Power Sinus Generator Mark II (PSG-2)

Photo 1: A Power Sinus Generator for a Turntable Synchronous AC Motor

1 Introduction

I like old Thorens turntables and I recently started to renovate a venerable TD 160 whose platter is belt driven by a synchronous AC motor. When I started the measurement of the TD 160, even with a brand new belt, the speed of this record spinner was 0.77 % lower than expected, giving 3126 Hz for the 3150 Hz signal of the test record. Not a big deal, but my hunt for perfection led me to start the design of a variable 50/60 Hz Sinus Generator that will enable a more precise speed.

The main advantages of the Power Sinus Generator are:

- Stable frequency (quartz generated)
- Possibility to change the frequency of the output signal by 0.4% step
- Pure output signal (compared to the Mains AC signal in my flat)
- Electronic 33/45 speed switch
- 110V/230V output.
- Optional 50Hz/60Hz output (by downloading the appropriate program to the processor).

In this document, the signal frequency is 50 Hz, but a software version is also available for 60 Hz signal.

Warning

This project is connected to 230VAC mains supply (alternatively 115VAC mains supply) and is potentially lethal. Furthermore, it generates lethal output voltages (again 115VAC/230VAC). As a result of this, please observe the following:

- Do NOT build this project unless you are completely familiar with main wiring practices.
- The circuit MUST be built into a fully enclosed case connected to the Earth or in an isolating plastic enclosure.
- Do NOT touch anything inside the case, when the circuit is powered (even if turned off).

2 Design

Today's technology will help us generate a signal that will vary around 50 (60) Hz by the use of a microprocessor. Fig 1 shows the block diagram of the PSG-1: a microprocessor running at 20 MHz drives a digital analog converter to generate a 50 Hz low voltage signal. Each period is generated with 200 intermediate steps. The signal then goes through a low pass filter that eliminates the staircase effect of the quantification. The final stage is an audio power amplifier driving a step-up transformer for an output signal of 115 or 230 VAC. A 9 positions switch allows for a 1,5% variation of the frequency around the nominal value. Different voltages are necessary for the PSG-1: +/-30V for the amplifier, +/-12V for the low pass filter and +5V for the microprocessor.

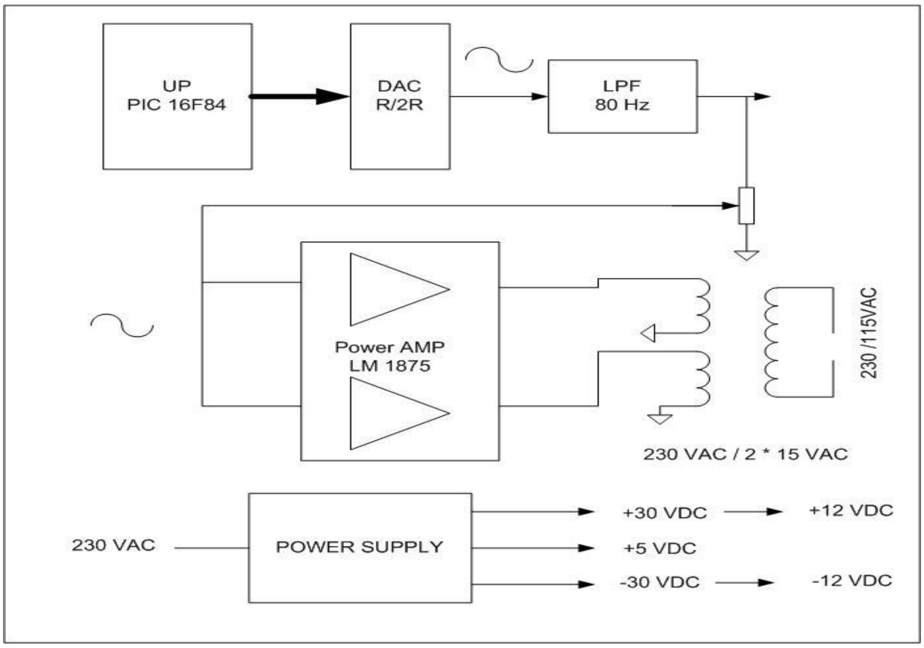

Figure 1: PSG-2 block diagram

3 Build

The PSG-2 is built around 3 different Printed Circuit Board:

- The front face PCB that houses the switches and the associated electronics
- The microprocessor and Low Pass Filter PCB (with additional +/-12V daughter board)
- The audio power amplifier

Photo 2: Physical arrangement of the different blocks in the cabinet

3.1 The Front face PCB

The front face PCB is a very simple board, parallel to the front face, that houses the 9 positions rotary switch for speed variation and the 33/45 switch. The electronic circuit is simple: a TTL 74LS147 or equivalent converts the signal from the rotary switch into a 4 digits value that will be acquired by the microprocessor.

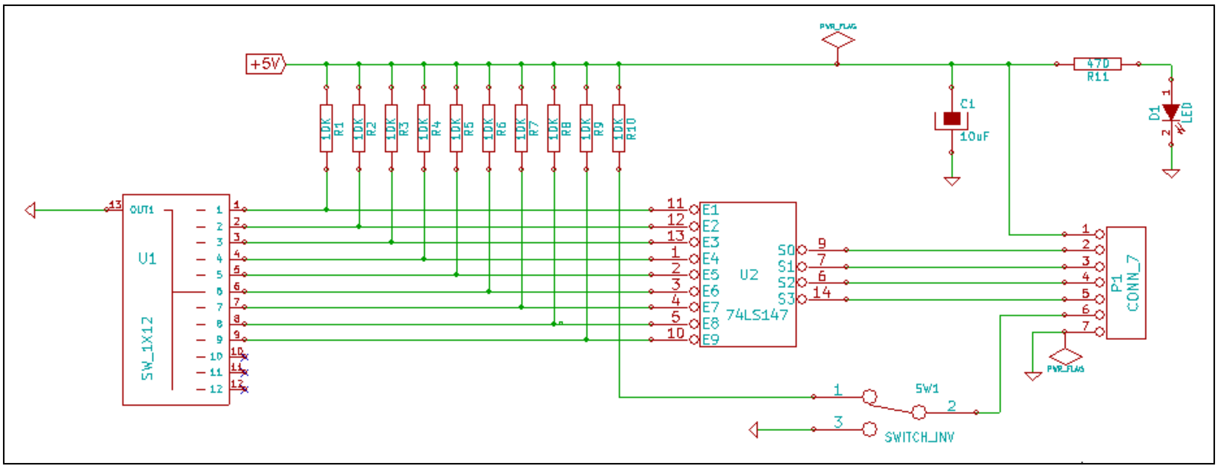

Figure 2: Front Face board schematics

3.2 The Microprocessor and LPF board

First the microprocessor: this is an old PIC 16F84 that I used because I had it in stock. Microchip produces now other references that provide more functionality in the same package. But the old 16F84 does the job. The 16F84 is clocked by 20MHz quartz and drives a 8 bits digital analog converter based on a R-2R topology. Connector P1 links the microprocessor to the front face PCB and connector P2 allows to connect the PICKIT2 debugger and memory loader.

Some words about the software: this is a very simple loop whose duration is based on the 33/45 switch. The duration of the loop, basically 100 microseconds for 33T speed, is modified in relationship with the position of the rotary switch. During these 100 microseconds, the microprocessor reads incrementally in a look-up table the value of the signal to be generated. After 200 cycles (200 * 100 uS = 20 mS or 50 Hz) the counter is reset and a new 50 Hz period is started.

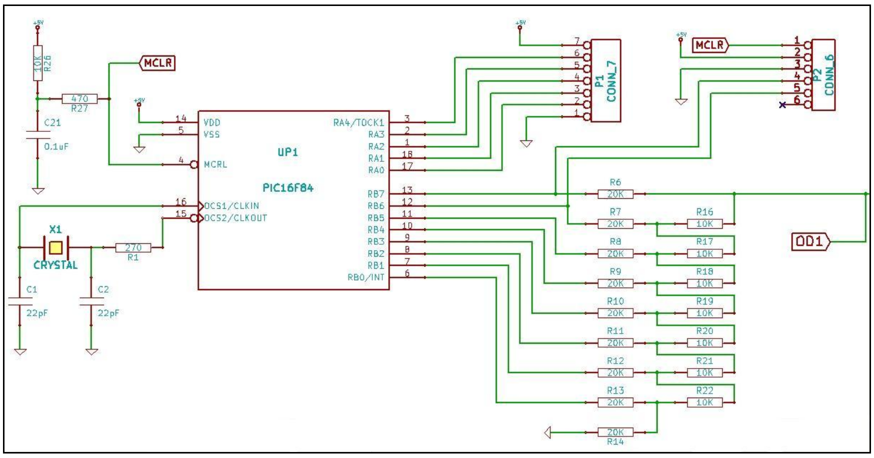

Figure 3: Microprocessor schematics

The low pass filter is a 12dB/Octave cell built around a double op amp (see Fig. 4). The potentiometer allows for tuning of the output voltage. The first op amp is just a buffer and the second op amp is used for a standard Salen-key filter structure. Cut-off frequency is around 70 Hz (as the output frequency will be 67.5 Hz for 45T operations) and can be adjusted by the replacement of C18 and C19. For a 60Hz operation, I will change the value of C18 and C19 for 33nF and 68nF respectively.

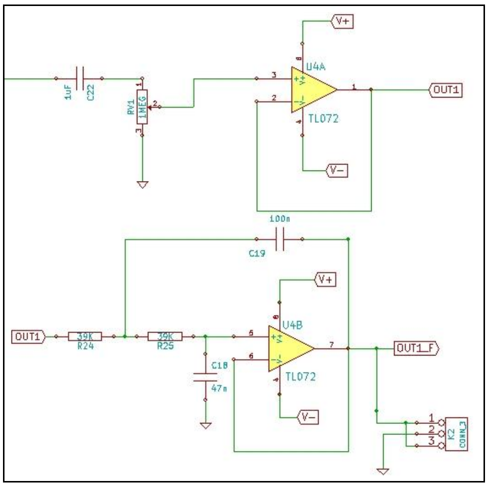

Figure 4: Low Pass Filter

The PCB, which is sandwiched with the front face PCB, is a double side PCB that has been designed using KICAD, a great CAD package available for free.
A nice feature of this package is the possibility to see a 3D picture of the PCB (see Fig.5)

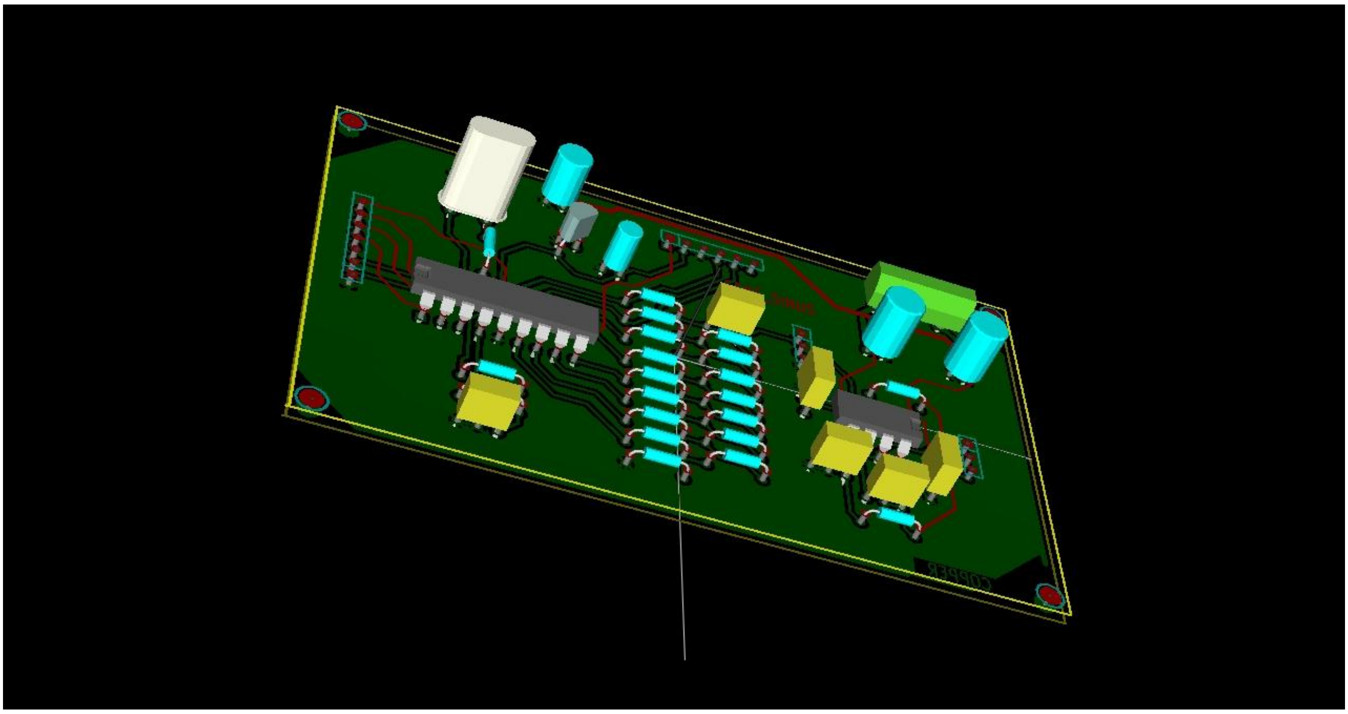

Figure 5: Microprocessor and LPF PCB

Note: My first plan was to use an audio amplifier board that would generate the +/- 12V DC but unfortunately it didn't fit the case I wanted to use. So I bought online another amplifier board and was forced to build a daughter board on a prototype board to generate the +/- 12VDC from the +/- 30 VDC of the amplifier board, using standard 7812 and 7912 regulators.

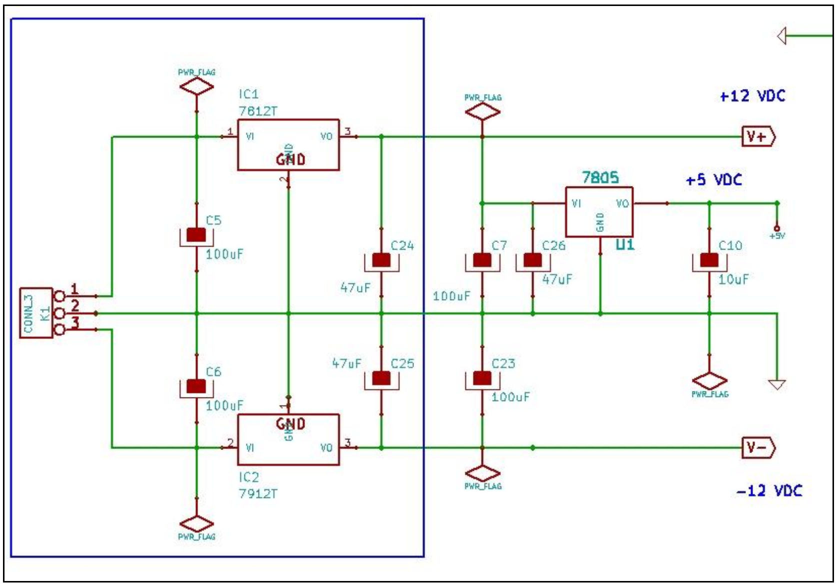

Figure 6: +/- 12VDC daughter board

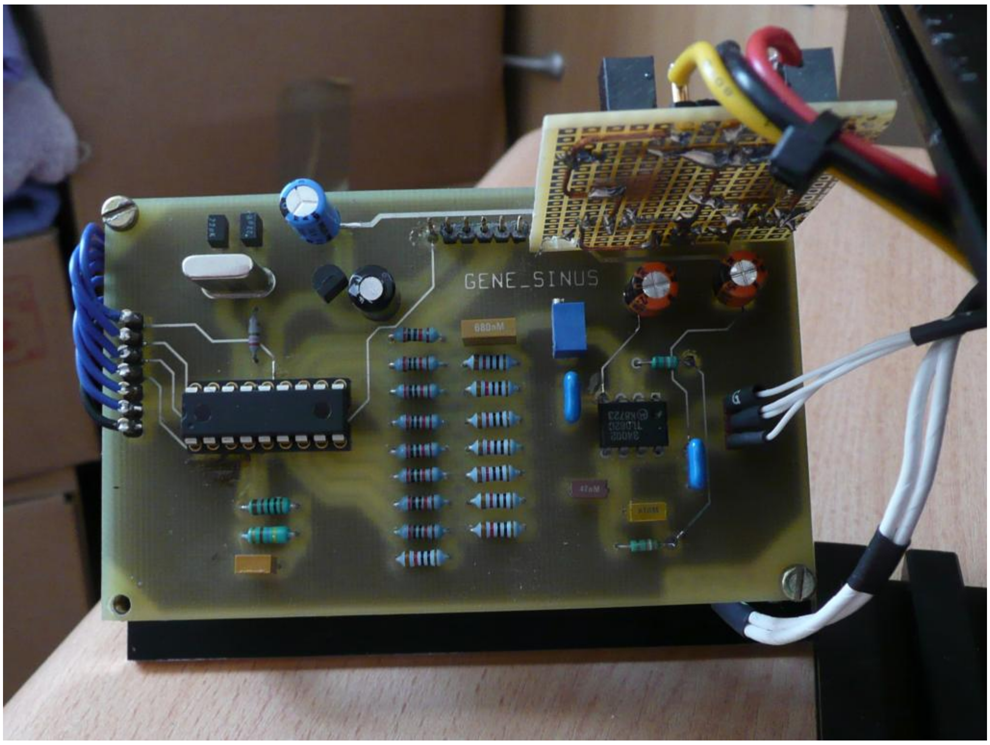

Photo 3: Microprocessor and LPF board

3.3 Amplifier Board

The amplifier board is a kit that uses LM 1875 devices available on eBay for about 22 USD plus shipping. Two channels being available, I choose to drive each side of the output transformer (2 * 15 VAC / 230VAC) by one amplifier channel. I use a spare heat sink to cool the two LM 1875. The board includes a diode rectifier and large power supply capacitors and should be connected to a 230 VAC / 2 * 20 VAC transformer.

Building the kit was straightforward and it worked the first time I powered it.

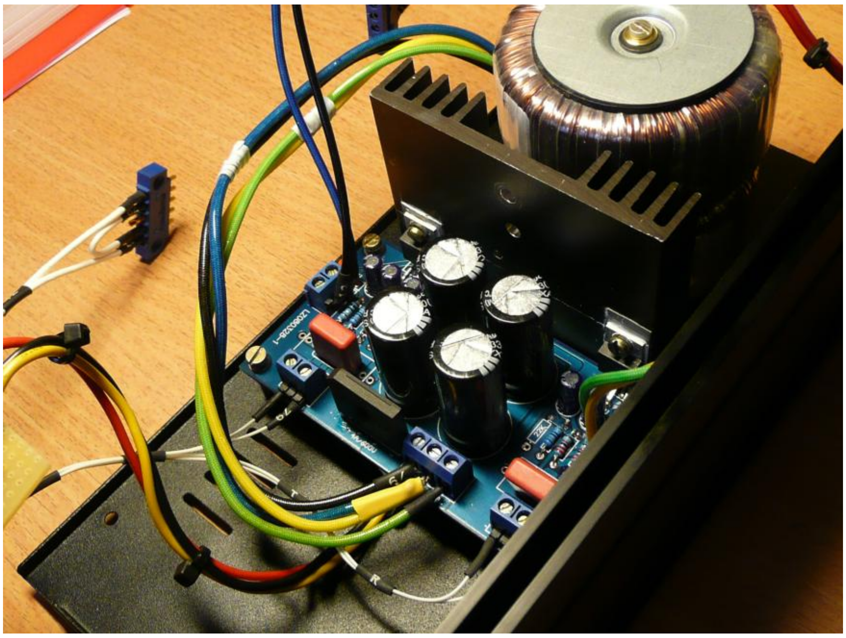

Photo 4: Audio Amplifier Board

3.4 Housing

The Housing of the PSG-II is a X*Y*W box available in France at http://… The box is pretty well stuffed by the transformer and the heat sink, leaving just enough room for the 3 PCBs at the front of the

Box. Front and rear plates have been designed thanks to the Front Designer software and have been manufactured by Schaeffer. It gives a professional and retro look to the PSG-II.

Photo 5: Rear Plate

Photo 6: Front Face

OK! The unit is nearly finished. It’s time to make some measurements

4 Tests & Measurements

Tests have been realized using a either a dummy 4.7 Kohms load or a real turntable. The instruments used for the tests are:

- PC running under Windows XP
- External Sound card E-MU 0404 USB
- Virtual Analyzer Software (*)
- HI-FI News test record & XXXX test record
- Frequency counter

(*) A great piece of software! Donate if you’re using it to allow for future development

Obviously, you need also some Hi-Fi stuff: a turntable (Thorens TD 160, with a DIY plinth), a Power amplifier (Denon PM 520A) and some loudspeakers (Mustang, a DIY loudspeaker).

Photo 7: HI-FI set-up used during tests & Measurements

4.1 Main versus PSG-II AC signal

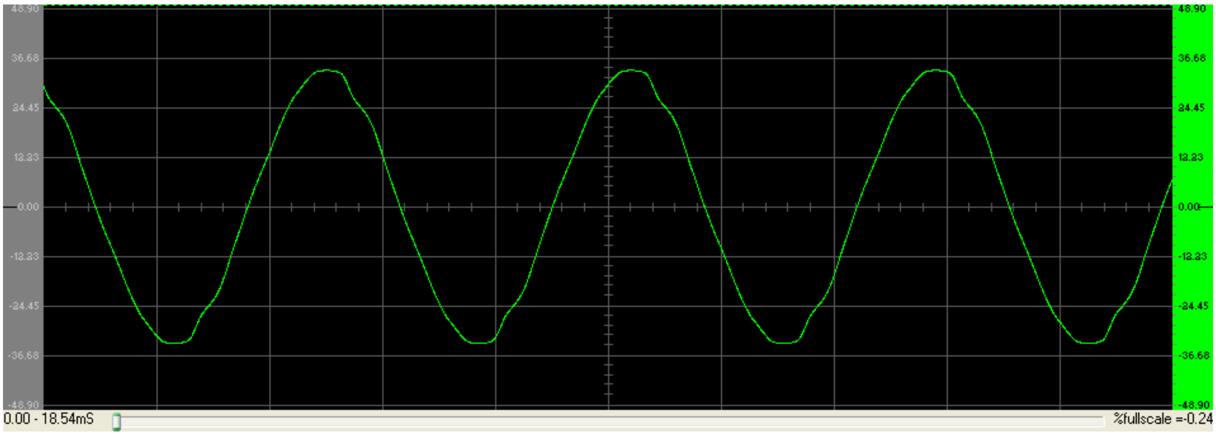

Figure 7: AC main signal

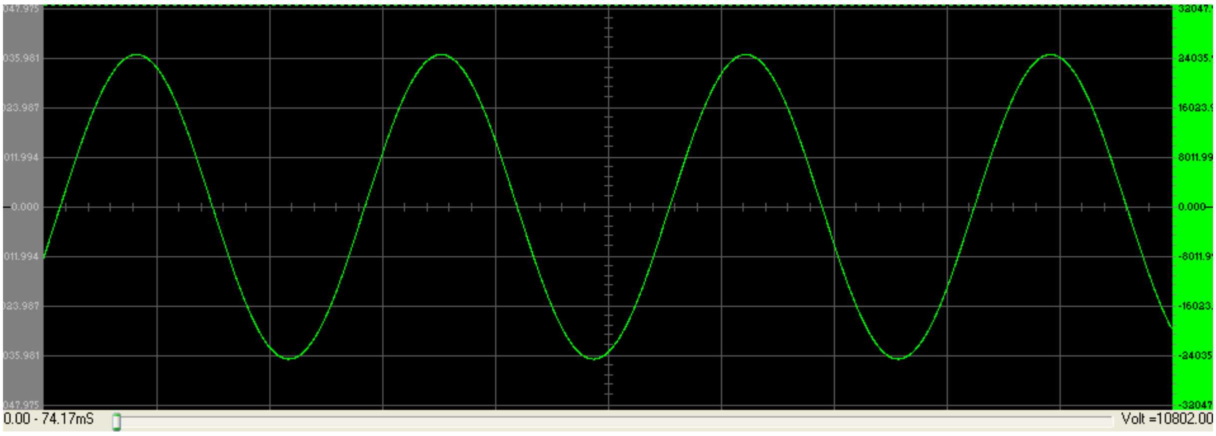

Figure 8: PSG-II Output Signal

Is it necessary to put words on these pictures? Not really: the AC Main signal is highly distorted compared to the PSG-II output signal. And the spectrum of the signals confirms what we see on the virtual oscilloscope: Total harmonic distortion is much higher for the AC main signal, with several odd harmonics being at –36dB compared to the fundamental signal. With the PSG-II, all harmonics are 66dB under the 50Hz signal.

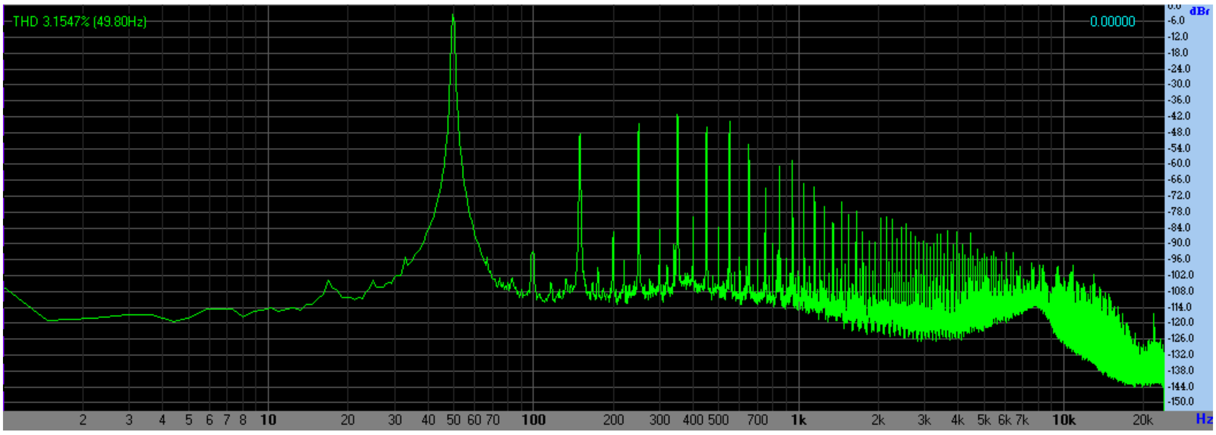

Figure 9: AC main spectrum

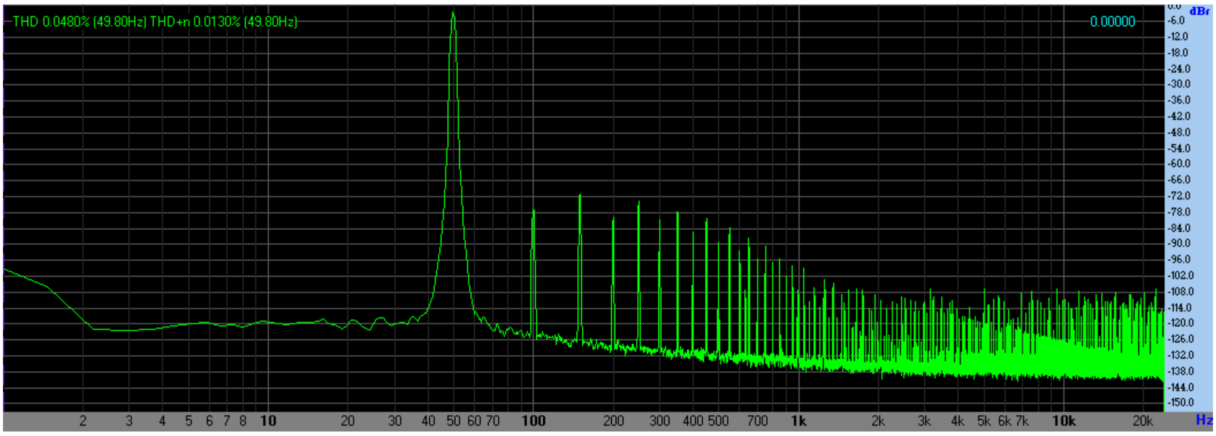

Figure 10: PSG-II Output Spectrum

4.2 Measurement with the turntable

The table below summarizes the performances in speed accuracy obtained with the PSG-II:

- With a 3150Hz signal generated by the test record, the turntable powered from the AC main delivers a 3126hz signal with a 0,76% error.
- The PSG-II is able, on position N°2, to achieve a 0,06% error, with a signal delivered at 3148Hz

Being honest, I should say that this result is a little bit lucky as the difference between two positions of the rotary switch is 0,4%. So depending on the turntable, the maximum error can reach this 0.4% figure. It can be improved by software at the expense of a more limited range of speed variation.

Switching to 45T, but using the same test record, the best accuracy is achieved on Position N°2, with 0.25 % error, compared to 1.24% error with AC main.

PSG-II

A	B	C	D	E
SWITCH POS	3150		1000	
	FRQ	ERROR %	FRQ	ERROR %
-4	3073	2,44%	976	2,39%
-3	3085	2,06%	980	2,00%
-2	3098	1,65%	984	1,61%
-1	3110	1,27%	988	1,21%
0	3122	0,89%	992	0,82%
1	3135	0,48%	996	0,43%
2	3148	0,06%	999	0,06%
3	3160	0,32%	1004	0,37%
4	3173	0,73%	1008	0,80%
AC	3126	0,76%	992	0,77%

Figure 11: 33T Speed Accuracy

SWITCH POS	4252,5		1350	
	FRQ	ERROR %	FRQ	ERROR %
1	4242	0,25%	1347	0,21%
2	4265	0,29%	1355	0,34%
AC	4200	1,237%	1333	1,259%

Figure 12: 45T Speed accuracy

5 Conclusion

Do I hear the difference between the turntable powered by Mains or PSG-II? I should say definitely Yes, but I'm not unbiased as I've built this equipment and I really want it to make a difference! In addition, I have never considered my ears as a reference and I'm over 50's. But now, I am sure that the turntable spins at the right speed and I suppose that Wow & Flutter have also been improved by the use of the PSG-II (I have no way to accurately measure it).

Further improvement of the PSG-II can be an LCD display and +/- push buttons instead of the rather old fashion rotary switch to vary the output frequency.

6 Acknowledgements

This paper was deeply inspired by the document: 'TTPSU - Power supply for turntables with AC motors' available at http://www.norre.dk

7 References

- KICAD: http://kicad.sourceforge.net
- Virtual Analyzer: http://www.sillanumsoft.org/
- Microchip Mplab: http://www.microchip.com/
- LM1875: http://www.national.com/mpf/LM/LM1875.html#Overview