

# Compact Rectangular Pulse Generator

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# Introduction

For a small project, I needed a rectangular pulse generator that could generate positive and negative voltage pulses. These positive-negative pulses are measured with an Arduino to check if the load is still open. When the voltage drops to zero (short circuit at the load side) the Arduino notices it and does something. Additionally there should be two parallel circuits, although the main challenge does not change with that.

- Why positive-negative pulses? - It is required by the application. And true negative voltage is needed, virtual ground solution is not sufficient.
- Arduino cannot measure negative voltage!?! - True and therefore only positive side of the pulse is measured.

For the rectangular pulses first one needs both positive and negative voltage. That will be the first topic. Thereafter different pulse generator circuits are shown and finally the chosen circuit is shown. Consequently different circuits as schematics and the measured curves are shown.

I have already long time noticed that it is not very convenient here in Instructables to add clearly several figures, thus I wrote the instructable and attached it as a pdf.

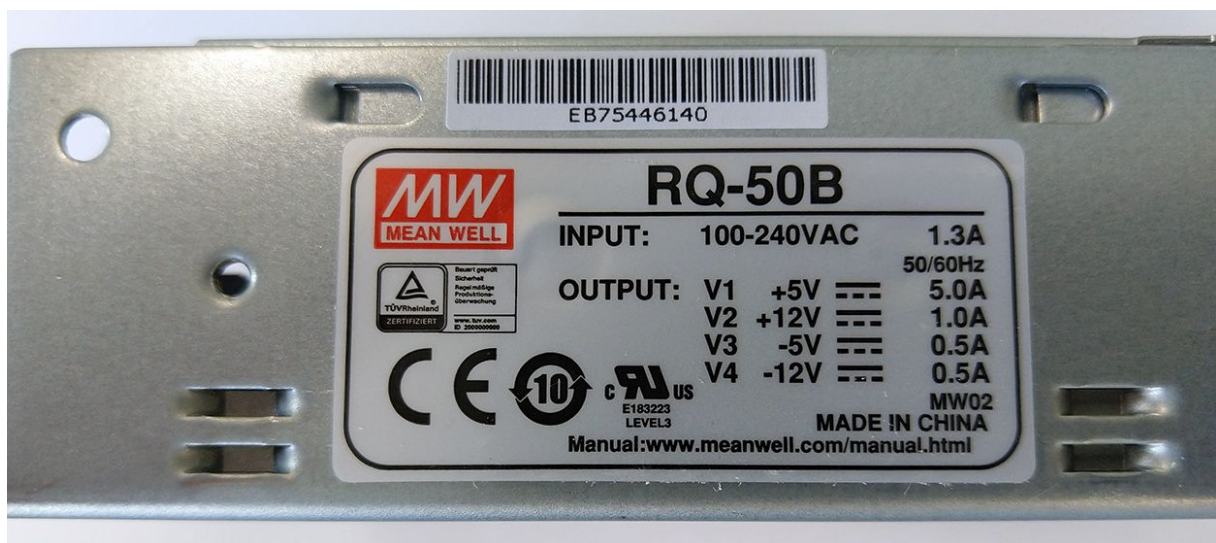
Hopefully this Instructable help somebody who needs a short summary how to generate limited negative voltage and build a rectangular pulse generator.

## Generating negative voltage

Requirements:

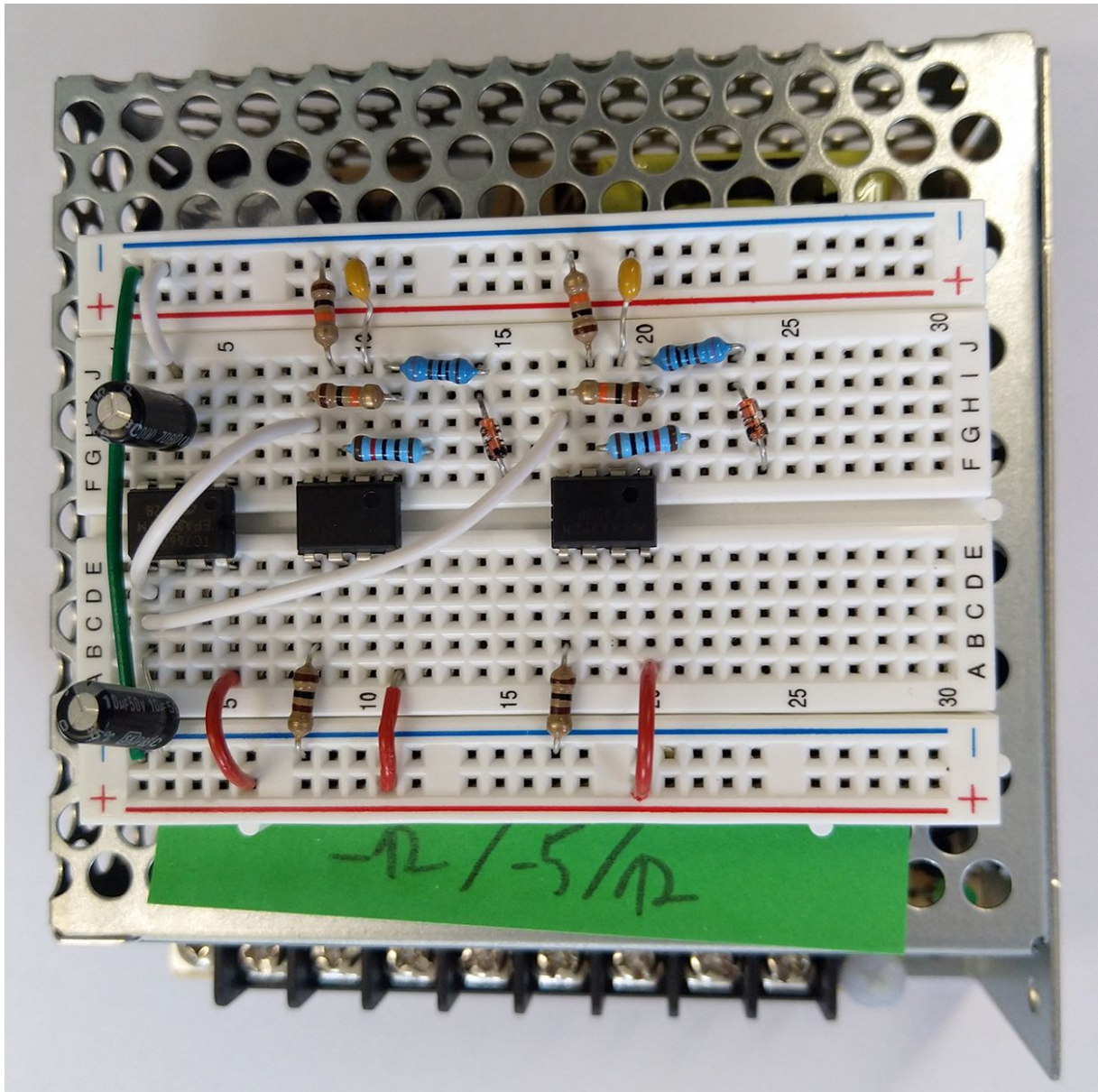
- Input voltage +5V
- Rectangular pulse - +/-5V peak
- Frequency - (not important) 0.5 to 1kHz
- Negative voltage close to the input voltage (+5V), does not have to be perfect -5V
- Load - approximately 1k $\Omega$

The easiest way to generate negative voltage is to use proper voltage supply. These can be relatively large and they provide a lot of power (obviously application depending). In the following figure is a PSU that produces +12, -12, +5 and -5V. Exactly what is needed, however the size is the main issue.



On the next figure, one can see the final breadboard circuit used in the application. As can be seen the size has a huge difference (the bradboard is a standard 430 points one).

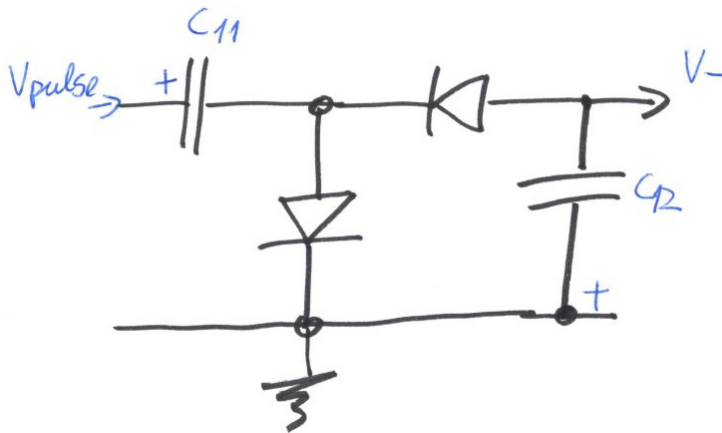
## Compact Rectangular Pulse Generation



I was looking for possibilities to generate the required negative voltage from the single positive input. There are some possibilities to use two power supplies and connect them so that there is a negative voltage. However, this solution is relatively complex and not all power supplies can do that. Therefore, I was not considering the latter.

The most common way to generate negative voltage is to use a diode pump circuit. More information can be found under this [Link](#). It is a simple circuit and will be shown later. A diode pump circuit can be seen in the following figure:

## Compact Rectangular Pulse Generation



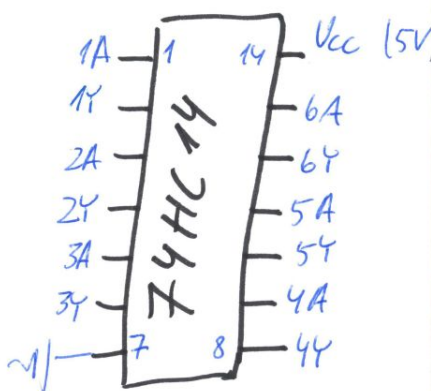
The main complication is to generate the capacitor charging voltage pulses ( $V_{pulse}$  in the diode charge pulse circuit). One possibility is to use a 74HC14 chip. It is a Schmitt-Trigger inverter and it is widely used (reference [Link](#) where I got the circuit idea).

Similarly a 555 chip could be used, but it was not tested (reference [Link](#) and an alternative [Link](#)). The performance should be very similar to the 74HC14 with reduced output power, thus not so interesting. And there was no 555 chip laying around to play with.

Otherwise, there are some special charge pump chips that can generate negative voltage without a hassle. There are many such chips available and for the searched application TC7660 sounded as a possible candidate. The price was low and it was readily available in Digikey during the testing phase.

### Using 74HC14 chip

74HC14 is an inverter and one can make it to “self pulsate” when a capacitor is used together with a resistor (it generates a rectangular pulse). In the following figure one can see the pinout of a 74HC14 chip. The chip has six inverters and one will be used to generate the rectangular pulse. More about this can be read under this [Link](#).



The output rectangular pulse does not have much power, thus the pulse can be driven into a second inverter for better performance/ more power. To increase the power even more, one can connect more and more inverters in parallel. Two cases have been tested:

- two inverters to drive the diode pump circuit

## Compact Rectangular Pulse Generation

- for inverters to drive the diode pump circuit

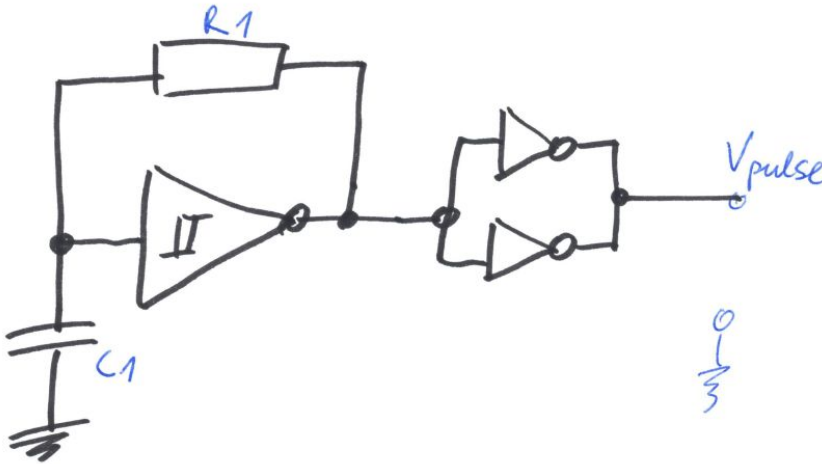
Theoretically five inverters could be connected in parallel. One can from [Texas Instruments 74HC14 datasheet](#) read that maximum output current is 20mA. One can assume that the real value slightly lower is. Adding more inverters in parallel can improve the output current considerably.

### 2 inverters in parallel

In the next figure one can see the 2 74HC14 circuit with 2 inverters in parallel. The circuit parameters are the following:

- $R1 = 1k\Omega$
- $C1 = 0.1\mu F$
- $C11 = 4.7\mu F$
- $C12 = 20\mu F$
- Input power: 5V from an Arduino UNO

On the  $V_{pulse}$  terminal the diode pump circuit is connected (refer to 4 inverter circuit for full schematics)!



The measured voltages (V-):

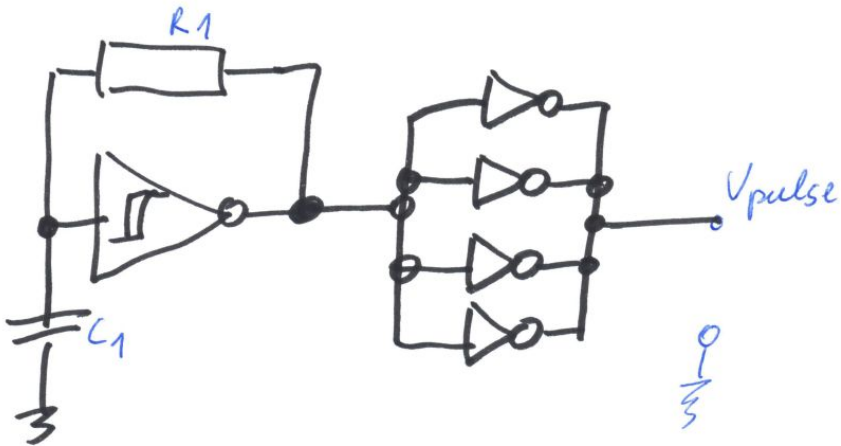
- $100\Omega$        $-0.76V$
- $500\Omega$       $-1.56V$
- $1k\Omega$        $-1.82V$
- no load       $-4.75V$

### 4 inverters in parallel

Very similar to the previous 2 inverter output circuit.

- $R1 = 1k\Omega$
- $C1 = 0.1\mu F$
- $C11 = 4.7\mu F$
- $C12 = 20\mu F$
- Input power: 5V from an Arduino UNO

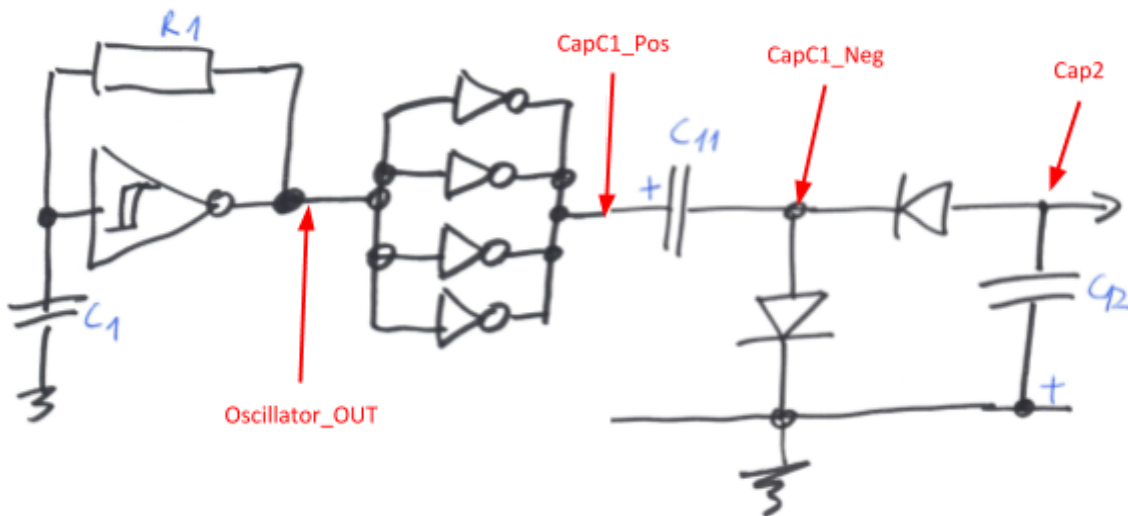
## Compact Rectangular Pulse Generation



The measured voltages:

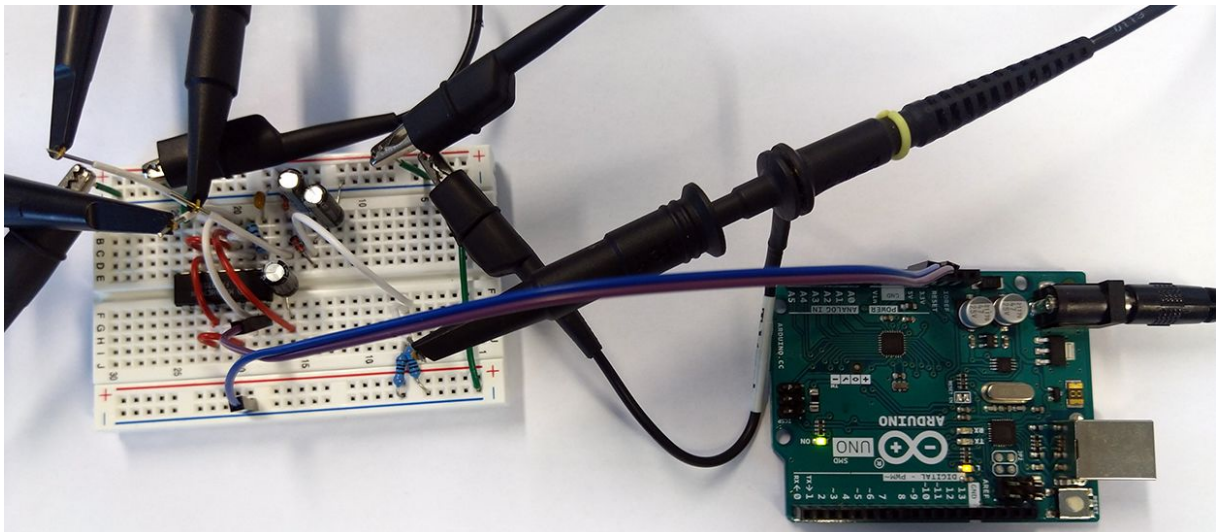
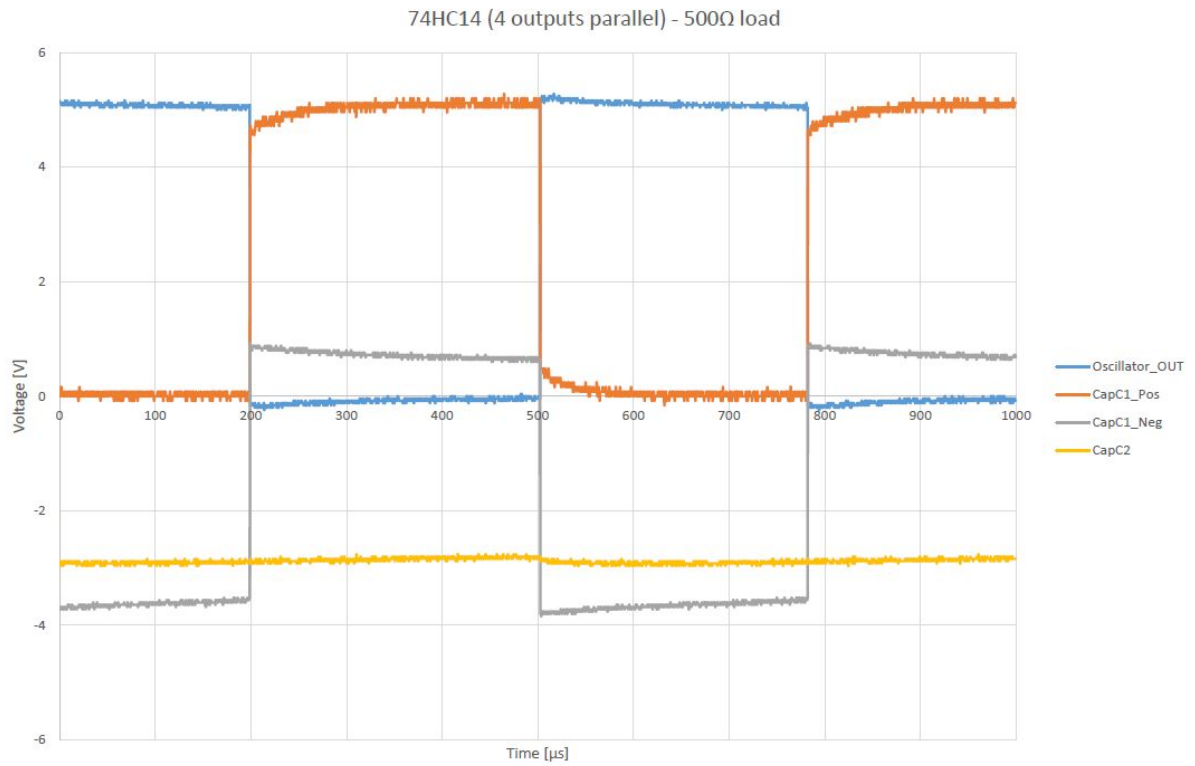
- 100  $\Omega$       -1.42V
- 500  $\Omega$       -2.85V
- 1k  $\Omega$         -3.26V
- no load        -4.76V

Here is the full schematics and measured voltages with a 500  $\Omega$  resistive load. One can clearly see the diode voltage drop when the (positive gray voltage).

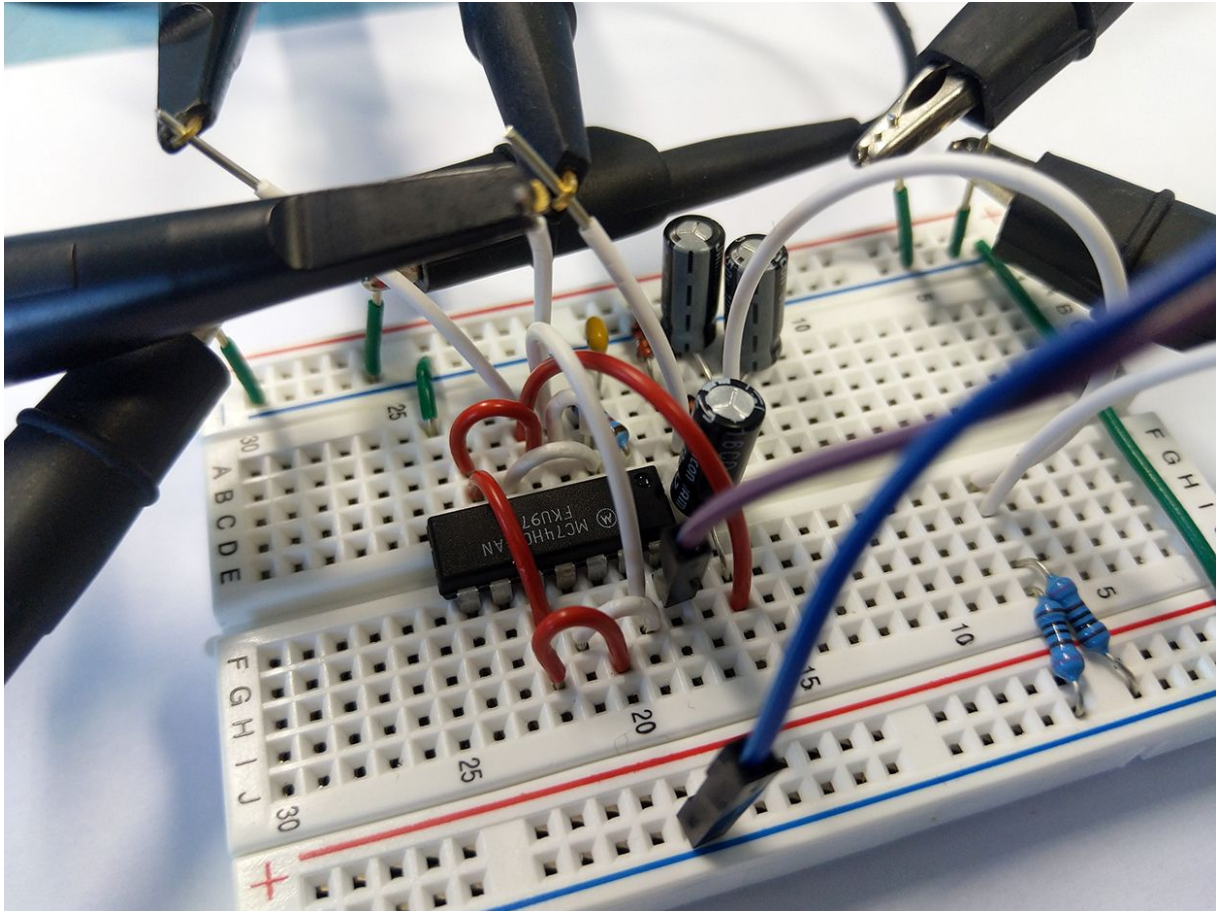




## Compact Rectangular Pulse Generation







### Using TC7660 chip

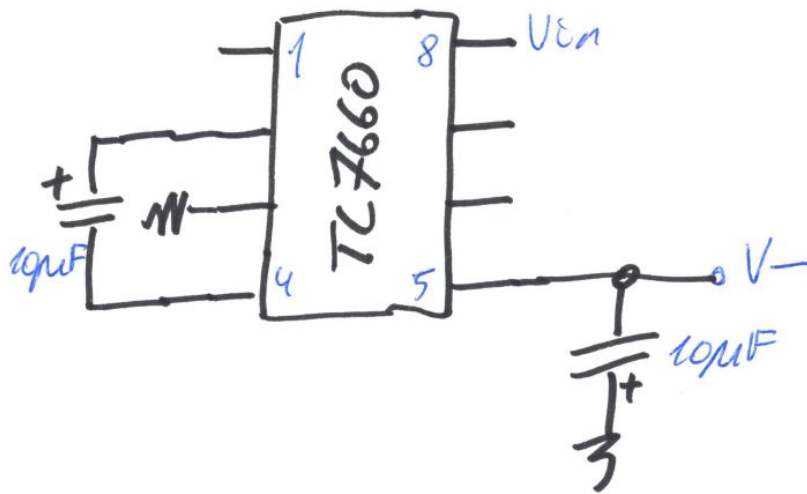
The 74HC14 works well for this application, however the output voltage is limited even with moderate loads. Thus a TC7660 circuit was tested. According to the [datasheet](#) the connections were very simple and only two additional 10 $\mu$ F capacitors were needed.

The output voltage was measured with different resistive loads:

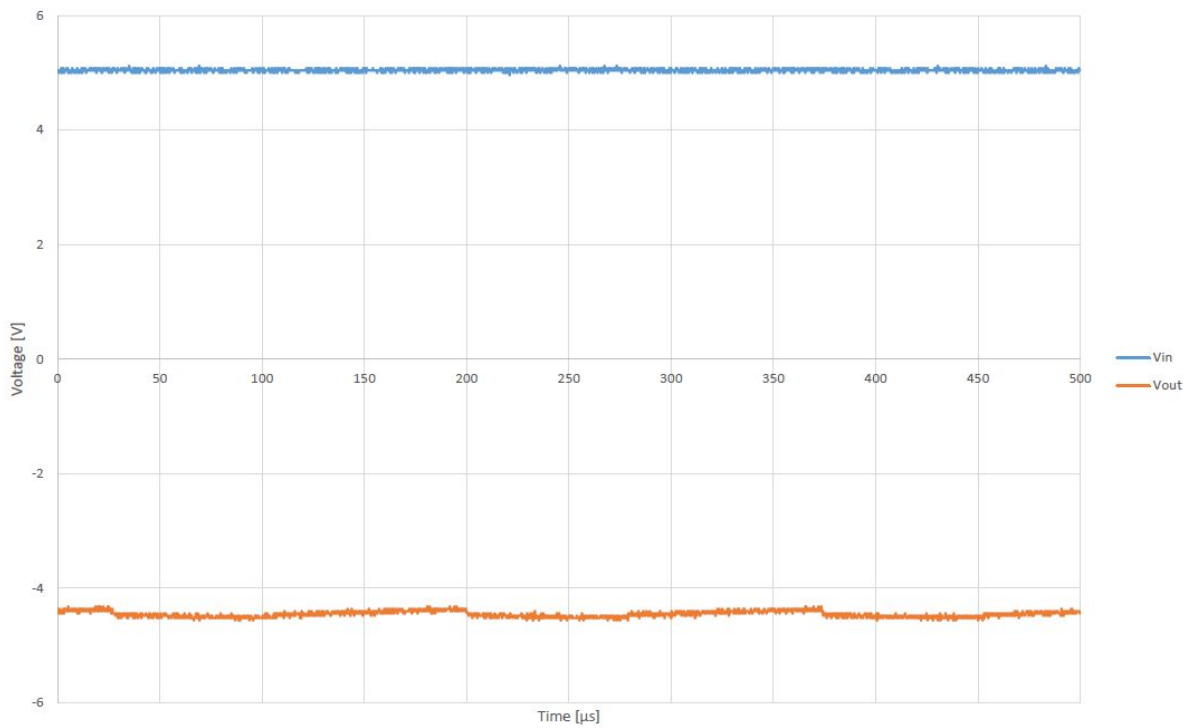
- 100  $\Omega$  -2.91V
- 500  $\Omega$  -4.38V
- 1k  $\Omega$  -4.67V
- no load -4.99V

Compared to the inverter the voltages are much closer to the input voltage (+5V).

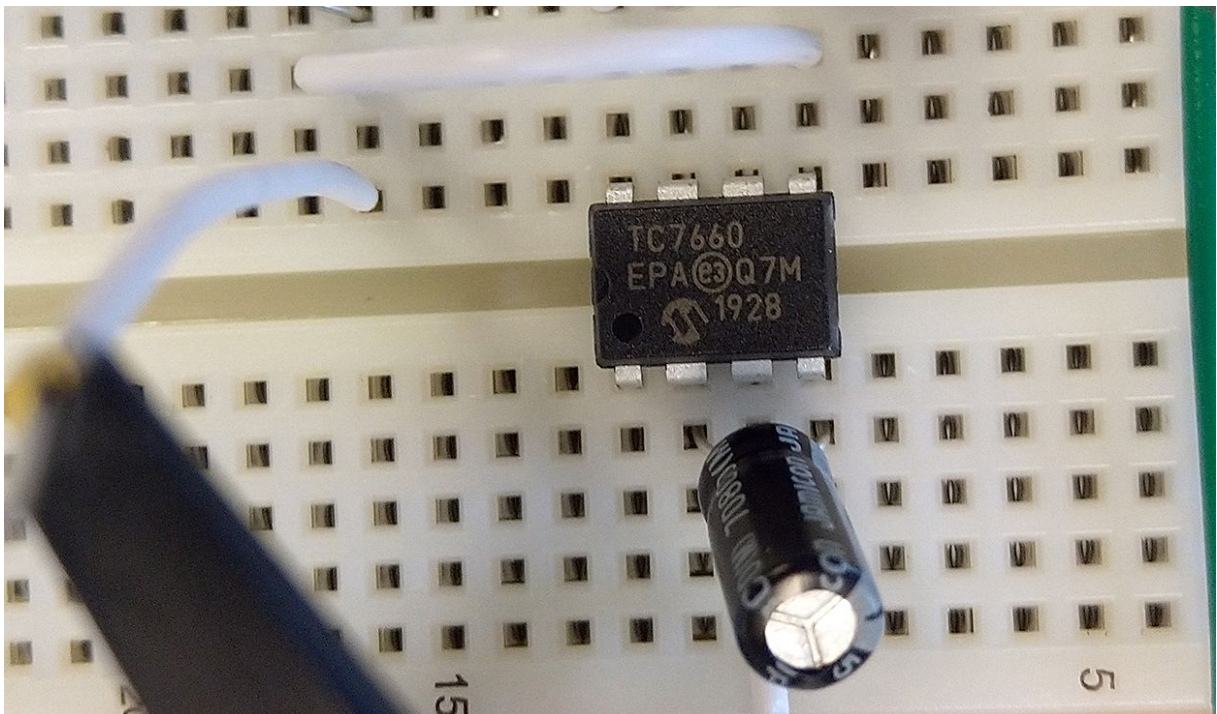
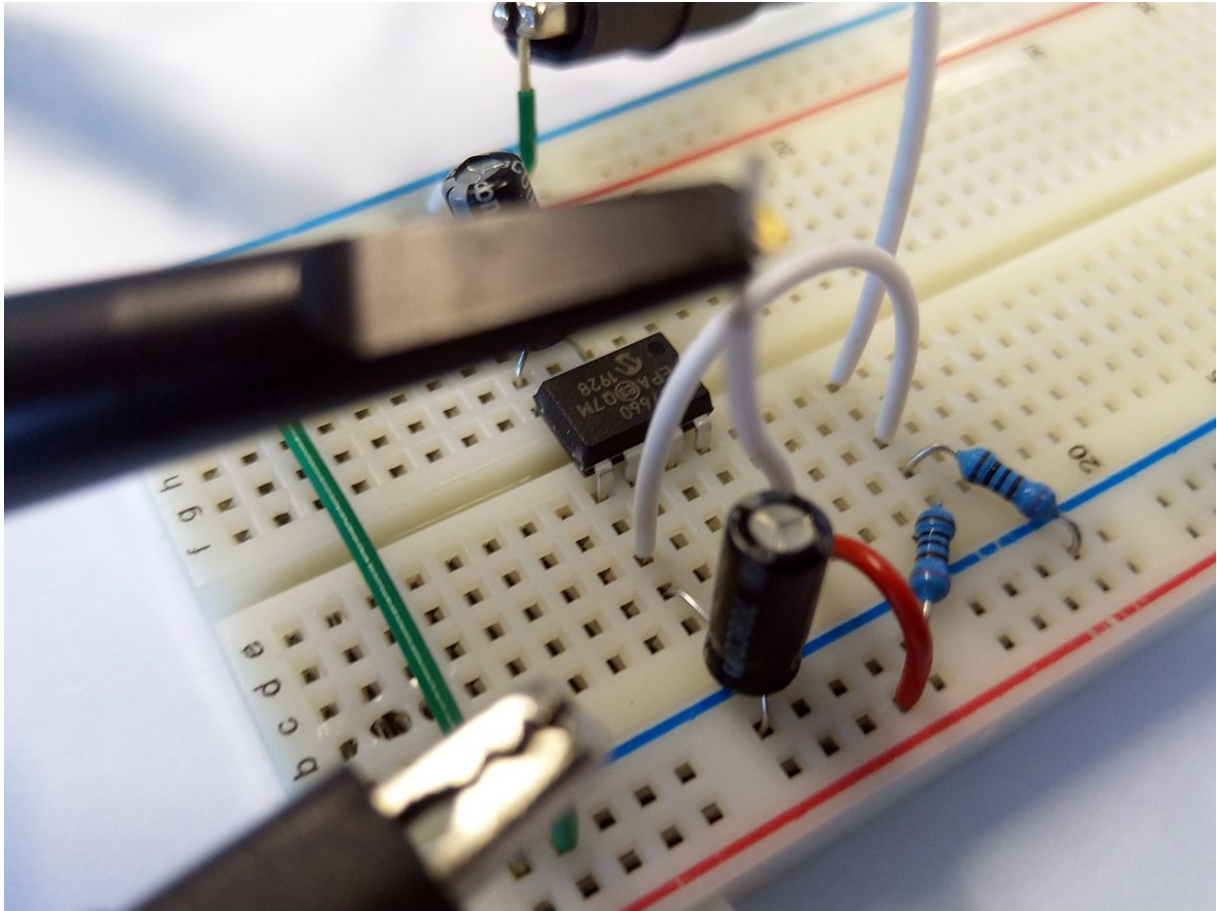
# Compact Rectangular Pulse Generation



TC7660 - 500Ω load



## Compact Rectangular Pulse Generation



## **Negative voltage generation summary**

A fast and compact solution was searched to generate negative voltage. Thus, a power supply with negative voltage supply was not an option.

Two different negative voltage generation methods were shown. The measurements indicate that the dedicated charge pump voltage converter TC7660 works better than an inverter. Therefore, the latter is used for the negative voltage generation in the following rectangular pulse generation test and in the final circuit.



# Rectangular pulse Generator

It was needed that the rectangular pulse goes from V+ (positive input voltage) to V- (negative voltage generated from the positive input voltage). In the ideal case it would mean (in this specific application) from +5 to -5 volts.

In the practical circuit the -5V cannot be reached, although it is not very critical in this application. Otherwise higher voltage must be generated. The maximum voltage that 74HC14 can handle is 6V and TC7660 10V. Alternative charge pump circuits may handle higher voltages.

Three different components were tested a pulse generator:

- Op-Amp LF353 (from the [datasheet](#) - "JFET input operational amplifier with very low input offset voltage")
- Op-Amp LM358 (a general Op-Amp)
- Transistor based circuit

The Op-Amp generator could be achieved with a self oscillating circuit or with an external trigger pulse. Both were tested and evaluated.

## Op-Amp circuit with LF353

As already mentioned two different circuits with Op-Amp were investigated:

- self-oscillating generator: [Link](#)
- externally triggered oscillation: [Link](#)

## Self-oscillating generator

The circuit of a self oscillating circuit can be seen in the following figure. The parameters are the following:

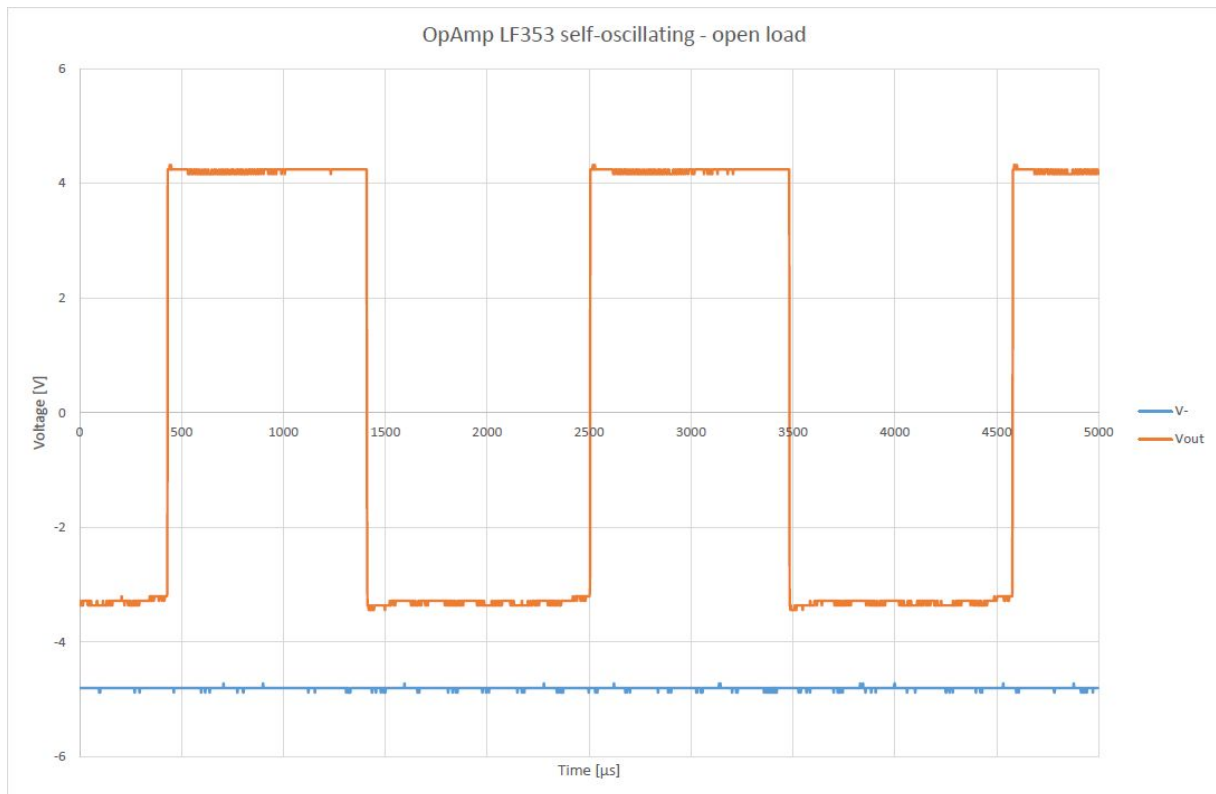
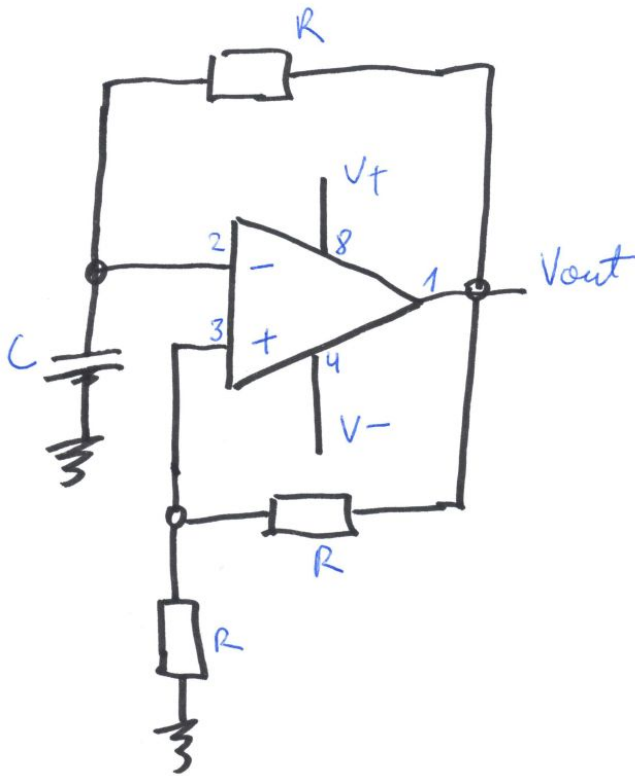
- $R = 10k\ \Omega$
- $C = 0.1\ \mu F$
- Power from Arduino 5V pin (Arduino powered with 12V)

The theoretical oscillation frequency is 455Hz ([calculator](#)) and the measured frequency is

- 488.8Hz - open load
- 482.7Hz -  $1k\ \Omega$  load

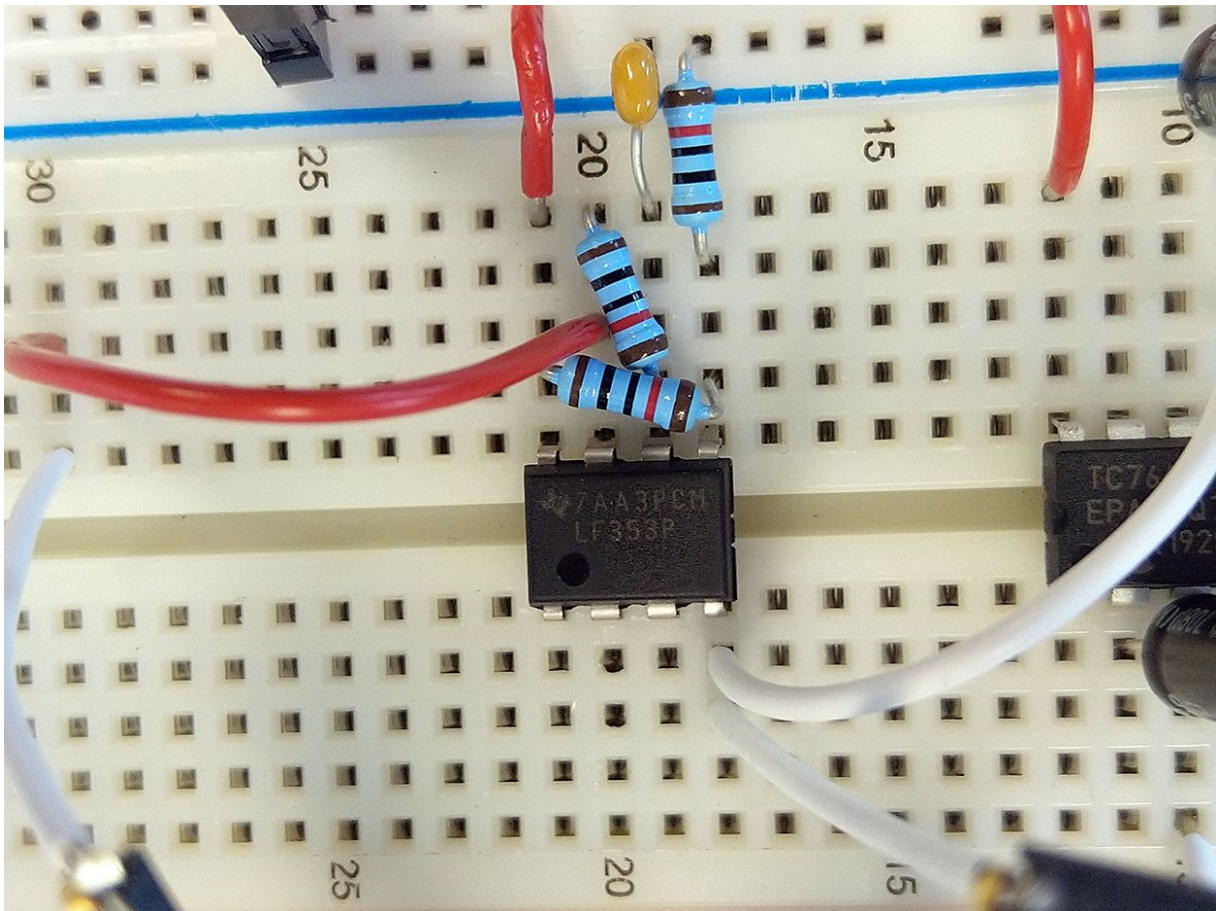
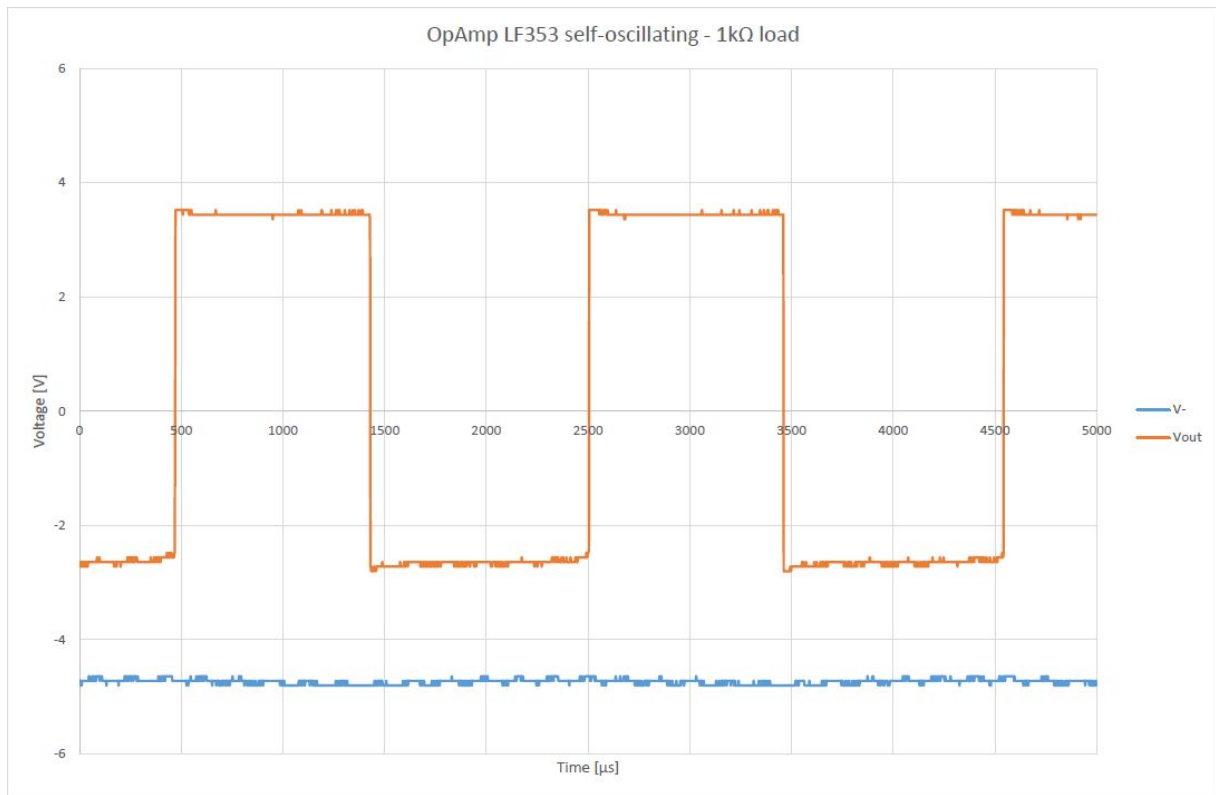
The frequency difference comes probably from the inaccuracy of the used components and the test circuit construction- everything is built on a breadboard with relatively long wires (refer to the following figures).

## Compact Rectangular Pulse Generation

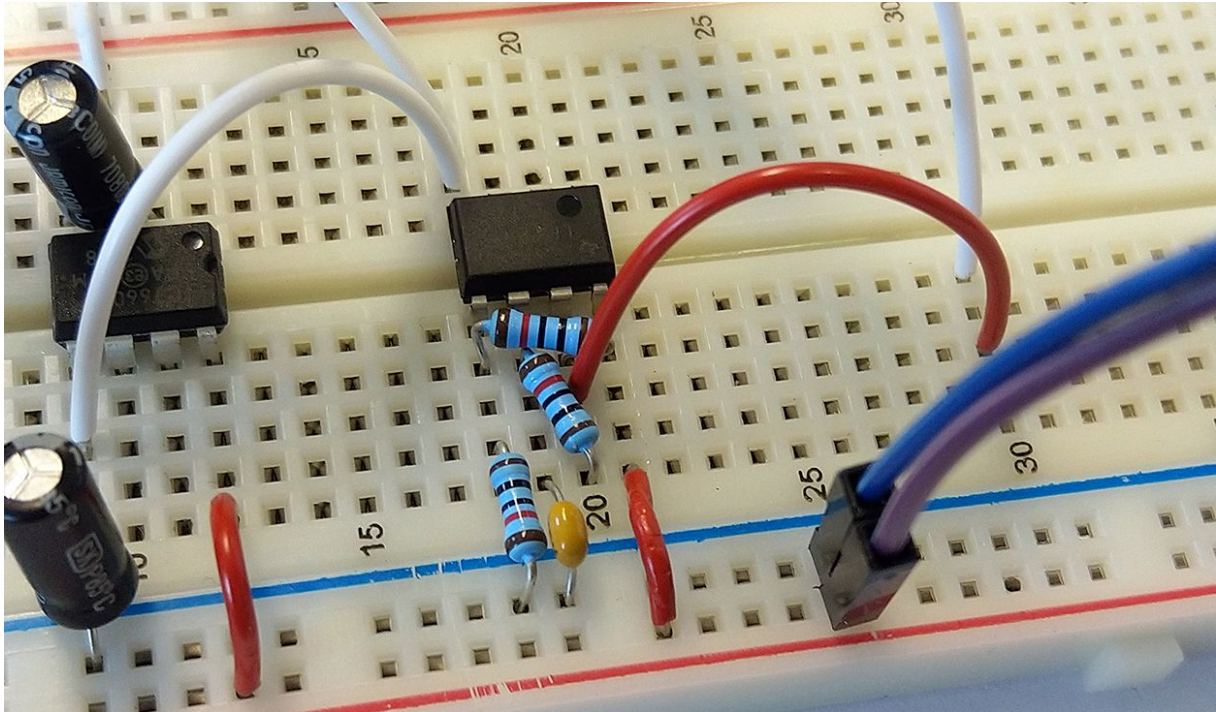




## Compact Rectangular Pulse Generation



## Compact Rectangular Pulse Generation



### Externally triggered generator

The circuit of a self oscillating circuit can be seen in the following figure. The parameters are the following:

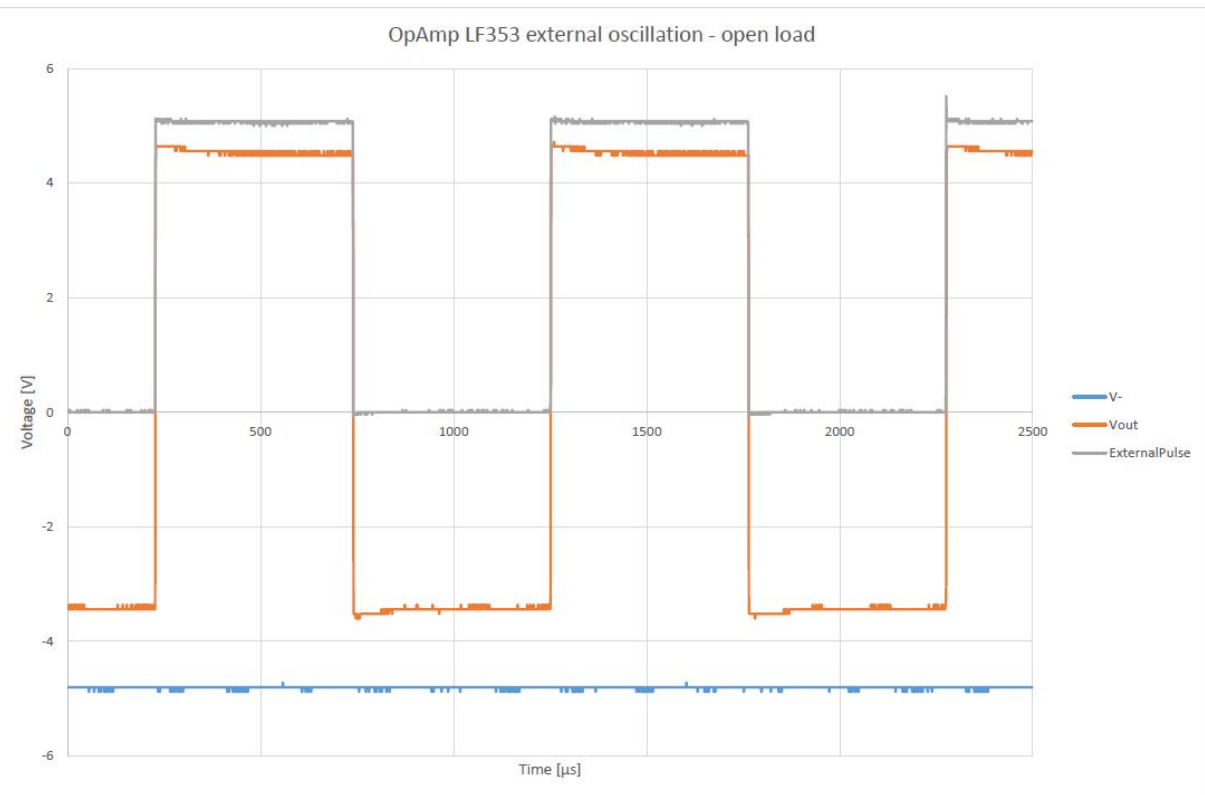
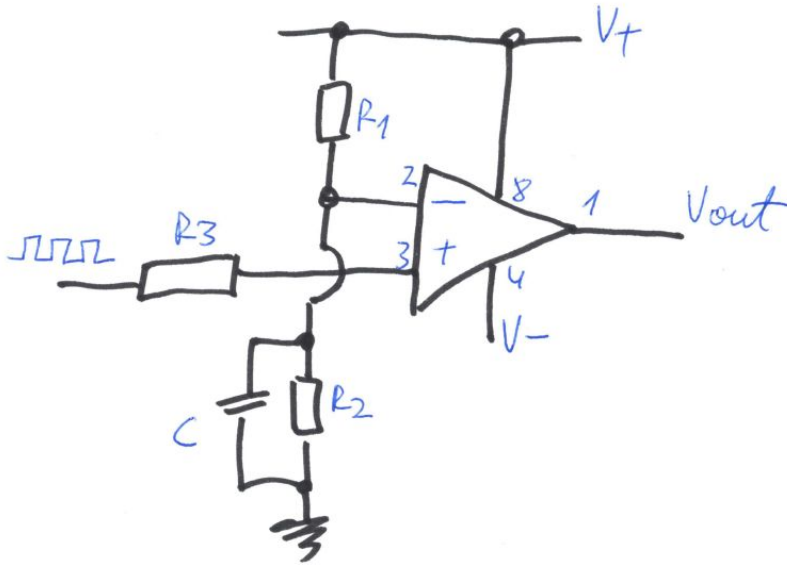
- $R1 = R2 = 10k\ \Omega$
- $R3 = 5k\ \Omega$
- $C = 0.1\ \mu F$
- External triggering from an Arduino
- Power from Arduino 5V pin (Arduino powered with 12V)

The theoretical oscillation frequency is 976.6Hz (Arduino D5 PWM frequency) and the measured frequency is

- 976.3Hz - open load
- 976.3Hz -  $1k\ \Omega$  load

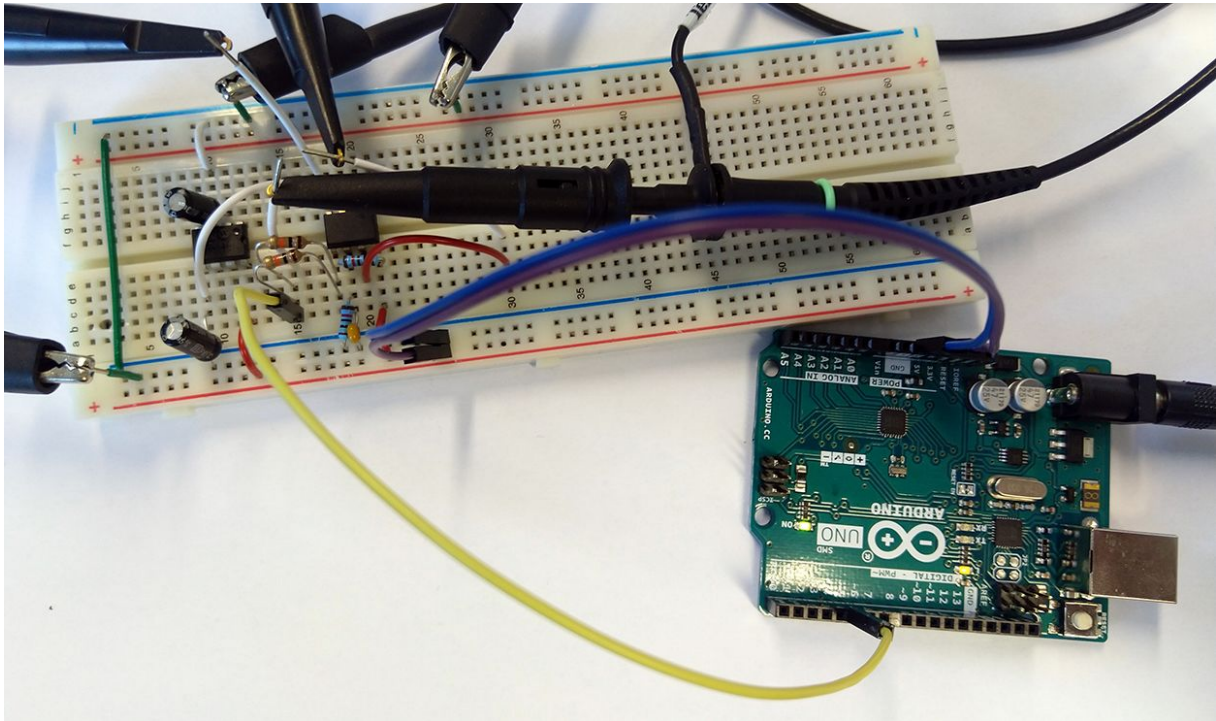
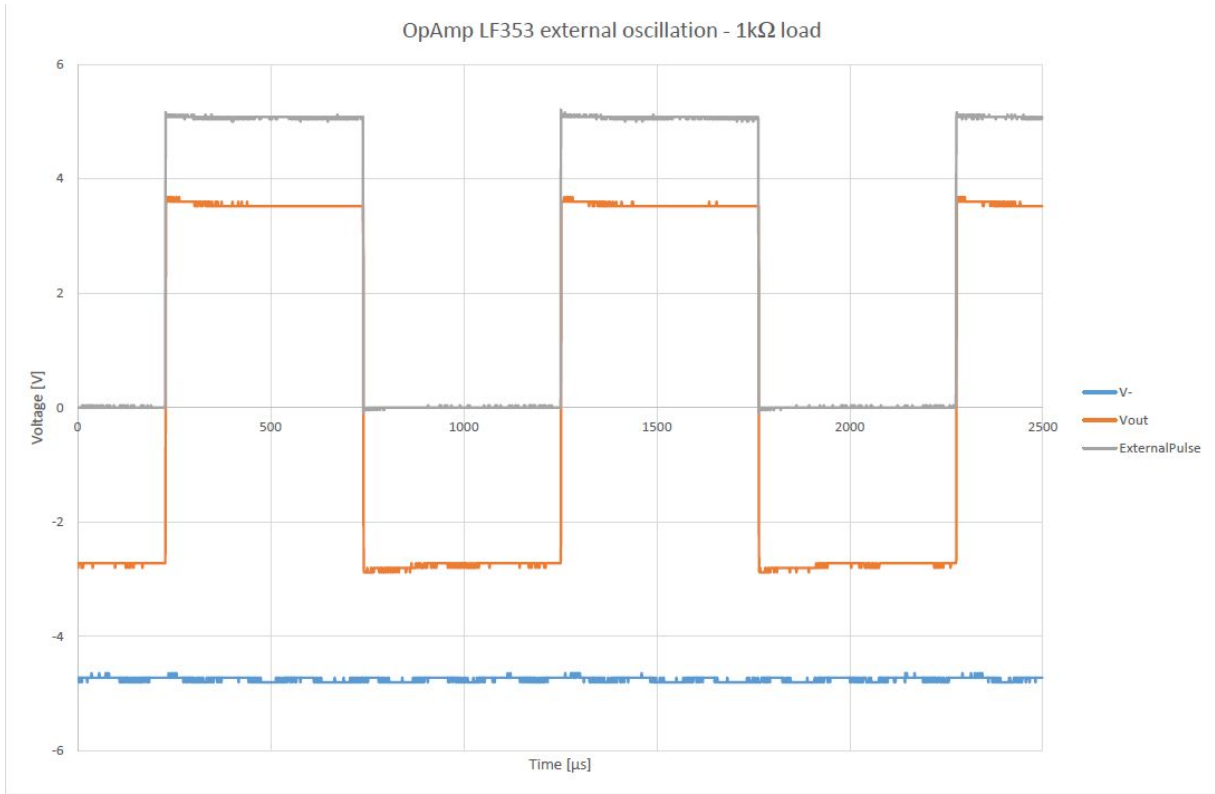
The frequency difference is negligible and follows ideally the theory.

## Compact Rectangular Pulse Generation

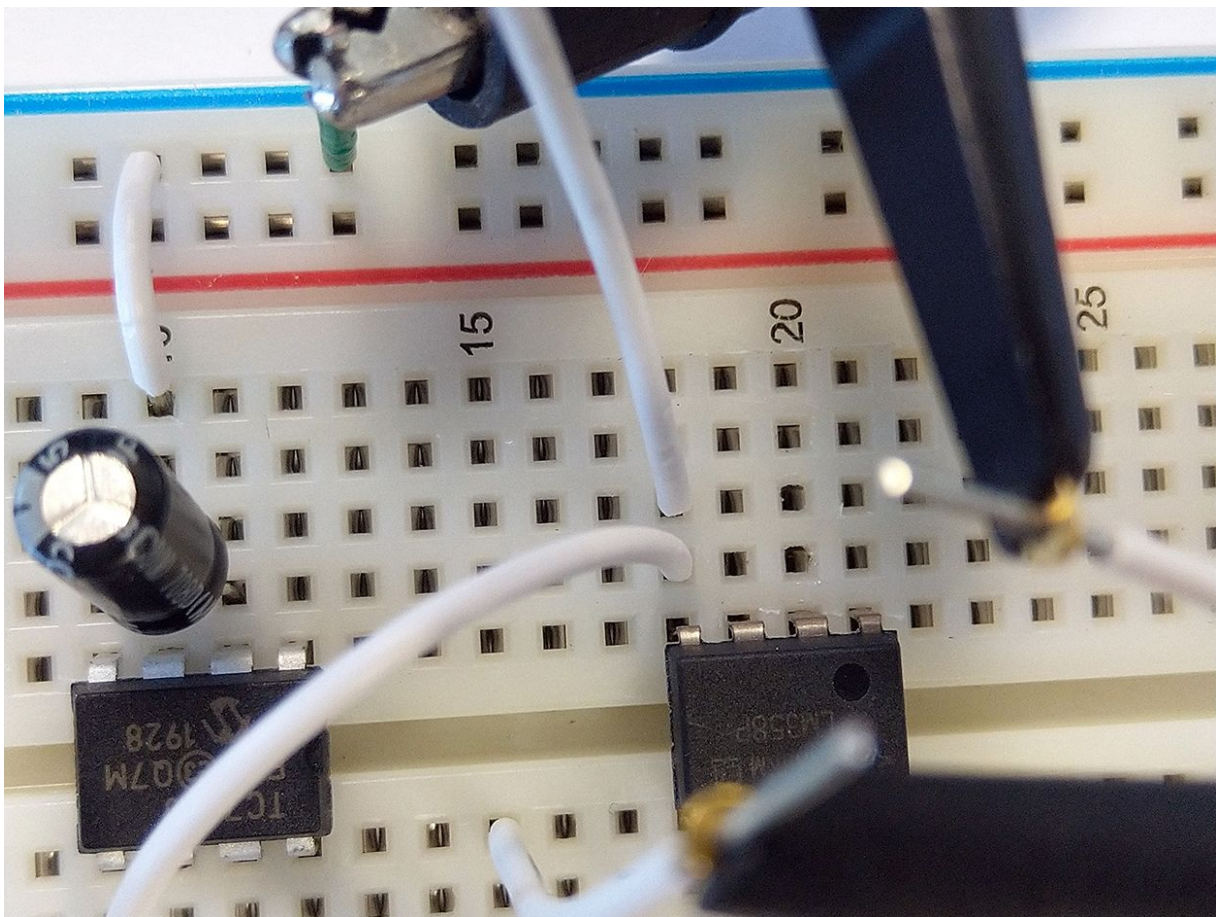
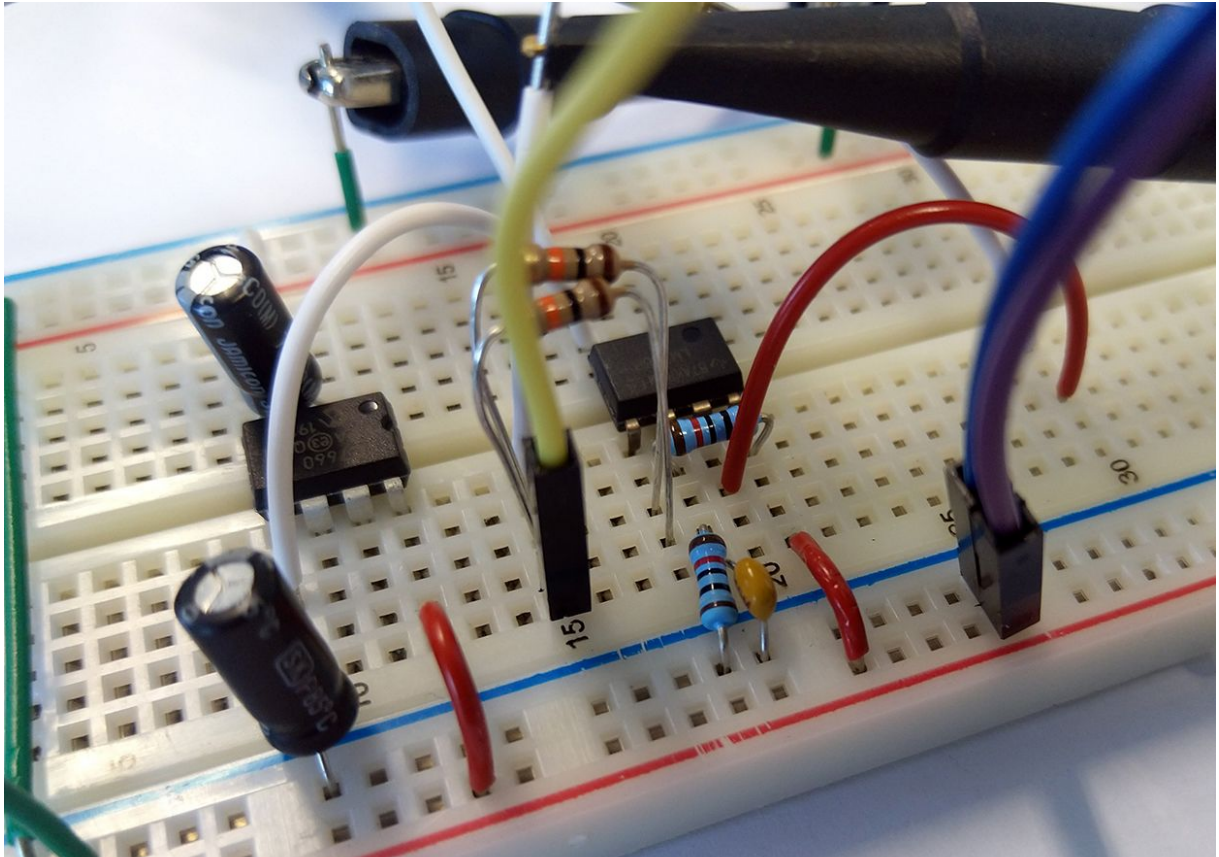




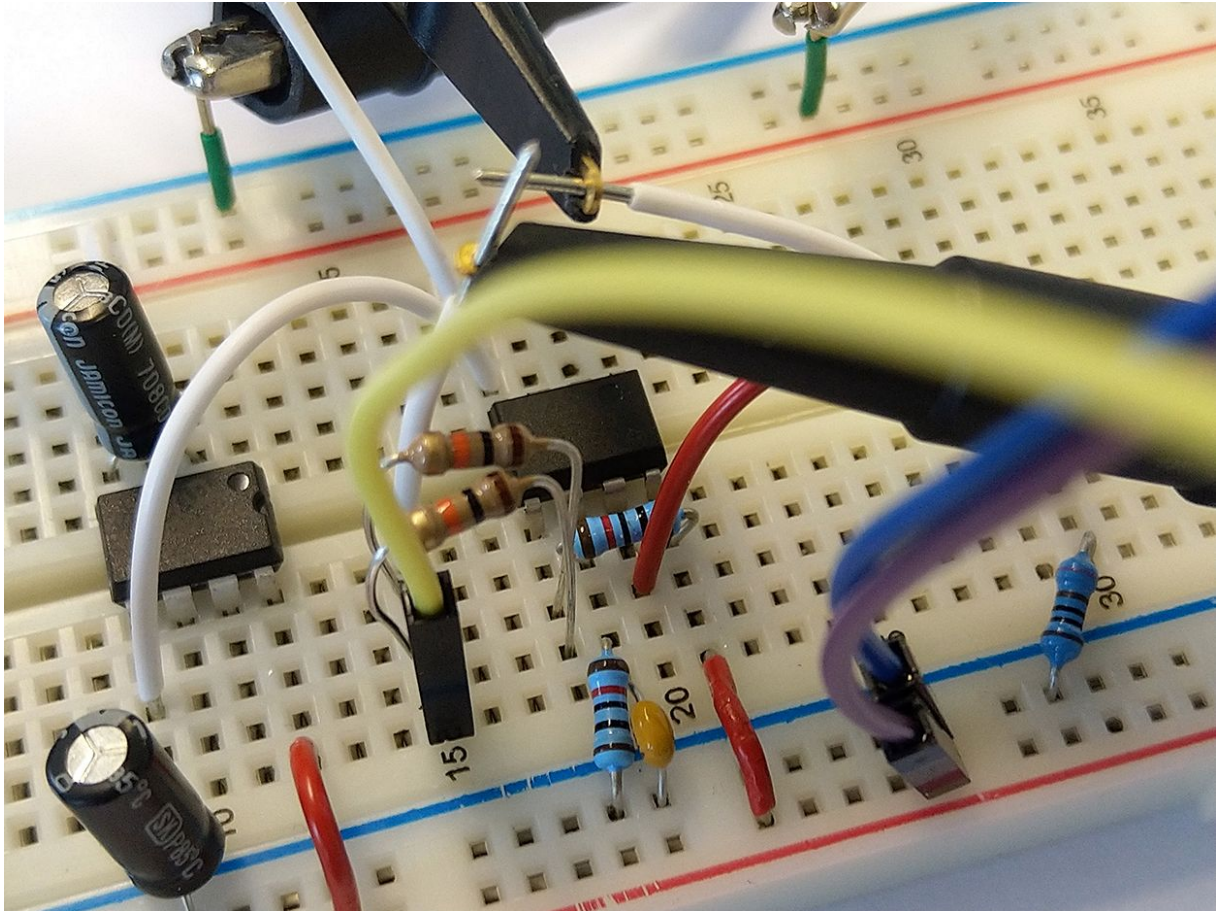
# Compact Rectangular Pulse Generation



## Compact Rectangular Pulse Generation







### Op-Amp circuit with LM358

General use Op-Amps are widely used and often readily available in from internal storage. Thus, it was interesting to compare the difference between a general use Op-Amp and a J-FET Op-Amp.

Same configuration and tests were made as with the LF353. Therefore, refer to LF353 for schematics and measurement figures. The Op-Amp chip was swapped during the testing and no other modifications were made.

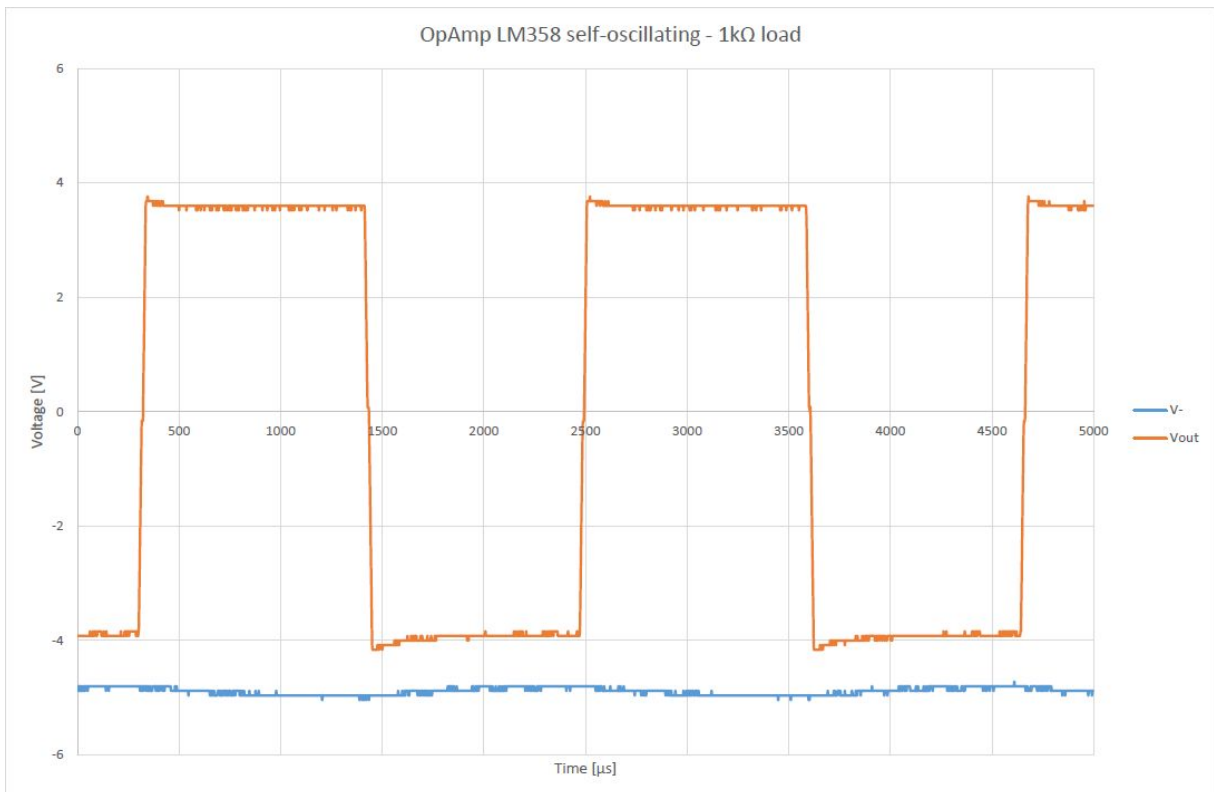
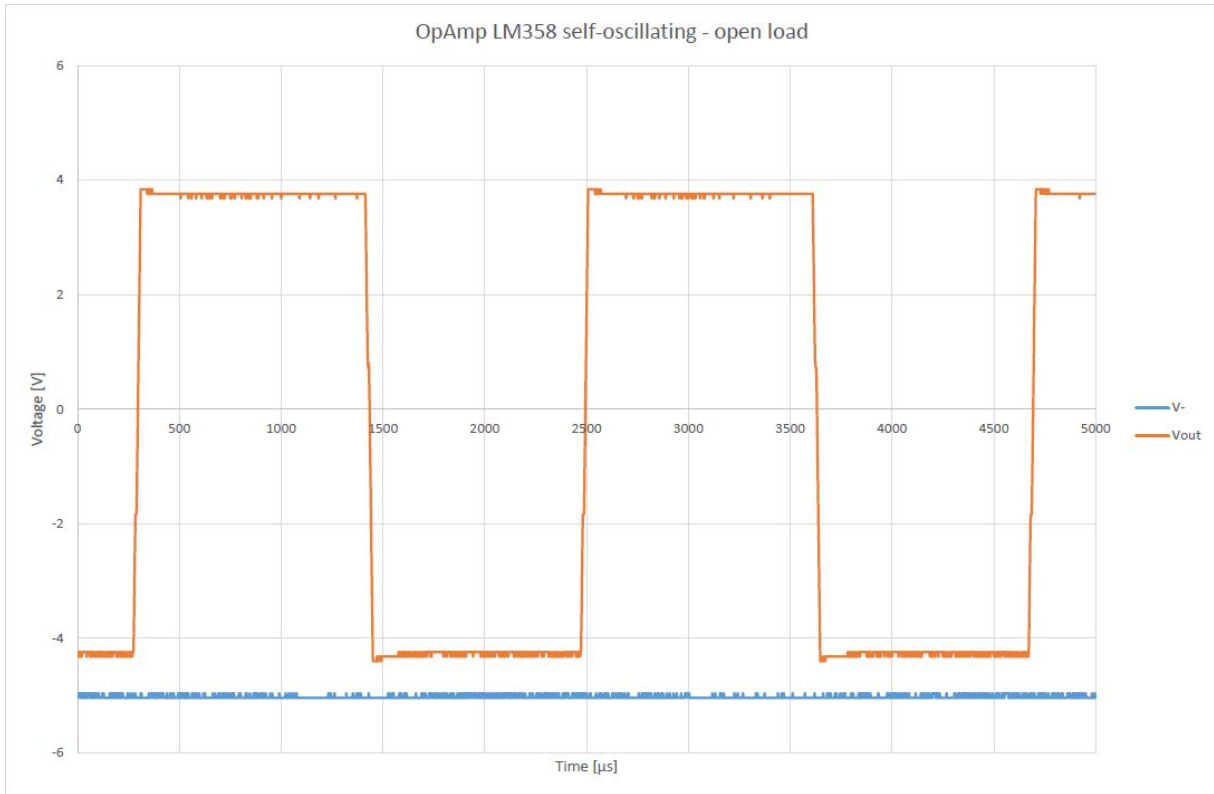
### Self-oscillating generator

Here the theoretical oscillation frequency (455Hz) matches better with the measured ones (460Hz) than it was with the LF353.

The output voltage is slightly reduced (positive peak) compared the LF353. On the contrary, the negative peak is slightly higher than LF353 has. The most significant difference is the slope of the voltage change. When the LF353 generated very steep voltage change then the LM358 requires some time. It is much better noticeable with the external triggered measurement curves.



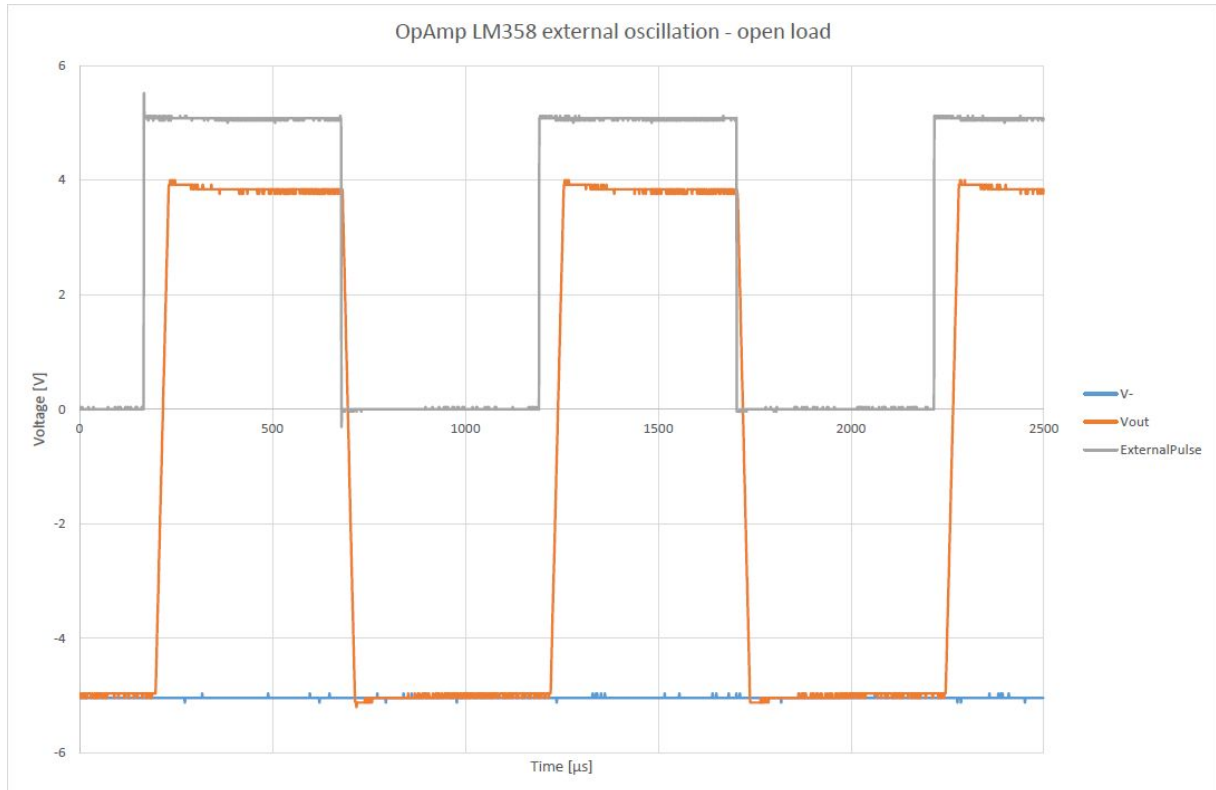
## Compact Rectangular Pulse Generation



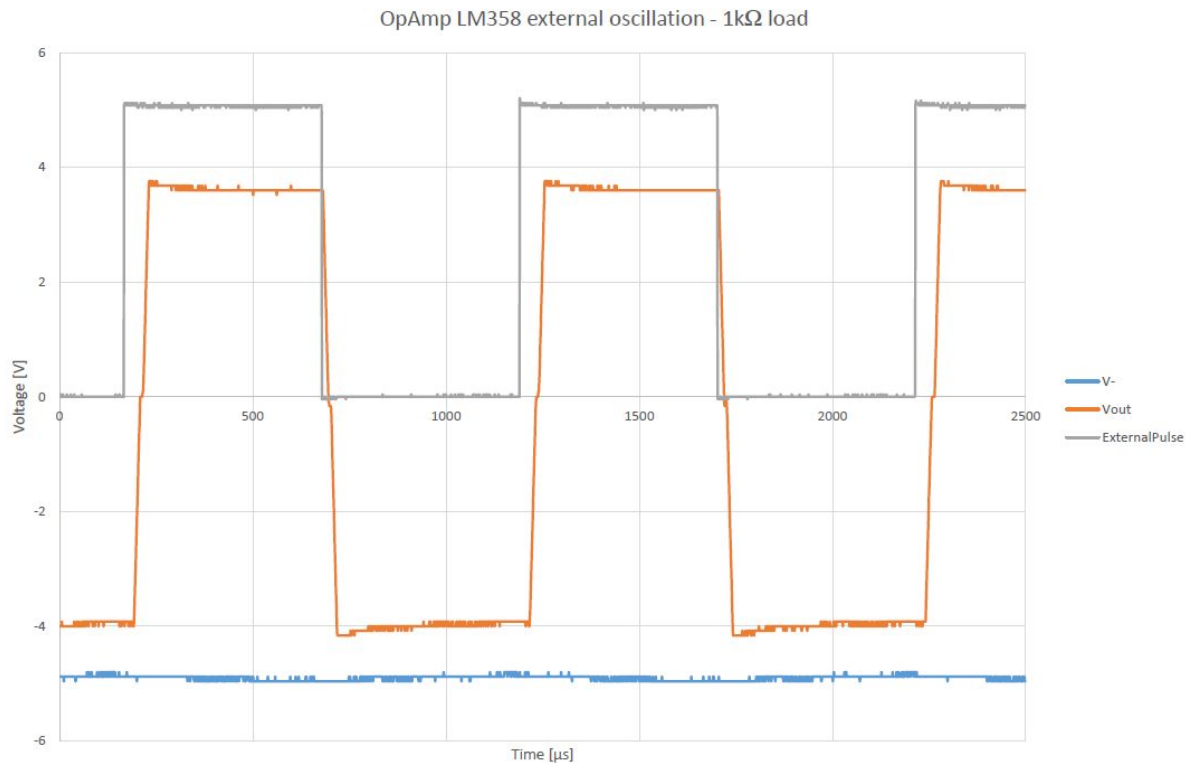
## Externally triggered generator

Again the theoretical frequency matches with the measured frequency 976Hz.

The output voltage is slightly reduced (positive peak) compared the LF353. On the contrary, the negative peak is slightly higher than LF353 has. The most significant difference is the slope of the voltage change. When the LF353 generated very steep voltage change then the LM358 requires some time.



## Compact Rectangular Pulse Generation



## Transistor based circuit

The schematic for this circuit can be seen under this [Link](#). The pulse is externally triggered by Arduino with approximately 976.6Hz frequency.

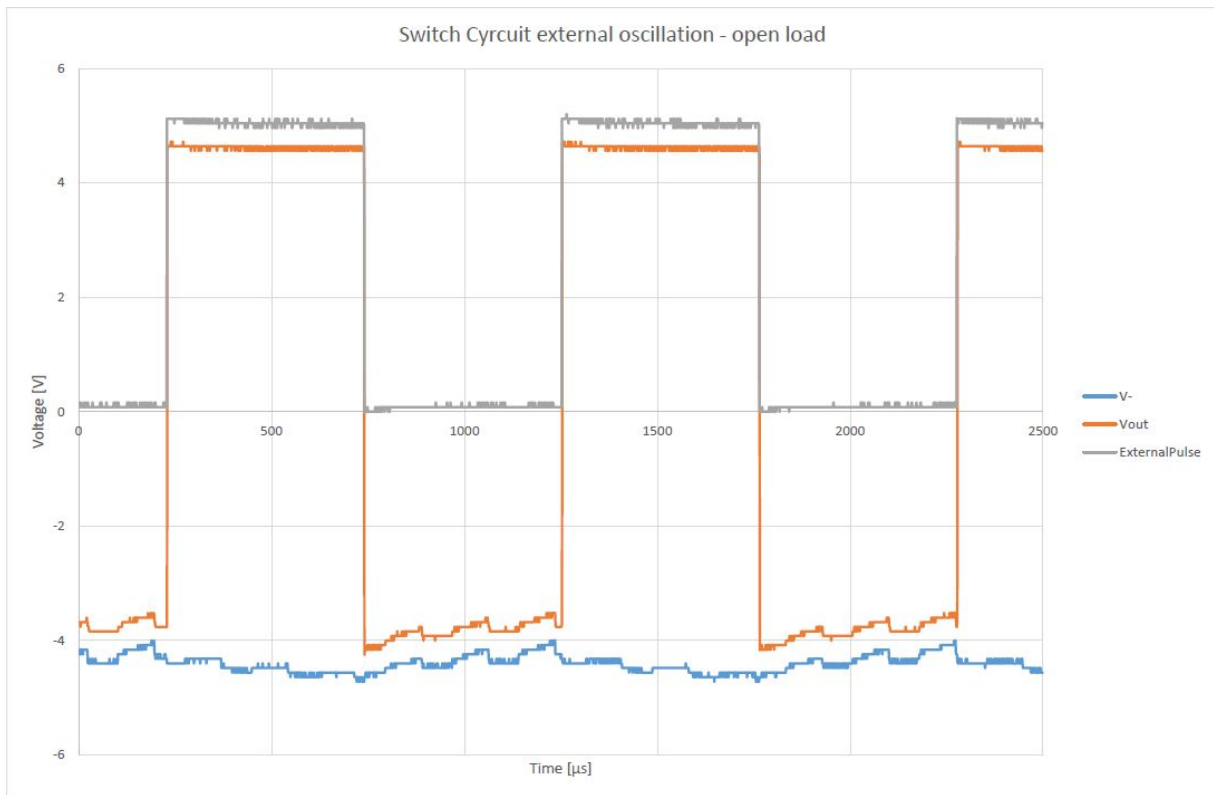
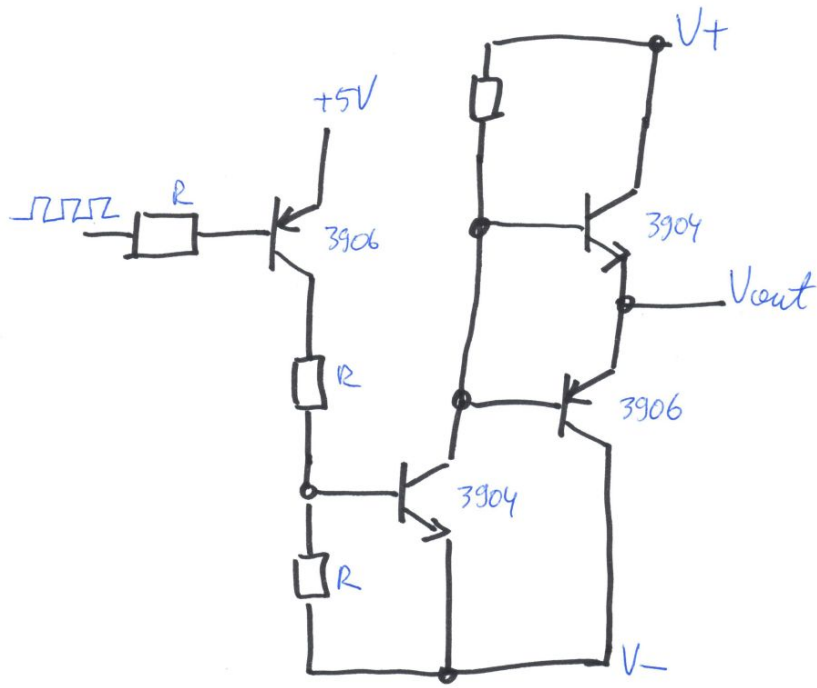
The parameters are the following:

- $R = 1\text{k}\Omega$
- Power from Arduino 5V pin (Arduino powered with 12V,  $V_+ = V_{in} = 5\text{V}$ ,  $V_-$  from TC7660)

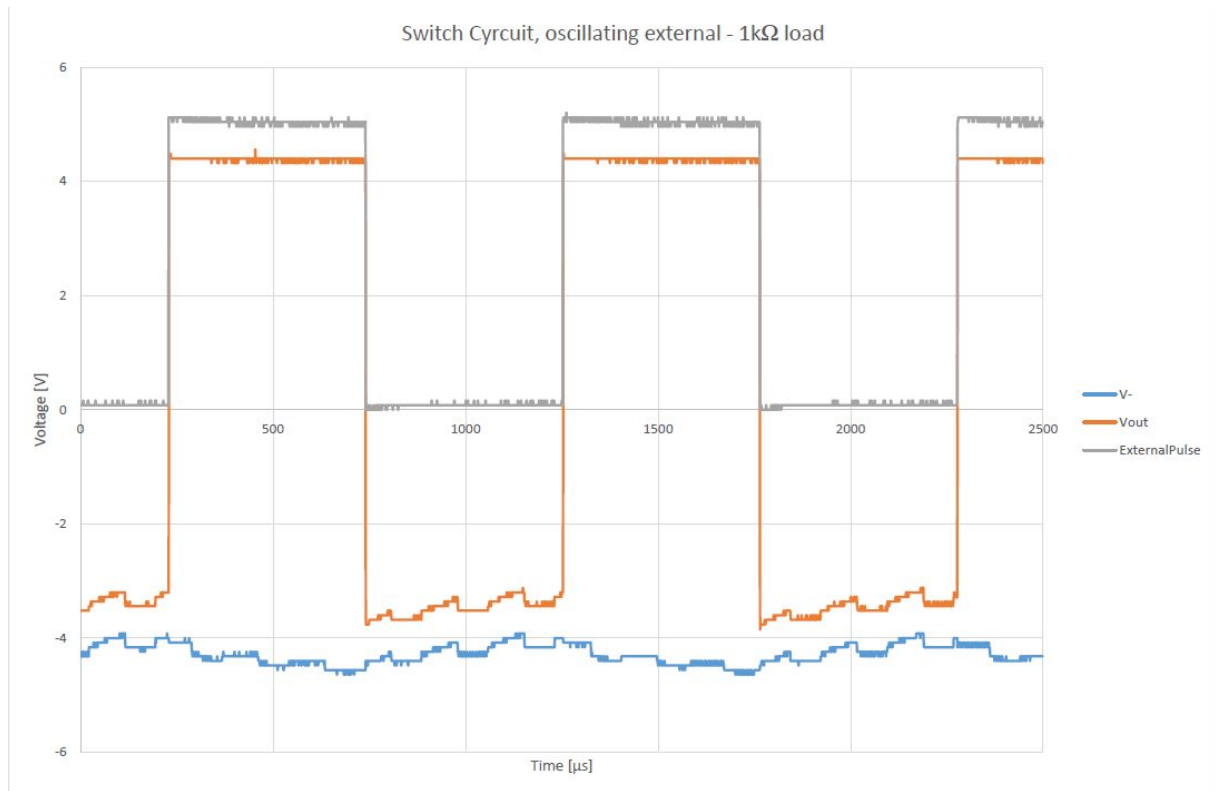
Positive with this circuit is that theoretically it can provide more power than an Op-Amp. Additionally, higher voltages could be possible. The Op-Amp LF353 can go up to  $\pm 18\text{V}$ , the used LM358  $\pm 16\text{V}$ . The transistors 2N3904 and 2N3906 could go up to 40V, however one should consider the voltage difference, thus 20V would be theoretical limit. In practical circuits the voltage should be lower. Nevertheless, there are some other transistors that can handle higher voltages and currents than these small cheap ones. Nevertheless, the Op-Amp will not reach its rail voltage whereas transistor circuit could go from rail to rail ( $+5$  to  $-5\text{V}$  in this example).

Otherwise the circuit is simple and there is not much to comment here. The schematics, measured curves and pictures from the test circuit can be seen in the following figures. The measured frequency (976.3Hz) follows ideally the theoretical one, as it should.

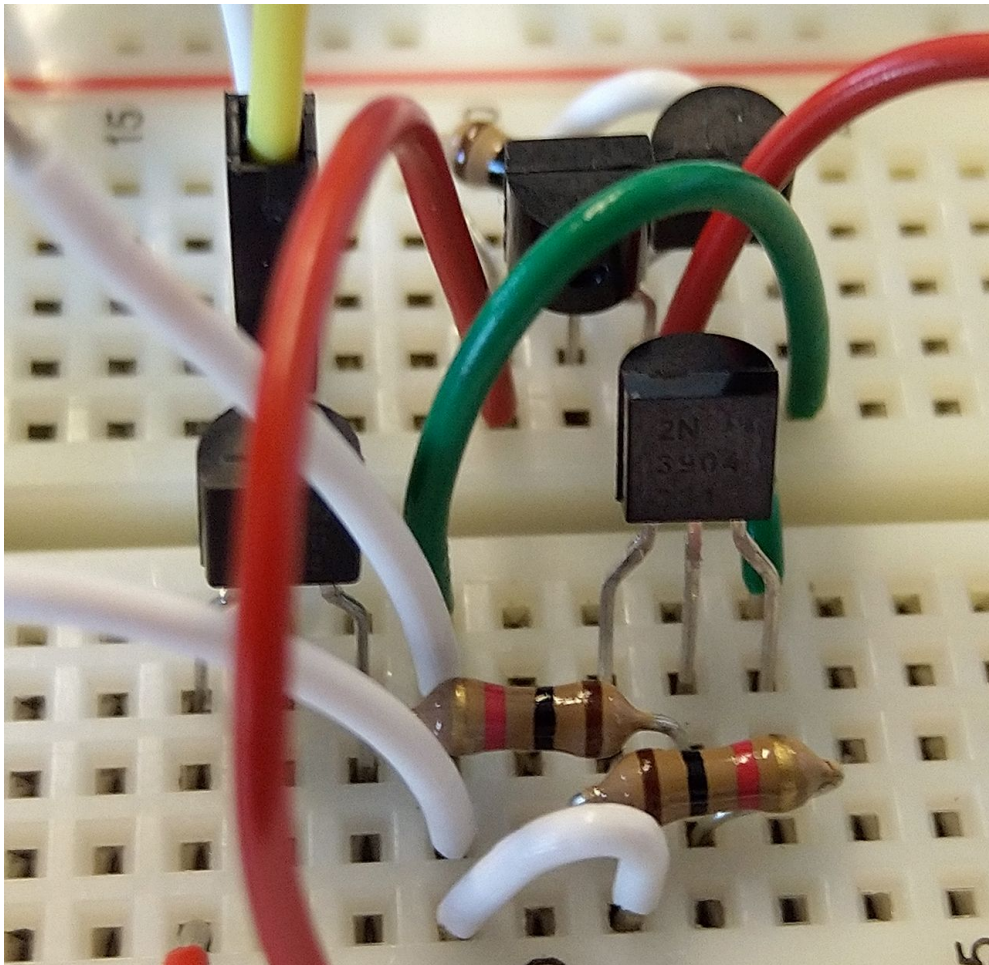
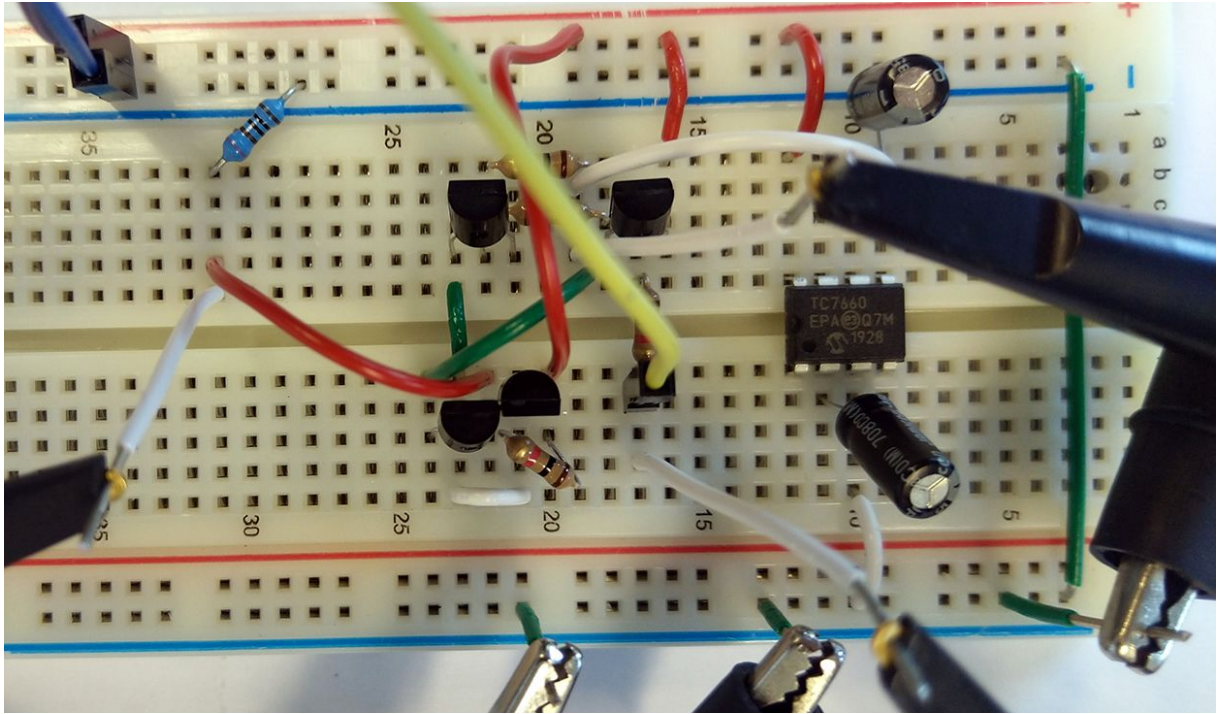
# Compact Rectangular Pulse Generation



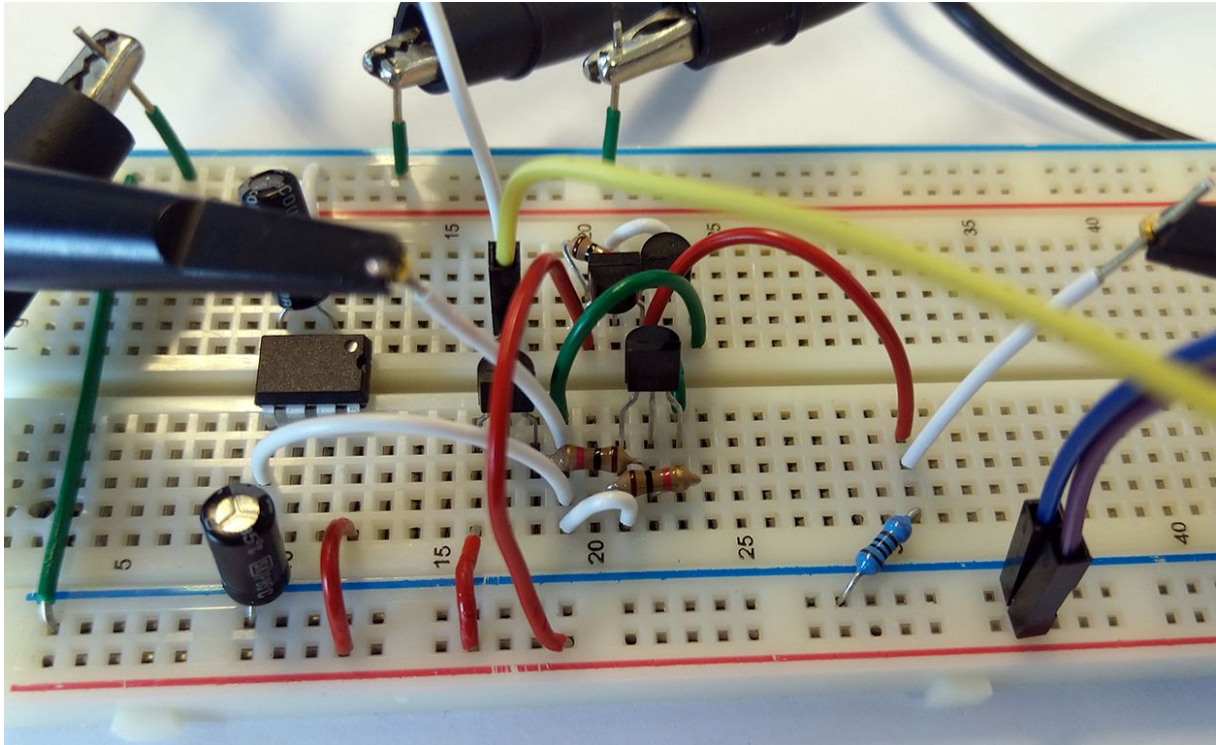
## Compact Rectangular Pulse Generation



# Compact Rectangular Pulse Generation







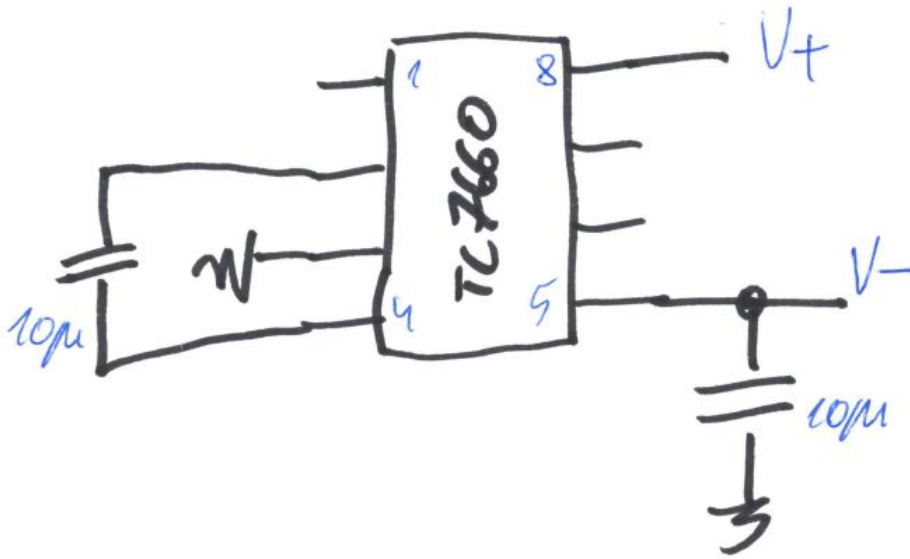
### Rectangular pulse generation summary

Three different circuits have been tested and they all perform similarly. Each circuit has its pros and cons, however there are none with a clear drawback. Even a general purpose Op-Amp could be used as its performance is very similar to the J-FET version. In the end due to the wish to have a compact solution the self-oscillating LF353 has been chosen as the best option. This circuit will be used in the final test circuit shown in the next chapter.

## Final circuit

The LF353 has two parallel circuits built in and that was the motivation to use this chip. After some testing it was noticed that using two circuits in parallel did not provide reliable results, very often the second channel rectangular pulse was just flat zero. Therefore, two Op-Amp circuits were built.

The negative power is provided by the TC7660 chip as in the previous chapter. The schematics can be seen here:

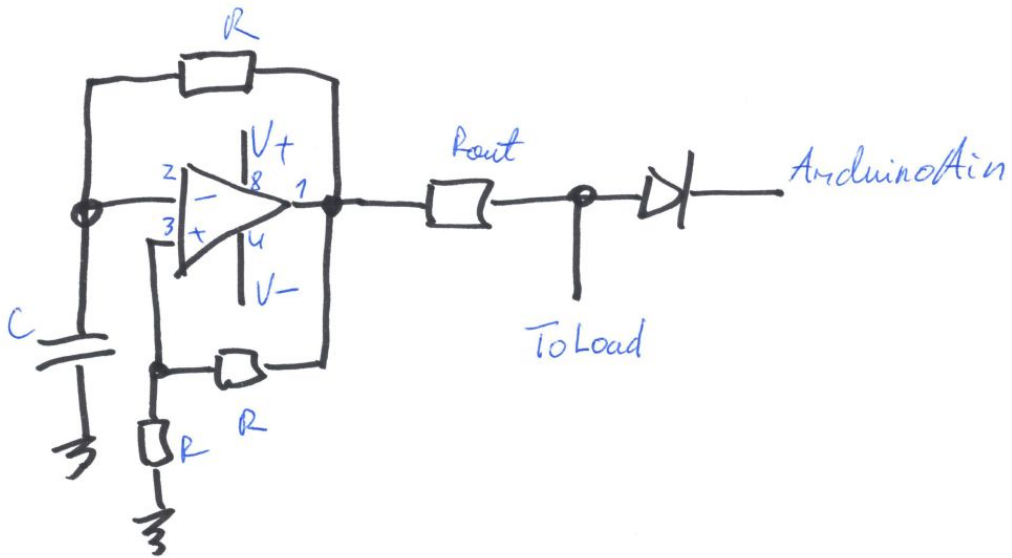


The Op-Amp schematics can be seen in the following. One could use a general one, here LF353 was used.

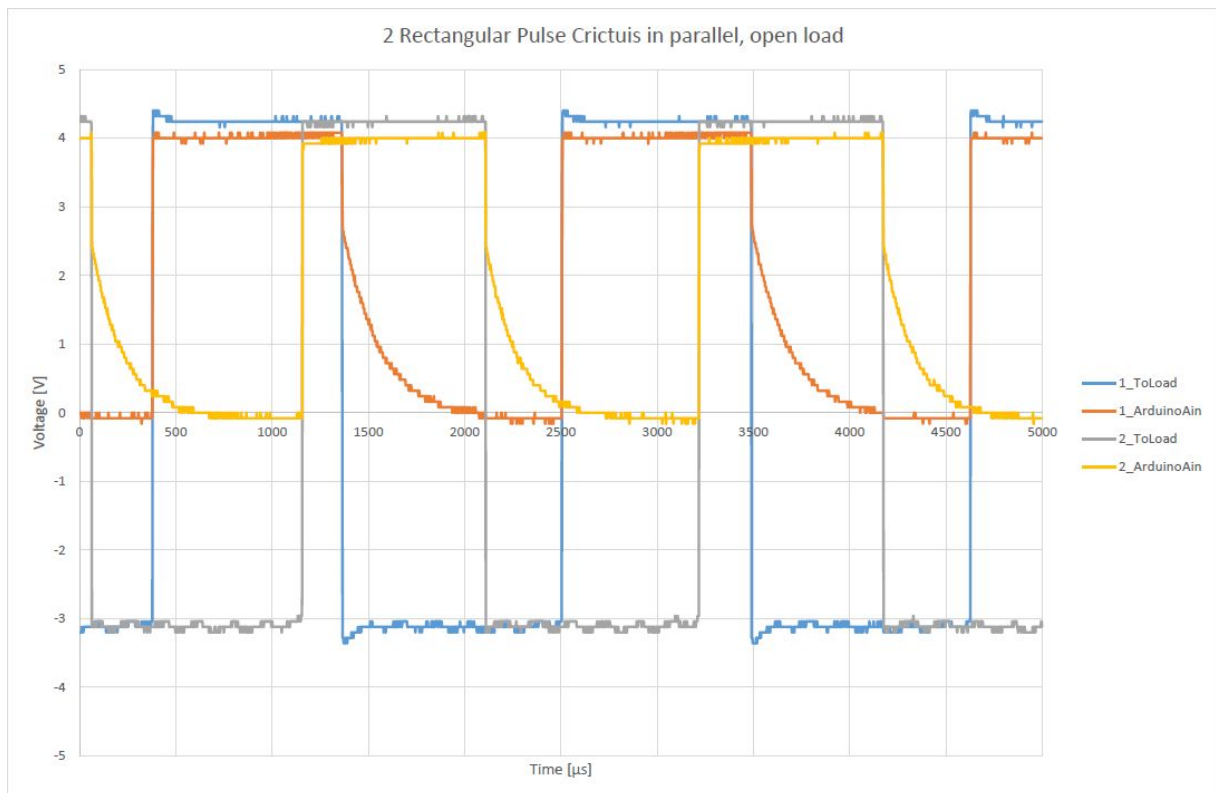
- $R = 10\text{k}\Omega$
- $C = 0.1\mu\text{F}$
- Power from Arduino 5V pin (Arduino powered with 12V)
- $R_{\text{out}} = 1\text{k}\Omega$

The resistors  $R_{\text{out}}$  protects the Op-Amp when the load will be shorted. The diode “rectifies” the rectangular pulse as the Arduino cannot handle negative voltage. Two of these Op-Amp generators were built in parallel to provide two separate rectangular waves to two different loads.

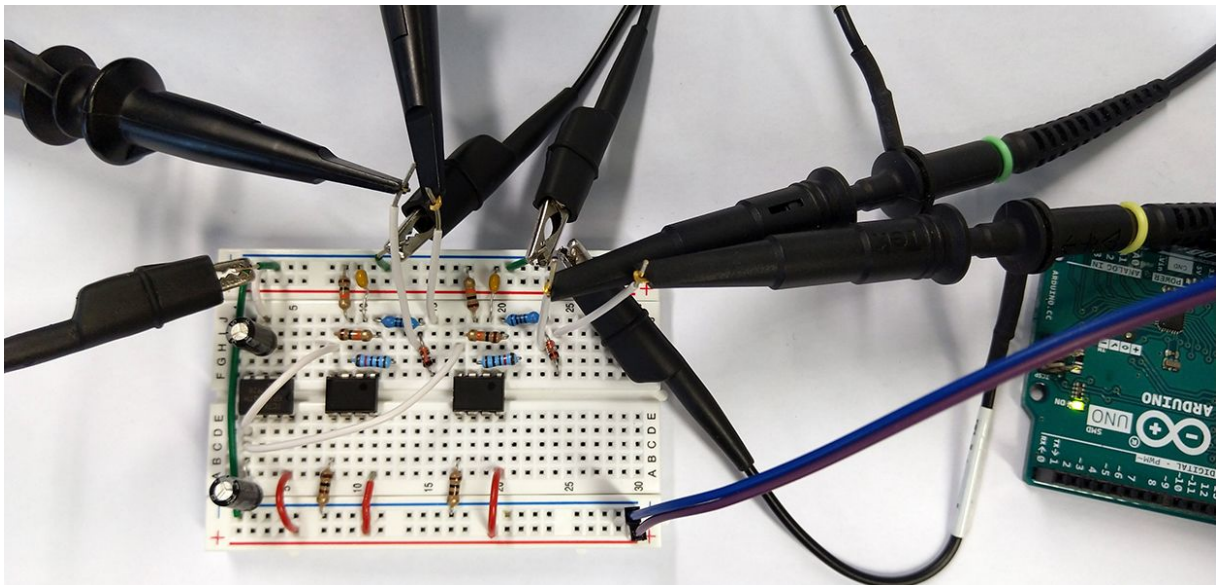
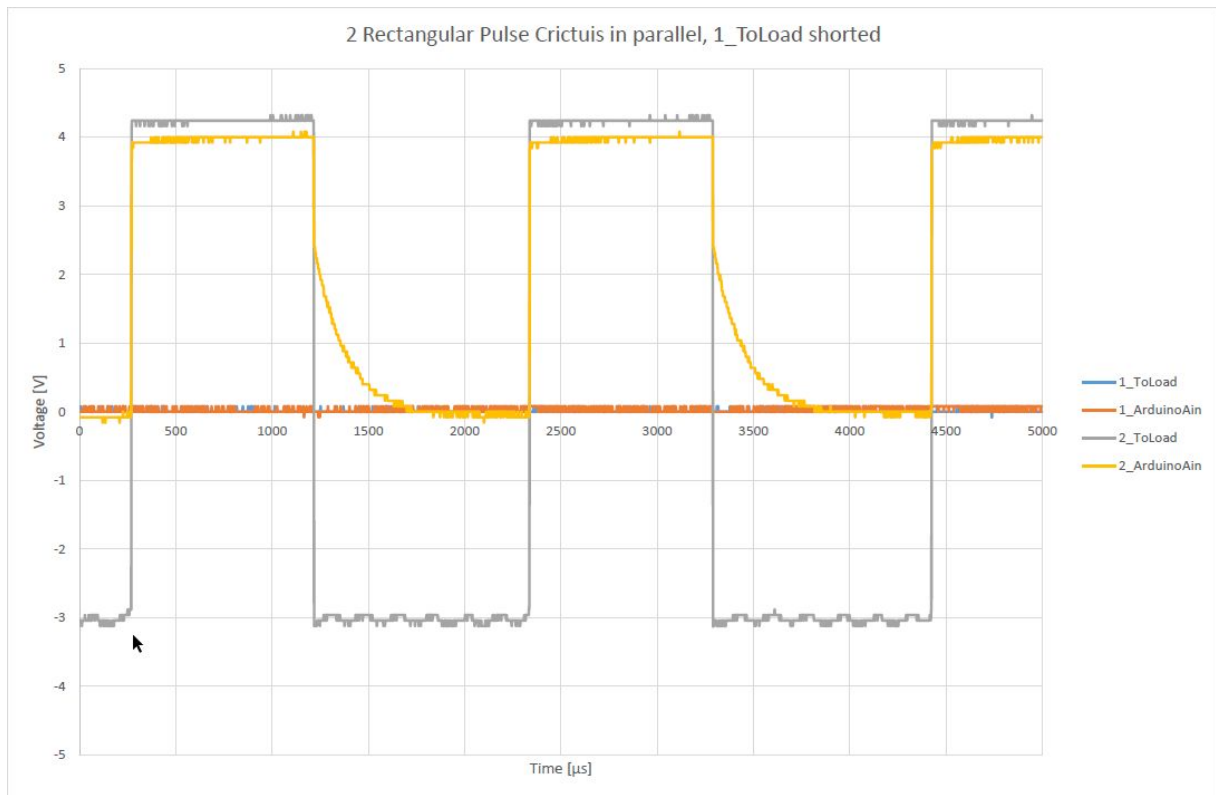
## Compact Rectangular Pulse Generation



From the measurement curves one can see that the Op-Amps are not synchronised, nevertheless that has no impact on the performance. The negative voltage generator can handle two Op-Amp loads without noticeable voltage drop. If one Op-Amp load was used the negative voltage was slightly over  $-3V$ . Even when one of the loads is shorted the negative voltage stays stable.

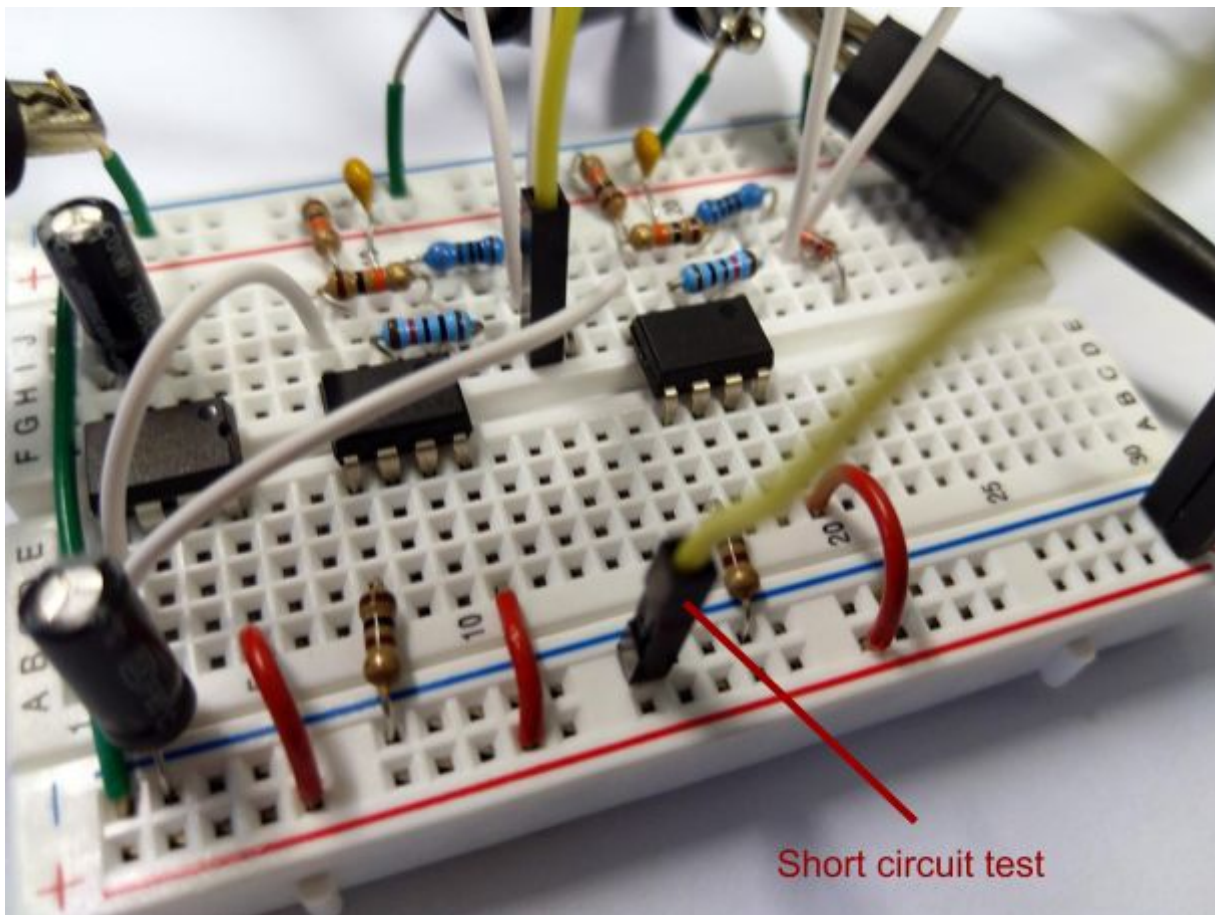
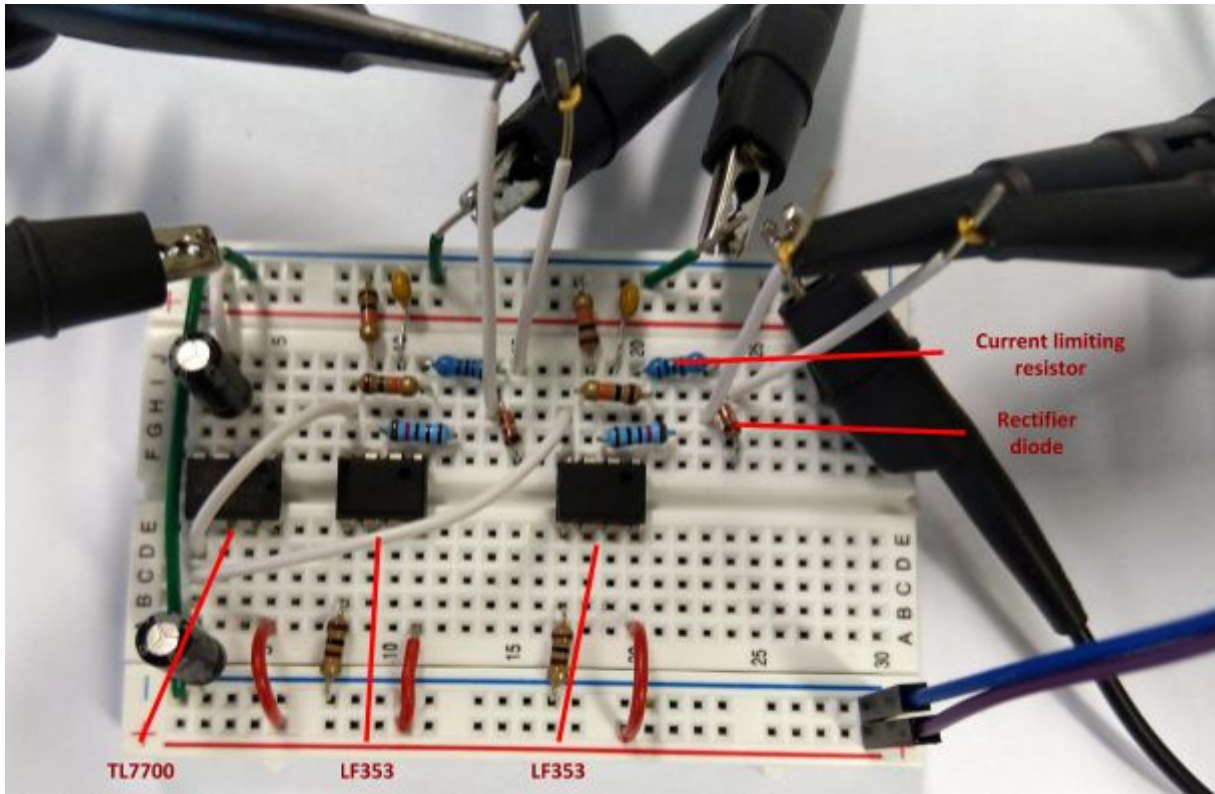


## Compact Rectangular Pulse Generation





# Compact Rectangular Pulse Generation



## Conclusion

The aim of this small project was to build a small rectangular pulse generator. First possible negative voltage sources and thereafter different pulse generators were investigated. In the end a breadboard setup was built. Although this version was not the smallest it was sufficient for this project. In the future a more compact PCB version could be made.

To conclude, one could achieve a rectangular pulse generator by just using one positive power supply. The output is very limited, however often it is just enough.