Two Sinus Generators

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by

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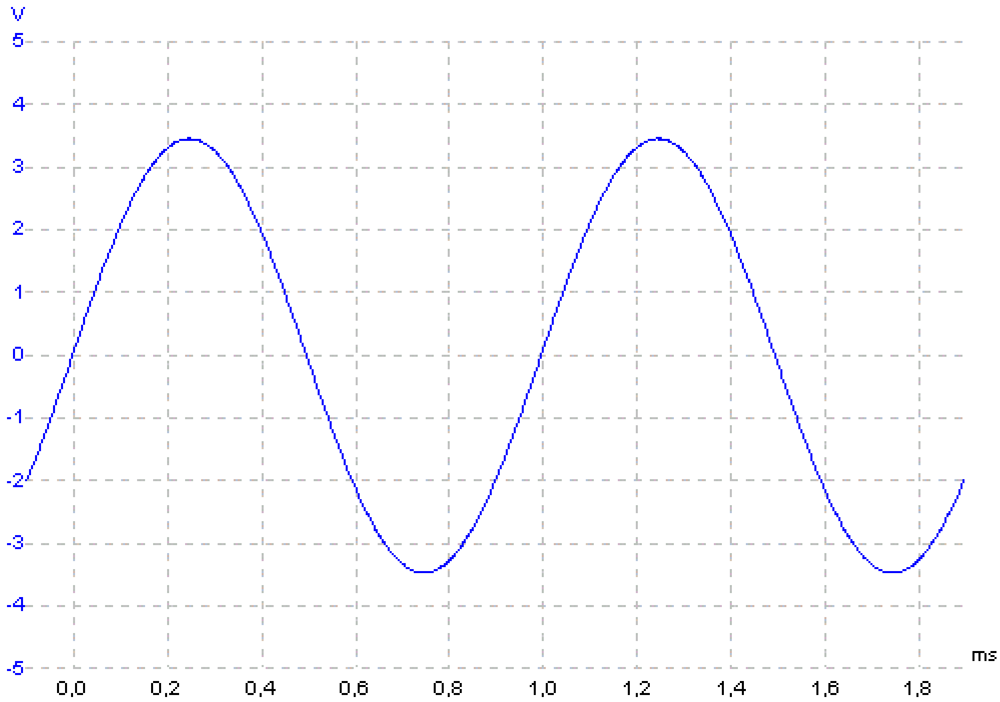

Contents

1. Introduction

To make electronic sinus wave generators with good properties is not a very easy task. Different methods to avoid distortion from higher order harmonics exist, and also methods to reduce noise of order 100 Hz from the surroundings and possibly also the power supply.

In this report two sinus wave generators are described, one designed by K. Johansson (modified Wien bridge) and one based on the integrated circuit ICL 8038. Circuit layouts are available with the authors comments and changes. An evaluation of the spectral properties of the generators is also present including oscilloscope views of signals and spectrum.

The modified generator by K. Johansson has a very low THD (Total Harmonic Distortion) of less than 0.05 % in the frequency range 300 Hz to 30 kHz and has very small even high order harmonics. It is somewhat sensitive to cooling of the lamp in the Wien bridge which makes distortion high at frequencies less than 300 Hz.

The ICL 8038 generator has relatively high high order harmonics and has a THD of about 1 % in the frequency range 300 Hz to 10 kHz and somewhat higher outside this range.

The results show that the modified sinus generator by K. Johansson has much better spectral properties than the ICL 8038 generator in the range 300 Hz to 30 kHz. On the other hand the ICL 8038 generator can also produce triangle and square wave signals and it is also able to produce signals at very low frequencies below 1 Hz.

2. Disclaimer

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3. Circuit information

3.1 Comments and changes by the author

The circuits of these sinus generators (Fig. 1, 2, 3 and 4) are relatively simple and can easily be built on a standard experimental board.

The main change due to the author is that the generator circuits were powered from + 30 V DC, not +/- 15 V with ground. A virtual ground for the generator output (i.e. at +15 V) was obtained by an extra operational amplifier that follow the +15 V voltage achieved by equally splitting +30 V by two 10 kOhm resistors. These resistors should have a resistance accuracy of 1 %. Some filtering capacitors were also added to the output of the operational amplifier. This technique to achieve output ground works well if the output current of the generator is low enough (i.e. less than 2 mA) to not overload the operational amplifier.

Another change was an extra operational amplifier that follows the signal from the generator circuit and works as buffered output. This works well if the output current is low enough (i.e. less than 2 mA) to not overload the operational amplifier.

It is best to use high quality components in the sinus generators. I.e. use metallic film resistors with an accuracy of 1 % and ceramic capacitors. To be able to fine tune the frequency it is good to use a linear thread-winded potentiometer with 10 revolutions.

According to K. Johansson it is very important to build the sinus generator in an aluminum box and to connect the signal ground to that box to avoid noise in the signal (especially 100 Hz noise).

3.2 Sinus generator by K. Johansson

The original circuit layout of the sinus generator made by K. Johansson is found in Fig. 1. One advantage with the generator is that the modified Wien bridge makes it possible to avoid stereo potentiometers, whose resistance layers are never identical. On the other hand the generator requires the connection of two equal capacitors for each frequency interval. Thus each capacitor pair should be connected by a dual connection miniature switch.

The author found that the large 1 MOhm potentiometer in Fig. 1 makes the circuit sensitive to 100 Hz noise. The first attempt to solve this problem was to make the potentiometer smaller to 250 kOhm (Fig. 2). By changing the potentiometer further to 20 kOhm and replacing the 10 kOhm resistors by 1 kOhm the noise was much reduced (Fig. 3). To make distortion as low as possible it is also better to adjust the resistance of the potentiometer as low as possible and select the capacitor C as large as possible for the suitable frequency range. Furthermore, by replacing the small lamp by 3 similar lamps in series the THD was reduced from about 0.2 % to well below 0.1 %. Then the 56 Ohm resistor must be replaced with one at 180 Ohm. See Figures 1 and 3. With these modifications the sinus generator in Fig. 3 has the best properties tested by the author.

3.3 Lamp data for sinus generator by K. Johansson

The miniature lamp in the Wien bridge of Johansson’s generator works as amplitude stabilizer. When the frequency is low (i.e. less than 300 Hz) the lamp has time to cool down somewhat during the oscillations. This gives a significant distortion of the sinus wave at low frequency. Data for a suitable lamp is found in Fig. 1. Such a lamp can be bought from the Swedish electronics component company ELFA (article number 33-538-10).

According to K. Johansson special glass covered PTC or NTC resistors that works as amplitude stabilizer in sinus generators are available. These resistors have better properties than a lamp, especially in the low frequency range. They are however not so common and it can be hard to find shops where to buy them.

3.4 Sinus generator based on ICL 8038

The sinus generator based on ICL 8038 (Fig. 4) is quite straight forward to build. Due to the manufacturer a distortion less than 1 % could be achieved by fine tuning the 10 kOhm (10 rev) resistors. The author also found that this was possible to achieve in the frequency range 300 Hz to 10 kHz. Also for this sinus generator it is best to choose the value of the frequency potentiometer as low as possible and select the capacitor C as large as possible for the suitable frequency range. According to the data papers for the ICL 8038 circuit the lowest distortion could be achieved when the circuit is running at +30 V. However the author’s circuit was burned when running at this voltage so it was changed to +24 V.

3.5 Power supply

The +30 V DC power supply (Fig. 5) was based on the integrated circuit LM 723 with an external power Darlington transistor. The sinus generator by K. Johansson requires a current of less than 70 mA why a small transformer of only 8 VA (2 x 15 V, max 250 mA) was used. The voltage can be fine adjusted with the potentiometer. By making the transformer larger and putting a cooling wing on the power transistor this power supply can be used for higher currents.

The ICL 8038 sinus generator also requires a very small current. But here a simple +/- 12 V DC power supply based on the voltage regulators 7812 and 7912 was used, although the ground between the regulators was not used. No circuit layout is available of this power supply. As an alternative the power supply mentioned above (Fig. 5) can be used also with this sinus generator but adjusted to +24 V.

To reduce 100 Hz ripple two capacitors (1000 uF and 100 nF) were connected in parallel between the power supply and the sinus generator circuits. These capacitors are not present in Figures 1 - 5.

4. Frequency ranges

4.1 Sinus generator by K. Johansson modified version 3 by the author

Each capacitor pair has it's own dual miniature switch, thus more than one capacitor pair can be connected at the same time. If for example capacitor value is 330 nF + 100 nF the frequency range will be 83 Hz to 383 Hz. To make distortion as low as possible use a high capacitor value and a low resistor value of the potentiometer. The frequency f (in Hz) can approximately be calculated by the formula f = k / (C * sqrt(R + 1000)) where C is given in Farad (F) and R in Ohm and the value of the constant k ~ 0.005. The sinus generator must be switched on for about 1 hour before the frequency is thermally stabilized. At 1 kHz the total frequency drift due to temperature variations is less than 15 Hz.

Nr	C (nF)	F_1 (Hz)	F_2 (Hz)
1	330	108	501
2	100	357	1.66 k
3	33	1.07 k	4.97 k
4	10	3.48 k	16.1 k
5	3.3	10.1 k	45.2 k
6	1.0	33.2 k	143 k

4.2 Sinus generator based on ICL 8038

Here only one capacitor can be selected at one time. To make distortion as low as possible use a high capacitor value and a low resistor value of the potentiometer. The sinus generator must be switched on for about 20 minutes before the frequency is thermally stabilized. At 1 kHz the total frequency drift due to temperature variations is less than 10 Hz.

Nr	C (nF)	F_1 (Hz)	F_2 (Hz)
1	33000	-	1.9
2	10000	-	5.6
3	3300	0.99	16.0
4	1000	3.22	51.9
5	330	9.61	155
6	100	31.9	513
7	33.0	97.8	1.57 k
8	10.0	324	5.19 k
9	3.30	936	14.5 k
10	1.00	3.24 k	51.2 k
11	0.33	8.54 k	137 k

5. Distortion and spectral properties

5.1 Sinus generator by K. Johansson modified version 3 by the author

Frequency range: 100 Hz – 140 kHz (6 ranges)
Output voltage: 2.40 V
Max output current: 2 mA

Measurement situation:

The load of the sinus generator was a resistor of 2 kOhm. This gives a current of approximately 1 mA. The spectrum was measured by a Pico Technology ADC-212 12-bit digital oscilloscope for PC with PicoScope version 5.07.3 software. The signal was averaged 100 samples before measurement.

Distortion:

In the table below the distortion is given in percent. THD means Total Harmonic Distortion and the numbers 2, 3, 4 and 5 refer to the high order harmonics. Oscilloscope images and spectrum can be found in the Figures 6a to 13a.

Tone	C (nF)	THD w noise	THD	1	2	3	4	5
100 Hz	330 + 100	0.597	0.148	100.000	0.006	0.148	0.002	0.002
300 Hz	330 + 100	0.285	0.030	100.000	0.004	0.030	0.002	0.002
1 kHz	100 + 33	0.271	0.038	100.000	0.008	0.037	0.001	0.001
3 kHz	33 + 10	0.323	0.044	100.000	0.013	0.042	0.001	0.001
10 kHz	10 + 3.3	0.251	0.032	100.000	0.008	0.031	0.001	0.001
30 kHz	3.3 + 1.0	0.177	0.037	100.000	0.029	0.022	0.004	0.006
100 kHz	1.0	0.323	0.091	100.000	0.080	0.041	0.003	0.009

5.2 Sinus generator based on ICL 8038

Frequency range: 1 Hz – 140 kHz (11 ranges)
Output voltage: 1.70 V
Max output current: 2 mA

Measurement situation:

The load of the sinus generator was a resistor of 2 kOhm. This gives a current of approximately 1 mA. The spectrum was measured by a Pico Technology ADC-212 12-bit digital oscilloscope for PC with PicoScope version 5.07.3 software. The signal was averaged 100 samples before measurement.

Distortion:

In the table below the distortion is given in percent. THD means Total Harmonic Distortion and the numbers 2, 3, 4 and 5 refer to the high order harmonics. Oscilloscope images and spectrum can be found in the Figures 6b to 13b.

Tone	C (nF)	THD w noise	THD	1	2	3	4	5
100 Hz	100	2.215	1.149	100.000	1.060	0.423	0.061	0.061
300 Hz	33.0	2.077	1.028	100.000	0.951	0.389	0.047	0.038
1 kHz	10.0	1.939	0.894	100.000	0.855	0.257	0.028	0.016
3 kHz	3.30	1.599	1.048	100.000	1.032	0.136	0.086	0.090
10 kHz	1.00	1.694	0.985	100.000	0.965	0.183	0.049	0.046
30 kHz	0.33	1.879	1.289	100.000	1.249	0.307	0.074	0.038
100 kHz	0.33	3.441	1.573	100.000	1.515	0.421	0.020	0.005

6. Summary

The circuits of the sinus generators described here are relatively simple and can easily be built on a standard experimental board. High quality components should be used.

The modified generator by K. Johansson (version 3) has a very low THD of less than 0.05 % in the frequency range 300 Hz to 30 kHz and has very small even high order harmonics. It is somewhat sensitive to cooling of the lamp in the Wien bridge which makes distortion high at frequencies less than 300 Hz.

The ICL 8038 generator has relatively high high order harmonics and has a THD of about 1 % in the range 300 Hz to 10 kHz and somewhat higher outside this range.

To make distortion as low as possible the frequency capacitor value must be selected as large as possible and the potentiometer resistance value as low as possible. The sinus generators must also be switched on for several minutes before being used to avoid frequency drift due to temperature variations.

The results show that the modified sinus generator by K. Johansson has much better spectral properties than the ICL 8038 generator in the range 300 Hz to 30 kHz. On the other hand the ICL 8038 generator can also produce triangle and square wave signals and it is also able to produce signals at very low frequencies below 1 Hz. The ICL 8038 generator also has somewhat smaller frequency drift due to temperature variations than the generator by K. Johansson.

7. Acknowledgement

This document was written with kind permission by Kenneth Johansson who designed the original version of one of the sinus generators. The author is very grateful to him. Many thanks also to him for critically reading the draft of this document. His comments and suggestions have been very valuable.

8. Appendix

8.1 Definition of THD

Total Harmonic Distortion (THD) is the ratio of the harmonic power to the power at the measured peek. In the following equation, v1 is the RMS value at the peek frequency and v2, v3, …, vn are RMS values at the harmonics.

THD = sqrt (v2^2 + v3^2 + … + vn^2) / v1

8.2 Definition of THD with noise

Total Harmonic Distorsion + Noise (THD + N) is the ratio of the harmonic power plus noise to the power of the measured peek. THD + N values will almost always be greater than the THD values for the same signal.

THD + N = sqrt (sum of squares of RMS values excluding measured peek) /

(RMS value of measured peek)

9. References

9.1 Article references

1. "ICL 8038 Precision Waveform Generator / Voltage Controlled Oscillator", by Harris Semiconductors, November 1996. The article can be downloaded from the web page of this document.

2. "Everything You Always Wanted to Know About the ICL 8038", by Intersil, November 1996. The article can be downloaded from the web page of this document.

3. "LM 723 / LM 723C Voltage Regulator", by National Semiconductor, December 1994. The article can be downloaded from the web page of this document.

4. "Wien-oscillator med låg distorsion" (in Swedish), (in English: "Wien oscillator with low distortion"), Project report by Daniela Stenhoff and Fredrik Tillman (supervisor Clas Agnvall), at the Department of Applied Electronics at Lund Institute of Technology, 1999. Please contact the author of this document to get a paper copy (in Swedish).

9.2 Internet references

5. This report “Two Sinus Generators” can be found on the web page:

http://www.astro.lu.se/~stefans/singen.html

6. The home page of the author Stefan Spännare can be found at:

http://www.astro.lu.se/~stefans/index.html

7. Elektronikhörnan (Electronics corner by Kenneth Johansson, in Swedish):

http://home8.swipnet.se/~w-87141/Elektronikh%F6rna.html

8. Sinus oscillator by Kenneth Johansson:

http://home8.swipnet.se/~w-87141/Ritningsaml/SINUSO26.htm

9. ELFA (A Swedish electronics component company):

http://www.elfa.se

10. Pico Technology. PC based oscilloscopes and data loggers:

http://www.picotech.com

11. L.A.N.Z.O. Sweden AB. PC baserade oscilloskop och dataloggrar (in Swedish):

http://www.lanzo.se/index.html

10. Figures

Figure 1. Sinus generator by K. Johansson, original circuit layout:

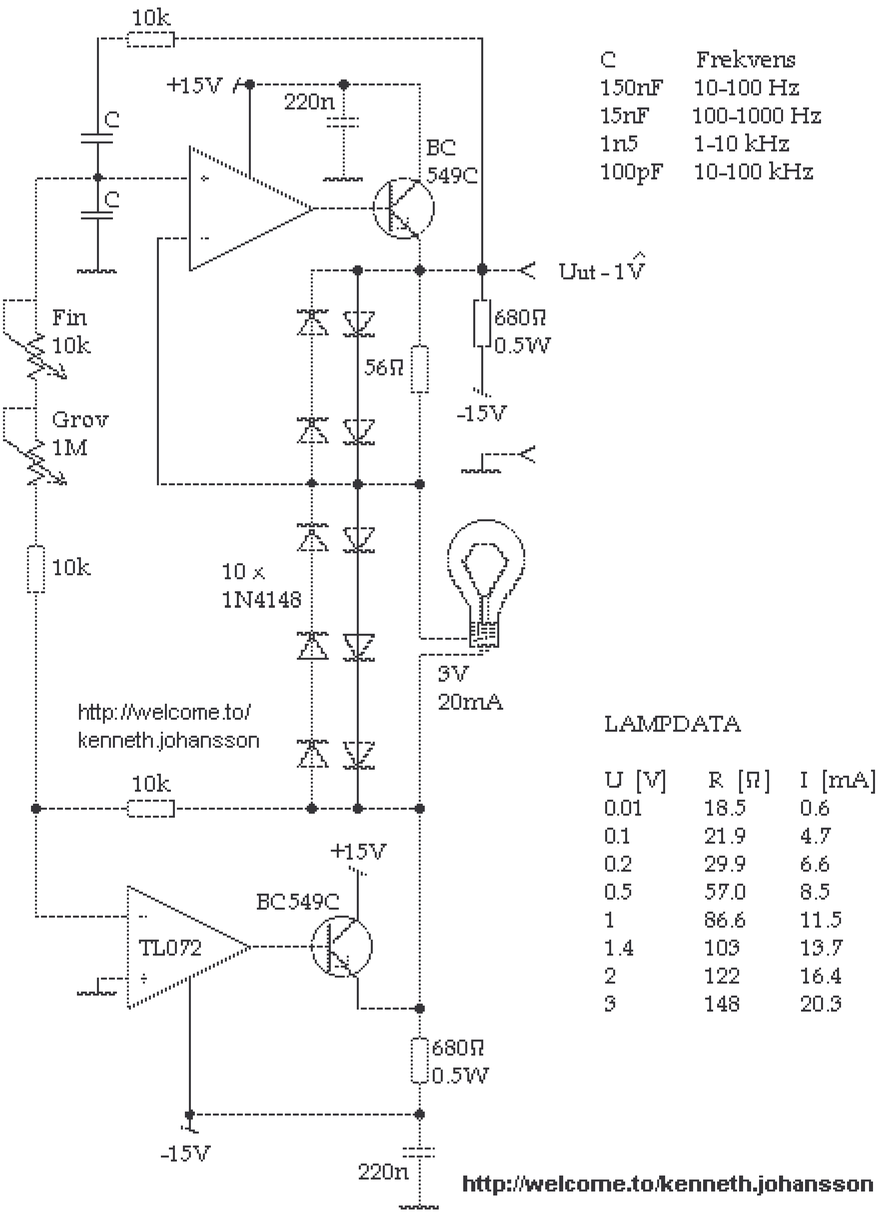


Figure 2. Sinus generator by K. Johansson, modified version 2 by the author:

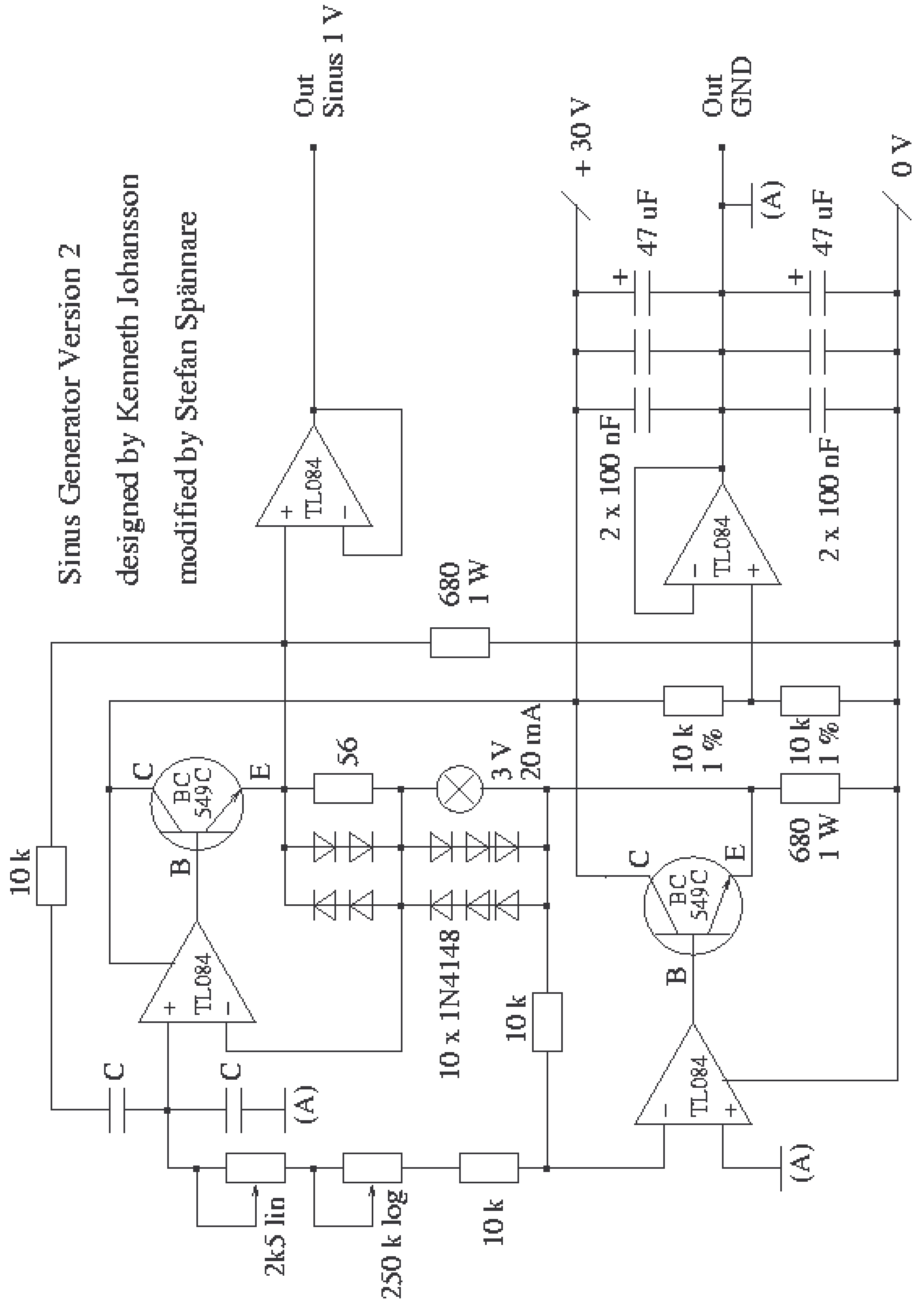


Figure 3. Sinus generator by K. Johansson, modified version 3 by the author:

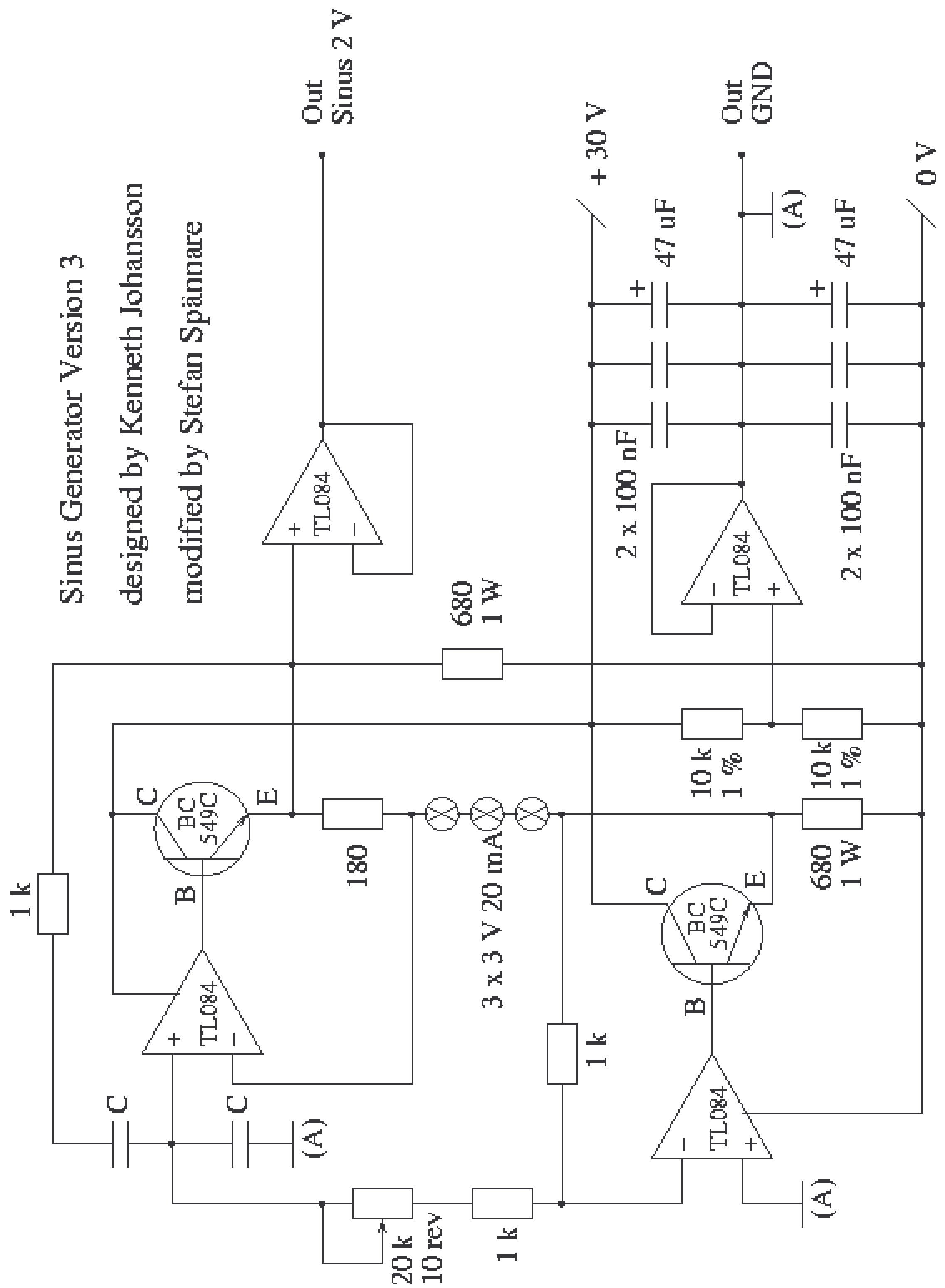


Figure 4. Sinus generator based on ICL 8038:

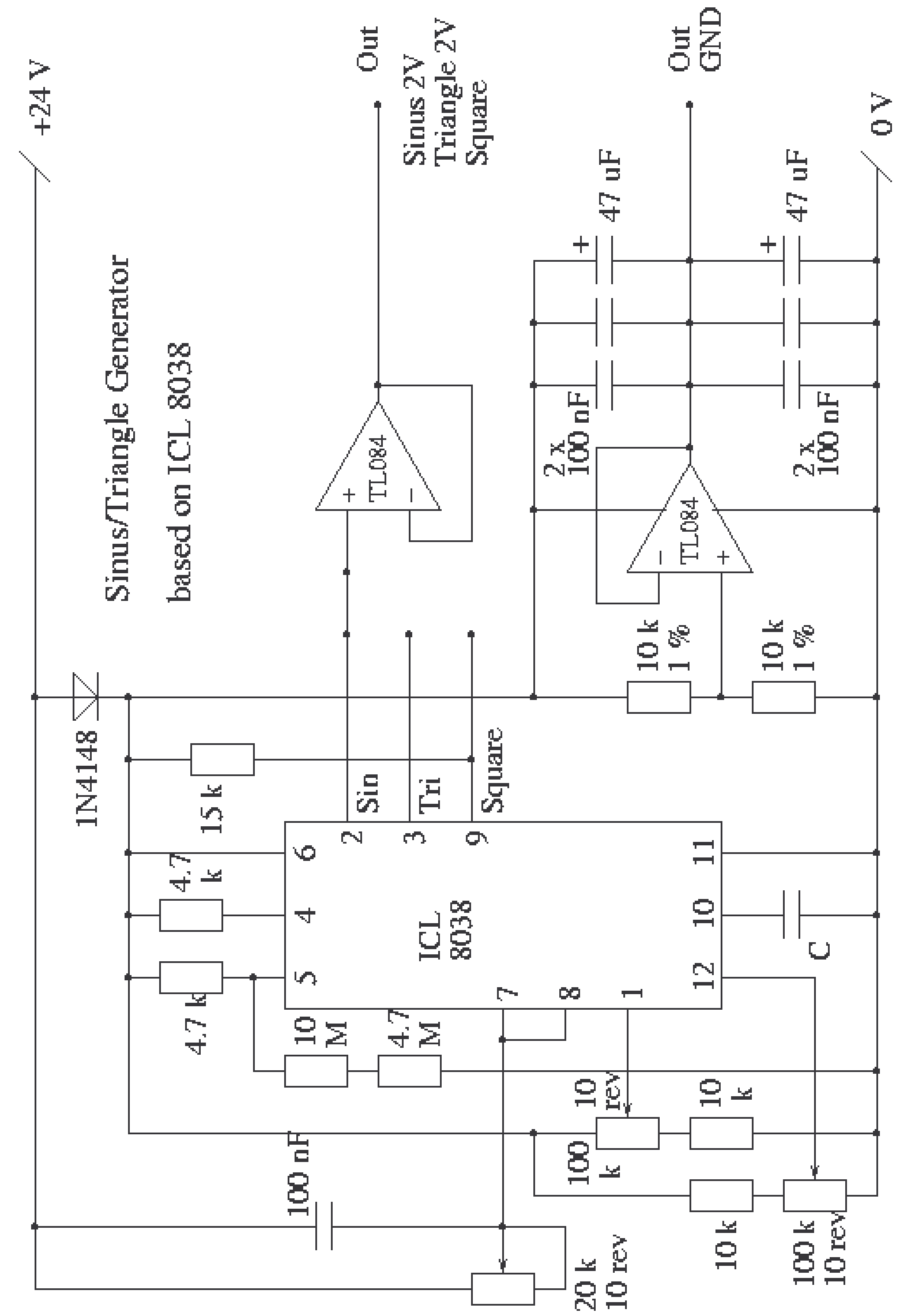


Figure 5. Power supply +30 V DC, max 250 mA, by the author:

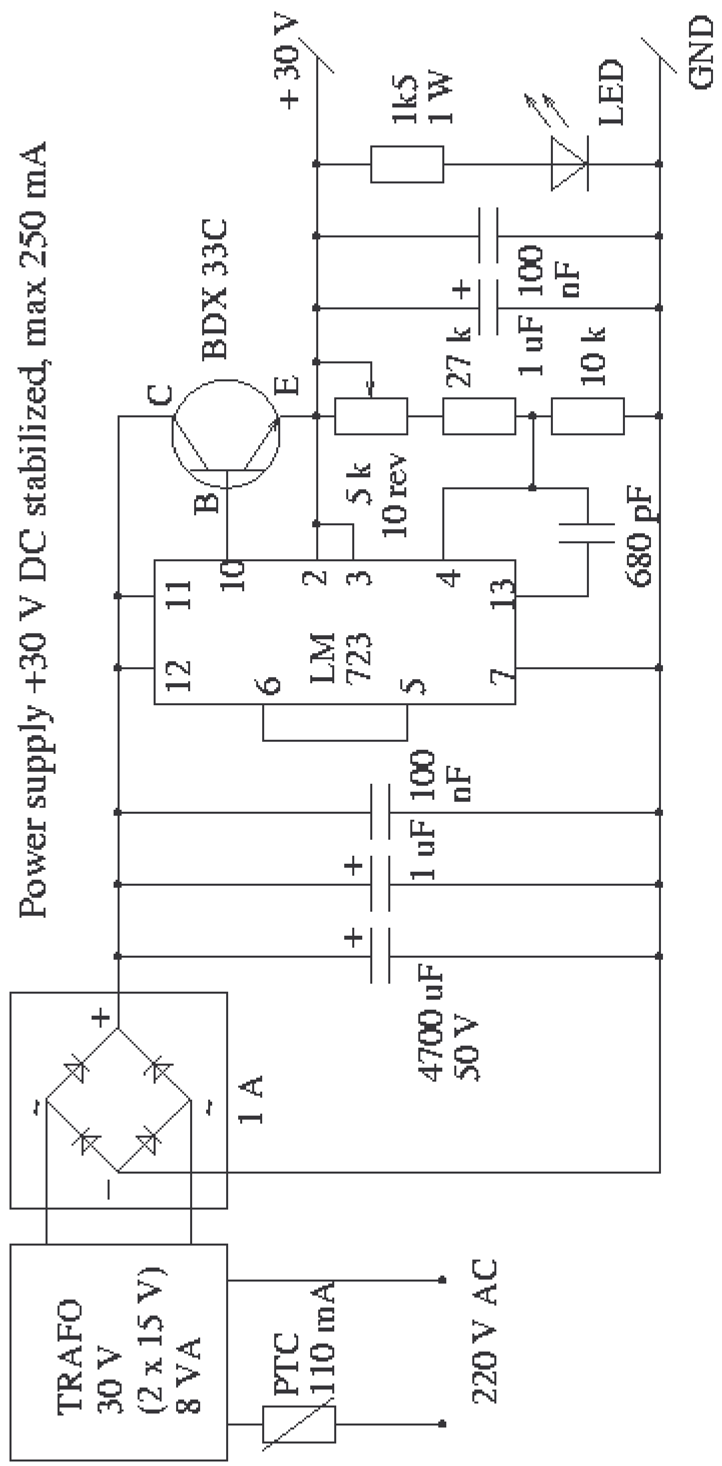


Figure 6a. K. Johansson (author version 3), oscilloscope view of signal 1 kHz:

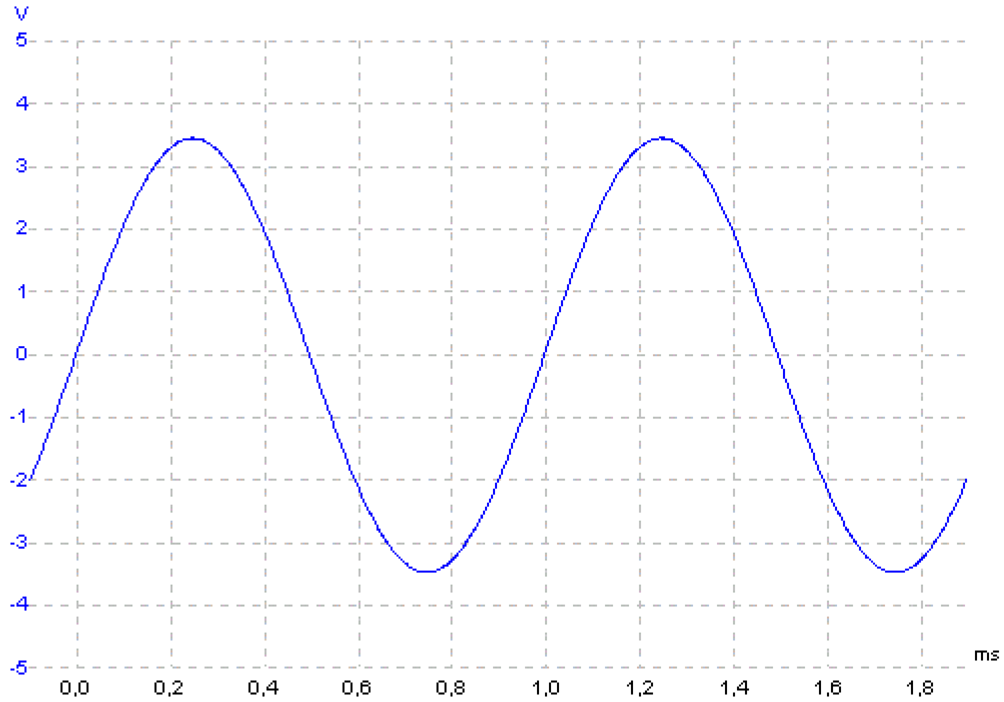


Figure 6b. ICL 8038, oscilloscope view of signal 1 kHz:

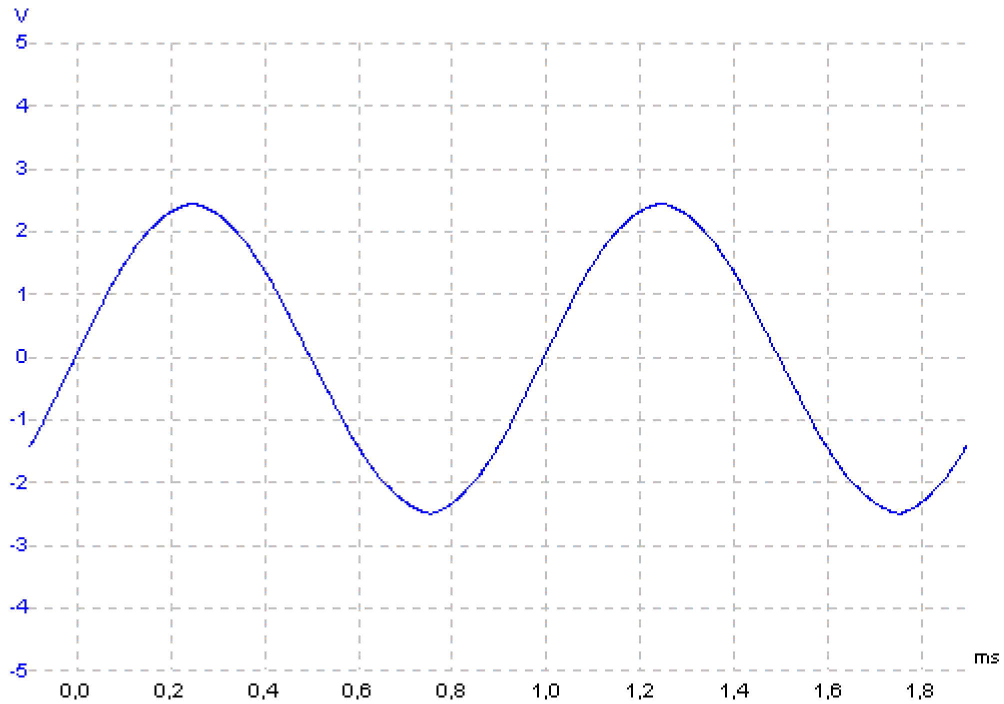
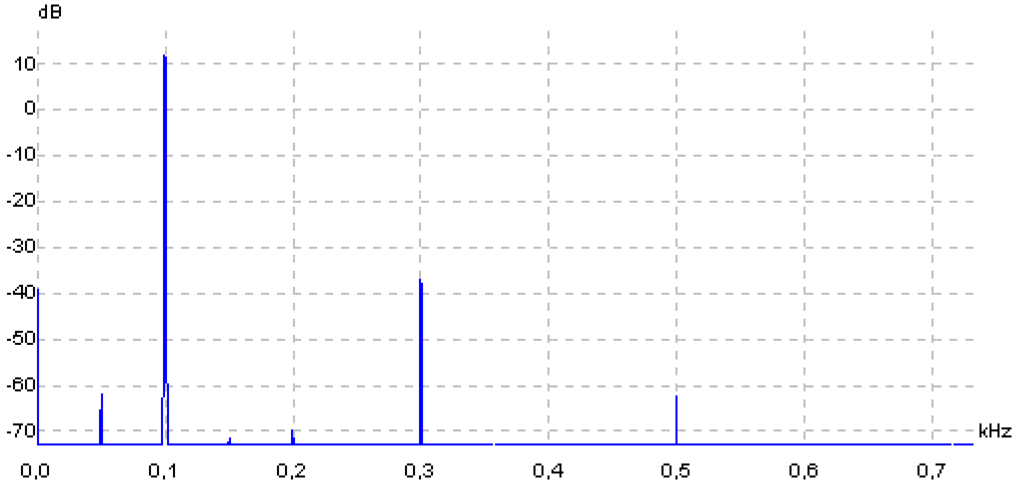
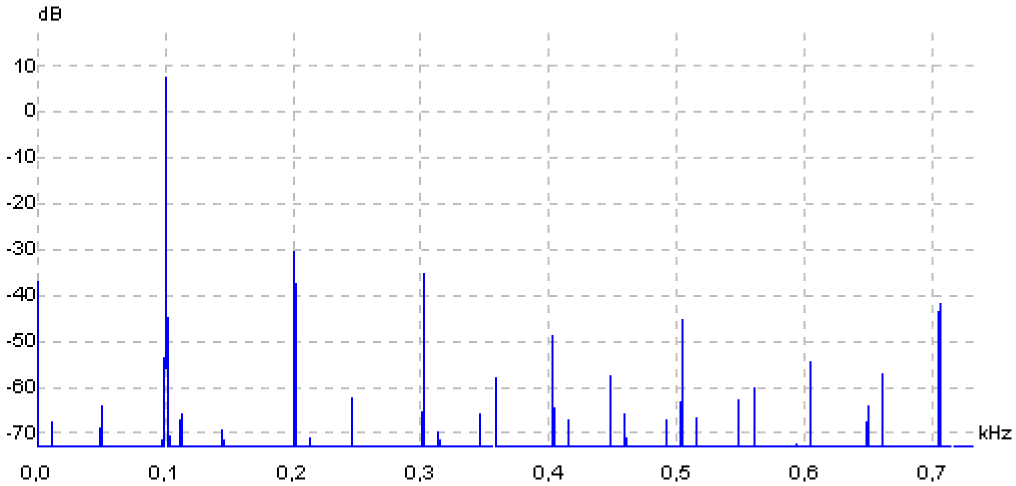


Figure 7a. K. Johansson (author version 3), spectrum 100 Hz:



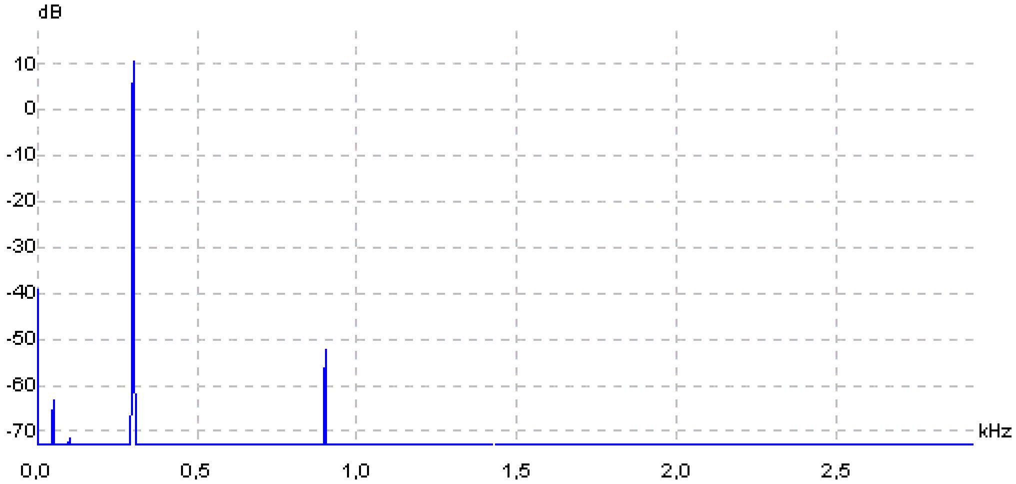
	Current v	Average
ch A: Frequency At peak (Hz)	99.86	99.93*
ch A: THD + Noise At peak (%)	0.5961	0.5913*
ch A: THD At peak (%)	0.1421	0.1480*
ch A: Second At peak (%)	0.0053	0.0059*
ch A: Third At peak (%)	0.1420	0.1478*
ch A: Fourth At peak (%)	0.0003	0.0011*
ch A: Fifth At peak (%)	0.0027	0.0014*

Figure 7b. ICL 8038, spectrum 100 Hz:



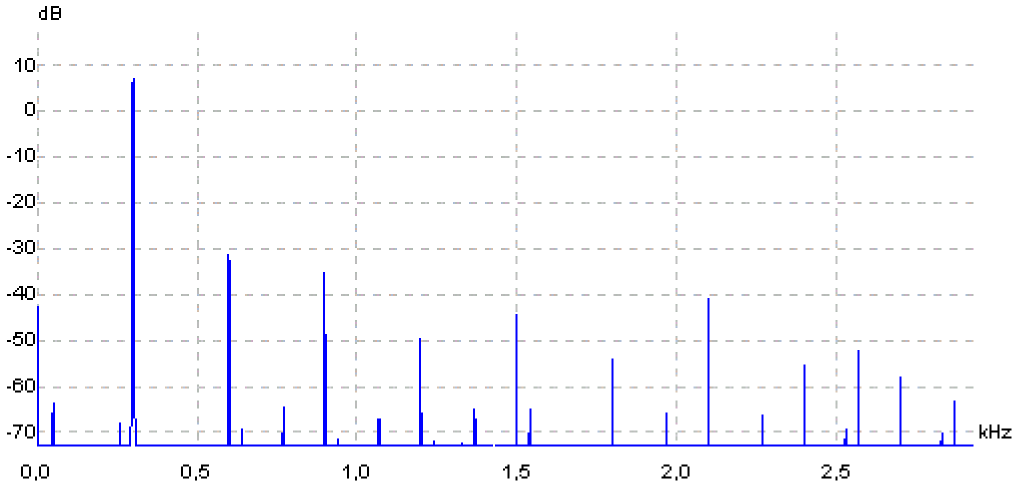
	Current v	Average
ch A: Frequency At peak (Hz)	100.8	100.7*
ch A: THD + Noise At peak (%)	2.181	2.215*
ch A: THD At peak (%)	1.215	1.149*
ch A: Second At peak (%)	1.115	1.060*
ch A: Third At peak (%)	0.4745	0.4228*
ch A: Fourth At peak (%)	0.0693	0.0601*
ch A: Fifth At peak (%)	0.0647	0.0606*

Figure 8a. K. Johansson (author version 3), spectrum 300 Hz:



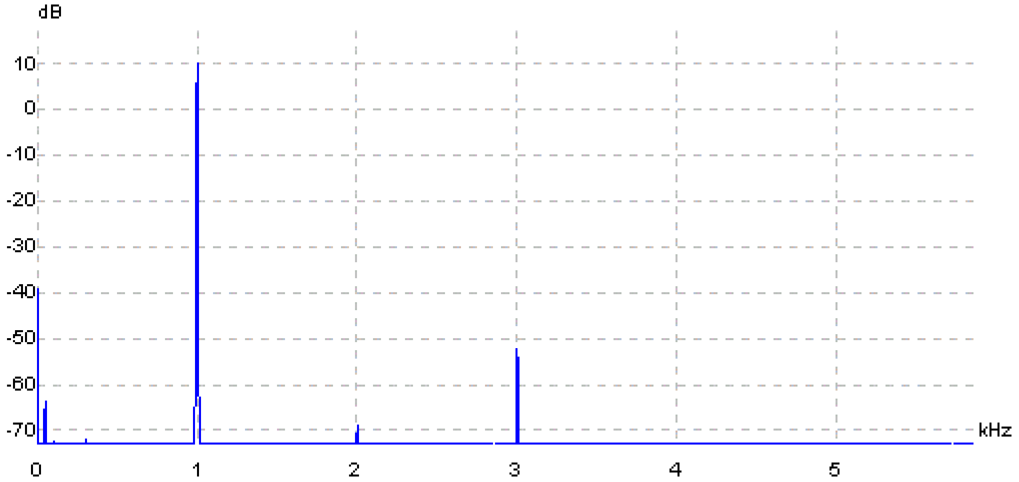
	Current v	Average
ch A: Frequency At peak (Hz)	300.0	300.0*
ch A: THD + Noise At peak (%)	0.2797	0.2846*
ch A: THD At peak (%)	0.0341	0.0299*
ch A: Second At peak (%)	0.0045	0.0037*
ch A: Third At peak (%)	0.0337	0.0296*
ch A: Fourth At peak (%)	0.0015	0.0012*
ch A: Fifth At peak (%)	0.0012	0.0013*

Figure 8b. ICL 8038, spectrum 300 Hz:



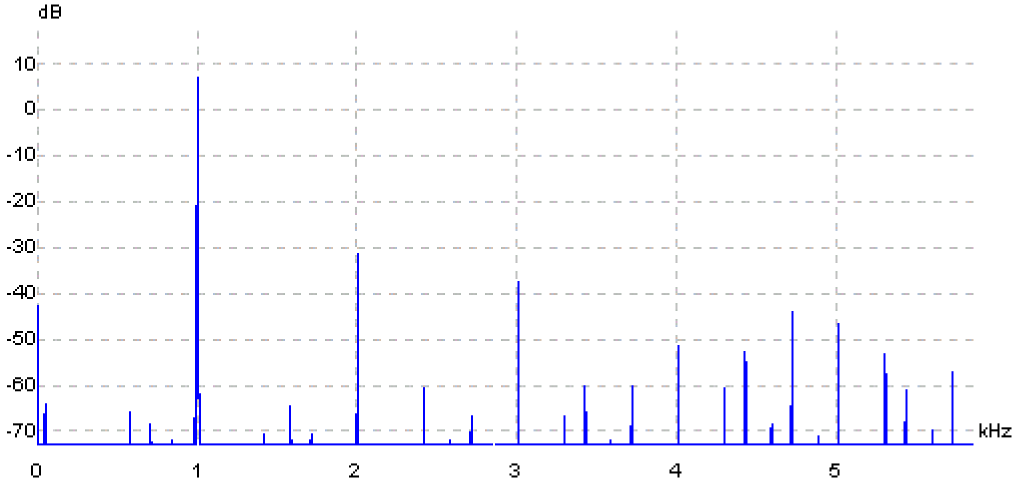
	Current v	Average
ch A: Frequency At peak (Hz)	300.0	300.0*
ch A: THD + Noise At peak (%)	2.046	2.077*
ch A: THD At peak (%)	1.069	1.028*
ch A: Second At peak (%)	0.9771	0.9501*
ch A: Third At peak (%)	0.4273	0.3882*
ch A: Fourth At peak (%)	0.0556	0.0463*
ch A: Fifth At peak (%)	0.0532	0.0378*

Figure 9a. K. Johansson (author version 3), spectrum 1 kHz:



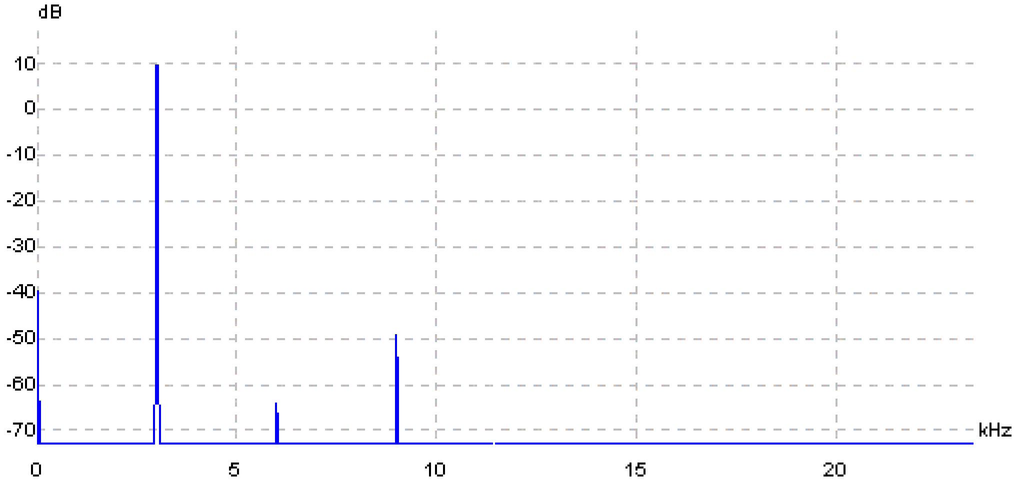
	Current v	Average
ch A: Frequency At peak (Hz)	999.5	999.5*
ch A: THD + Noise At peak (%)	0.2733	0.2702*
ch A: THD At peak (%)	0.0383	0.0371*
ch A: Second At peak (%)	0.0080	0.0072*
ch A: Third At peak (%)	0.0374	0.0363*
ch A: Fourth At peak (%)	0.0008	0.0010*
ch A: Fifth At peak (%)	0.0011	0.0010*

Figure 9b. ICL 8038, spectrum 1 kHz:



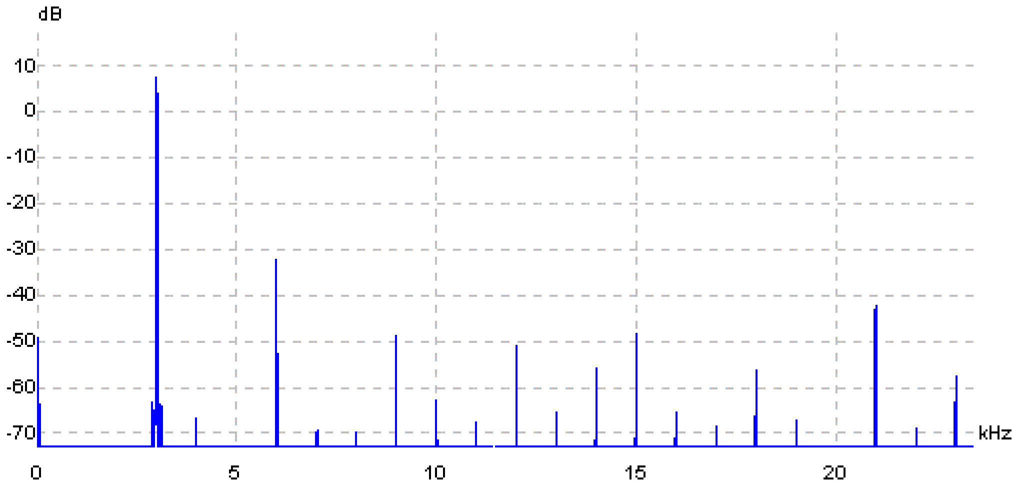
	Current v	Average
ch A: Frequency At peak (kHz)	1.002	1.002*
ch A: THD + Noise At peak (%)	1.889	1.939*
ch A: THD At peak (%)	0.9696	0.8933*
ch A: Second At peak (%)	0.9169	0.8546*
ch A: Third At peak (%)	0.3114	0.2566*
ch A: Fourth At peak (%)	0.0393	0.0271*
ch A: Fifth At peak (%)	0.0293	0.0154*

Figure 10a. K. Johansson (author version 3), spectrum 3 kHz:



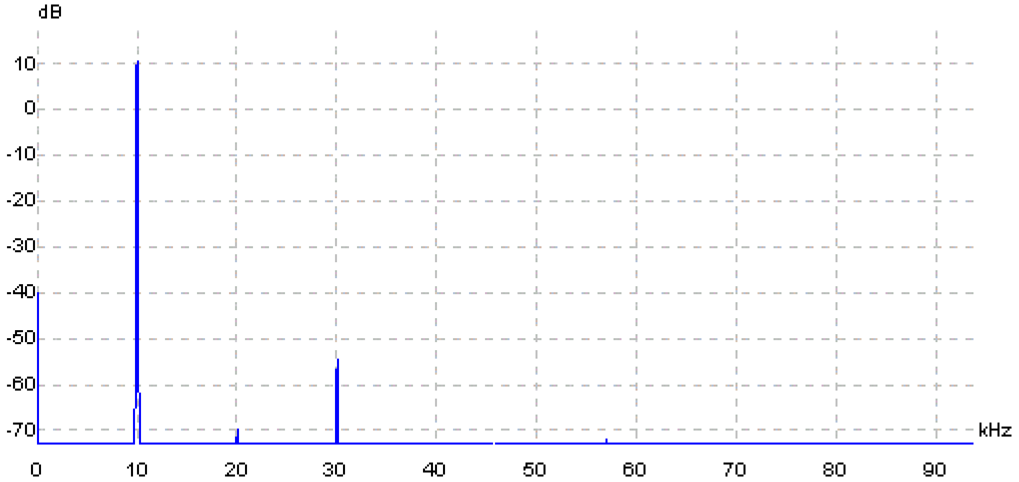
	Current v	Average
ch A: Frequency At peak (kHz)	3.001	3.001*
ch A: THD + Noise At peak (%)	0.3234	0.3225*
ch A: THD At peak (%)	0.0422	0.0431*
ch A: Second At peak (%)	0.0132	0.0126*
ch A: Third At peak (%)	0.0400	0.0411*
ch A: Fourth At peak (%)	0.0019	0.0010*
ch A: Fifth At peak (%)	0.0006	0.0010*

Figure 10b. ICL 8038, spectrum 3 kHz:



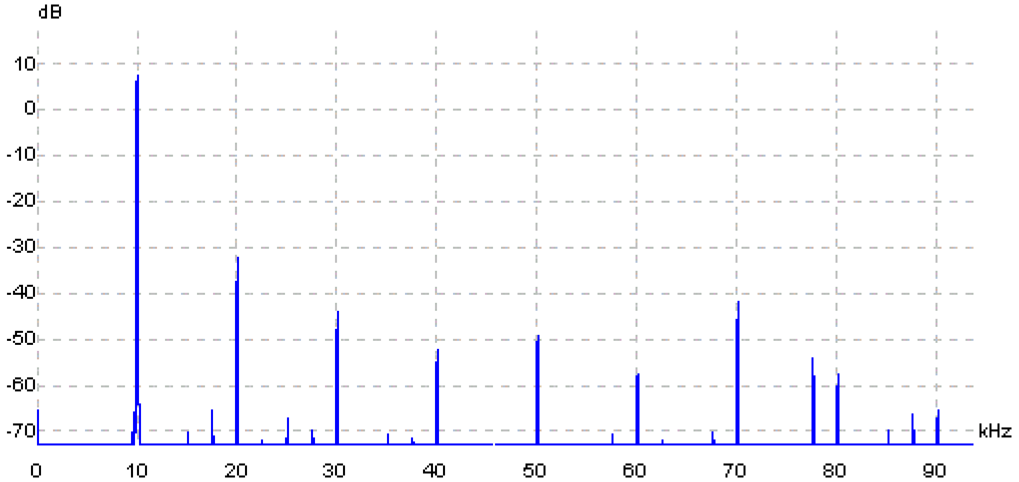
	Current v	Average
ch A: Frequency At peak (kHz)	2.996	2.996*
ch A: THD + Noise At peak (%)	1.596	1.599*
ch A: THD At peak (%)	1.058	1.048*
ch A: Second At peak (%)	1.040	1.032*
ch A: Third At peak (%)	0.1393	0.1357*
ch A: Fourth At peak (%)	0.0894	0.0853*
ch A: Fifth At peak (%)	0.0964	0.0900*

Figure 11a. K. Johansson (author version 3), spectrum 10 kHz:



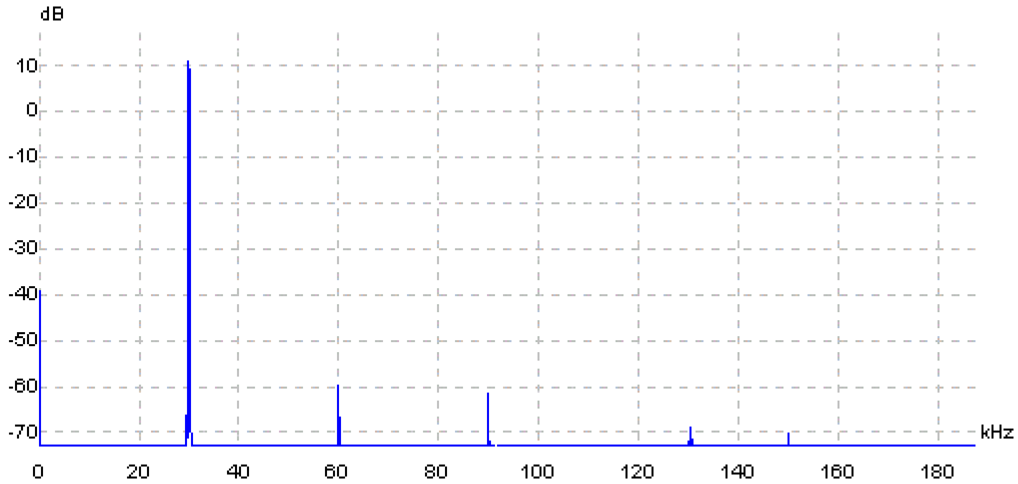
	Current v	Average
ch A: Frequency At peak (kHz)	10.01	10.01*
ch A: THD + Noise At peak (%)	0.2503	0.2503*
ch A: THD At peak (%)	0.0316	0.0319*
ch A: Second At peak (%)	0.0081	0.0079*
ch A: Third At peak (%)	0.0305	0.0309*
ch A: Fourth At peak (%)	0.0007	0.0009*
ch A: Fifth At peak (%)	0.0006	0.0010*

Figure 11b. ICL 8038, spectrum 10 kHz:



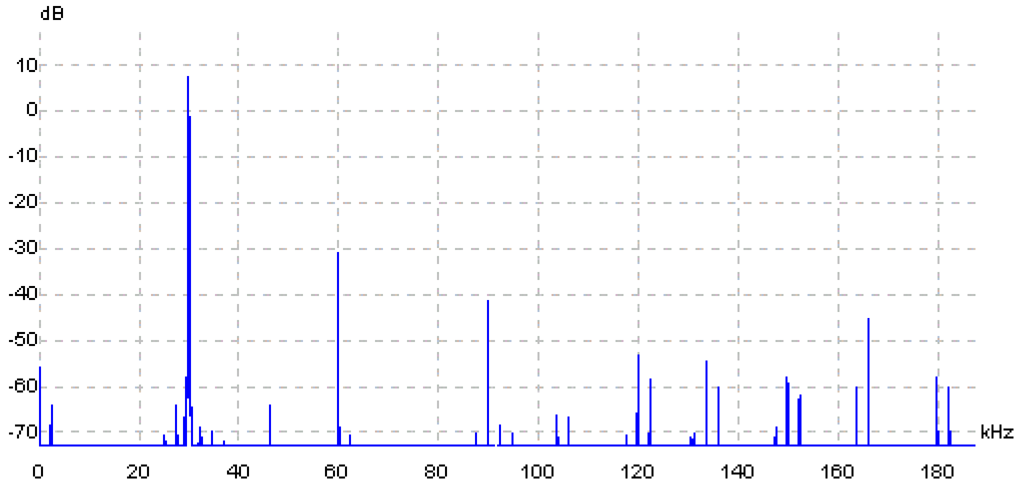
	Current v	Average
ch A: Frequency At peak (kHz)	10.01	10.01*
ch A: THD + Noise At peak (%)	1.666	1.694*
ch A: THD At peak (%)	1.035	0.9844*
ch A: Second At peak (%)	1.010	0.9648*
ch A: Third At peak (%)	0.2070	0.1826*
ch A: Fourth At peak (%)	0.0613	0.0481*
ch A: Fifth At peak (%)	0.0651	0.0458*

Figure 12a. K. Johansson (author version 3), spectrum 30 kHz:



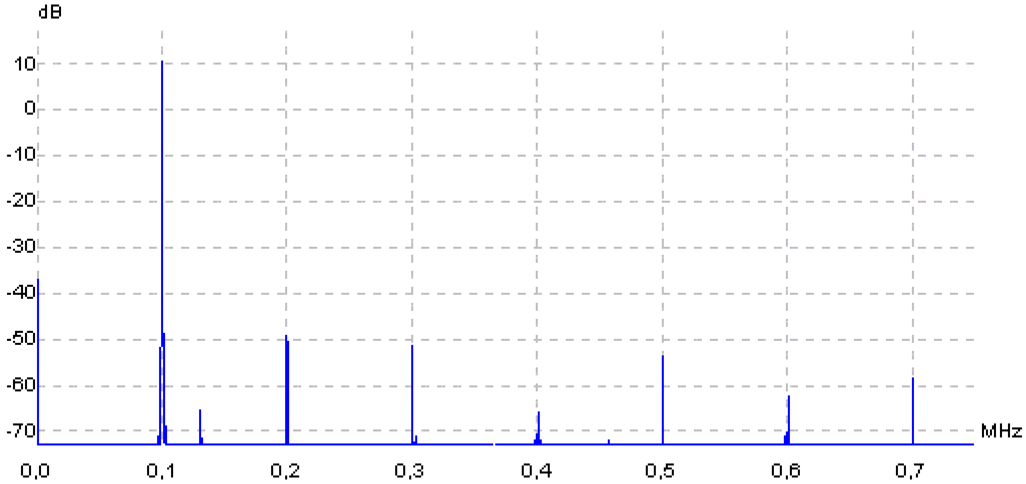
	Current v	Average
ch A: Frequency At peak (kHz)	29.97	29.97*
ch A: THD + Noise At peak (%)	0.1715	0.1766*
ch A: THD At peak (%)	0.0377	0.0368*
ch A: Second At peak (%)	0.0292	0.0289*
ch A: Third At peak (%)	0.0231	0.0218*
ch A: Fourth At peak (%)	0.0023	0.0031*
ch A: Fifth At peak (%)	0.0051	0.0054*

Figure 12b. ICL 8038, spectrum 30 kHz:



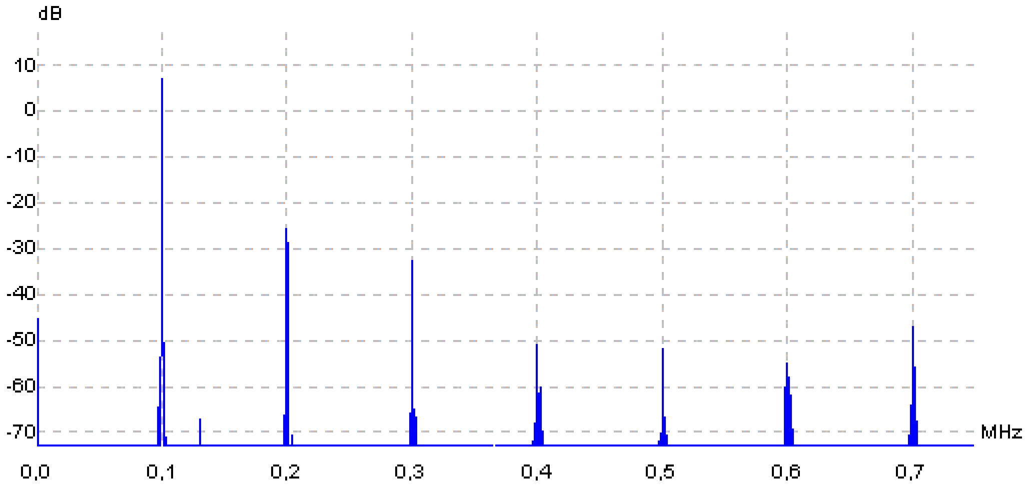
	Current v	Average
ch A: Frequency At peak (kHz)	29.92	29.92*
ch A: THD + Noise At peak (%)	1.929	1.879*
ch A: THD At peak (%)	1.203	1.289*
ch A: Second At peak (%)	1.174	1.249*
ch A: Third At peak (%)	0.2570	0.3069*
ch A: Fourth At peak (%)	0.0514	0.0734*
ch A: Fifth At peak (%)	0.0212	0.0372*

Figure 13a. K. Johansson (author version 3), spectrum 100 kHz:



	Current v	Average
ch A: Frequency At peak (kHz)	100.1	100.1*
ch A: THD + Noise At peak (%)	0.3069	0.3223*
ch A: THD At peak (%)	0.0915	0.0903*
ch A: Second At peak (%)	0.0809	0.0800*
ch A: Third At peak (%)	0.0416	0.0409*
ch A: Fourth At peak (%)	0.0019	0.0021*
ch A: Fifth At peak (%)	0.0093	0.0089*

Figure 13b. ICL 8038, spectrum 100 kHz:



	Current v	Average
ch A: Frequency At peak (kHz)	99.89	99.89*
ch A: THD + Noise At peak (%)	3.473	3.441*
ch A: THD At peak (%)	1.519	1.573*
ch A: Second At peak (%)	1.470	1.515*
ch A: Third At peak (%)	0.3842	0.4201*
ch A: Fourth At peak (%)	0.0172	0.0197*
ch A: Fifth At peak (%)	0.0034	0.0049*