TECHNICAL UNIVERSITY
OF CLUJ-NAPOCA

Faculty of Electronics, Telecommunications, and Information Technology

CAD Techniques
-Project-

TRIANGULAR AND RECTANGULAR SIGNAL GENERATOR

Coordinating Teacher: **Student:**

Dr. Eng. Raul Traian Fizeşan **Câcu Răzvan**

Faculty of Electronics, Telecommunications and Information Technology

Contents

-INTRODUCTION-

Design a triangular and rectangular signal generator using the software package OrCAD. It is required for the components to be sized so that they will satisfy the following requirements.

I.Requirements

Bandwidth [Hz]	The min. amplitude of the rectangular signal [V]	The min. amplitude of the triangular signal [V]	The max. amplitude of the triangular signal [V]	The output resistance [Ω]
1800-9600	**8**	**4**	6	**25**

II.Theoretical support

Various waveforms, including rectangular (pulse) and triangular waves, can be created using Operational Amplifiers (Op-Amps).

We'll now examine the theoretical foundation of each waveform's generation process:

I. The Rectangular Signal

The Op-amp comparator compares one analogue voltage level with another analogue voltage level, or some preset reference voltage, VREF and produces an output signal based on this voltage comparison. In other words, the op-amp voltage comparator compares the magnitudes of two voltage inputs and determines which is the largest of the two.

We will use a non-inverting comparator. At its output we will obtain a rectangular signal with an amplitude equal to the supply voltage.

The VTC of the comparator is represented in figure 1.2, where: $V_{OH} = +E$ and $V_{OL} = -E$.

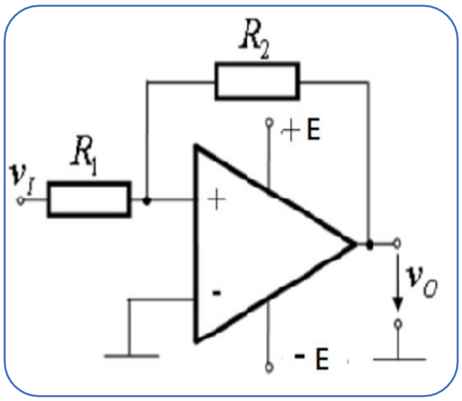


Figure 1.1 Non-Inverting Amplifier

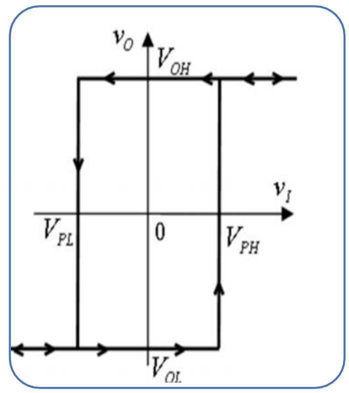


Figure 1.2 VTC

II. The Triangular Signal

A capacitor will be charged and discharged with a steady current to produce the triangle signal. A power supply connected to a resistor can be used to get consistent current. The rectangle signal—more specifically, the one from the output of the capacitor—now provides the power supply. We will calculate the current across the capacitor by measuring the current flowing through the resistor (Ir = Ic).

The current through the capacitor: $\boldsymbol{iC = \frac{C*dV}{dtiC}}$

The voltage on the capacitor: $\boldsymbol{Vc(t) = \frac{(-Ic \ * \ t)}{C + Vc\,(\,0\,)}}$

By Ohm's Law: $\boxed{I_R = \frac{V_R}{R} = \frac{(V_i - V_{out})}{R}}$

In this case we will have no constant current through the capacitor because VR varies.

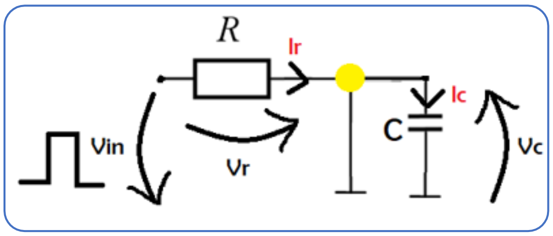


Figure 1.3

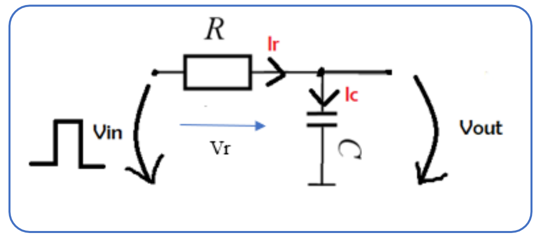


Figure 1.4

- If a ground is added at the yellow node, the voltage VR will remain constant during intervals of VR=Vi, resulting in a constant current IC. There won't be any current via the capacitor if all the IR current flows to ground.

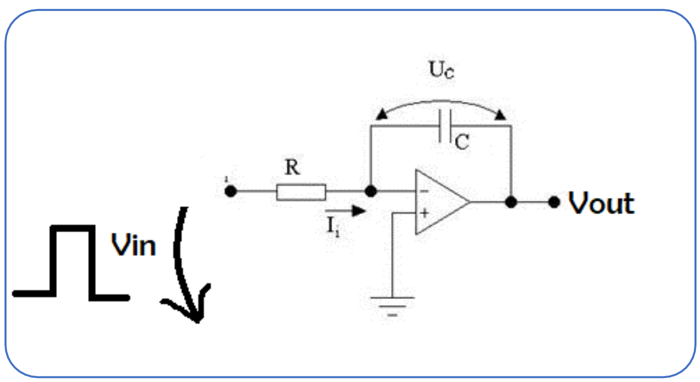


Figure 1.5

- We will replace the ground in the circuit shown in Figure (1.1) with an operational amplifier because it has resistance which tends to ∞, which means that all current will flow through the capacitor. So, we'll get an integrator circuit with the A.O. (figure (1.2))
-

-HOW THE CICUIT OPERATES-

At the inverting input (AO2), the output voltage from the comparator's output (AO1) travels through the resistor R. When the integrator's input voltage is -V, the integrator's output voltage rises from the VPI level until it reaches the VPS level. At this point, the integrator's output voltage slopes downward from the VPS level to the VPI level, and the comparator changes to its highest positive +V setting. When this value is reached, the dial gauge turns negative, and the cycle continues.

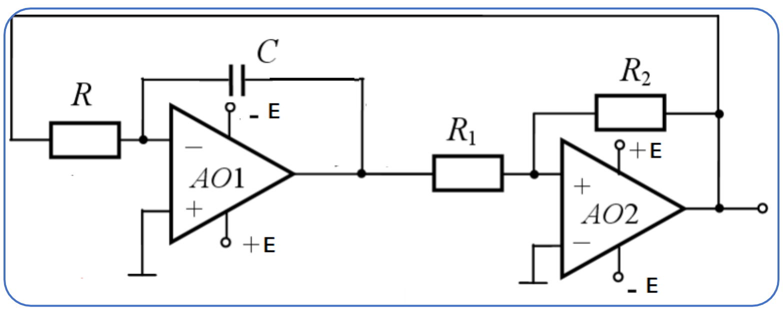


Figure 1.6

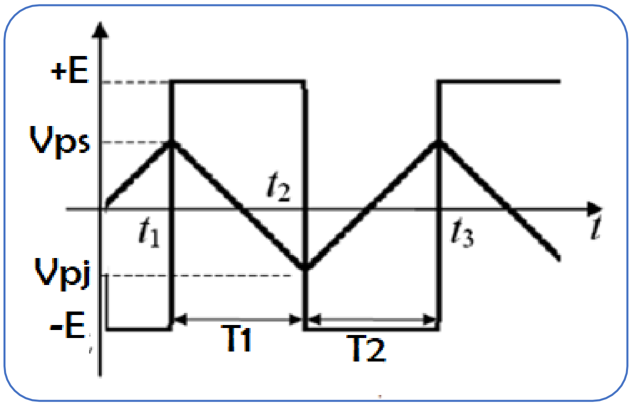


Figure 1.7 Output Signals

The signal period will be $\boxed{T=\frac{1}{frequency}}$

To get period value between 1/fmax=.11ms and 1/fmin= 0.55ms, we will add in series with resistance R we will put a potentiometer.

I.Block Diagram

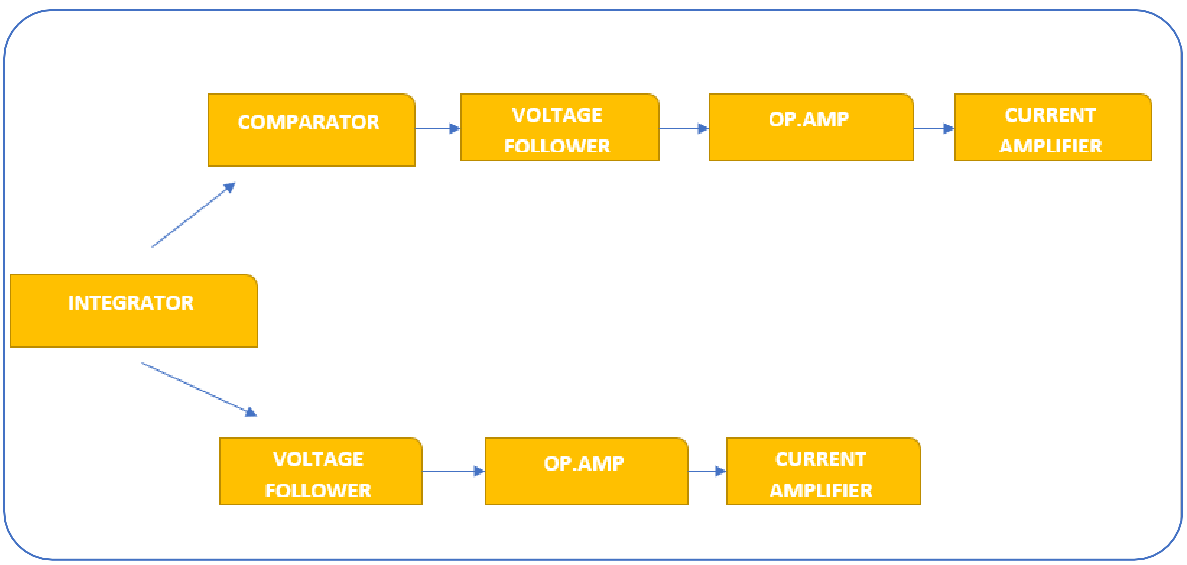


Figure 1.8 Block Diagram

II.Circuit Design

To generate the signals:

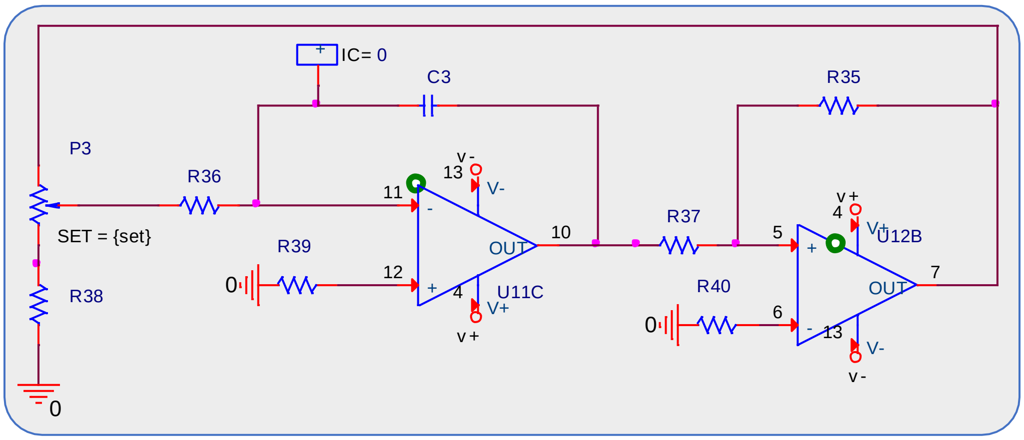


Figure 2.1

- Integrator -produces a triangular signal equal to the amplitude and frequency of the input signal.
- Comparator - can be used as a function generator between the 2 supplies.

We will add the following to get the desired amplitude for the signals:

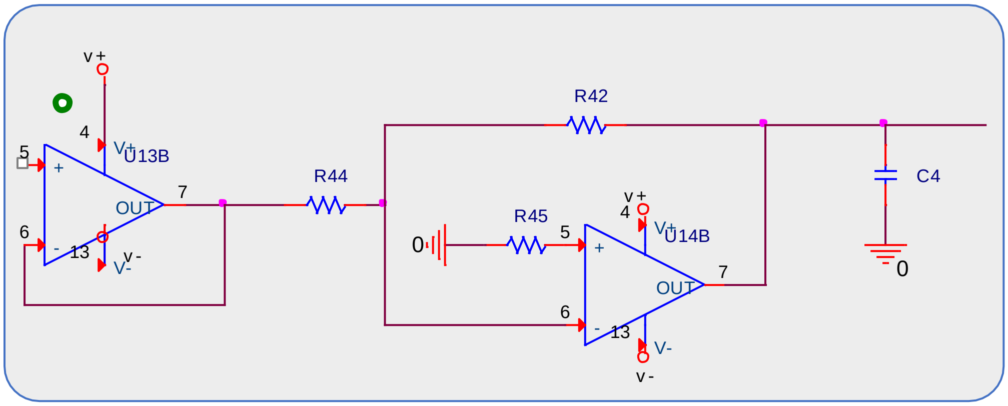


Figure 2.2 Rectangular Signal Amplitude Adjustment

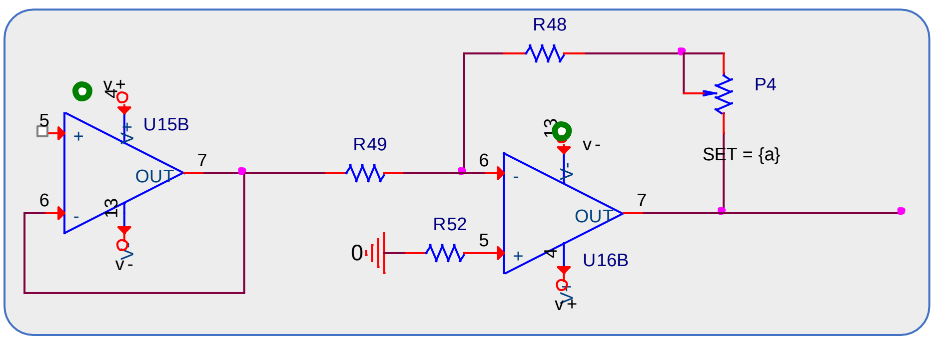


Figure 2.3 Triangular Signal Amplitude Adjustment

- Voltage follower to each signal output that has unitary voltage gain and is used to separate the impedances and to attenuate the distortions of the circuit.
- A new OP-AMP with fixed gain that needs to be calculated to get the desired amplitude for the rectangular signal.
- A new OP-AMP that has a potentiometer connected to the inverting input to get an adjustable gain for the desired range of amplitude.

For each output we will add a class AB power amplifier:

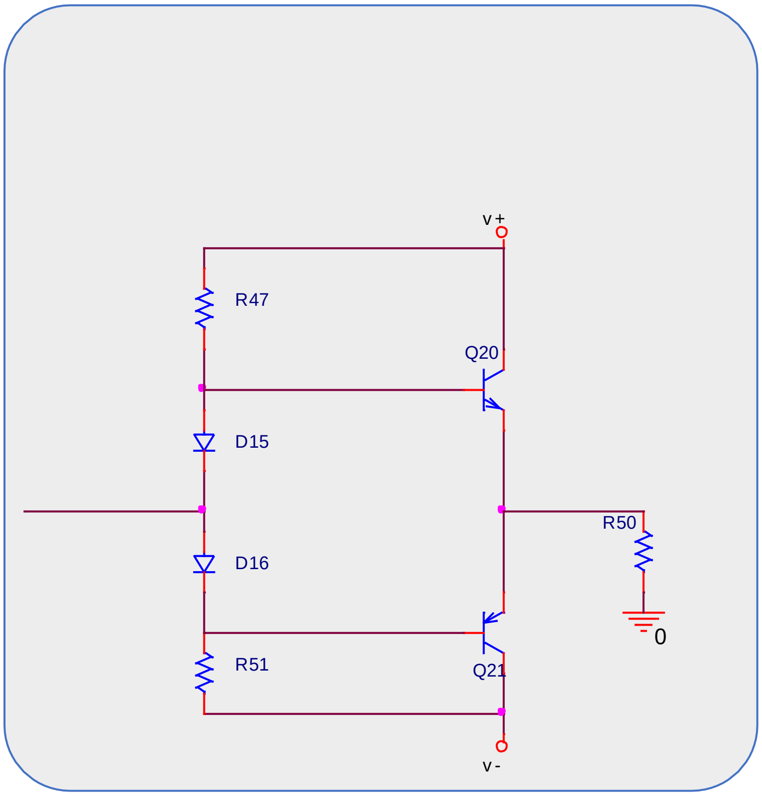


Figure 2.4 Class AB Amplifier

- They are designed to provide the efficiency of the Class B amplifier and the linearity of the Class A amplifier.
- Class AB amplifier can be used to amplify the output signal to a desired level.

III.Complete Circuit Design

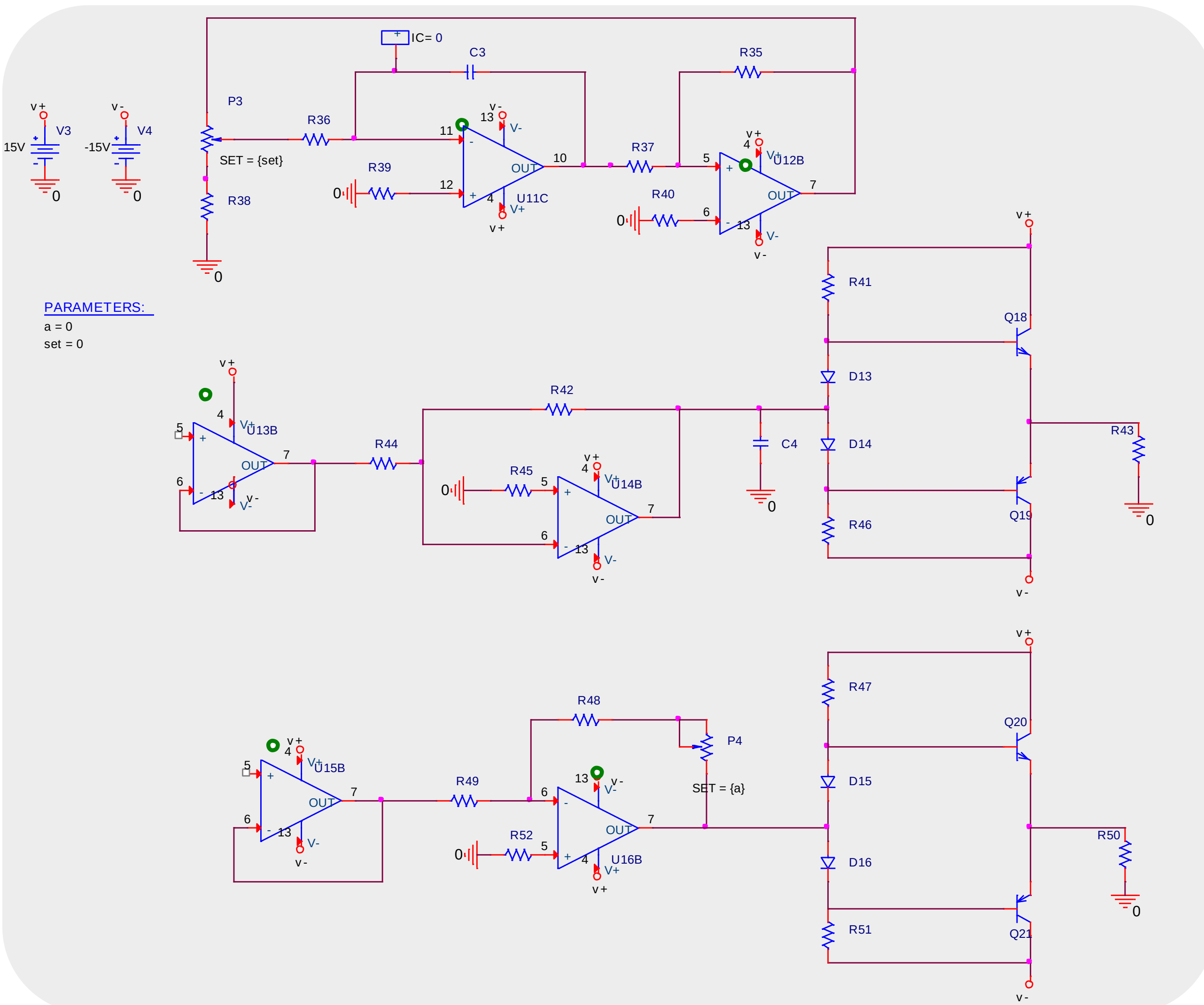


Figure 2.5 Complete Circuit Design

-CALCULUS-

I. Sizing the components for the Rectangular Signal

The calculus is done using VPS=+-13.3V.

We know the frequency bandwidth, so we can calculate the period bandwidth.

$$\begin{cases} T_{min} = \frac{1}{f_{max}} = \frac{1}{9{,}6\text{KHz}} = 0{,}104\text{ms} \\ T_{max} = \frac{1}{f_{max}} = \frac{1}{1.8\text{KHz}} = 0{,}55\text{ms} \end{cases}$$

We will write VPS based on R5, R6 and the desired amplitude of the rectangular signal.

$$V_{PS} = \frac{R5 * V_{drept}}{R6}$$

We will get the following relation:

$$\frac{R5}{R6} = \frac{V_{PS}}{V_{drept}} \rightarrow \frac{R5}{R6} = \frac{13.3}{8} \rightarrow R_5 = 1.6625 * R_6$$

Choosing R6 as 10 kΩ will result into:

$\boxed{R_6 = 5.1\text{k}\Omega}$ => R_5 = 1.66 * 10kΩ = 5,1 kΩ => $\boxed{R_5 = 8.478\ \text{k}\Omega}$

II. Sizing the components to obtain the required frequency adjustment.

The formula used in this case represents $\frac{1}{T}$, where $T = 4 * (R1 + P1K) * C1 * \frac{R3}{R4}$

Resulting:

$$f = \frac{1}{T} = \frac{1}{4 * (R1 + P1K) * C1 * \frac{R3}{R4}}$$

I chose $R_3 = R_4 = 10K\Omega$ and $C_1 = 10$ n.

For K = 0:

f_{max} = 9600Hz. (II)

$$=> R1 = \frac{fmax * 10\text{^}9}{40} = 2{,}604\ k\Omega$$

For K = 1 :

The value of the potentiometer is chosen as 10k, being a common standard value.

$$\begin{cases} f_{min} = 1800Hz. \\ fmin = 4 * R1 * C1 * \frac{R4}{R3} * \frac{R6}{R6+P1} \end{cases}$$

Resulting in R6=2.303 k Ω.

III. The amplitude adjustment for the Triangular Signal between (4V - 6V)

We will impose the negative input resistance R7as 10kΩ.

Using the following formula, $R7 = \frac{V_{PS} * R8}{V_{tri\_min}}$ we will get R8= 3.007k Ω.

The sizing of the potentiometer is done using the following formula. $P2 = \frac{V_{tri\_max} * R7}{V_{PS}} - R8$

We will get the P2= 1,5k Ω which is already a standard value and does not need any further changes.

IV.The circuit design with calculated values

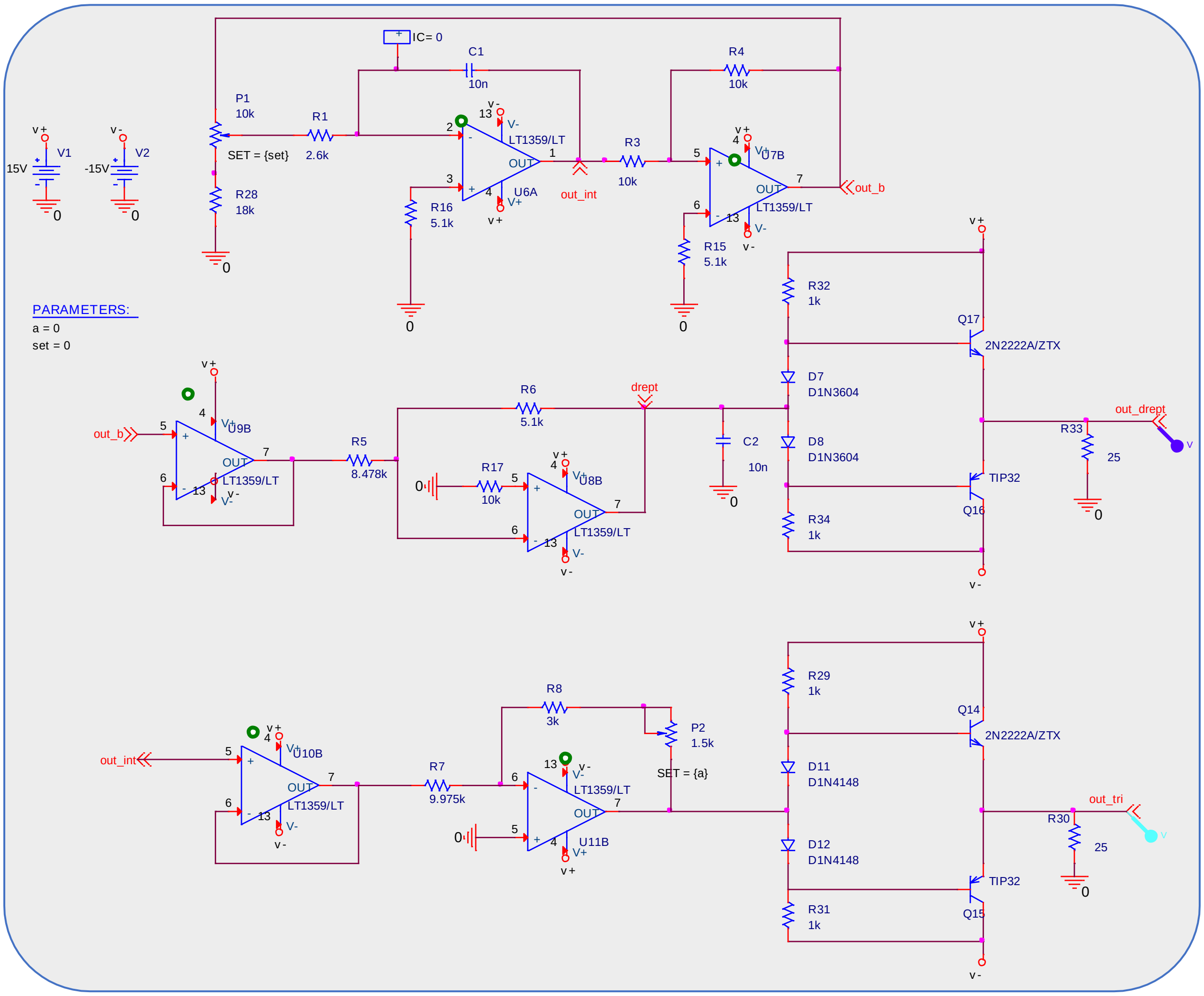


Figure 3.1 Circuit Design with calculated values

	Evaluate	Measurement	1	2
	☑	Max(V(out_drept))	7.81828	7.82128
	☑	Min(V(out_drept))	-7.90117	-7.85074
	☑	Min(V(out_tri))	-3.91353	-3.90575
▶	☑	1/Period_XRange(V(out_tri),1ms,2ms)	9.66247k	1.80093k
	☑	Max(V(out_tri))	3.87475	3.86701

Figure 3.2 Circuit measurements with calculated values

We can see that the calculated values don't exactly match the desired values that being caused by the internal structure of the amplifiers. The values are close to the requirements so recalcaultions are not needed. While choosing standard values for all the components we will chose such as the real values would be as close as possible to the requirements values.

-STANDARDIZATION-

I. The Standardization of the Components

While calculating the values I chose standard values for most of the components resulting in non-standard values only for R5=8.475k kΩ and R7= 9.975 kΩ.

R5 would become 8.3 kΩ and R7 10 kΩ.

We must standardize the values of the resistances and capacitors, so we can add to our circuit existent components. I used E24, E24, E48, E96 RESISTOR SERIES and Standard Capacitor Values Conversion Chart pF - nF - µF.

At the Standardization Step I have added tolerances for all the components respecting the standardization tables from above.

R1 will have a tolerance of 1% because if it was chosen higher than this, it would affect the frequency bandwidth significantly.

R5 will have a tolerance of 2% because if it was chosen higher than this, it would affect the amplitude of the rectangular signal significantly.

I have chosen the LT1359 because of its high-performance attributes, being both high-speed and high precision.

It offers low noise, which ensures better signal integrity. It is designed for a wide range of supply voltages, providing great flexibility, and features low power consumption.

II. The Circuit after Standardization

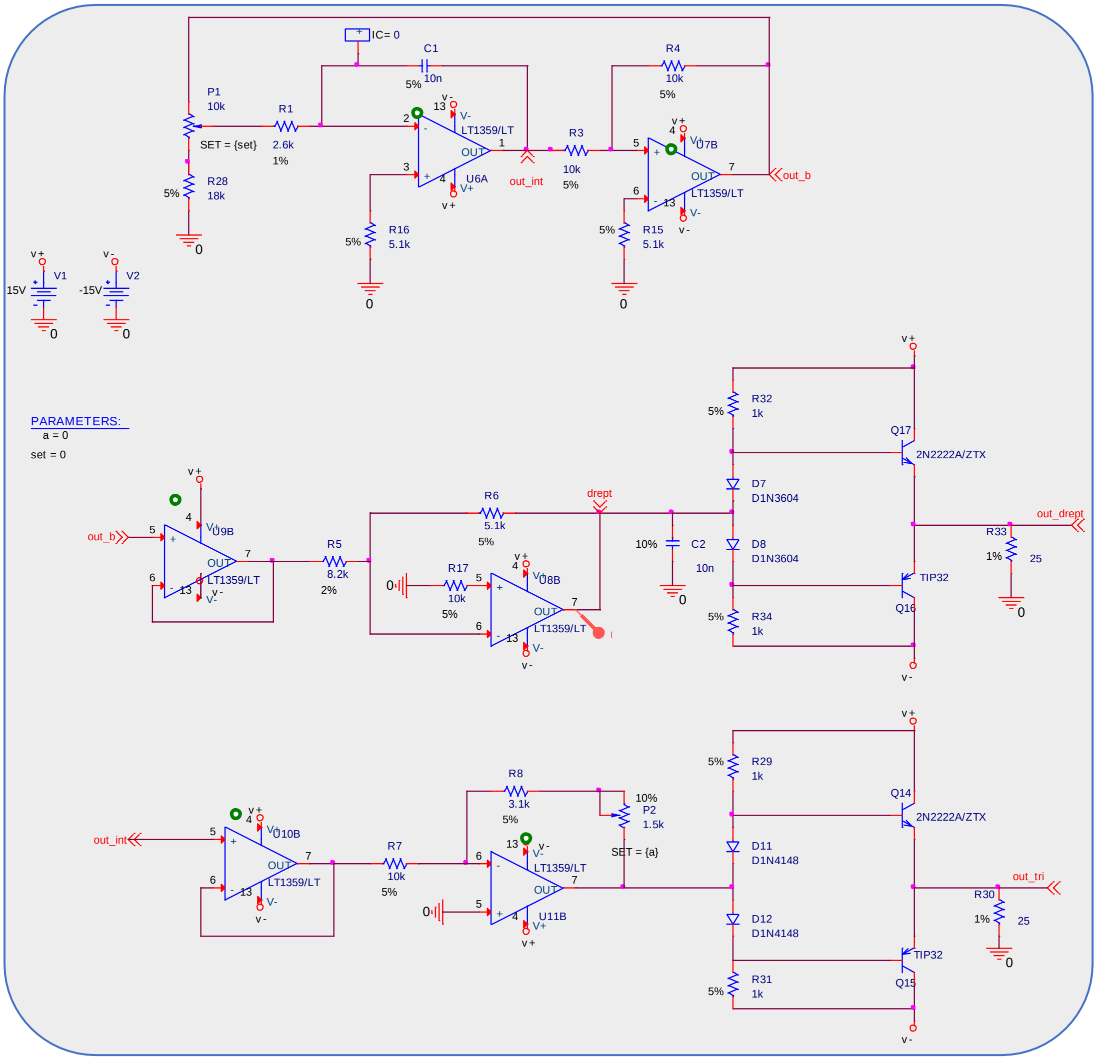


Figure 3.3 Circuit scheme after Standardization

	Evaluate	Measurement	1	2
	☑	Max(V(out_drept))	7.99000	7.98467
	☑	Max(V(out_tri))	5.92298	5.91127
▶	☑	1/Period_XRange(V(out_tri),1ms,2ms)	9.66575k	1.80095k

Figure 3.4 Measurements after standardization

-Bill of Materials-

Manufacturer Part Number	Description	Quantity	Unit Price $
LT1359IN#PBF	IC VOLTAGE FEEDBACK 4 CIRC 14DIP	6	13.8051
RSMF2JT18K0	RES 18K OHM 5% 2W AXIAL	1	0.03333
CF1/4W10KJTB	RES 10K OHM 5% 1/4W AXIAL	4	0.01144
CF1/4W5K1JTB	RES 5.1K OHM 5% 1/4W AXIAL	4	0.01144
CF1/4W8K2JTB	RES 8.2K OHM 5% 1/4W AXIAL	1	0.01144
RM04F2601CT	RES SMD 2.6K OHM 1% 1/16W 0402	1	0.00129
CF1/4W1KJTB	RES 1K OHM 5% 1/4W AXIAL	4	0.01144
1N4148TR	DIODE GEN PURP 100V 200MA DO35	4	0.01195
TIP32	TRANS PNP 40V 3A TO220-3	2	0.17
2N2222	TRANS NPN 30V 0.8A TO18	2	0.5
C1812X103KDRACAUTO	CAP CER 1812 10NF 1000V X7R 10%	2	1.2185
PAC100002509FA1000	RES 25 OHM 1W 1% AXIAL	2	0.23331
RV4NAYSD152A	POT 1.5K OHM 2W CARBON LINEAR	1	15.6248
3590S-8-103L	POT 10K OHM 2W WIREWOUND LINEAR	2	16.0921

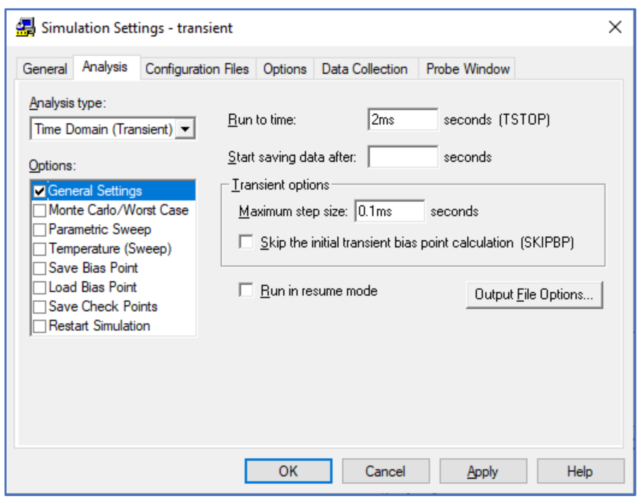
-SIMULATIONS-

- set- global parameter to change the frequency of both signals.
- a - global Parameter to change the amplitude of the triangular signal.

I.Transient Analysis

Using the analysis, we can observe how the circuit behaves in the time domain, considering all nonlinearities of the circuit.

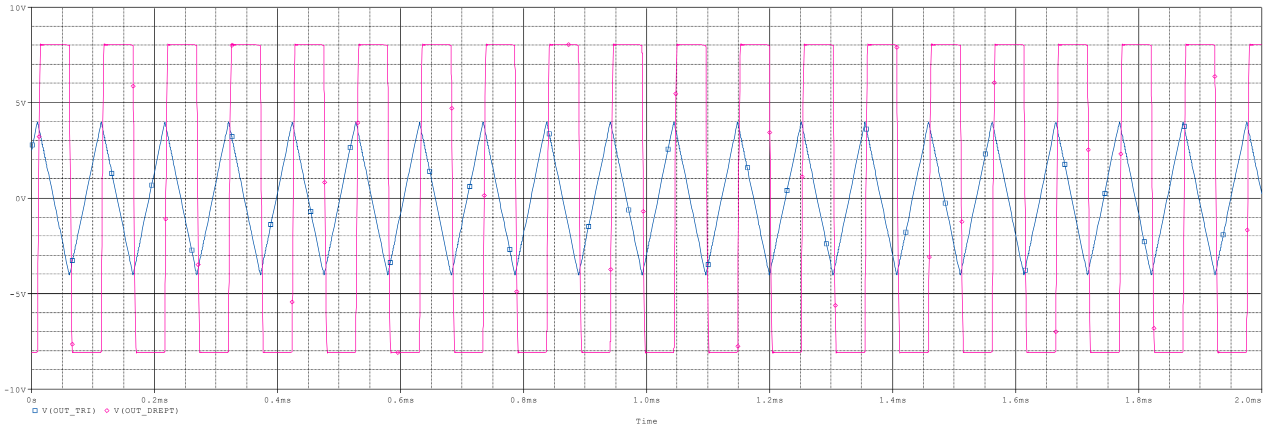
- Simulation profile



- Given the maximum period of 0.55ms, we will choose a runtime of 2ms to allow us to observe the signals for a minimum of three complete periods.
- A step size of 0.1 ms provides a reasonable level of accuracy while still being computationally efficient for a 2 ms simulation. It allows for capturing dynamics that change moderately within the 2 ms time frame.
- These will be valid General Settings for all the following simulations.

❖ Simulation results

➢ For a & set = 0

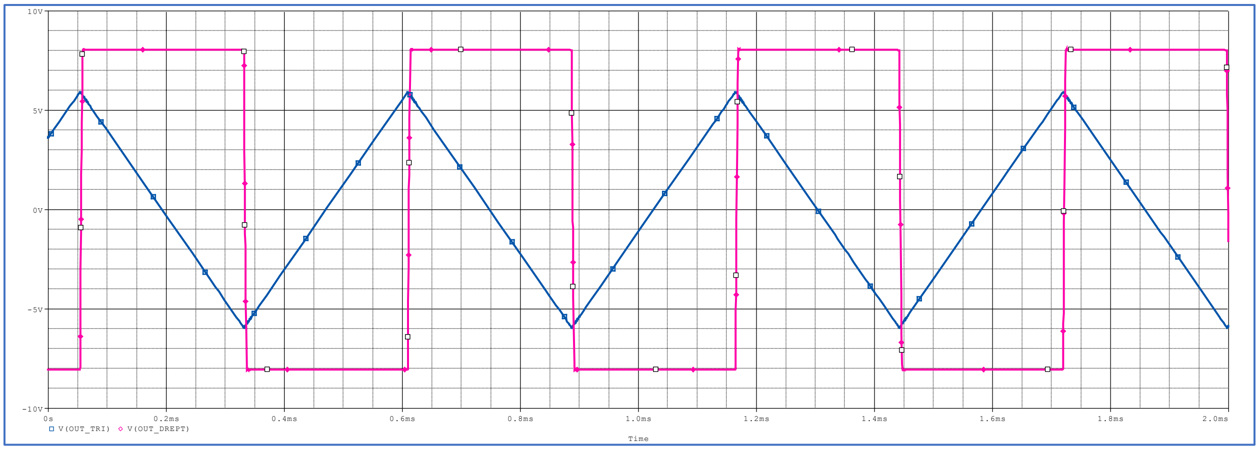


Evaluate	Measurement	Value
☑	Max(V(out_tri))	3.99422
☑	Max(V(out_drept))	8.08117
☑	1/Period(V(out_tri))	9.66411k
☑	1/ Period(V(out_drept))	9.66813k

We can observe that the values do not match the theoretical ones, due to the tolerances of the components, but they are very close; the same thing will happen to the next plots as well.

By setting the parameters to '0' we will get the minimum amplitude of 4V for the triangular signal and the maximum frequency of 9600 Hz for the entire circuit.

➢ For a & set =1



Evaluate	Measurement	Value
☑	Max(V(out_tri))	5.91220
☑	Max(V(out_drept))	8.08166
☑	1/Period(V(out_tri))	1.80086k
☑	1/ Period(V(out_drept))	1.80090k

We can observe that the values still do not match the theoretical ones, due to the tolerances of the components, but they are very close.

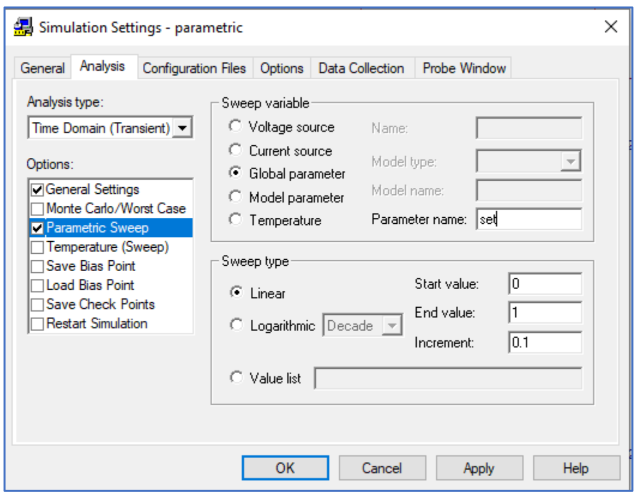
By setting the parameters to '1' we will get the maximum amplitude of 6V for the triangular signal and the minimum frequency of 1800 Hz for the entire circuit.

II.Parametric Analysis

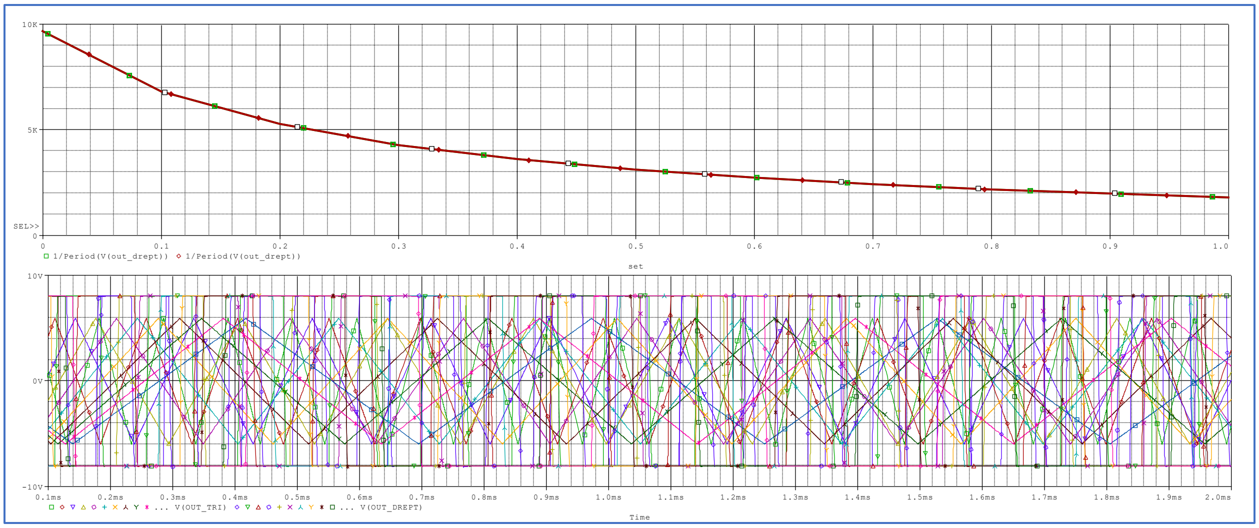
Parametric analysis is used to perform multiple iterations of the same domain analysis while sweeping a global parameter, a simulation model parameter, a component value or the temperature. The effect is the same analysis is run several times, a run for each value of the swept variable.

- Parametric Analysis for the Frequency of the circuit

  To analyze the output signal in the time domain, I chose the transient analysis and utilized a parametric analysis to observe how the signal period varies with different values of the parameter "set".



- I selected a step size of 0.1 due to its ability to provide a satisfactory level of accuracy while keeping the computation time relatively short.



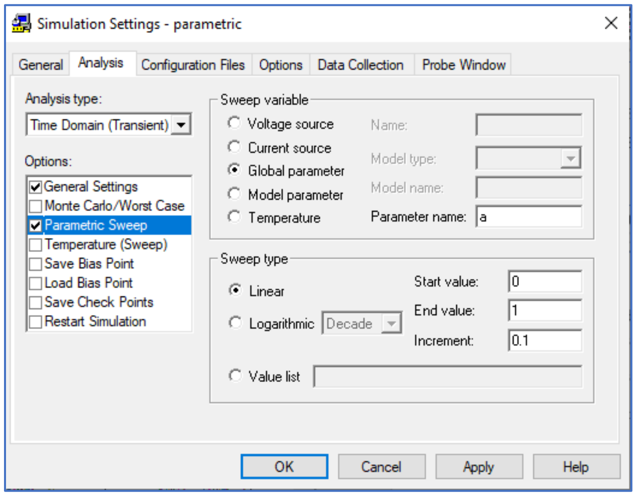
➢ By adding the Performance Analysis, we can observe that the frequency does not vary linearly.

Evaluate	Measurement	1	2	3	4	5	6	7	8	9	10	11
☑	Max(V(out_drept))	8.07394	8.07999	8.07387	8.08394	8.08216	8.06910	8.08470	8.07684	8.07304	8.08263	8.07666
☑	Max(V(out_tri))	5.92370	5.92139	5.91981	5.91815	5.91698	5.91601	5.91490	5.91407	5.91329	5.91259	5.91227
☑	1/Period(V(out_tri))	9.66323k	6.81450k	5.25346k	4.26995k	3.59010k	3.09407k	2.71455k	2.41529k	2.17231k	1.97086k	1.80091k
☑	1/Period(V(out_drept))	9.66446k	6.81504k	5.25464k	4.26962k	3.59031k	3.09376k	2.71457k	2.41513k	2.17233k	1.97101k	1.80090k

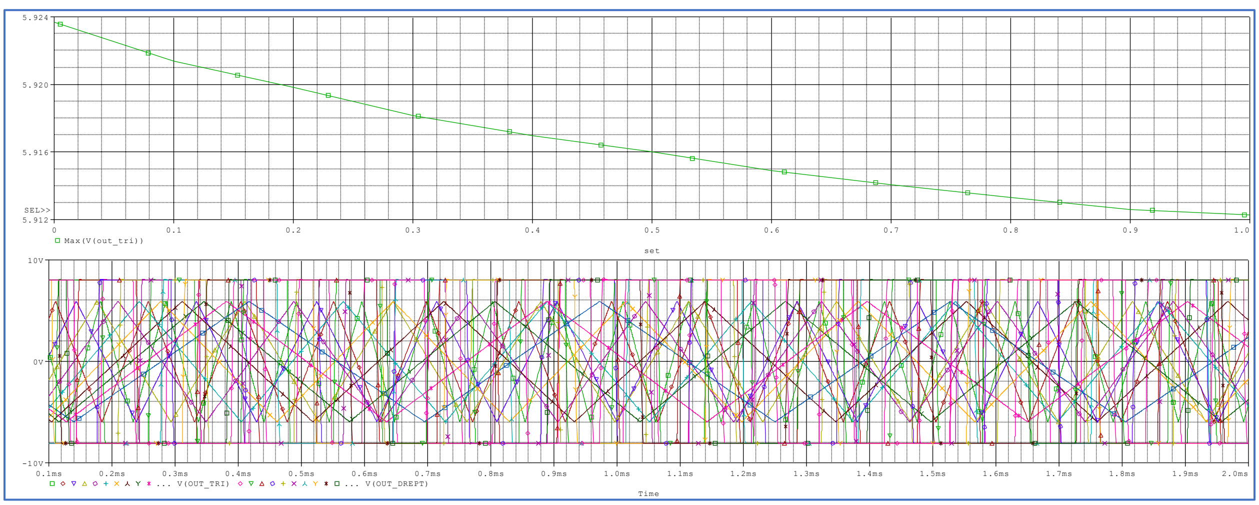
➢ By adding Measurement Evaluations, we can observe how the frequency varies based on the values of the parameter.

➢ We can also observe that both signals keep their amplitude constant for any frequency.

❖ Parametric Analysis for the Amplitude of the Triangular Signal.



➢ I selected a step size of 0.1 due to its ability to provide a satisfactory level of accuracy while keeping the computation time relatively short.



Measurement Results

Evaluate	Measurement	1	2	3	4	5	6	7	8	9	10	11
☑	Max(V(out_drept))	8.07394	8.07999	8.07387	8.08394	8.08216	8.06910	8.08470	8.07684	8.07304	8.08263	8.07666
☑	Max(V(out_tri))	5.92370	5.92139	5.91981	5.91815	5.91698	5.91601	5.91490	5.91407	5.91329	5.91259	5.91227

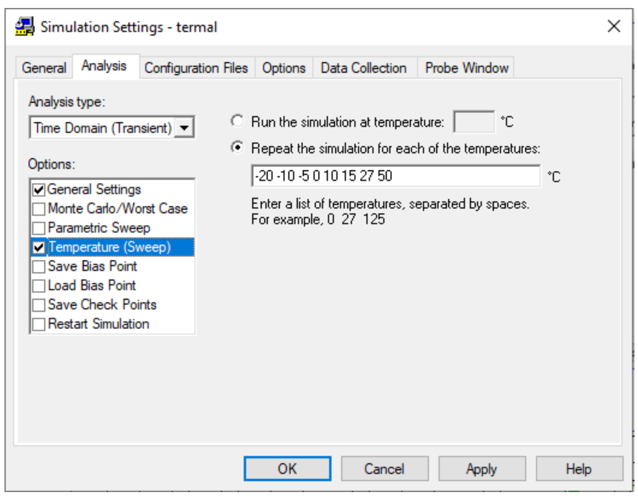
➢ We can observe that the amplitude varies almost linearly with the value of the parameter.

- By adding the Measurement Evaluations, we can observe how the amplitude of the triangular signal varies with the value of the parameter.
- We can also observe that the amplitude of the rectangular signal is constant.

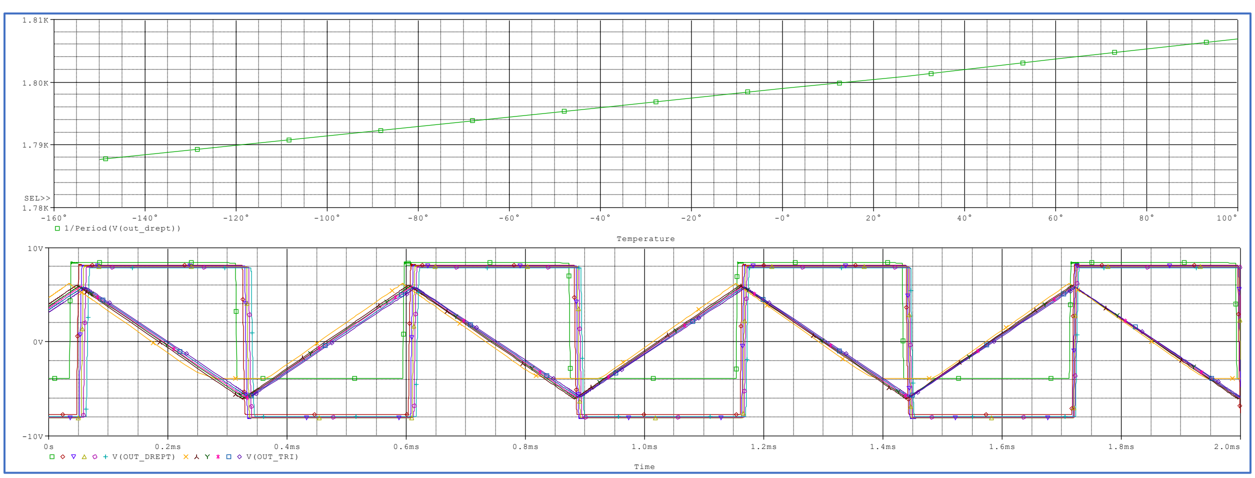
III.Temperature Sweep Analysis

Using this analysis, we can observe how the circuit behaves at different values for the temperature.

- Simulation Profile



- Simulation Results:



	Evaluate	Measurement	1	2	3	4	5	Measuremer 6
▸	☑	Max(V(out_drept))	8.51747	8.26291	8.15193	8.07398	7.98872	7.89205
	☑	Max(V(out_tri))	6.20878	6.02724	5.95980	5.91236	5.85298	5.77942
	☑	1/Period(V(out_drept))	1.78774k	1.79598k	1.79898k	1.80098k	1.80366k	1.80687k
	☑	1/Period(V(out_tri))	1.78785k	1.79587k	1.79908k	1.80105k	1.80352k	1.80687k

- We can observe that the frequency of the circuit will decrease along with the temperature, but it won't increase if the temperature is increasing.
- The amplitude of both signals tends to increase when the temperature decreases and tends to decrease as the temperature decreases.
- The variations are relatively small, so we can conclude that the temperature will not affect the functionality of the circuit.

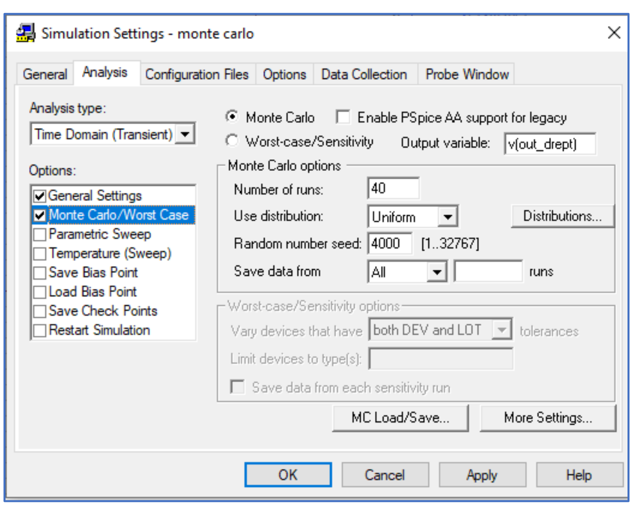
IV.Monte-Carlo Analysis

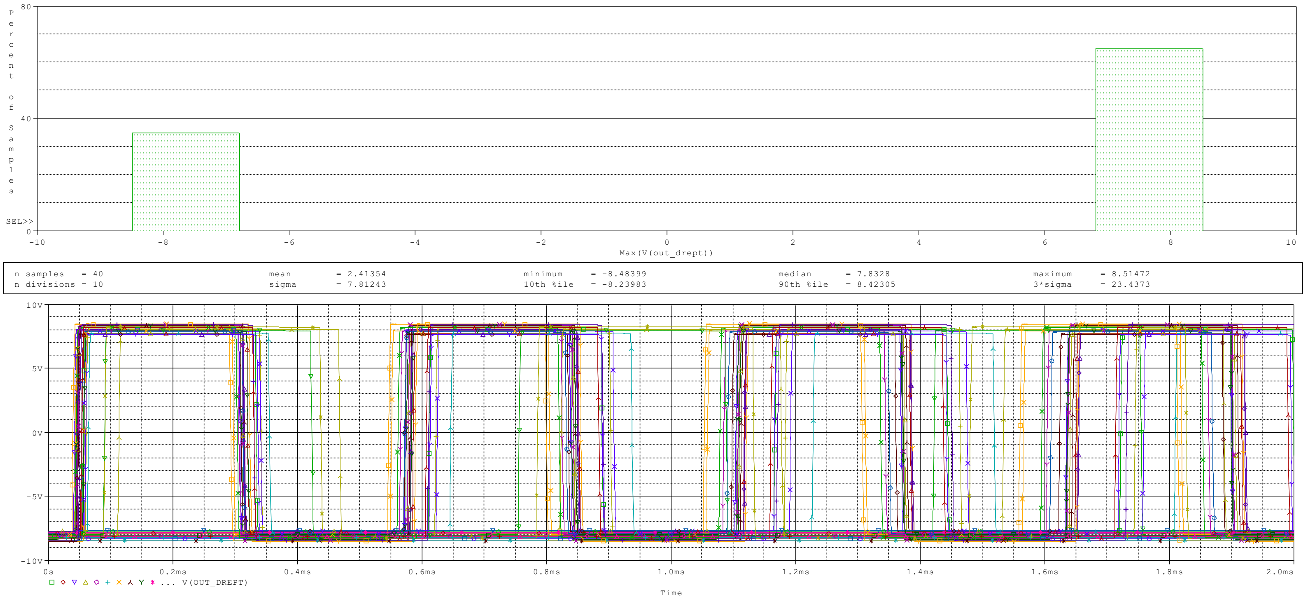
- Monte Carlo predicts the behavior of a circuit statistically when part values are varied within their tolerance range.

1. For Rectangular Signal with set=0.

- Simulation Profile

The Number of runs represents the total number of runs. The first run of the analysis is done at the nominal value of the components. I chose the primary analysis to be Time domain analysis, the distribution is Uniform.

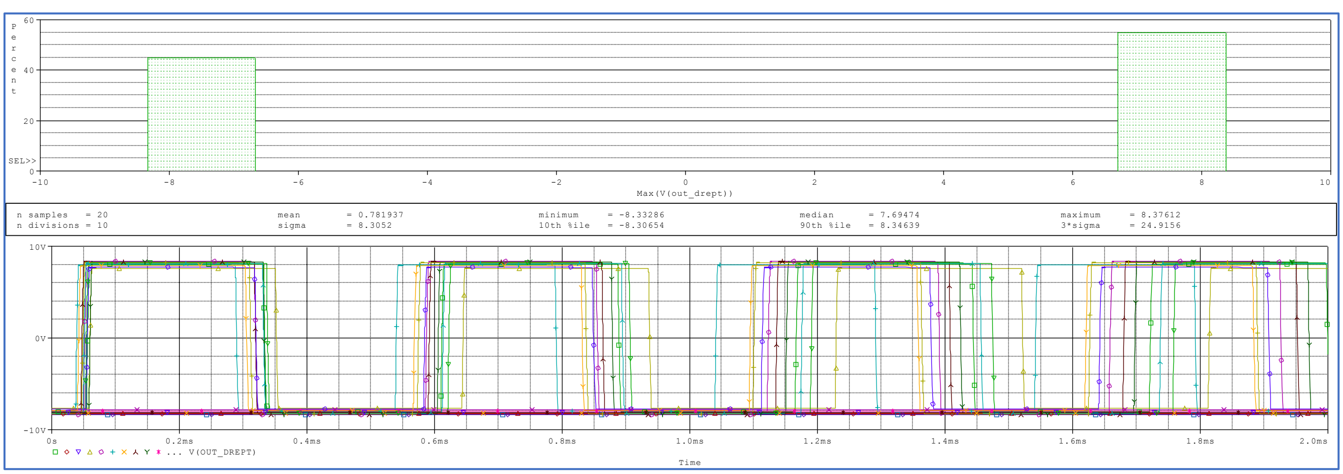




- We can observe the tendency value of the signal to be 35% around 8.4V and 65% around 7.8V.
- This is not always true, because the values are chosen randomly for every run, and they may vary.

2. For Rectangular Signal with set =1

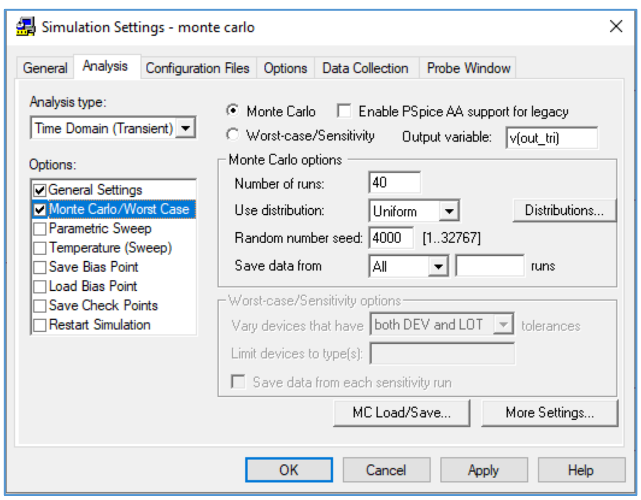
   - The simulation profile will have the same settings as above.



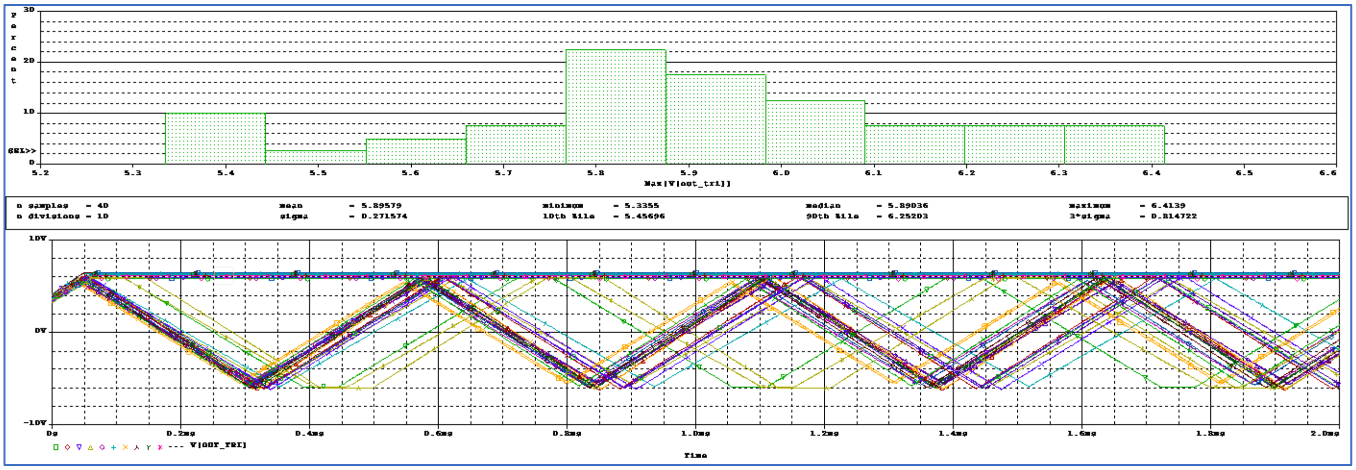
- We can observe the tendency value of the signal to be 45% around 8.4V and 55% around 7.8V.
- This is not always true, because the values are chosen randomly for every run, and they may vary.

3. *For Triangular Signal with set & a = 1.*

- The analysis settings are the same as for the previous one, but the output variable is the triangular signal this time.



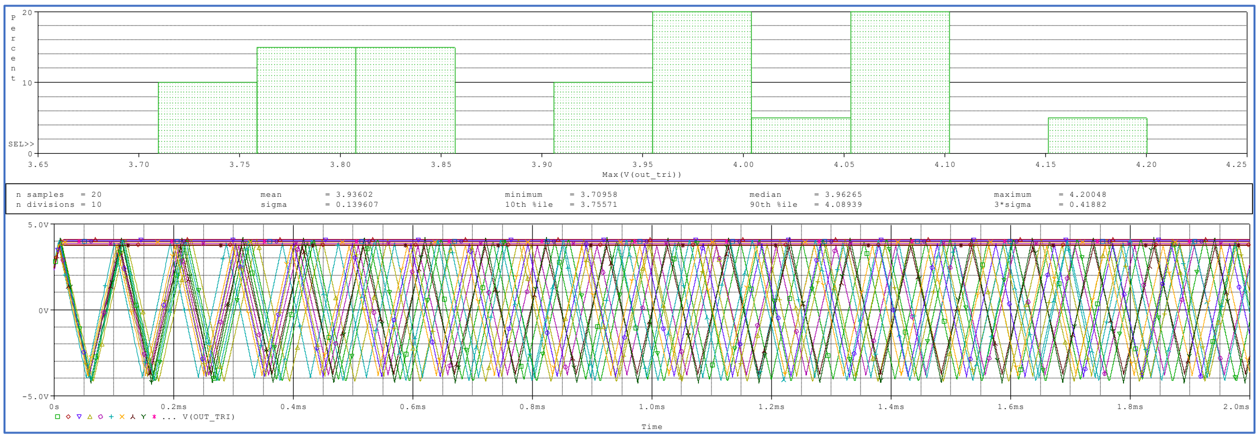
❖ Simulation results



- We can observe that in most cases the output signal tends to be around 5.85V, using cursors we can find that 10% to 20% tends to be around 6.3V and 7.5% to 15% tends to be around 5.5V.
- We can also find some unfavorable cases where the components make the poles of the OP-AMP s to get closer one to another, resulting in instability, therefore the oscillations not being present.

4. *For Triangular Signal with set & a = 0.*

- The simulation profile will have the same settings as above.

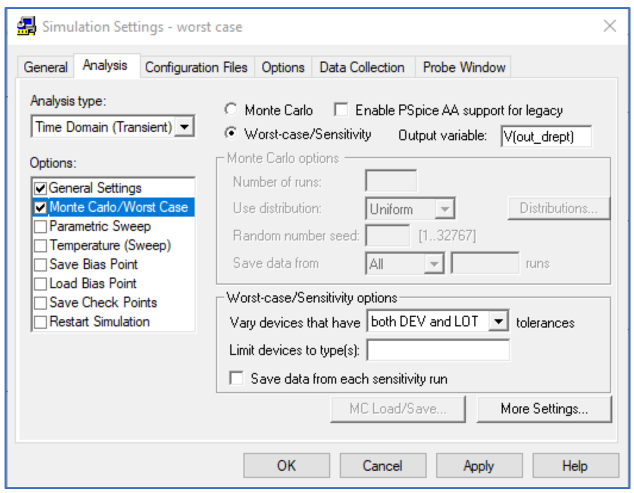


- We can observe that in most cases the output signal tends to be around 4V, using cursors we can find that 10% to 20% tends to be around 3.8V and 7.5% to 20% tends to be around 4.1V.
- We can also find some unfavorable cases where the components make the poles of the OP-AMP s to get closer one to another, resulting in instability, therefore the oscillations not being present.

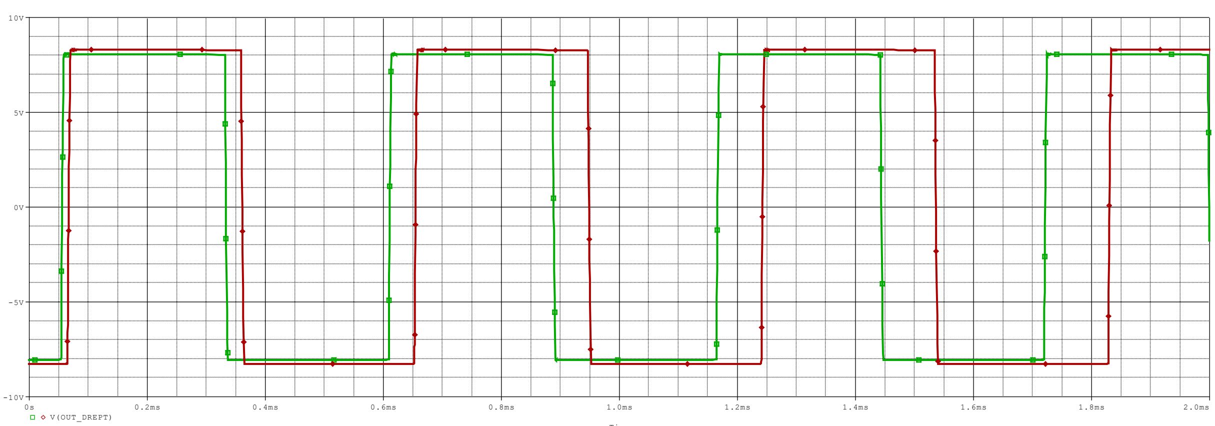
V.Worst Case/Sensitivity Analysis

Sensitivity identifies which parameters are critical to the circuit operation. This analysis determines to what extent each component affects the circuit operation (single action or with other components). In addition, it changes all the values to simulate the worst case.

- For the Rectangular Signal with set=1.
  - Simulation Profile



  - Simulation results



- The green signal is the rectangular signal with nominal standard values.

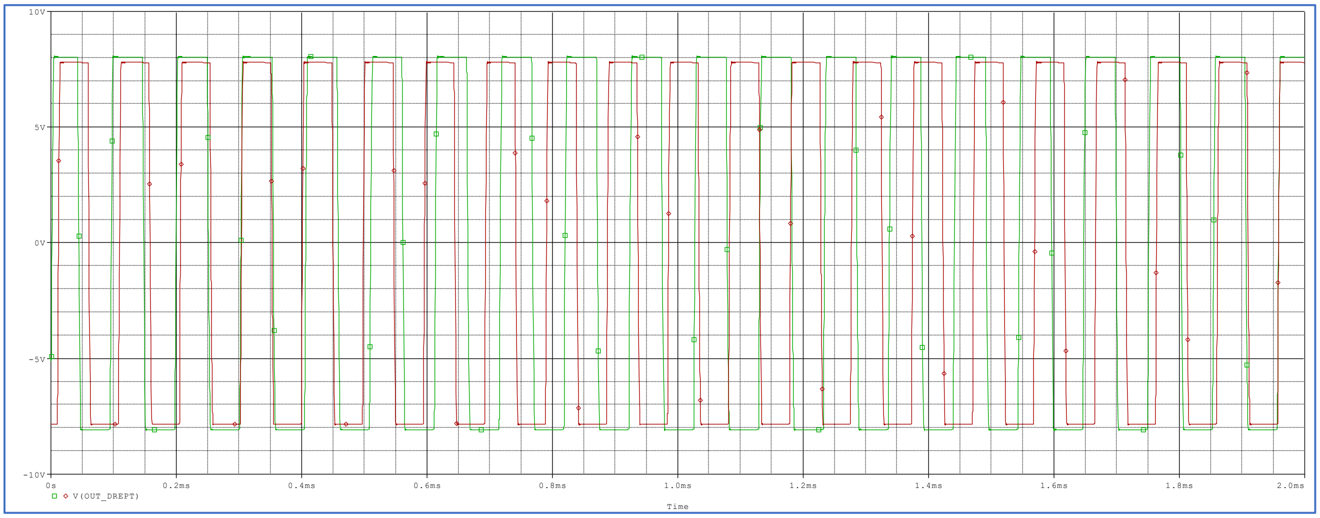
➢ The red signal is the worst-case rectangular signal described by the output file as:

Device	MODEL	PARAMETER	NEW VALUE	
C_C2	C_C2	C	1.1	(Increased)
C_C1	C_C1	C	1.05	(Increased)
R_R34	R_R34	R	1.05	(Increased)
R_R31	R_R31	R	1.05	(Increased)
R_R32	R_R32	R	.95	(Decreased)
R_R5	R_R5	R	1.02	(Increased)
R_R6	R_R6	R	1.05	(Increased)
R_R17	R_R17	R	1.05	(Increased)
R_R8	R_R8	R	1.05	(Increased)
R_R29	R_R29	R	1.05	(Increased)
R_R30	R_R30	R	1.01	(Increased)
R_R1	R_R1	R	1.01	(Increased)
R_R15	R_R15	R	1.05	(Increased)
R_R28	R_R28	R	.95	(Decreased)
R_R3	R_R3	R	.95	(Decreased)
R_R7	R_R7	R	.95	(Decreased)
R_R16	R_R16	R	.95	(Decreased)
R_R4	R_R4	R	.95	(Decreased)
R_R33	R_R33	R	.99	(Decreased)

- For the Rectangular Signal with set=0.

  The Simulation Profile settings will be the same as above.

  - Simulation Results:

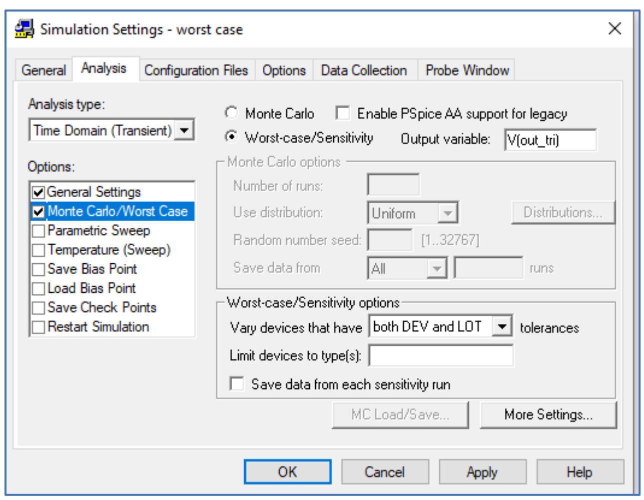


➢ The green signal is the rectangular signal with nominal standard values.

- The red signal is the worst-case rectangular signal described by the output file as:

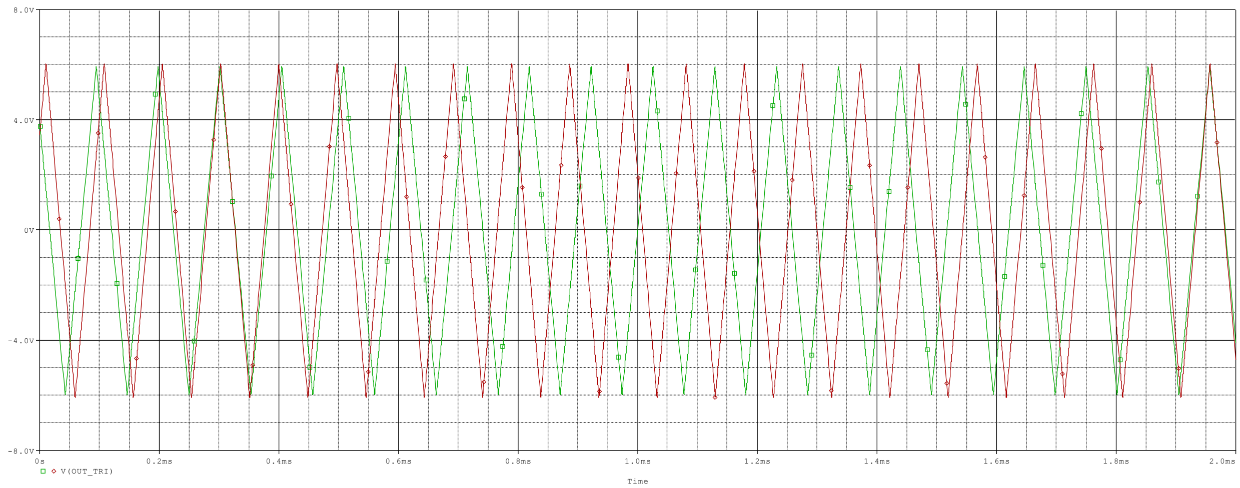
Device	MODEL	PARAMETER	NEW VALUE	
C_C2	C_C2	C	.9	(Decreased)
C_C1	C_C1	C	.95	(Decreased)
R_R34	R_R34	R	.95	(Decreased)
R_R31	R_R31	R	.95	(Decreased)
R_R32	R_R32	R	.95	(Decreased)
R_R5	R_R5	R	.98	(Decreased)
R_R6	R_R6	R	.95	(Decreased)
R_R17	R_R17	R	.95	(Decreased)
R_R8	R_R8	R	.95	(Decreased)
R_R29	R_R29	R	.95	(Decreased)
R_R30	R_R30	R	.99	(Decreased)
R_R1	R_R1	R	.99	(Decreased)
R_R15	R_R15	R	.95	(Decreased)
R_R28	R_R28	R	.95	(Decreased)
R_R3	R_R3	R	.95	(Decreased)
R_R7	R_R7	R	.95	(Decreased)
R_R16	R_R16	R	.95	(Decreased)
R_R4	R_R4	R	.95	(Decreased)
R_R33	R_R33	R	.99	(Decreased)

- For the Triangular Signal with a & set=0.
  - Simulation Profile:



> The Simulation Profile is identical as for the rectangular signal, but the output variable is the triangular signal voltage.

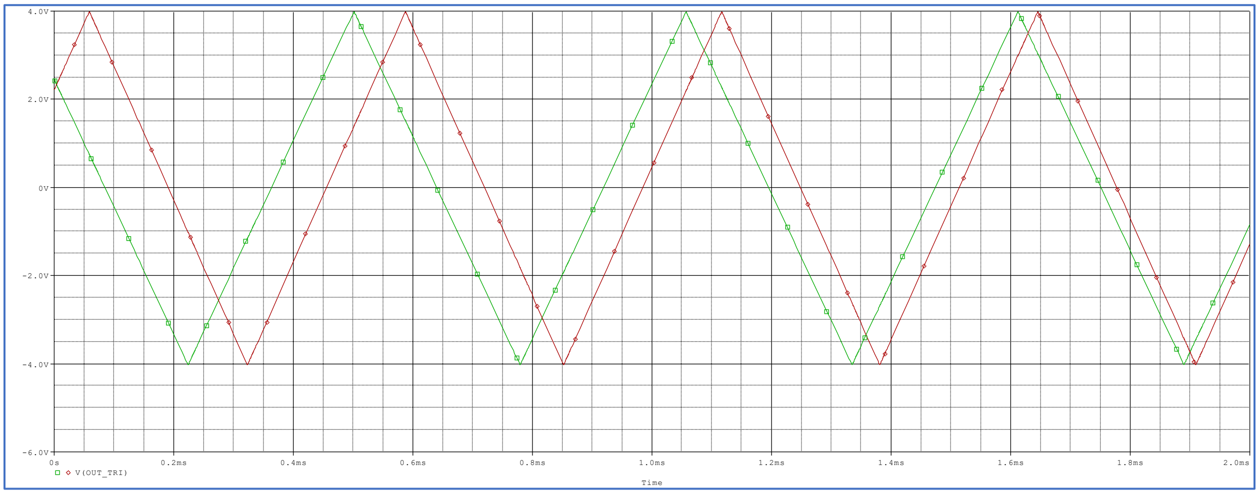
  - Simulation Results:



- The green signal is the triangular signal with nominal standard values.
- The red signal is the worst-case triangular signal described by the output file as:

Device	MODEL	PARAMETER	NEW VALUE	
C_C2	C_C2	C	.9	(Decreased)
C_C1	C_C1	C	.95	(Decreased)
R_R34	R_R34	R	.95	(Decreased)
R_R31	R_R31	R	.95	(Decreased)
R_R32	R_R32	R	.95	(Decreased)
R_R5	R_R5	R	.98	(Decreased)
R_R6	R_R6	R	.95	(Decreased)
R_R17	R_R17	R	.95	(Decreased)
R_R8	R_R8	R	.95	(Decreased)
R_R29	R_R29	R	.95	(Decreased)
R_R30	R_R30	R	.99	(Decreased)
R_R1	R_R1	R	.99	(Decreased)
R_R15	R_R15	R	.95	(Decreased)
R_R28	R_R28	R	.95	(Decreased)
R_R3	R_R3	R	.95	(Decreased)
R_R7	R_R7	R	.95	(Decreased)
R_R16	R_R16	R	.95	(Decreased)
R_R4	R_R4	R	.95	(Decreased)
R_R33	R_R33	R	.99	(Decreased)

- For the Triangular Signal with a & set=1.
  - The Simulation Profile settings will be the same as above.
  - Simulation Results:

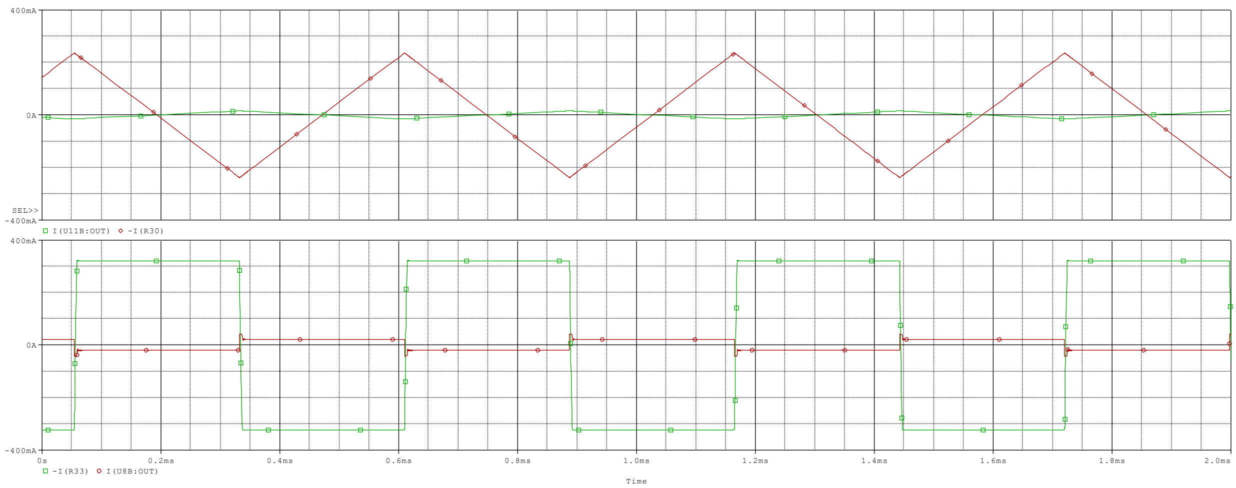


- The green signal is the triangular signal with nominal standard values.
- The red signal is the worst-case triangular signal described by the output file as:

Device	MODEL	PARAMETER	NEW VALUE	
C_C2	C_C2	C	.9	(Decreased)
C_C1	C_C1	C	1.05	(Increased)
R_R34	R_R34	R	1.05	(Increased)
R_R31	R_R31	R	.95	(Decreased)
R_R32	R_R32	R	.95	(Decreased)
R_R5	R_R5	R	.98	(Decreased)
R_R6	R_R6	R	.95	(Decreased)
R_R17	R_R17	R	.95	(Decreased)
R_R8	R_R8	R	.95	(Decreased)
R_R29	R_R29	R	1.05	(Increased)
R_R30	R_R30	R	.99	(Decreased)
R_R1	R_R1	R	1.01	(Increased)
R_R15	R_R15	R	1.05	(Increased)
R_R28	R_R28	R	.95	(Decreased)
R_R3	R_R3	R	1.05	(Increased)
R_R7	R_R7	R	1.05	(Increased)
R_R16	R_R16	R	1.05	(Increased)
R_R4	R_R4	R	1.05	(Increased)
R_R33	R_R33	R	.99	(Decreased)

VI.Transient Analysis – Power Amplifier

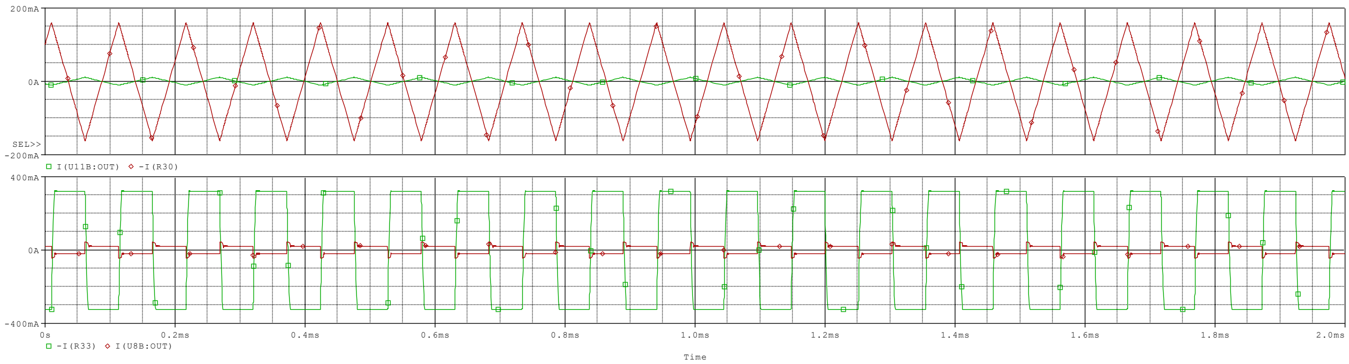
- For set & a = 1
  - The Simulation Profile Settings will be identical to the previous transient analysis.
  - Simulation Results



Evaluate	Measurement	Value
☑	Max(I(R33))	324.15287m
☑	Max(I(U8B:out))	42.32819m
☑	Max(I(R30))/Max(I(U8B:out))	5.63257
☑	Max(I(R30))	238.41633m
☑	Max(I(u11b:out))	16.09551m
☑	Max(I(R30))/Max(I(U11b:out))	14.81260

➢ We can observe the amplifier is working well, multiplying the current for the rectangular signal by 5.6 times, and the current for the triangular signal by 14.8 times.

- For set & a = 0
  - Simulation Profile settings will be identical to the previous ones.
  - Simulation Results:



Evaluate	Measurement	Value
☑	Max(I(R33))	324.30113m
☑	Max(I(U8B:out))	42.32913m
☑	Max(I(R30))/Max(I(U8B:out))	3.81139
☑	Max(I(R30))	161.33287m
☑	Max(I(u11b:out))	11.26982m
☑	Max(I(R30))/Max(I(U11b:out))	14.31547

- We can observe the amplifier is working well, multiplying the current for the rectangular signal by 3.8 times, and the current for the triangular signal by 14.3 times.

CONCLUSIONS

In conclusion, I tried to generate a rectangular signal and a triangular signal, designing a circuit compatible with the requirements received. We simulated according to various analyzes and measured with the help of cursors the results.

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