with different charging and discharging paths.
- A transistor (BJT or MOSFET) across the integrating capacitor acts as a reset switch.
- Comparator triggers the transistor when output reaches a threshold.

Alternative circuit: Using a constant current source to charge capacitor (linear ramp) and a switch (transistor) to discharge rapidly.

Diagram prompt:

[DG PROMPT]

Title: Sawtooth wave generator using op-amp and transistor reset

Description: Draw an op-amp integrator: inverting input via resistor R to a constant voltage source (or input square wave). Feedback capacitor C across inverting input and output. A transistor (npn) with collector to inverting input, emitter to ground, base driven by a

comparator output. Comparator compares integrator output with a reference voltage. When output reaches reference, comparator triggers transistor ON → capacitor discharges quickly. Then transistor OFF, capacitor charges again. Show sawtooth output waveform.

Working (using a constant current source):

- Constant current I charges capacitor C : $V_o = (I/C)t$ (linear ramp).
- When V_o reaches V_{ref} , comparator resets by shorting capacitor (discharge).
- Discharge time very small compared to charge time → sawtooth shape.

Frequency: $f = \frac{I}{CV_{ref}}$.

Applications: CRT sweep circuits (old oscilloscopes), PWM generation, analog clock generators.

Q.4 – Explain how op-amp can be used to generate free-running square wave.

(4 marks)

(Already covered in Q.1 – same as square wave generator. Provide a short answer.)

Ans:

An op-amp can generate a free-running square wave using the **astable multivibrator** circuit (also called Schmitt trigger oscillator).

Key components:

- Op-amp with positive feedback (resistors R_1, R_2 from output to non-inverting input).
- RC timing network (resistor R and capacitor C) connected from output to inverting input, and capacitor to ground.

Operation (brief):

- Output switches between $+V_{sat}$ and $-V_{sat}$ due to hysteresis set by R_1, R_2 .
- Capacitor charges and discharges through R between the two threshold voltages $\pm\beta V_{sat}$ where $\beta = R_1/(R_1 + R_2)$.
- No external trigger needed – self-oscillating.

Frequency: $f = \frac{1}{2RC \ln \left(\frac{1+\beta}{1-\beta} \right)}$. For $R_1 = R_2$, $f \approx 0.455/(RC)$.

Real-world application: Simple clock pulse generator, LED flasher, tone generator.

Miscellaneous / Cross-Unit Definitions and Clippers

Q.5 – Give full forms: CMRR, PSRR, PLL, ADC, HPF, VCO, ECL, VCVS, GBP.

(4 marks)

Ans:

Abbreviation	Full Form
CMRR	Common-Mode Rejection Ratio
PSRR	Power Supply Rejection Ratio
PLL	Phase-Locked Loop
ADC	Analog-to-Digital Converter
HPF	High-Pass Filter
VCO	Voltage-Controlled Oscillator

Abbreviation	Full Form
ECL	Emitter-Coupled Logic
VCVS	Voltage-Controlled Voltage Source
GBP	Gain-Bandwidth Product

Note: These are common acronyms in analog circuit design and GTU exams.

Q.6 – What is need of clipper circuit? Explain op-amp as positive and negative clipper. (4 marks)

Ans:

Need of clipper circuit:

- To remove unwanted portions of a signal (e.g., spikes, noise beyond a threshold).
- To protect circuits from overvoltage (e.g., ADC input protection).
- To shape waveforms (e.g., convert sine to square or rectangular).

Op-amp as positive clipper (using Zener diode in feedback):

Circuit: Inverting or non-inverting amplifier with two back-to-back Zener diodes in parallel with feedback resistor.

Operation (positive clipper):

- When output tries to exceed $V_Z + 0.7V$, the Zener conducts, clamping the output to that level.
- Positive portion is clipped; negative passes unchanged (if single Zener). For dual polarity, use two Zeners opposite.

Op-amp as negative clipper:

- Similar circuit but diode polarity reversed.
- Output clamped to a negative reference voltage.

Precision clipper using op-amp and reference voltage:

- Op-amp with diode and voltage reference at output to clip accurately without diode drop error.

Diagram prompt (positive clipper):

[DG PROMPT]

Title: Op-amp positive clipper (inverting)

Description: Draw inverting op-amp with input resistor R_1 and feedback resistor R_f . In parallel with R_f , connect a Zener diode (cathode to output, anode to inverting input) and a regular diode in series? Or simply a Zener to ground. Better: Draw a Zener diode from output to ground to clip positive peaks. Label V_Z . Output waveform shows positive peaks flattened at V_Z .

Real-world application: Overvoltage protection for microcontroller inputs, waveform shaping in function generators.
