An Open Source Turntable for Electro-Acoustical Devices Characterization

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August 28, 2021

Audio Engineering Society
Convention e-Brief 129
Presented at the 151st Convention
2021 October, Las Vegas, NV, and Online

An Open Source Turntable for Electro-Acoustical Devices Characterization

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ABSTRACT

This work introduces an Open Source turntable for the measurement of electro-acoustical devices. The idea is to provide an inexpensive and highly customizable device that can be adjusted according to specific measurement needs. Development of such turntable devices in the past required significant investment. Specific mechanical and motor control design skills were needed, leading to both costly and time-consuming processes. Recent developments in mechatronics and 3D printing allow to design and build a cost-effective solution.

1 Introduction

The characterization of the directivity of electro-acoustic systems, such as loudspeakers and microphones, is a key activity during the research and development process of a product.

A simple but effective method to collect loudspeaker directivity data[1] is to rotate a microphone over a circular arc around the device and sample the impulse response with a given angular resolution. Usually to simplify the setup the loudspeaker is placed on a turntable and the measuring microphone is left at a fixed position. The acquired data can be shown on what is commonly referred as a *polar plot*. This plot is representing the magnitude of the response in a given frequency range versus the scan line angle. The plot is usually normalized to 0 dB for the device on-axis direction. These plots represent only a single scan line of the directional response of a loudspeaker, depending on the device's geometry this could not be a full description of its spatial response.

According to the AES56-2008 standard on loudspeaker polar radiation measurements[1], the response should be sampled on a spherical surface surrounding the device using a regular grid in spherical coordinates. Methods to extrapolate data from limited sets of polar scan lines are available in literature[2].

Specific computer-controlled turntables are available on the market but choices are limited. Usually those devices are expensive and bulky, because they are meant to be used with heavy loads of professional loudspeaker boxes. This discourages many small manufacturers and independent researchers to include polar measurement in their research and development routine.

The market offers also robots to rotate a loudspeaker in spherical coordinates, but they are not less expensive and bulkier than the above mentioned turntables. Other methods using near field scanning over cylindrical surfaces recently appeared on the market but they are also

[1]The same applies to a microphone.

expensive and outside the budget for many independent researchers and small companies. We think that a low-cost, highly customizable computer-controlled turntable could be a welcome addition.

2 An Open Source Solution

The development of such turntable devices usually involves significant investments, as specific mechanical, electrical and motor control design skills are needed, leading to both costly and time-consuming processes. Recent developments in mechatronics and 3D printing allowed us to design and build a cost-effective turntable for small loudspeakers.

As many other companies in the audio field we recently started to include Fused Filament Fabrication (FFF) RepRap[2] 3D printing and CNC machining in our R&D routine.

In order to reduce costs we used easy to find off-the-shelf parts and completed the device with 3D printed plastic parts. This also opens the possibility to easily customize the turntable or at least some parts of it to specific needs using minimal modifications.

We decided to release the design under a Creative Commons Attribution-ShareAlike 4.0 International Public License to allow others to use, modify and sell this design or derived works. The Open Source approach, which uses standard components and protocols, means that there are no apparent limits in improving the hardware, for example using a more precise bearing or a different drive mechanism. We expect others to embrace this proposal and improve our basic design[3].

2.1 Turntable Design

The design is based on a ball-bearing swivel plate belt driven by a stepper motor controlled by an Arduino[4] microcontroller running Grbl[5] firmware.

In our build, we decided to use a small yet inexpensive swivel bearing plate that can be easily found in online shops. These plates can be found in online shops using the keywords “Lazy Susan Hardware” [6] and are commonly used for kitchen turntables and rotating stools.

[2]https://reprap.org/wiki/RepRap

[3]Complete design with 3D parts files is available at the URL https://www.audiomatica.com/wp/?page_id=3024

[4]https://www.arduino.cc/

[5]https://github.com/gnea/grbl

[6]https://en.wikipedia.org/wiki/Lazy_Susan

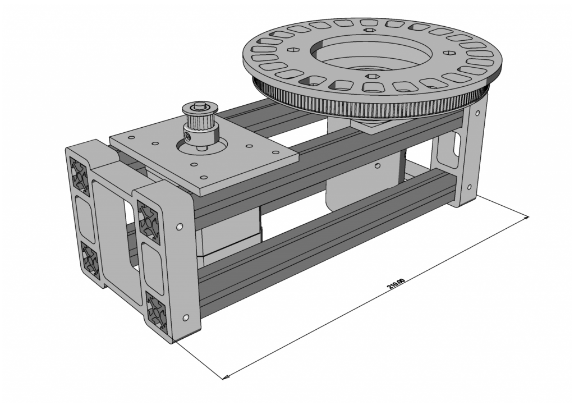

Fig. 1: Turntable design.

In our design we chose a 3 inch model which can stands up to 60 kg loads.

Arduino is a mature computing platform widely adopted by the do-it-yourself CNC machines community alongside the Grbl firmware. This firmware is meant to be used in three axes machines but can be adapted to our turntable with minimal effort. As a motor we chose a NEMA-17 stepper motor which is a standard choice for 3D printing machines with an A4988 motor driver. All these parts can be easily found. In our case the main source of components were scrap parts from an old unused 3D printer. The motor is connected to the turntable plate through a GT2 6 mm timing belt. The mechanical design is completed by Open Beams 15 x 15 mm aluminum beams to support the turntable structure.

One of the aim of the design was to have a compact device with the possibility to place the turntable on a planar surface (such as a table) and on a standard loudspeaker pole stand. We were able to fit a 3D printed pole receptacle inside the aluminum beams.

The turntable plate has a 135 mm diameter and the frame has 90 x 90 x 210 mm dimensions.

2.2 Turntable build

We went through several builds to refine the design which leaded to the Open Source design we released. The design process took only few weeks, and we were able to keep costs at minimum by modifying and refining the design of the printed parts. At the end we

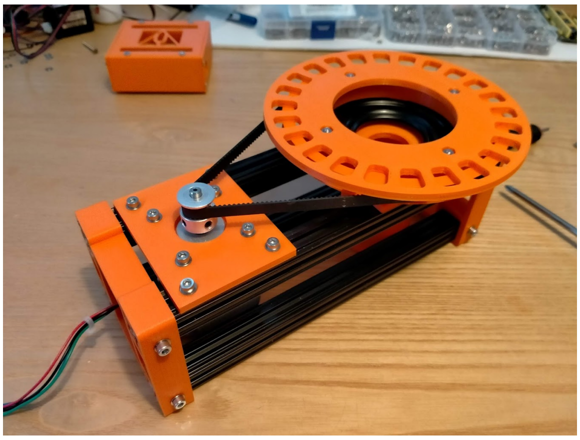

Fig. 2: Turntable build #2.

were able to easily build two turntables which are both functioning to perform mechanical tests, work on the Grbl firmware settings and computer control via USB communication.

At the time of writing, building cost estimate did not exceed 150 Euros except for 3D printed parts.

The Grbl firmware is actually meant to be used for CNC machines and cannot manage rotation angles, but it can still fit this project well. The advanced control of the stepper motors movement leads to a very smooth and precise rotation of the turntable. We need only the x-axis control using degrees instead of mm when sending commands to Grbl, in this respect the firmware is not aware of our choice and accepts our commands without issues. The trick is to set the Grbl parameter steps/mm in steps/degrees instead. Details on settings are reported in the Open Source Turntable building instructions.

By running the Grbl firmware on the Arduino board, the turntable is able to accept simple G-Code[7] commands via USB such as `G1X90F1440`. The above command should be read as move (G1) to 90 degrees position (X90) with speed 1440 degrees/minute (F1440). The turntable status can be polled using the Grbl `"?"` command which returns a string with the status and position of the machine that can be easily decoded:

```
<Idle|WPos:0.000,0.000,0.000
|FS:0,0|WCO:0.000,0.000,0.000>
```

[7] https://en.wikipedia.org/wiki/G-code

The mechanical performance of the turntable has been briefly evaluated checking the position of the turntable's plate with a protractor against a fixed needle. The turntable exhibits a slight backlash probably due to the tension of the belt in conjunction with the tolerances of the unloaded swivel plate bearing. Despite this, the turntable seems precise and repeatable with sub-degree accuracy. More detailed and documented tests should be carried out using a proper angular measurement setup.

3 Integration with measurement platforms

The turntable accepts G-code style Grbl commands and can be controlled using Serial Communication, thus it should be easily integrated with any PC based measurement system.

Example scripts described in the following sections are available at the Open Source Turntable project web page[8].

3.1 Turntable control from Scilab

Our first attempt was to use Scilab to control the turntable via Serial Communication and Audiomatica CLIO 12 QC measurement system through remote TCP/IP communication. The remote control of CLIO 12 QC is alreday covered in a technical document[3].

Serial[9] and Socket[10] toolboxes must be installed in Scilab[11].

Grbl serial protocol is very simple and can be easily implemented in Scilab. Once the serial communication channel is opened using the `openserial` command, the Arduino controller accepts G-code moving commands and can be polled for status. It is possible to write a Scilab function to move the turntable at a given angle and wait for the movement to complete by polling the Grbl status:

```
function rd=GOTOangle(h,angle)
writeserial(h,"G1X"+string(angle)+
"F1440"+ascii(13))
sleep(100)
```

[8] https://www.audiomatica.com/wp/?page_id=3024
[9] https://github.com/sengupta/Scilab-Serial
[10] http://www.reveyrand.fr/SOCKET2.html
[11] The tests have been carried out with Scilab 6.1 release under Windows 10.

```
 rd=readserial(h)
 // wait until becomes 'Idle' again
 while isempty(strindex(rd,'Idle'))
  writeserial(h,'?')
  sleep(100)
  rd=readserial(h)
 end
endfunction
```

Although in this document the example of use with the CLIO software is reported, the above approach is compatible with any measurement methodology that can be controlled or implemented in Scilab[12].

3.2 CLIO QC scripting

Another possibility is to use CLIO QC scripting language to control the turntable by sending serial port commands using the software `SERIALOUT` keyword.

In this case the process is managed by CLIO QC, due to the limitations of the scripting language it is not possible to use the polling approach to check the turntable status and instead a fixed delay value should be added after the `SERIALOUT=G1X15F1440@H0D` movement command.

3.3 DLL approach and integration into CLIO 12 software

As a last step we were able to wrap the serial communication calls to Grbl in a .dll library and integrate the turntable control into our CLIO 12 system software. In this way the control of the turntable is seamless and similar to the other commercial turntable solutions available.

4 Polar measurements of a two-way loudspeaker

We were able to measure the horizontal and vertical polar scan lines of a small two-way loudspeaker. Since we did not had access to an anechoic chamber we carried out the measurements in a small laboratory using time windowing technique to cut out room reflections. The turntable has been placed on a loudspeaker pole stand, to raise the loudspeaker under test at an height which is approximately half of the height of the room.

A Spinorama plot according to CTA-2034[4] standard has been created with a Scilab script, using the collected data.

[12]The same approach is also possible using a different programmable environment such as MATLAB, Phyton or LabView.

Fig. 3: Small two way loudspeaker measurement setup

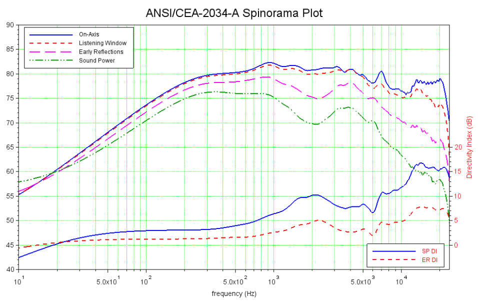

Fig. 4: ANSI/CTA-2034-A Spinorama Plot

5 Polar measurement of a microphone

We designed and 3D printed an adapter for a microphone boom stand. We were able then to use the turntable to measure the polar response of a microphone. Thanks to the rails connected to the turnable plate, the microphone can be rotated around its capsule.

Polar response of an Audiomatica MIC-02 has been measured using the above setup.

Fig. 5: Setup for polar measurement of a microphone.

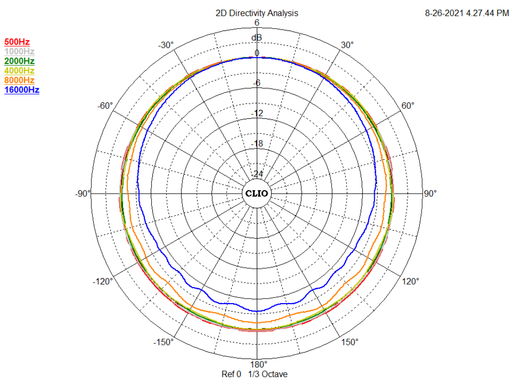

Fig. 6: Polar response of an Audiomatica MIC-02 microphone.

6 Summary

In this work we introduced a low cost open-source approach to polar measurement testing hardware. We were able to show that with minimal effort it is possible to build usable hardware.

The Open Source approach, which uses standard components and protocols, means that there are no apparent limits in improving the hardware, for example using a more precise bearing or a different drive mechanism. We expect others to improve our basic design. The usage of the widely adopted Grbl firmware has a double benefit: from the hardware perspective it allows to modify the mechanical part of the turntable without the need to redesign the firmware, from the measurement software perspective an implementation of communication with Grbl[13] will be then compatible with other turntables based on the same firmware. We can envision a family of Open Source turntables that can be based on this simple proposal.

Pratical examples of usage of the turntable for the measurement of the polar pattern of a small two-way loudspeaker and a microphone have been reported, showing the possibility to use the device in actual research and development activity.

References

[1] AES56-2008 (r2019), "AES standard on acoustics - Sound source modeling - Loudspeaker polar radiation measurements," *Audio Engineering Society, Inc.*, 2019.

[2] Panzer, J. and Ponteggia, D., "Inverse Distance Weighting for Extrapolating Balloon-Directivity-Plots," *AES 131st Convention, Preprint 8473*, 2011.

[3] Ponteggia, D., "Develop Custom Tests With CLIO QC TCP/IP Remote Control Through SCILAB," *Audiomatica Application Note 005*, 2007.

[4] ANSI/CEA-2034-A, "Standard Method of Measurement for In-Home Loudspeakers," *Consumer Technology Association*, 2015.

[13]For clarity we should write: by using Grbl and the assumption that x-axis is in degress instead millimeters.