

# Xylophone Project

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## **Abstract**

This document describes the building of an electromechanical xylophone. Copper

# 1 Introduction

## 2 Pipes

### 2.1 Materials

We use copper pipes as vibrating elements. The main reasons being copper is simple to work with, easily found in local stores and cheap.



### 2.2 Computing pipe length

The length depends on 3 factors:

- the required frequency,
- the vibrating element shape,
- the sound propagation speed in the medium.

According to [wiki\_acous\_reson], the formula for a cylinder is:

$$f = \frac{nv}{2(l+0.8d)}$$

where:

- $f$  the frequency in  $hz$ ,
- $n$  an integer (1, 2, 3 ...),
- $v$  the speed of sound in medium in  $ms^{-1}$ ,
- $l$  the length in  $mm$ ,
- $d$  the cylinder diameter in  $mm$ .

However, we found an apparently better formula in [tamhigh\_xylo] which accounts for the pipe radius of gyration. The  $n$ th transversal frequency is given by:

$$f_n = \frac{\pi v k}{8l^2} m^2$$

where:

- $f_n$  the frequency in  $hz$ ,
- $v$  the speed of sound in medium in  $ms^{-1}$ ,
- $k$  the gyration of radius,
- $l$  the length in  $mm$ ,
- $m$  a value such that:
  - $m = 3.0112$  when  $n = 1$ ,
  - $m = 5$  when  $n = 2$ ,
  - $m = 7$  when  $n = 3$ ,
  - $m = 2(n + 1)$  otherwise.

For a cylinder, the gyration of radius is:

$$k = \frac{1}{2} \sqrt{i^2 + o^2}$$

where:

- $i$  the inner diameter in  $mm$ ,
- $o$  the outter diameter in  $mm$ .

The copper sound propagation speed is:

$$3700ms^{-1}$$

Since we want the whole device small, we keep the pipe as short as possible. However, we want to build it using relatively inaccurate drilling and cutting tools. Thus, we ended up choosing the 8th frequency mode, which results in the folloing table:

<i>frequency (hz)</i>	<i>length (mm)</i>	<i>first node (mm)</i>	<i>second node (mm)</i>
2093.000000	0.141960	0.031799	0.110161
2349.313067	0.133993	0.030014	0.103978
2637.014757	0.126472	0.028330	0.098142
2793.819815	0.122872	0.027523	0.095349
3135.956712	0.115976	0.025979	0.089997
3519.992394	0.109466	0.024520	0.084946
3951.057873	0.103322	0.023144	0.080178
4186.010000	0.100381	0.022485	0.077896

## 2.3 Cutting the pipes

The easiest and most accurate way to cut the pipe is by using a pipe cutter:



*pipe cutter*

We found experimentally that we must add roughly 1.5mm to the previously computed length. This is due to the transversal holes and the vibration effects when the pipe is finally mounted. By the way, it is always better to have a longer pipe, since we can reduce it with a lime for tuning until it reaches the correct frequency.

## 3 Assembling

### 3.1 Drilling the base

Drill the pipe transversal holes before drilling the base holes. Once this is done, mark the base to prepare the drilling. It helps correcting small errors made while percing he pipe holes.

### 3.2 Mounting the pipes



## 4 Bill of materials

<i>reference</i>	<i>reseller</i>	<i>description</i>	<i>quantity</i>	<i>price (euros)</i>
copper pipe				



## 5 References

- wiki\_acous\_reson: [http://en.wikipedia.org/wiki/Acoustic\\_resonance](http://en.wikipedia.org/wiki/Acoustic_resonance)
- tamhigh\_xylo: [staff.tamhigh.org/lapp/xylophone.pdf](http://staff.tamhigh.org/lapp/xylophone.pdf)