Function Generator

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Description and functionality of the circuit

Project requirements:

Design a Function generator having the following parameters:

- Frequency : [4000-10000] Hz
- Amplitude Rectangular Signal : [4,7] V
- Amplitude Sinusoidal Signal : 3 V
- Supply Voltage : [-12V 12V]
- Output Resistance : 20 Ohms

Description

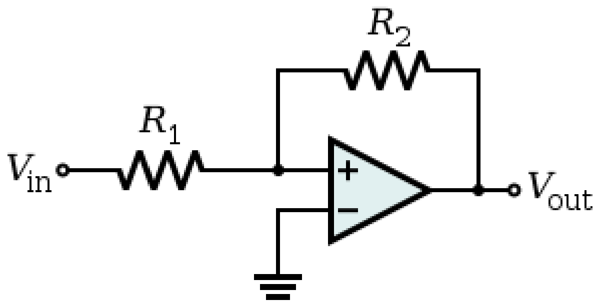
A function generator is a device which produces simple repetitive waveforms. Such devices contain an electronic oscillator, a circuit that is capable of creating a repetitive waveform. (Modern devices may use digital signal processing to synthesize waveforms, followed by a digital to analog converter, or DAC, to produce an analog output). The most common waveform is a sine wave, but sawtooth, step (pulse), square, and triangular waveform oscillators are commonly available as are arbitrary waveform generators (AWGs).

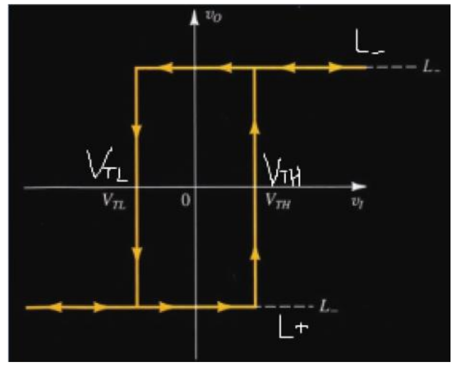
My solution was firslty to implement a rectangular and triangular oscillator by using a cascade connection of an “Integrator” and a Schmitt trigger circuit. The output of the “Integrator” will become the inpot of the triangle to sine converter by using a changeable slope mechanism.

Working principle

Schmitt Trigger:

The Schmitt trigger is essentially a comparator in which the reference voltage is derived from a divided fraction of the output voltage. As in a comparator, the output is forced to either a positive or negative saturation limit whenever the magnitude of VI exceeds that of the reference voltage. Unlike the comparator, the Schmitt trigger ”remembers” its most recent positive or negative output and hold its output voltage even when the input voltage returns to zero.





We can see in figure 1 the Schmitt trigger configuration as well as its transfer characteristic. The important reference voltage is given by:

$$V_{TL} = -L_{+}(\frac{R_1}{R_2})$$

$$V_{TH} = -L_{-}(\frac{R_1}{R_2})$$

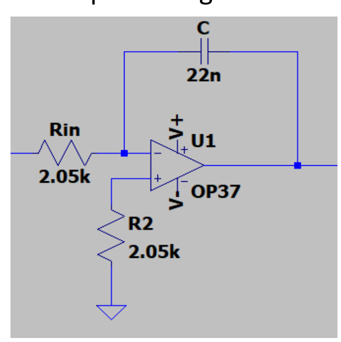
where L− and L+ are the negative and positive saturation voltages of the opamp, respectively.

Integrator:

As its name implies, the Op-amp Integrator is an operational amplifier circuit that performs the mathematical operation of Integration, that is we can cause the output to respond to changes in the input voltage over time as the op-amp integrator produces an output voltage which is proportional to the integral of the input voltage.

In other words the magnitude of the output signal is determined by the length of time a voltage is present at its input as the current through the feedback loop charges or discharges the capacitor as the required negative feedback occurs through the capacitor.

The rate at which the output voltage increases (the rate of change) is determined by the value of the resistor and the capacitor, “RC time constant“. By changing this RC time constant value, either by changing the value of the Capacitor, C or the Resistor, R, the time in which it takes the output voltage to reach saturation can also be changed for example.

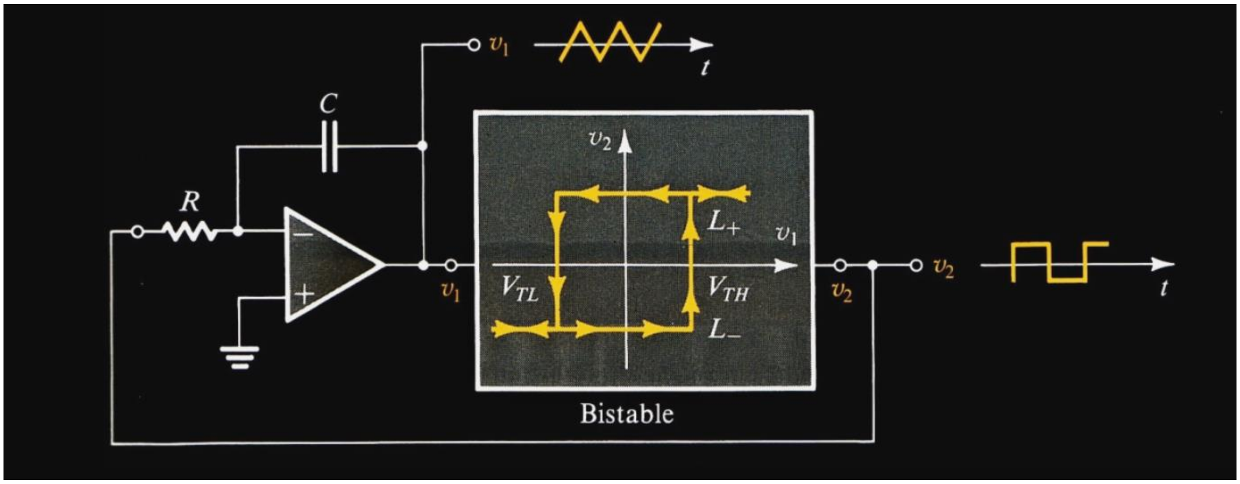


Ideal voltage output for the Op-amp Integrator:

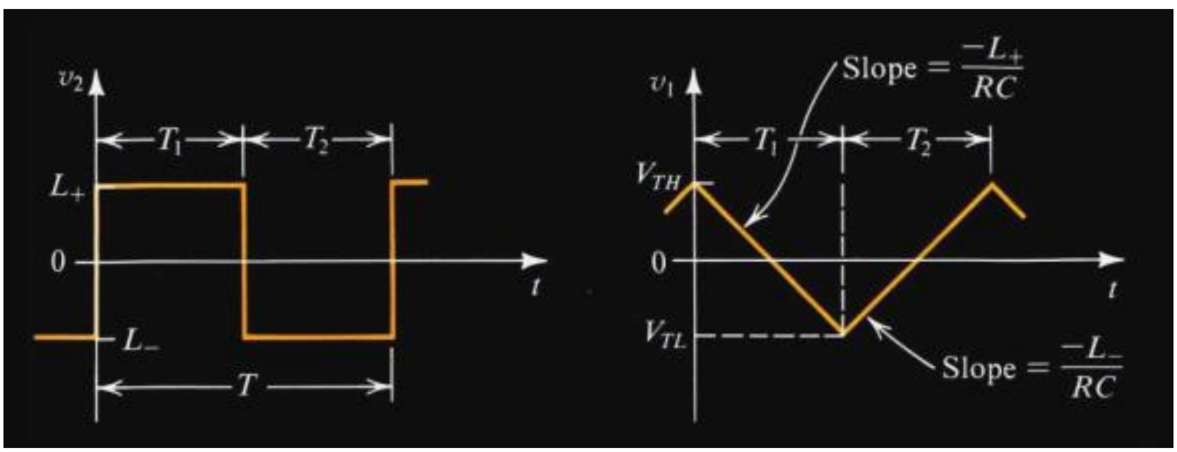
$$V_{out} = -\frac{1}{R_{in}C}\int_0^t V_{in}\,dt = -\int_0^t V_{in}\frac{dt}{R_{in}.C}$$

To simplify the math’s a little, this can also be re-written as: $V_{out} = -\frac{1}{jwRC} * V_{in}$

Cascade Connection



Since the output of the Schmitt trigger will be at either saturation levels V2= L− or V2= L+ , it causes a current flow through R and C. If V2 is at L+ level, the current flow through R and C increases Vc and causes V1 to decrease. As soon as V1 reaches VTL level, the Schmitt trigger toggles its saturation level to V2= L+ . Then the charged capacitor reversely discharges through R and V1 starts to increase. After V1 reaches $V_{TH}$the whole cycle starts again and that yields an oscillation, where V1 has a triangular form and V2 has a square-wave form.



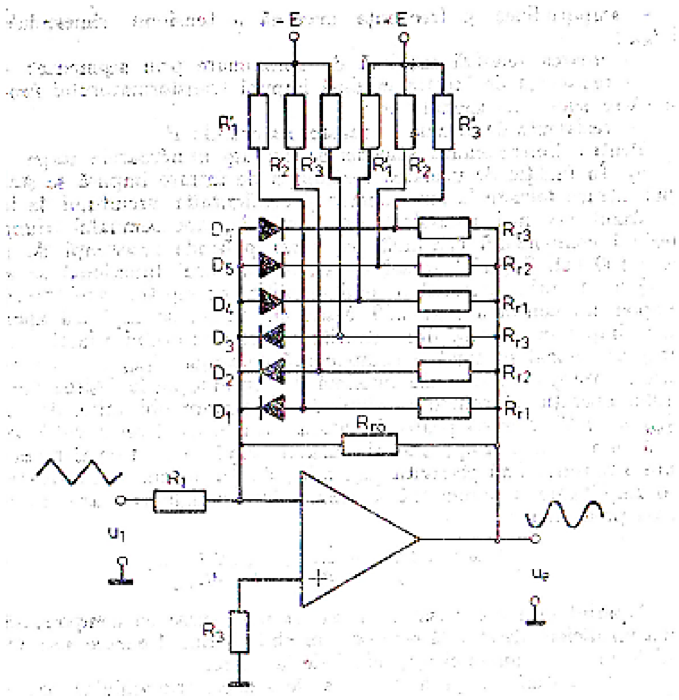
Using $I = C\frac{dv}{dt}$, we can write,

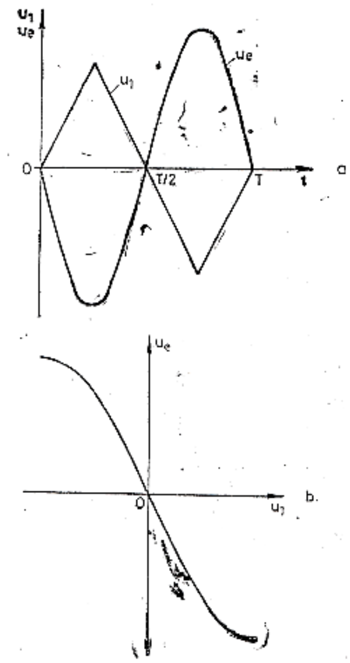
$$\begin{cases} \dfrac{-L_+}{R} = -C\dfrac{V_{TH} - V_{TL}}{T1} \\ \dfrac{-L_-}{R} = -C\dfrac{V_{TH} - V_{TL}}{T2} \end{cases}$$

To obtain a symmetrical square wave, we should have : L+ = - L- = L and T1 = T2 = T/2

Then, we can find: $f = \frac{1}{T} = \frac{1}{4RC} * \frac{R_2}{R_1}$

Triangle to Sine Wave Converter



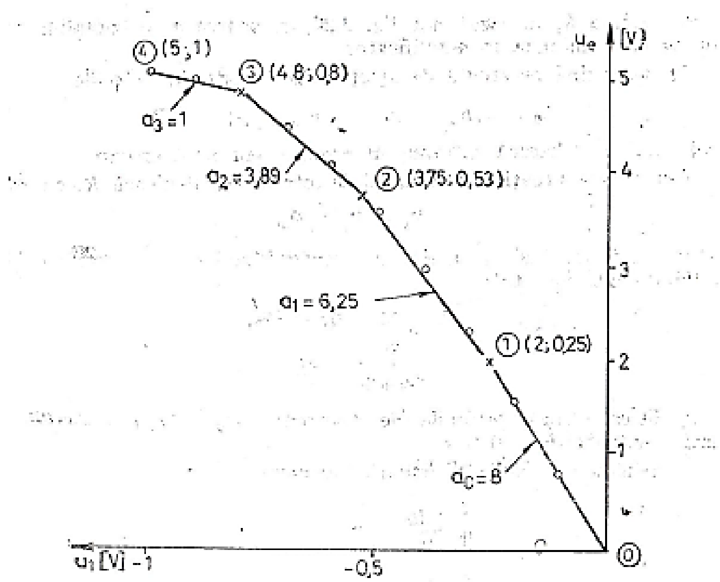


In the figure above, it is presented the functional transformer from sinusoidal signal to triangular signal (u_1), applied at the inverting input. The transfer characteristic is divided in 2 parts. The second quadrant of the transfer function is realised by the diodes D_1, D_2, D_3, whilst the fourth quadrant is realised by the use of diodes D_4, D_5, D_6. Due to symmetry, the resistors of the two networks are identical.

The biggest advantage of this circuit is that it can be used for very low sinusoidal frequencies.

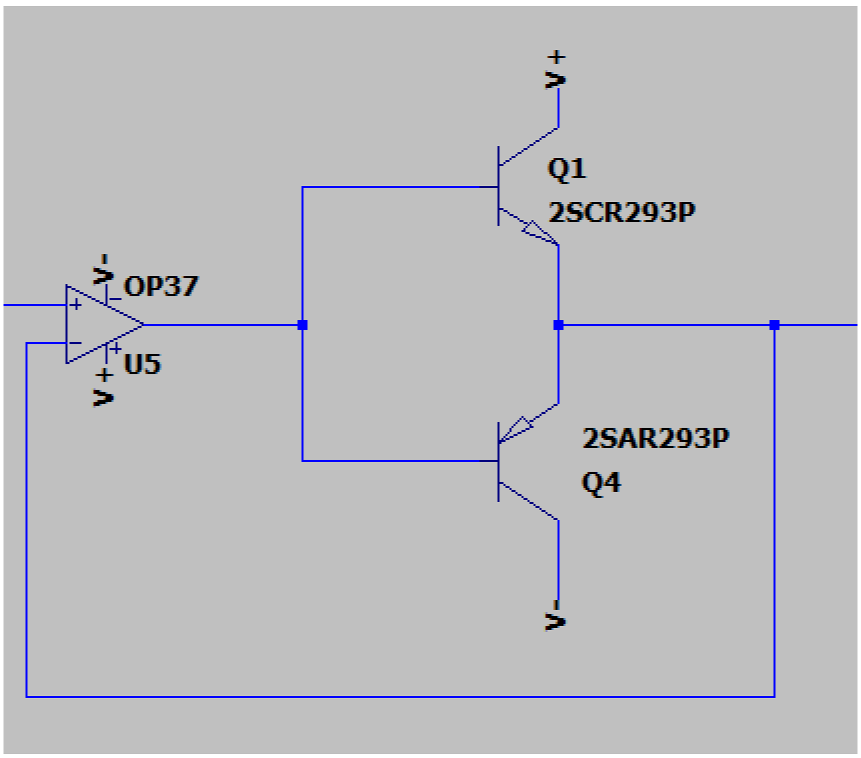
The ideea behind this circuit is that the triangular wave (from 0 to u_{max}) will be sectioned in 4 parts – 3 breaking points generated by the 3 diodes on each network. Each part will be a straight line with a different slope, this way the bending of the triangle wave in a calculated way will generate a sinusoidal wave.

In the graph presented in the right are given the points and the suitable slopes for a sine of 5V and a triangle of 1V amplitude. For different values this transfer characteristic can be transformed proportionally with the given values.

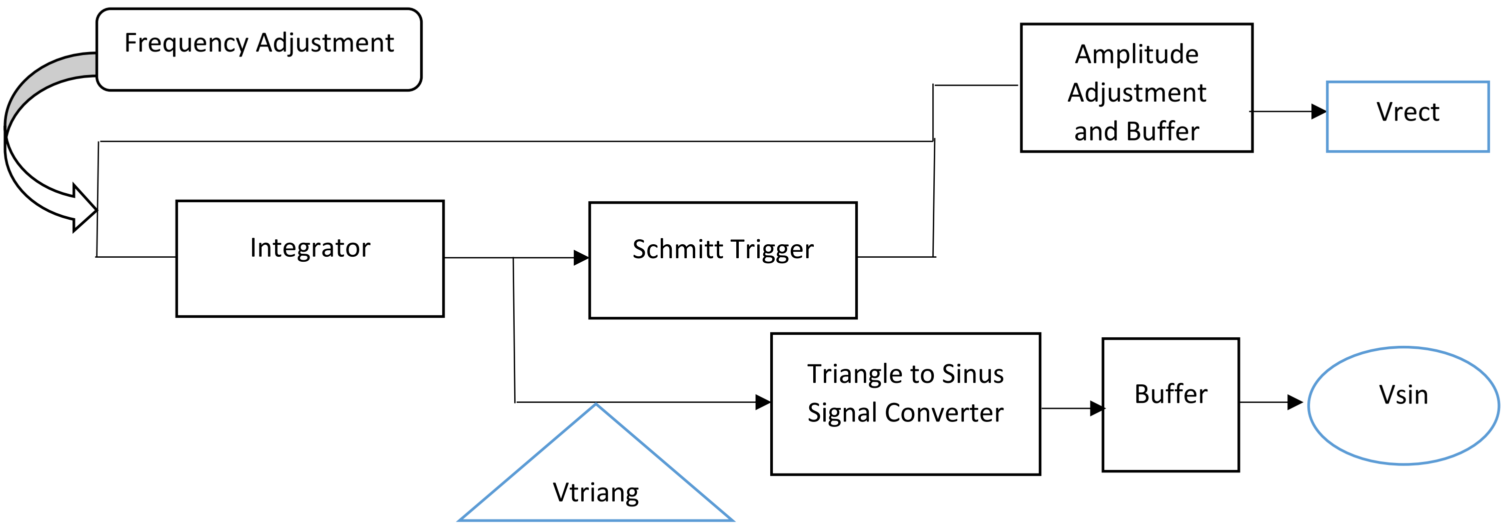


Buffer

For ensuring that for every load that will be connected to the output of the generator, the desired amplitude of the signal will always be obtained (the load doesn't influence the output signal), a class B amplifier and an OpAmp with global negative feedback is used, as this type of amplifier has neglectable distortions. The n-type transistor will be active for the positive alternance of the voltage, while the p-type for the negative alternance. Transistors are used to ensure that at the output any type of impedance can be put, as they will amplify, if necessary, the output current from the OpAmp (max 15mA for this type), in order to ensure the same amplitude of the voltage even for a low impedance without affecting the circuit or the OpAmp.



Block Diagram



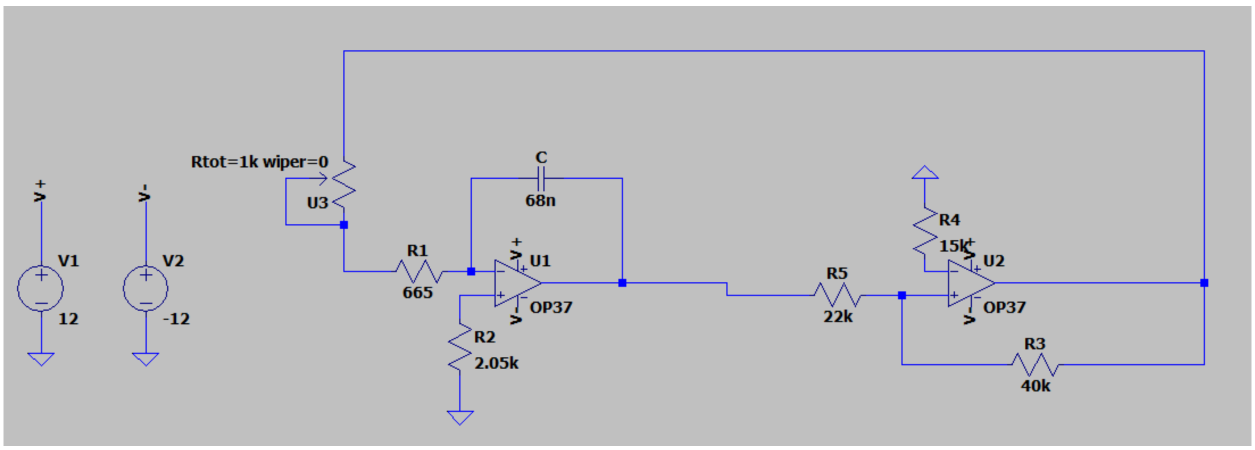
Amplitude Adjustment at the output circuit:

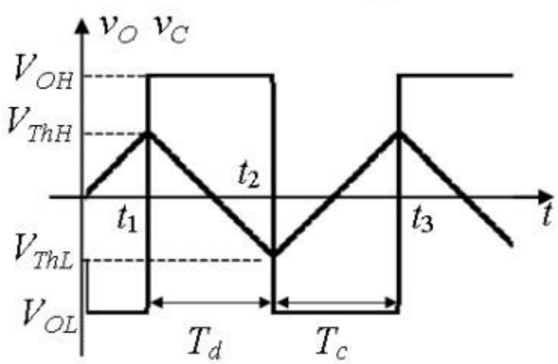
- Add a voltage divider circuit (2 resistors and a potentiometer), to divide the voltage given by the Schmitt Trigger (which is equal to the power supplies - dV)

- Connect the resulted voltage to a class B amplifier with global negative feedback, to ensure that at the output an impedance of any type can be connected without affecting the amplitude of the output voltage or any other components.

Electrical Schematic and theoretically computed nominal values for components

Rectangular and Triangular Oscillator





VPS=12V, -VPS=-12V

From the topology of the circuit, there can be noticed that the capacitor C charges and discharges under a constant current (Ic = +/- VPS/R due to virtual ground at the inverting input of U1 due to the negative feedback and the non-inverting input connection to ground), so that the voltage on it will have a triangular shape -> triangular signal generator. (R2 and R4 have the role to balance the input of the opamps; it is not good to connect them directly to ground).

Typically, C is in nF and R1, R3, R5 in kΩ

I chose the amplitude of the triangular signal to be 6V. We observe that Voh and Vol are equal to 11V.

$V_{TL} = -V_{OH}(\frac{R_5}{R_3})$

$V_{TH} = -V_{OL}(\frac{R_5}{R_3})$

$\Rightarrow$ R5/R3 = 6/11 $\Rightarrow$ I chose R5= 22k and R3 = 40k

due to cheaper resistances with 1% tolerance at this values

Frequency Adjustment

$$f = \frac{1}{T} = \frac{1}{4RC} * \frac{R_3}{R_5}$$

Choose C=68nF

First case : f=4000Hz $\Rightarrow$ R = 1.67k

Second case : f=10000Hz $\Rightarrow$ R = 0.668k

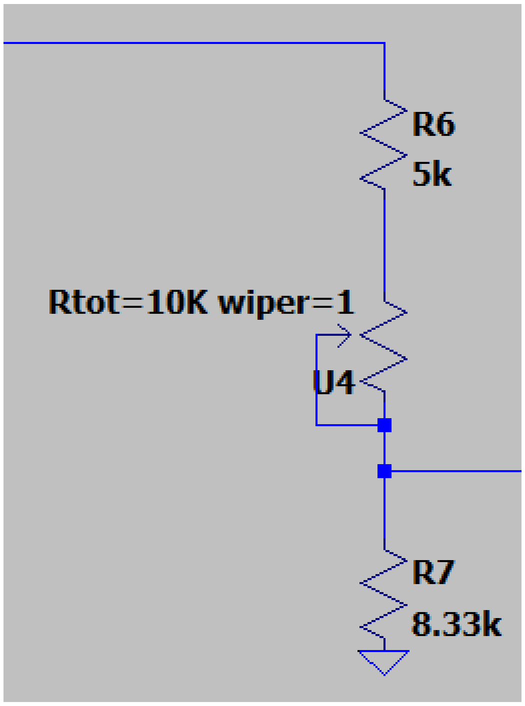
$\Rightarrow$ R1 = 0.668k and we use a potetiometer to vary the frequency between 4000-10000 Hz.

Rtot = 1k

R2 = 4k (for stability)

R4 = R3 || R5 = 15k

Amplitude Adjustment (Rectangular Signal)



| Voh | = | Vol | = 11 V

We need the amplitude of the rectangular signal to be between 4 and 7 V.

So we need a voltage divider with a potentiometer in order to have free range between these values.

$$Vrect = \frac{R_7}{R7+R_x} * Voh$$

Choose Rtot = 10k $\Longrightarrow$ Rx' – Rx = 10k

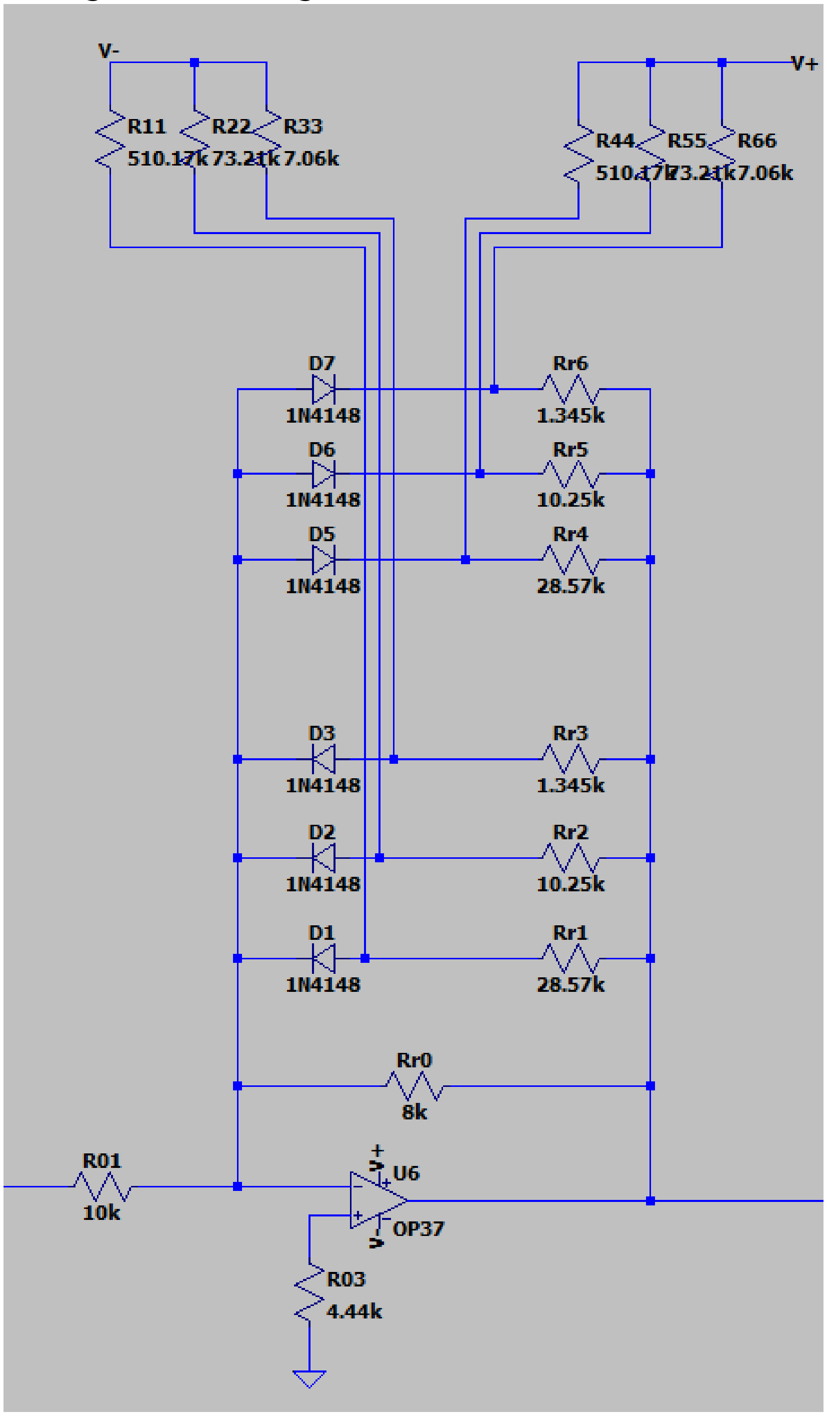
First case : Vrect = 7V $\Longrightarrow$ 7 * Rx = 4*R7 $\Longrightarrow$ 40 – 3* Rx =3*R7

Second case : Vrect = 4V $\Longrightarrow$ 4 * Rx' = 7 * R7

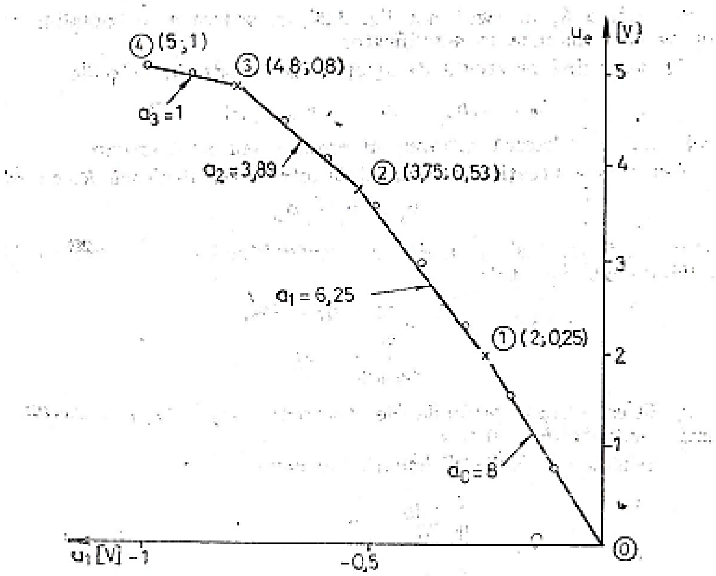
Choose Rx=5k $\Longrightarrow$ 3*R7 = 25 $\Longrightarrow$ R7=8.33k

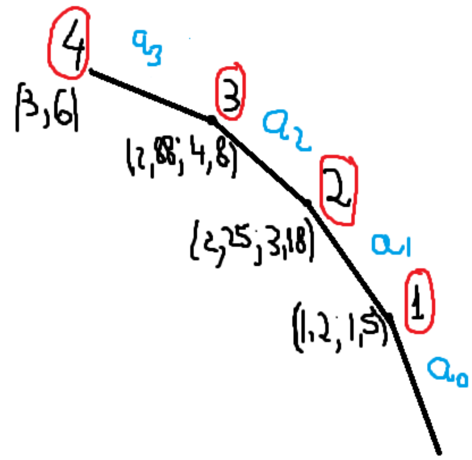
R6 = Rx = 5k

Triangle to Sinus Signal Converter



In the graph below are given the points and the suitable slopes for a sine of 5V and a triangle of 1V amplitude. We need a sine of Us = 3 V amplitude and a triangle of Ut = 6V amplitude.





Horizontal factor of $\frac{Us}{5} = \frac{3}{5} = 0.6$

Point 1 : Ue1 = 0.6 *2 = 1.2V

Point 2 : Ue2 = 0.6*3.75 = 2.25V

Point 3 : Ue3 = 0.6*4.8 = 2.88V

Point 4 : Ue4 = 0.6 *5 = 3V

Verical factor of $\frac{Ut}{1} = 6$

Point 1 : 6*0.25 = 1.5V

Point 2 : 6*0.53 = 3.18V

Point 3 : 6*0.8 = 4.8V

Point 4 : 6*1 = 6V

a_0 = 1.2/1.5 = 0.8

$a_1 = \frac{2.25-1.2}{3.18-1.5} = \frac{1.05}{1.68} = 0.625$

$a_2 = \frac{2.88-2.25}{4.8-3.18} = \frac{0.63}{1.62} = 0.389$

$a_3 = \frac{3-2.88}{6-4.8} = \frac{0.12}{1.2} = 0.1$

R_{01}=10k $\Longrightarrow$ $R_{r0} = a_0 * R_{01} = 0.8 * 10k = 8k$

$R_{03} = R_{01}||R_{r0} = 4.44k$

$U_D = 0.5\ V$ (Vth of the diode)

$$\begin{cases} R_{ech1} = a_1 * R_{01} \\ \frac{U_{e1}-U_D}{E+U_D} = \frac{R_{r1}}{R_{11}} \end{cases} \Longrightarrow \begin{cases} \frac{8*R_{r1}}{8+R_{r1}} = 0.625 * 10 \\ \frac{1.2-0.5}{12+0.5} = \frac{R_{r1}}{R_{11}} \end{cases} \Longrightarrow \begin{cases} R_{r1} = 28.57k \\ R_{11} = 510.17k \end{cases}$$

$$R_{ech1} = \frac{R_{r0}*R_{r1}}{R_{r0}+R_{r1}} = \frac{8*R_{r1}}{8+R_{r1}} = 6.25k$$

$$\begin{cases} R_{ech2} = a_2 * R_{01} \\ \frac{U_{e2}-U_D}{E+U_D} = \frac{R_{r2}}{R_{22}} \end{cases} \Longrightarrow \begin{cases} \frac{6.25*R_{r1}}{6.25+R_{r1}} = 0.389 * 10 \\ \frac{2.25-0.5}{12+0.5} = \frac{R_{r2}}{R_{22}} \end{cases} \Longrightarrow \begin{cases} R_{r2} = 10.25k \\ R_{22} = 73.21k \end{cases}$$

$$R_{ech2} = \frac{R_{rech1}*R_{r2}}{R_{rech1}+R_{r2}} = \frac{6.25*R_{r1}}{6.25+R_{r1}} = 3.89k$$

$$\begin{cases} R_{ech3} = a_3 * R_{01} \\ \frac{U_{e3}-U_D}{E+U_D} = \frac{R_{r3}}{R_{33}} \end{cases} \Longrightarrow \begin{cases} \frac{3.89*R_{r3}}{3.89+R_{r3}} = 0.1 * 10 \\ \frac{2.88-0.5}{12+0.5} = \frac{R_{r3}}{R_{33}} \end{cases} \Longrightarrow \begin{cases} R_{r3} = 1.345k \\ R_{33} = 7.06k \end{cases}$$

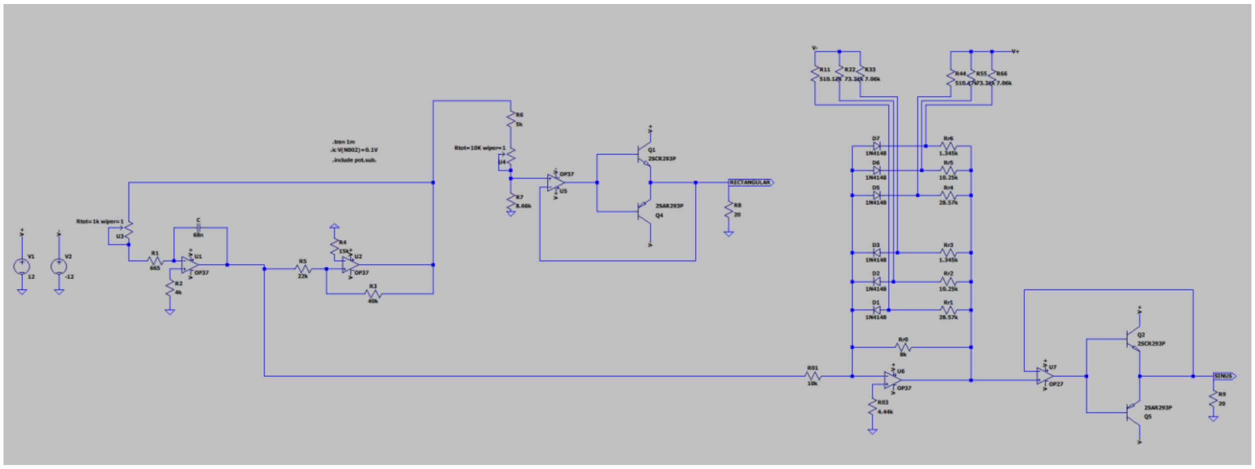
$$R_{ech3} = \frac{R_{rech2}*R_{r3}}{R_{rech2}+R_{r3}} = \frac{3.89*R_{r3}}{3.89+R_{r3}} = 1k$$

Conditions for OpAmp and Supply:

Vps > Us + 2…3V = 5…6 V - TRUE

SR = 17 * 10^6 V/s > 8*PI*$U_s * f_{max} = 8 * 3.1415 * 3 * 10^4 = 0.75 * 10^6\ V/s$ - TRUE

Schematic with theoretically computed values



Choosing standard components

Op Amps

The type of OpAmps, that is used in the circuit are 4 * OP37GSZ and one OP27GSZ.

OP37GSZ

The slew rate is relatively high (17V/us) compared to the common value of 10V/us, and it stabilizes the output voltage in a short time as a response to a sudden change in the input voltage (as it is the case here, when the voltage switches from a low value to a high value, transition that needs to happen in a short time). Also, it is suitable to be used in the triangular signal generator, as the triangular signal has a slope of 177 mV/us. The bandwidth (5-8 MHz) is also suitable for this circuit, as the frequencies of the rectangular, as well as that of the sinusoidal signal, are between 4 -10 kHz. Also, it is a low power amplifier, so it provides a very high accuracy and a very low power consumption, suitable for using in power amplifier circuits, as well as in signal generator circuits, because of its precision.

OP27GSZ

It is more expesive than the previos one but it is needed as buffer for the sinusoidal waveform in order to maintain its continuity, especially around the 0 value. A gain bandwidth product of 8 MHz and a 2.8 V/µs slew rate provide excellent dynamic accuracy in high speed, data-acquisition systems.

Passive components diodes and transistors

Start with the most difficult to find component, the capacitor.

- The capacitor chosen of 68nF is perfectly viable for the circuit since it is easy to find. The capacitor C1206C683J1RECTU has a tolerance of 5%. The capacitor chosen as It also has a good voltage rating for this circuit.

- The resistances

The resistance from the triangular and rectangular oscillator have values that are easy to find in reality.

R1=665 Ohms

R2 = 4.02k(theoretically 4k)

R3 = 40k

R4 = 15k

R5 = 22k

Rtot = U3 = 1k (Potentiometer)

The resistance from the amplitude adjustment have values that are easy to find in reality, except R7.

R7 = 8.66k (theoretically 8.33k)

Rtot = U4 = 10k (Potentiometer)

R6 = 5k

R01 = 10k

Rr0 = 8k

Rr1 = Rr4 = 28.7k (theoretically 28.57k)

Rr2 = Rr5 = 10.2k (theoretically 10.25k)

Rr4 = Rr6 = 1.33k (theoretically 1.345k)

R11 = R44 = 510k (theoretically 510.17k)

R22 = R55 = 73.2k (theoretically 73.21k)

R33 = R66 = 7.06k

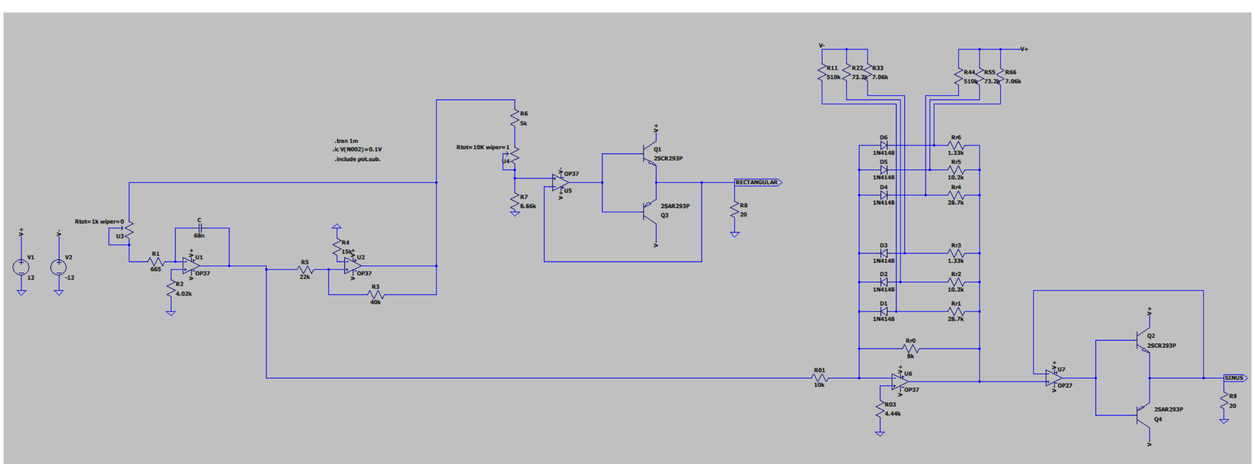
Transistors

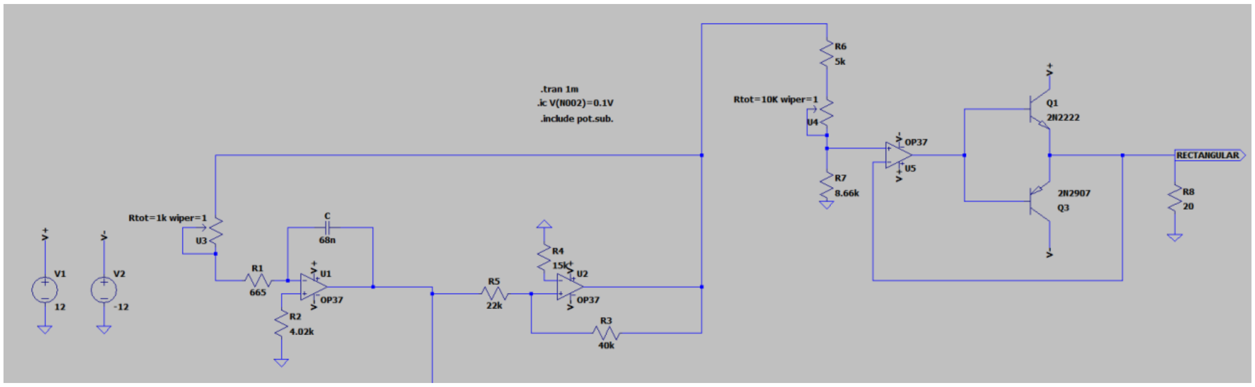
For the transistors that compose the class B amplifier, for the n-type transistor a BJT 2N2222 is chosen because it has a maximum collector current 0.6 A and a DC current gain of 100. The high collector current ensures the possibility to put low impedances at the output of the signal generator, keeping the amplitude of the voltage at the desired level (provides the necessary current through the impedance without affecting the rest of the circuit and by amplifying the output current of the opamp). It has a threshold voltage of 0.65V, so a normal value for this parameter, keeping a low level of distortions of this class B amplifier with global negative feedback that are neglectable. The product that corresponds to this transistor is 2N2222A. In the same logic, for the p-type transistor is made a similar choice. The model's name would be 2N2907A, having the same maximum collector current as the n-type transistor, 600mA. In this way, the circuit can work correctly for a minimum impedance of 8.33Ω (=5V/600mA) for an amplitude of 5 V (at the output around 4.7V in this case, out of 5V, will be obtained), which is not the case if a voltage follower is used, where the minimum output impedance for which the circuit works correctly is limited by the output current of the OpAmp that is used (typically 20mA; the AD8031, 15mA).

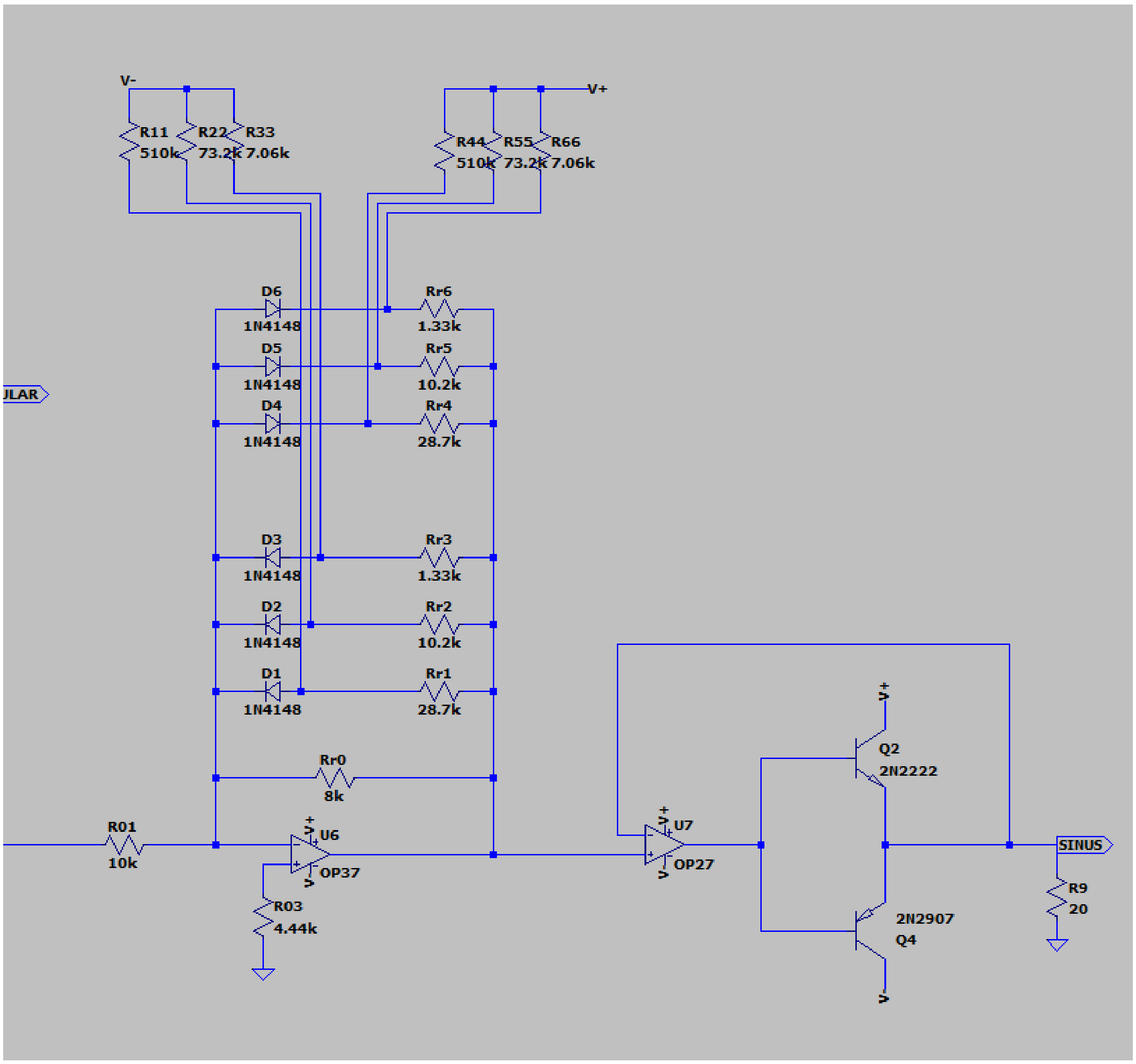
Diodes

I chose the clasical diodes 1N4148, they are suitable for the circuit with an approximated Vth = 500 mV. Their main advantage is the high switching speed = max 4 ns!

The circuit with standard nominal values

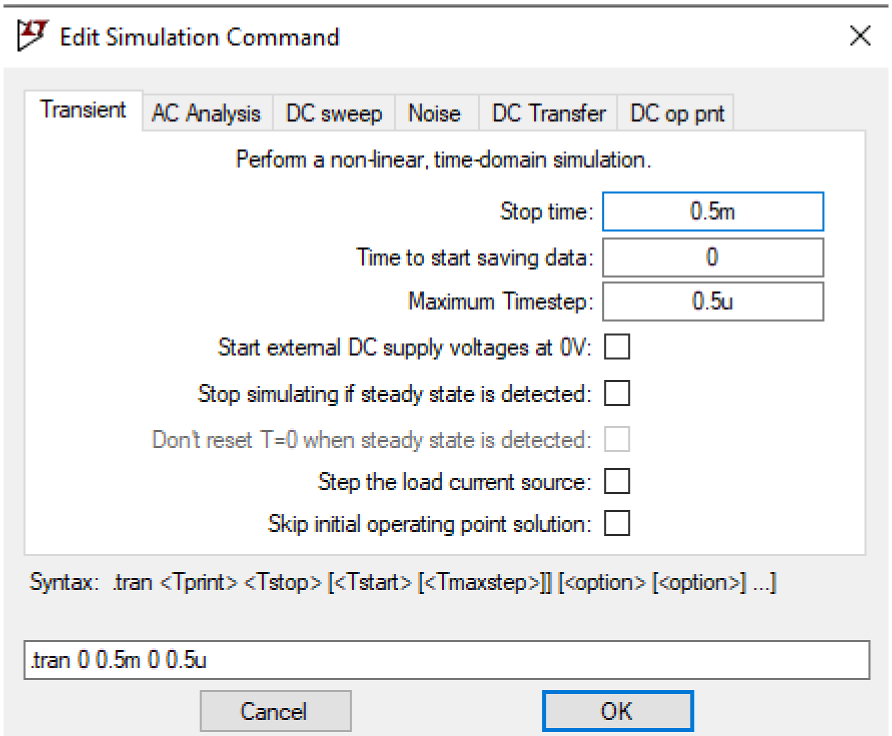



.tran 1m
.ic V(N002)=0.1V
.include pot.sub.
Rtot=10K wiper=1
Rtot=1k wiper=1
R6
5k
R7
8.66k
OP37
U5
Q1
2N2222
2N2907
Q3
RECTANGULAR
R8
20
V1
12
V2
-12
U3
R1
665
C
68n
U1
OP37
R2
4.02k
R4
15k
U2
OP37
R5
22k
R3
40k

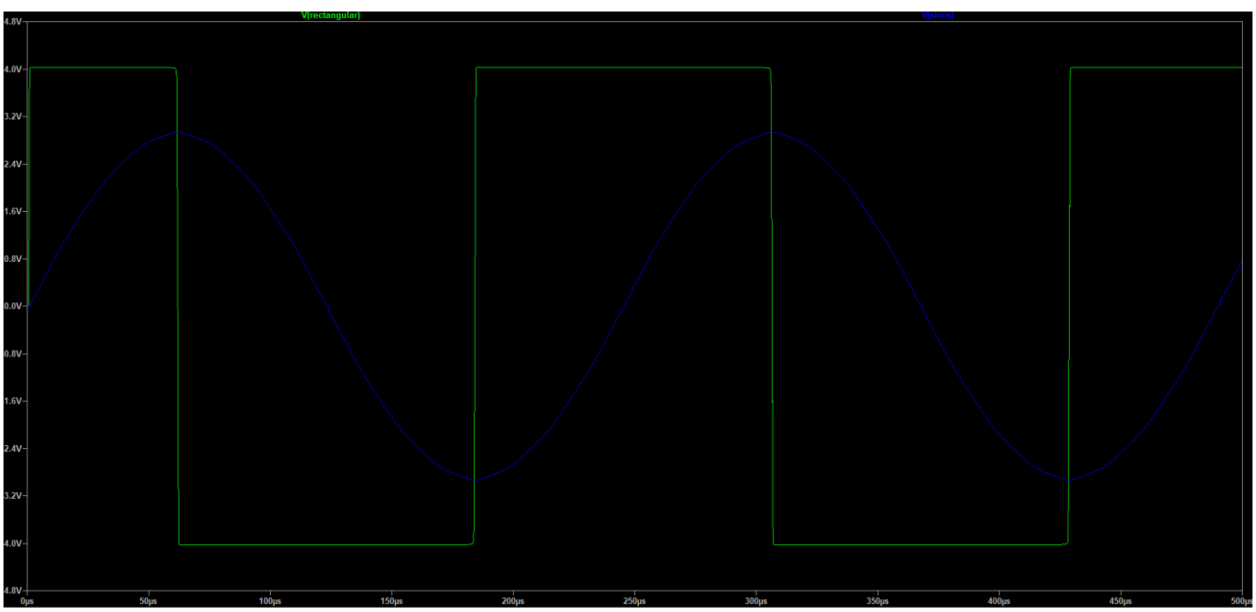

V-
V+
R11
510k
R22
73.2k
R33
7.06k
R44
510k
R55
73.2k
R66
7.06k
D6
1N4148
Rr6
1.33k
D5
1N4148
Rr5
10.2k
D4
1N4148
Rr4
28.7k
D3
1N4148
Rr3
1.33k
D2
1N4148
Rr2
10.2k
D1
1N4148
Rr1
28.7k
Rr0
8k
R01
10k
U6
OP37
R03
4.44k
U7
OP27
Q2
2N2222
2N2907
Q4
SINUS
R9
20

Simulations and Analysis

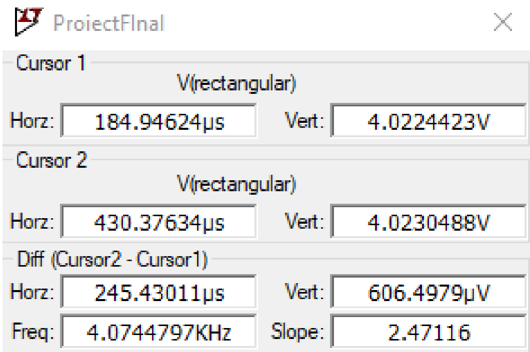
Time-domain simulation

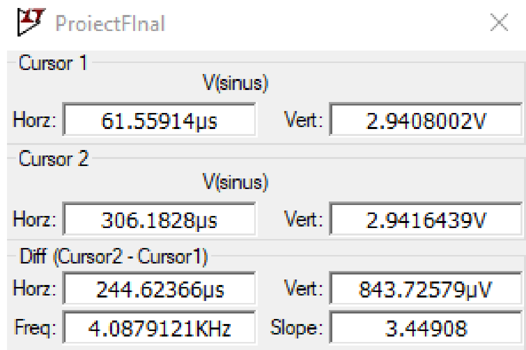


(simulation profile)



A simulation in time with the potentiometers with wiper = 1;

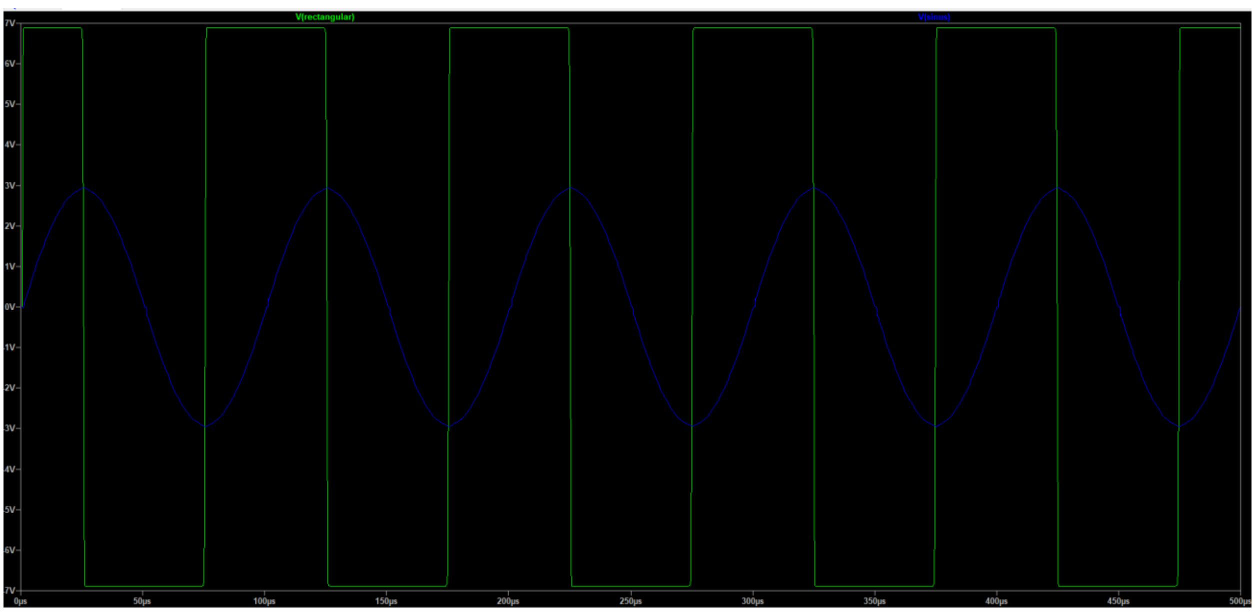


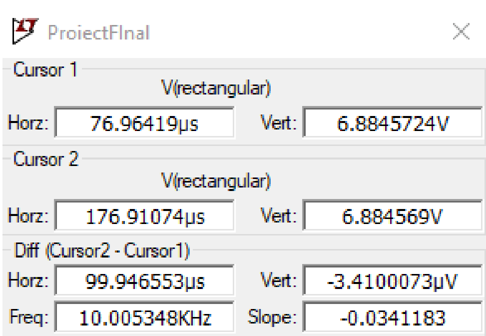


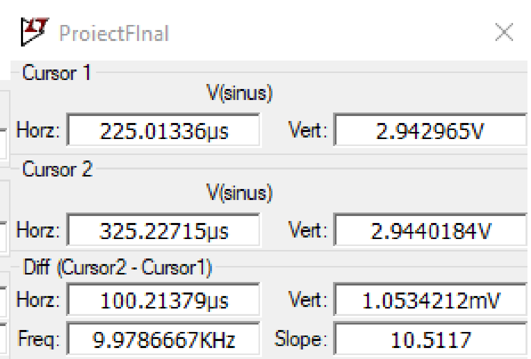
We can observe a frequency of 4074Hz and a Vrect = 4.02V

We can observe a frequency of 4087Hz and a Vsin = 2.94V

Another simulation with the potentiometers with wiper=0;



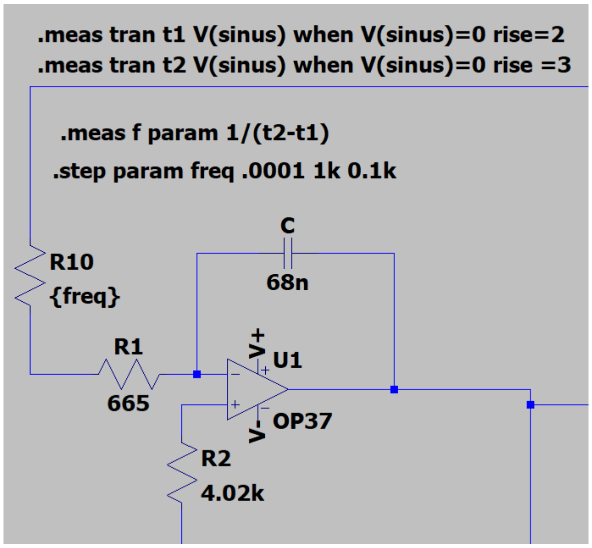


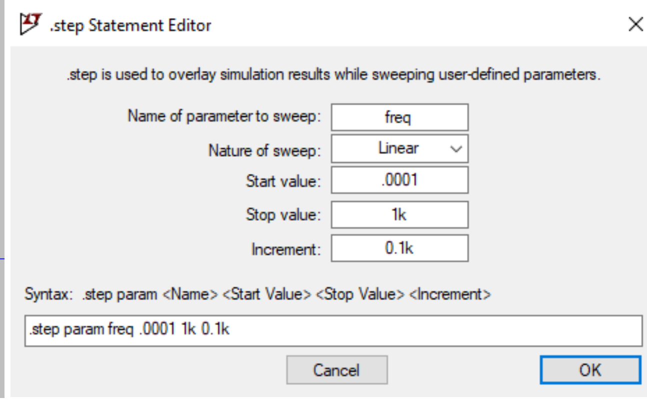


We ca observe a frequency around 10000Hz, a Vrect = 6.88V and a Vsin = 2.94V

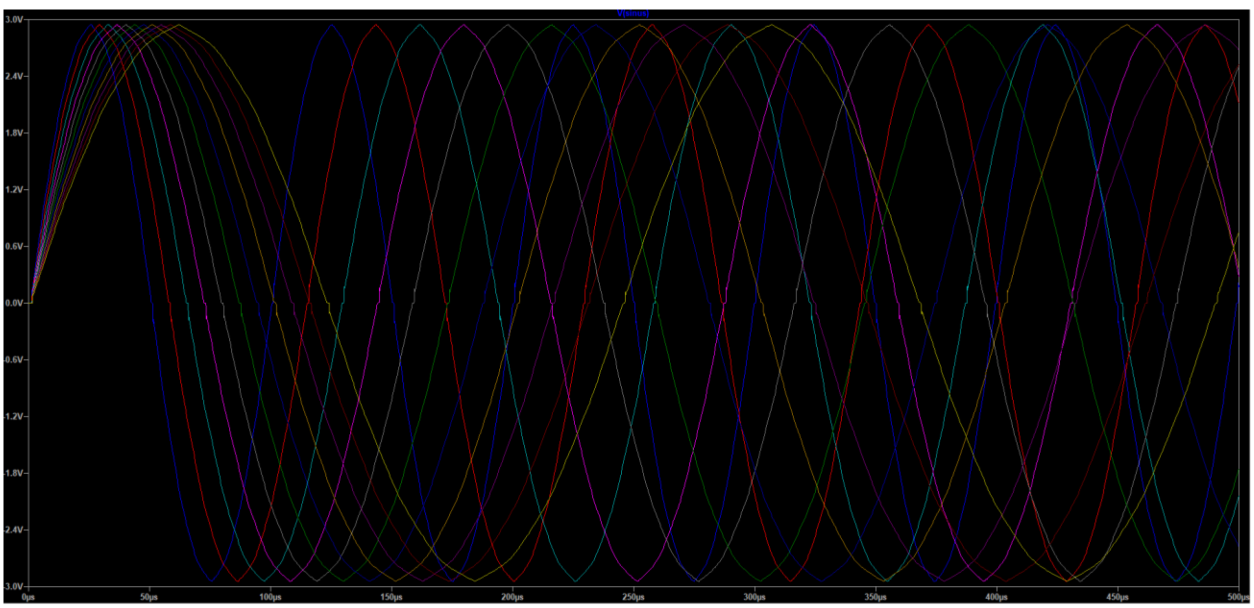
Parametric analysis – varying frequency

- Varying the parameter *freq* from 0k to 1k with a step of 0.1k we should obtain frequencies between 4000-10000





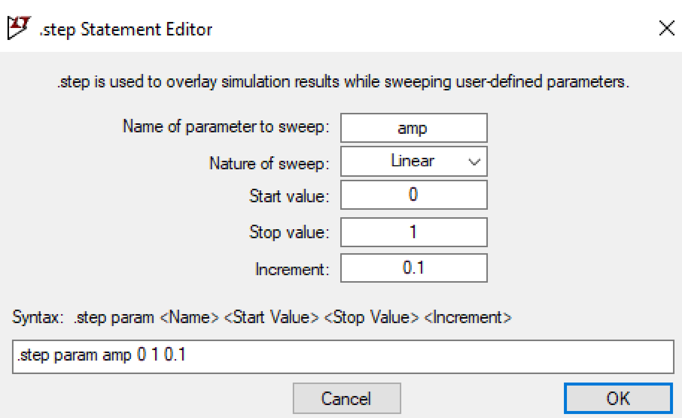
(simulation profile)

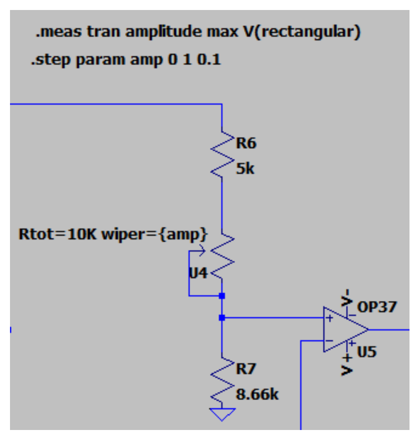


```
Measurement: f
  step           1/(t2-t1)
     1           10037.9
     2           8760.05
     3           7771.67
     4           6983.53
     5           6340.99
     6           5806.65
     7           5355.68
     8           4969.77
     9           4635.92
    10           4344.04
    11           4086.74
```

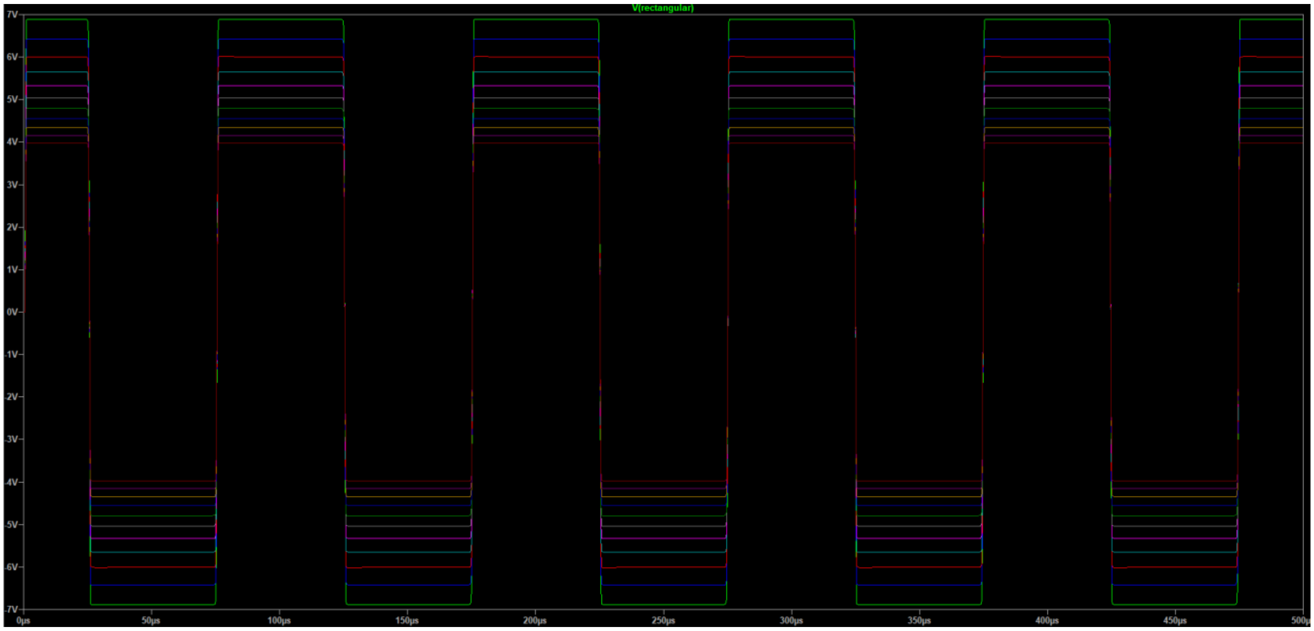
Parametric analysis – varying the amplitude

- Varying the parameter *amp* from 0 to 1 with a step of 0.1 the amplitude of the rectangular signal should vary between 4 and 7 V.





(simulation profile)

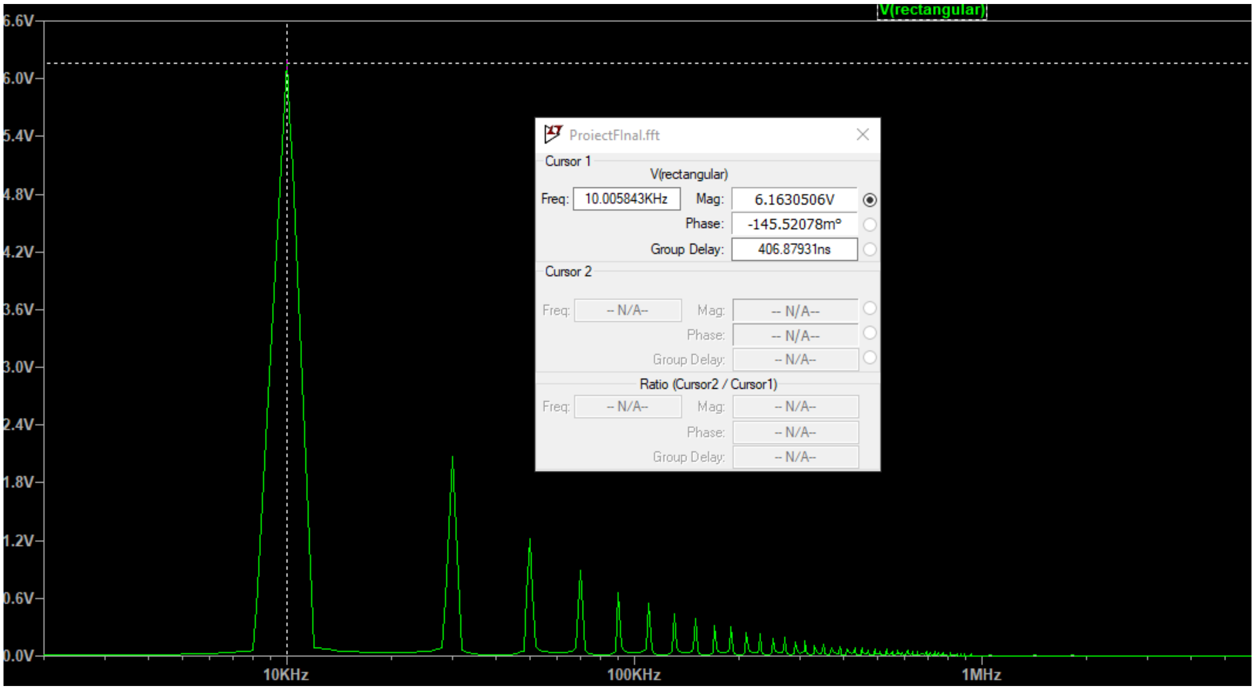


Measurement: amplitude

step	MAX(v(rectangular))	FROM	TO
1	6.88464	0	0.0005
2	6.42008	0	0.0005
3	6.01042	0	0.0005
4	5.64989	0	0.0005
5	5.33016	0	0.0005
6	5.04466	0	0.0005
7	4.78819	0	0.0005
8	4.55654	0	0.0005
9	4.34627	0	0.0005
10	4.15454	0	0.0005
11	3.9807	0	0.0005

FFT (Fast Fourier Transform)

- Analysis done to demonstrate that the output signal is rectangular. - Rectangular signal spectrum:

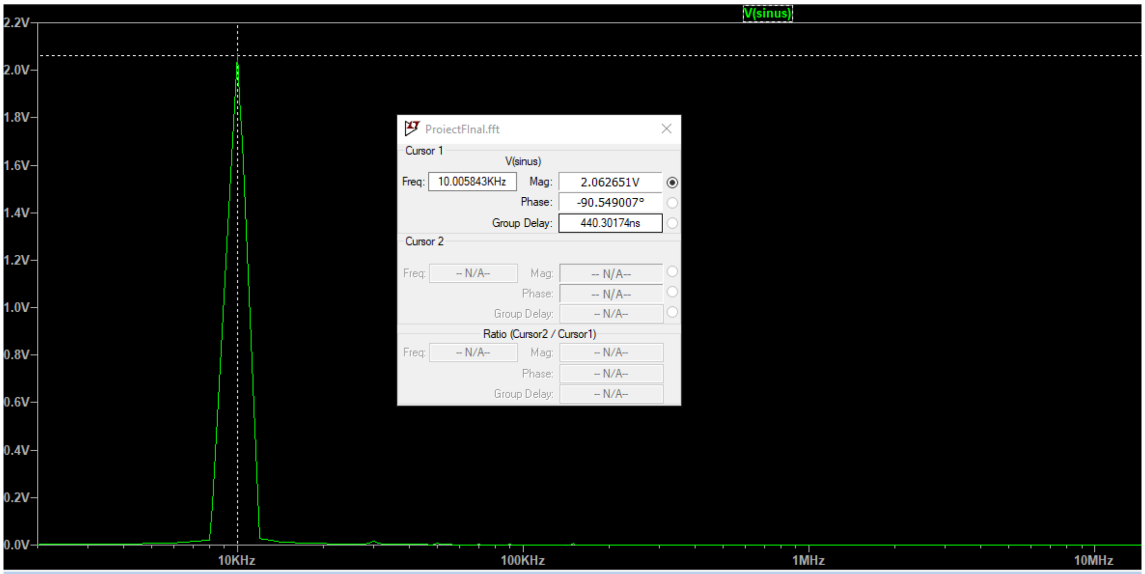


At the working frequency of approx. 10kHz the harmonic is the biggest one (the central harmonic) and the spectrum is a sinc function, so it corresponds to the spectrum of the rectangular signal. (Ampl of Vout=7V and duty cycle= 50%)

The spectrum has to be discrete (consisting of harmonics at multiple of f) because the signal is periodic in time.

So, knowing the graph of the spectrum and that the spectrum looks like a sinc, it can be said that the signal is a rectangular one with the central frequency of about 10kHz.

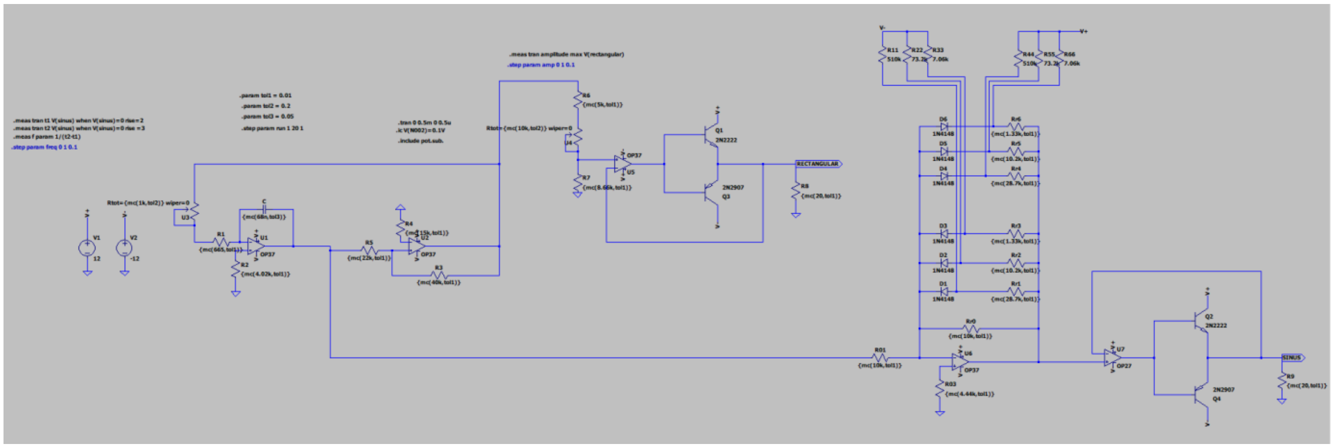
Sinusoidal signal spectrum:



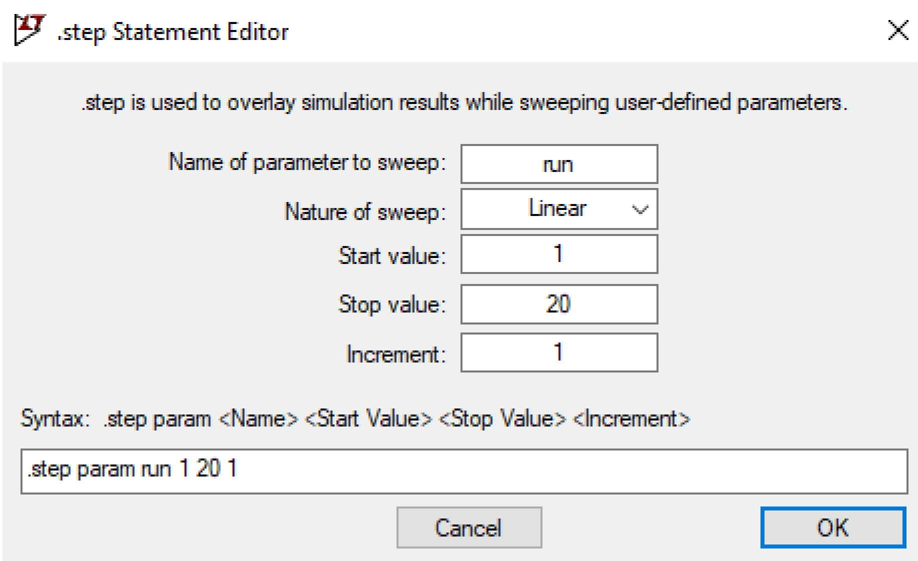
The central frequency is at about 10kHz and there can be seen that there is only one harmonic, as it should. So we can say we have a sine wave with a frequency of 10 kHz.

Monte Carlo analysis

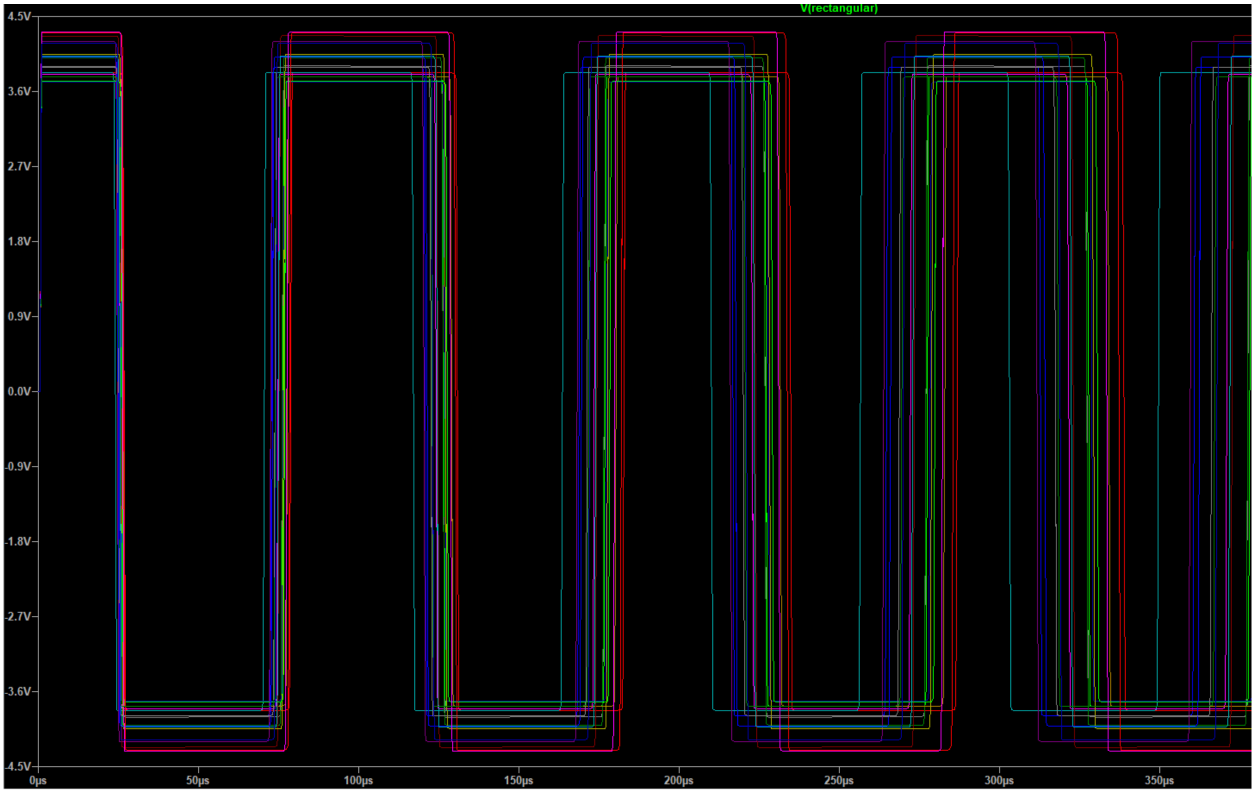
- Adding tolerances to the components and see their behavior (for a desired amplitude of the rectangular signal of 4V and a frequency of 10000 Hz)

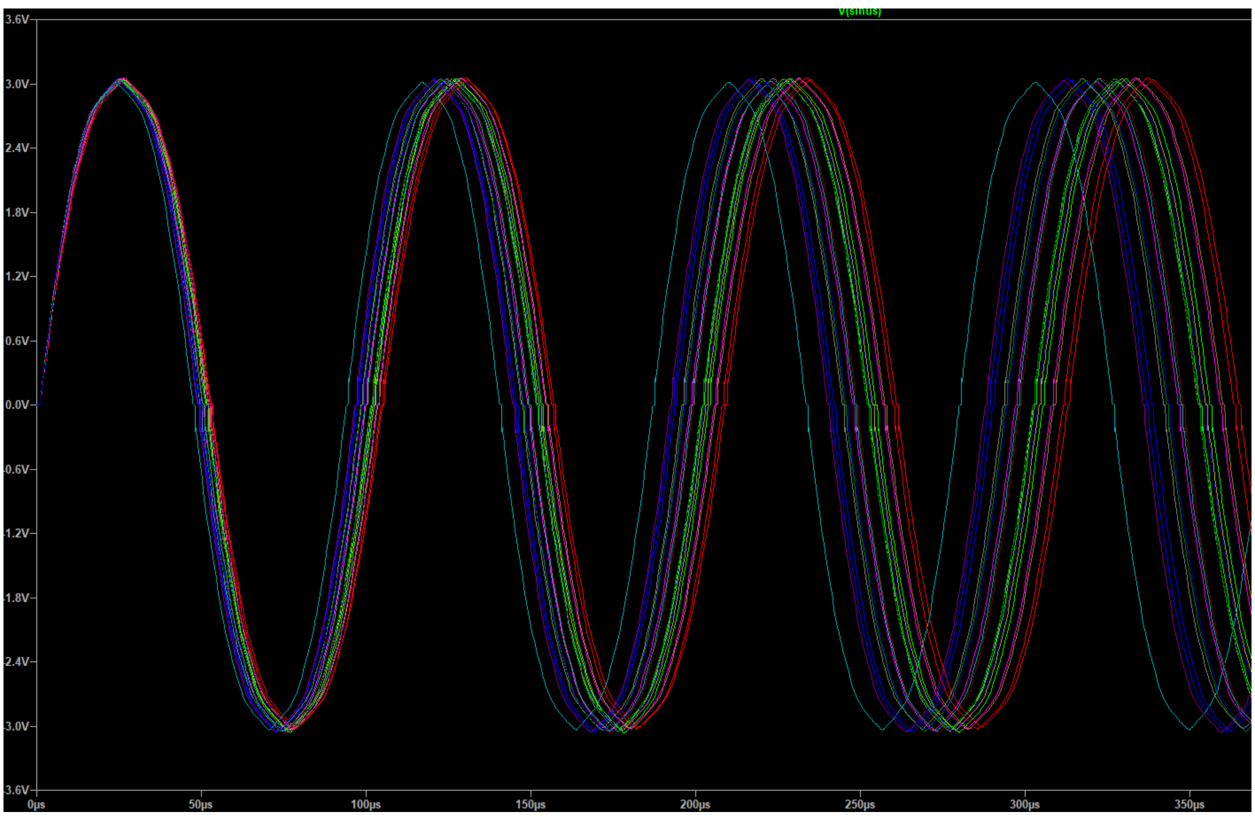


(the circuit with tolerances of all components)



(simulation profile to run monte carlo; big number of runs to get a better overview of the impact of the tolerances on the functioning of the circuit)





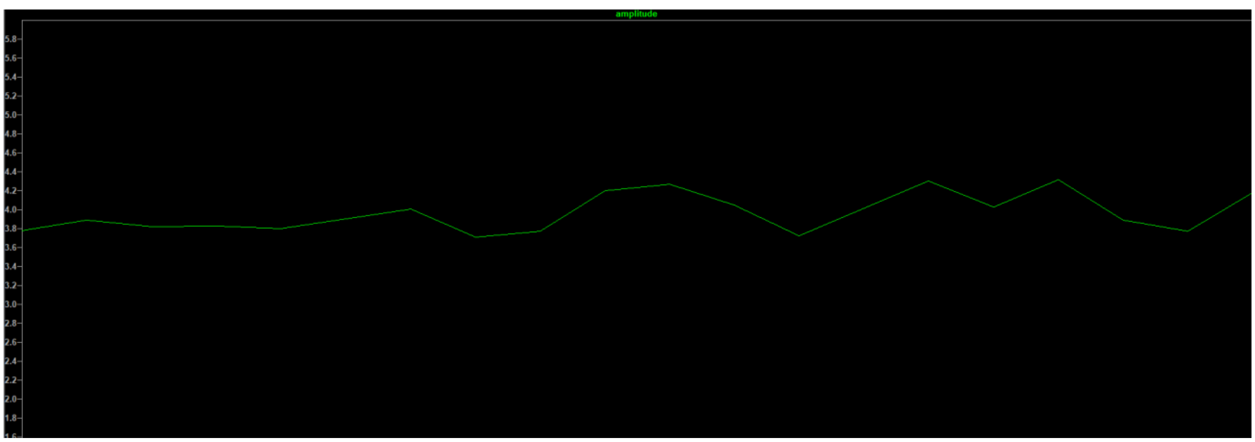
(Variation of Vout in time after monte carlo analysis)

With the *.meas* command the amplitude of the output signal is measured (the method to measure the amplitude of V(rectangular) was defined previously) and get:

Measurement: amplitude

step	MAX(v(rectangular))	FROM	TO
1	3.78046	0	0.0005
2	3.89147	0	0.0005
3	3.8231	0	0.0005
4	3.82754	0	0.0005
5	3.80333	0	0.0005
6	3.90531	0	0.0005
7	4.00827	0	0.0005
8	3.71112	0	0.0005
9	3.77404	0	0.0005
10	4.20237	0	0.0005
11	4.2674	0	0.0005
12	4.04917	0	0.0005
13	3.72246	0	0.0005
14	4.01071	0	0.0005
15	4.30097	0	0.0005
16	4.02524	0	0.0005
17	4.31515	0	0.0005
18	3.89262	0	0.0005
19	3.7712	0	0.0005
20	4.17693	0	0.0005

So, the minimum amplitude is 3.71V and the maximum amplitude 4.31V, an acceptable range of variation. This variation is mainly from the potentiometer which has a big tolerance of 20%. In the graphic from below there can be seen that this variation is tolerable for the functioning of the circuit, an amplitude that has very little variation from its desired value of 4V is obtained:



(amplitude of Vrectangular vs simulation run)

In the same manner, the variation of the frequency of the sinus/rectangular signal is obtained (method to measure the frequency was defined previously):

Measurement: f

step	1/(t2-t1)
1	9938.35
2	10417.9
3	9614.98
4	10749
5	10130.8
6	9954.83
7	9956.85
8	9907.46
9	9748.43
10	10454.2
11	10085.8
12	9891.31
13	9855.41
14	10370.7
15	9658.26
16	10105.6
17	9770.12
18	10263.4
19	10235.9
20	10217.3

So, the frequency has a variation from 9614Hz to 10749kHz. This interval is decent, if we want to improve it we need to use smaller tolerance capacitors, but it will become more expensive.

In conclusion, the chosen components have very little impact on the functioning of the circuit, so they can be use to build a signal generator with the specified design parameters.

Bill of materials

Nr Crt	Model name	Description	Units	Comp	Price per unit [RON]	Total price [RON]
1	14D1003700	Operational Amplifiers - Op Amps IC DIP OP37GPZ PDIP-8P OP AMP ADI	4	U1, U2, U5,U6	15.89	26.58
2	OP2177ARZ	Precision Amplifiers DUAL, PRECISION LOW NOISE OP AMP	1	U7	25.34	25.34
3.	C1206C683J1RECTU	Multilayer Ceramic Capacitors MLCC - SMD/SMT 100V .068uF X7R 1206 5%	1	C	1.5	1.5
4	CRCW0402665RFKED	Thick Film Resistors - SMD 1/16watt 665ohms 1%	1	R1	0.47	0.47
5	CR0603-FX-4021ELF	Thick Film Resistors - SMD 4.02K ohm 1%	1	R2	0.47	0.47
6	CRCW080540K0FKEA	Thick Film Resistors - SMD 1/8watt 40Kohms 1%	1	R3	0.614	0.614
7	CR0603-FX-1502ELF	Thick Film Resistors - SMD 15K 1% 1/10W	1	R4	0.47	0.47
8	MCS04020C2202FE000	Thin Film Resistors - SMD .063W 22Kohms 1% 0402 50ppm	1	R5	0.658	0.658
9	RC0402FR-075KL	Thick Film Resistors - SMD 5 kOhms 62.5mW 0402 1%	1	R6	0.47	0.47
10	CR1206-FX-8661ELF	Thick Film Resistors - SMD 8.66K 1%	1	R7	0.47	0.47
11	PTV09A-4020F-B102	Potentiometers 1K 20% 9MM CARBON POT	1	U3	4.7	4.7
12	PT10RV10-103A2020-PM-S	Trimmer Resistors - Through Hole 10mm control/sensor trimmr potentiometer 20% 10k	1	U4	3.63	3.63

13	ERJ-2RKF20R0X	Thick Film Resistors - SMD 0402 20.0ohms 1% Tol AEC-Q200	2	R8,R9	0.47	0.94
14	2N2222A	Bipolar Transistors - BJT Bipolar Transistor, TO-92, 40V, 600mA, NPN	2	Q3,Q4	0.39	0.78
15	2N2907A	Bipolar Transistors - BJT Bipolar Transistor, TO-92, 60V, 600mA, PNP	2	Q1,Q2	0.39	0.78
16	CR1206-FX-1002ELF	Thick Film Resistors - SMD 10K 1%	1	R01	0.47	0.47
17	0201WMF2801TEE	Thick Film Resistors - SMD 0201 1/20W 1% 2.8K T/R-15000	1	Rr0	0.59	0.59
18	CR1206-FX-2872ELF	Thick Film Resistors - SMD 28.7K 1%	2	Rr1,Rr4	0.47	0.94
19	ERJ-3EKF1022V	Thick Film Resistors - SMD 0603 10.2Kohms 1% AEC-Q200	2	Rr2,Rr5	0.47	0.94
20	CR0805-FX-1331ELF	Thick Film Resistors - SMD 1.33K 1%	2	Rr3,Rr5	0.47	0.94
21	CRCW0402510KFKED	Thick Film Resistors - SMD 1/16watt 510Kohms 1% 100ppm	2	R11,R44	0.47	0.94
22	CR0603-FX-7322ELF	Thick Film Resistors - SMD Res 0603 73k2 1% 100mW TC100	2	R22,R55	0.47	0.94
23	RN73H1JTTD7061F100	Thin Film Resistors - SMD 7.06kOhm,0603,1%,10ppm,100mW,75V	2	R33,R66	1.84	3.68
24	1N4148W_R1_00001	Diodes - General Purpose, Power, Switching 100Vll Signal Switching Diodes 4A	6	D1-D6	0.658	3.948
TOTAL						81.26

Conclusions

This rectangular and sinusoidal signal generator is based on the idea of creating a complex signal generator that goes through all 3 main forms of signals : Rectangular, Triangular, Sinusoidal. The Oscillator is quite simple, a Trigger Schmitt and an Integrator. Although, the triangular to sinusoidal signal converter is quite complicated and has many components, it is easily adaptable to any change of amplitude and frequency. The frequency adjustment and the amplitude adjustment for the rectangular signal are done by the help of potentiometers.

The components that are chosen to build this circuit and their tolerances have a small impact on the performance of the circuit (demonstrated in the previous chapters), although they produce a variation of the parameters of the circuit (amplitude, frequency), this variation is in an acceptable interval. So, they are suitable to be considered when build such a circuit with the given parameters.

The circuit was designed in LTSpice, as well as the simulations and analysis were done with the help of the same simulator.

References

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