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Open source laboratory sample rotator mixer and shaker

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ABSTRACT

An open-source 3-D printable laboratory sample rotator mixer is developed here in two variants that allow users to opt for the level of functionality, cost saving and associated complexity needed in their laboratories. First, a laboratory sample rotator is designed and demonstrated that can be used for tumbling as well as gentle mixing of samples in a variety of tube sizes by mixing them horizontally, vertically, or any position in between. Changing the mixing angle is fast and convenient and requires no tools. This device is battery powered and can be easily transported to operate in various locations in a lab including desktops, benches, clean hoods, chemical hoods, cold rooms, glove boxes, incubators or biological hoods. Second, an on-board Arduino-based microcontroller is incorporated that adds the functionality of a laboratory sample shaker. These devices can be customized both mechanically and functionally as the user can simply select the operation mode on the switch or alter the code to perform custom experiments. The open source laboratory sample rotator mixer can be built by non-specialists for under US$30 and adding shaking functionality can be done for under $20 more. Thus, these open source devices are technically superior to the proprietary commercial equipment available on the market while saving over 90% of the costs.

1. Introduction

The success of free and open source development of software is now well established and this method of development outside of purely software has grown most rapidly in electronics such as with the Arduino microcontroller [1]. The open-source Arduino is already established for use in low-cost high-quality scientific and engineering equipment [2–7] including: an ambient sensor cloud system using OpenFS (open field server) for high-throughput phenotyping [8], electrophoresis [9], imaging [10,11], mass spectrometry [12,13], mechatronics [14], microscopy [15,16], oceanographic research [17], optics [5,6,18], sensors for open hardware [19], including for colorimetry [20], in-vivo optimal imaging [21], nephelometry [22], pressure monitoring [23], smart plugs [24], soil moisture [25], Skinner boxes [26], vision research [27] and developing a wireless sensor node to monitor poultry farms [28]. Arduinos are also an established technology for controls [29], used as controllers on numerous challenging projects such as for aerial vehicles [30], robots [31,32] and microfluidics [33].

One of the most important control projects for scientists is the use of the Arduino for the open source 3-D printing community around the self-replicating rapid protoyper (RepRap) 3-D printer family [34–38]. The combination of free and open software and hardware design can be combined with RepRap 3-D printing for distributed digital fabrication of

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low-cost scientific equipment [3,6,39] including: automated sensing arrays [40], biotechnological and chemical labware [41–43], colorimeters [20], DNA nanotechnology lab tools [44], liquid autosamplers [45], mass spectroscopy equipment [46], compatible components for medical apparatuses [47], microfluid handlers [48] and wax printing of microfluidics [49], turbidimeters [22,50], optics and optical system components [5], and phasor measurement units [51]. In addition, the delta style RepRaps can be converted into a scientific tool itself by taking advantage of the mobile and stationary tool modes [52] including laboratory auto-stirring, measuring and probing, automated fluid handling, shaking and mixing [53] and 3-D automated microscopy [16].

In general digital replication with RepRap 3-D printers has reduced capital cost of scientific equipment by 90–99% from the cost of conventional equipment [3,6], which has created substantial value [54] resulting in hundreds and even thousands of percent return on investment for science funders [55].

To contribute to this trend, this paper presents the concept of a low-cost laboratory sample rotator mixer capable of combining the benefits from digital replication using a RepRap 3-D printer and controls logic from the Arduino-based microcontroller. The 3-D printable open-source laboratory sample rotator mixer is developed here in two variants, which allow users to opt for the level of functionality, cost saving and associated complexity required for their laboratories. First a simple laboratory sample rotator mixer is developed, which can be used for tumbling of samples in a variety of tube sizes by gently mixing them horizontally, vertically, or any position in between. This wireless battery-powered device can be easily transported to operate in various locations in a lab including desktops, benchtops, clean hoods, chemical hoods, cold rooms, glove boxes, incubators or biological hoods. Second, the mixer is enhanced with an on-board open source Arduino-based microcontroller to add the functionality of a shaker mixer. The user can select the operation mode with a switch. The cost saving of each of these variants was computed against commercially available products with similar functionality.

2. Materials and methods

The full bill of materials (BOM) is available with all the design files for both variants of the mixer in registered [56] and live format [57] (including links to components available online) and can be seen in Tables 1 and 2. All values in the BOMs are given in U.S. dollars. The BOM can be broken into two categories: (1) custom 3-D printable mechanical components and (2) off-the-shelf mechanical and electrical components. Tables 1a and 2a list of hardware that is to be 3-D printed on a RepRap or similar 3-D printer is shown. The custom parts of this sample rotator were designed using version 0.15 of FreeCAD – an

Table 1a
Open source laboratory sample rotator mixer 3-D printed components, mass and cost.

Printed component		Quantity	PLA mass (15% infill)	Cost of print (USD)
1. Small pillar	×	1	29 g	0.67
2. Central shaft	×	1	12 g	0.28
3. Rotisserie for test tubes	×	4	72 g	1.67
4. Big pillar	×	1	50 g	1.15
5. Motor cover	×	1	23 g	0.53
6. Battery cover	×	1	6 g	0.14

Table 1b
Open Source Laboratory Sample Rotator Mixer list of hardware to be purchased for assembly with the printed parts including component, quantity and cost.

Component		Quantity	Total cost
1. Bearing	×	1	USD 1.45
Details: This is the widely available roller skates bearing: O.D. = 21 mm and I.D. = 8 mm			
2. Battery	×	1	USD 2.05
Details: 9 V alkaline widely available (bought in pack of 8)			
3. Rocker switch	×	1	USD 0.45
Details: This can be purchased from Amazon or similar			
4. Geared motor 60 rpm 12 V DC	×	1	USD 12.98
Details: This can be purchased from Amazon or similar			
5. Battery clip	×	1	USD 0.24
Details: This can be purchased from Amazon or similar			
6. Rubber sheet (printed version cost)	×	2	USD 3.12
Details: This is sandwiched between the Rotisseries to grip the test tubes. Multiple options available on Amazon or similar			
7. O-rings	×	4	USD 2.04
Details: 9/16″ outer diameter × 5/16″ inner diameter × 1/8″ wall or 14 mm × 8 mm × 3 mm			
8. 5/16″ (or M8) screw 195 mm long	×	2	USD 2.80
9. 5/16″ (or M8) nuts	×	6	USD 0.60

Total equipment cost: USD 30.17 (including battery).