# Advanced tactile feedback with dual-rotor vibrotactor

Ákos Miklós[1], Zsolt Szabó[2]

## Abstract

*A novel solution is presented for generating advanced tactile feedback in haptic applications. The concept utilizes the benefits of the eccentric rotating mass (ERM) vibrotactors and eliminates the problem of the frequency-dependent amplitude by using two eccentric rotors. Operational region of the dual-rotor vibrotactor is showed in the frequency-amplitude domain considering tactile sensing threshold of the human skin, and the possibility of changing the intensity of the tactile stimuli by the dual-rotor vibrotactor is compared to common ERM vibrotactors.*

## Sensing of mechanical vibrations

Utilizing the tactile sensing of the man is very important for nowadays handheld and mobile devices. With mechanical vibrations transmitted to the skin it is possible to inform the user or give alarm in case of predefined events even in noisy or dark environment, where auditive and visual capabilities are limited. Since the tactile sensing performance of the skin is strongly frequency-dependent (see the region of operation), it is meaningful to adjust the frequency and amplitude of the vibration independently to increase information transfer density. [1]

## Vibrotactors

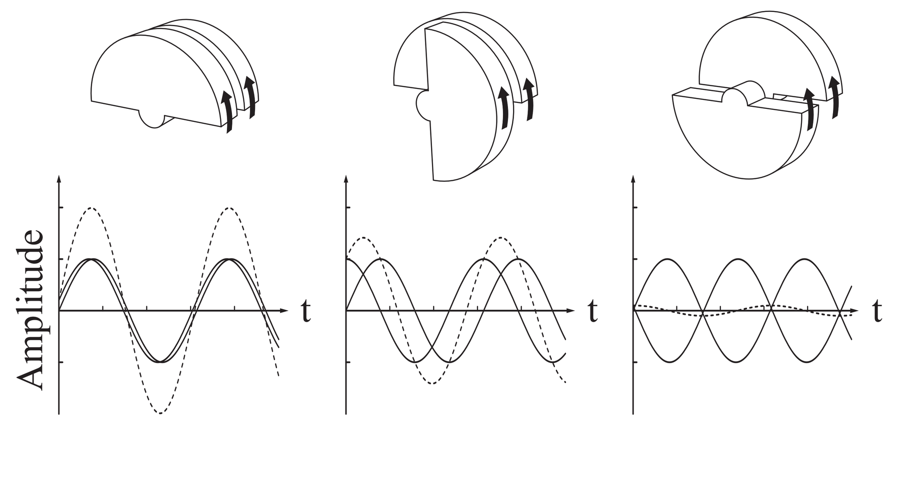
There are many solutions for generating mechanical vibrations. In mobile and handheld devices and in haptic applications the most widespread solution is the eccentric rotating mass (ERM) vibrotactor. Its benefit is the simplicity of the design and the wide frequency range, however the magnitude of the generated force depends on the frequency. It is possible to eliminate this dependency via linear resonant actuators (LRA), but on the other hand the frequency range of such actuators is limited to their resonant frequency. [2]

## Dual-rotor vibrotactor

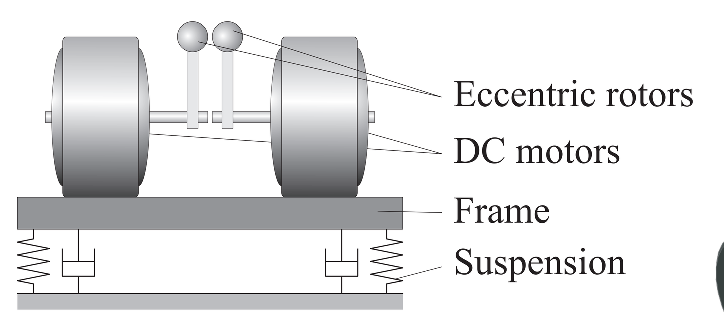
To reach the independent frequency and amplitude at a wide frequency range a dual-rotor vibrotactor—called Dual Excenter—has been constructed. This device unifies the advances of ERM and LRA vibrotactors, while it keeps the design simple and the size compact. The two eccentric rotors of the device are arranged coaxial and are driven by two DC motors. With the control of the phase angle between the rotors the resulting eccentricity—thus the vibration amplitude—can be set frequency-independent. [3]

## Development of the dual-rotor vibrotactor

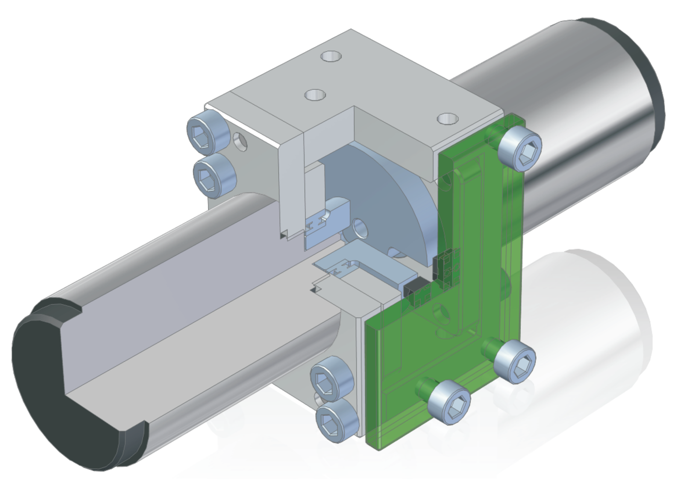
The development of the Dual Excenter was carried out at the Department of Applied Mechanics at the Budapest University of Technology and Economics. The concept has been proven by analytical and numerical methods, which revealed some interesting mechanical phenomena (self-synchronization and the Sommerfeld-effect) [4]. After the parameters were defined by numerical simulations, the prototype device has been designed and constructed, which made it possible to validate the Dual Excenter concept experimentally.



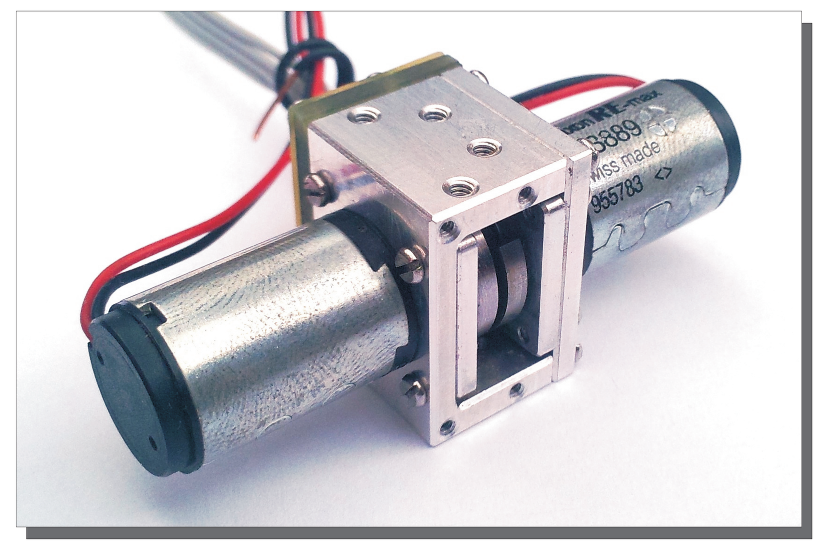

The dual-rotor concept




Main components



CAD model of the vibrotactor



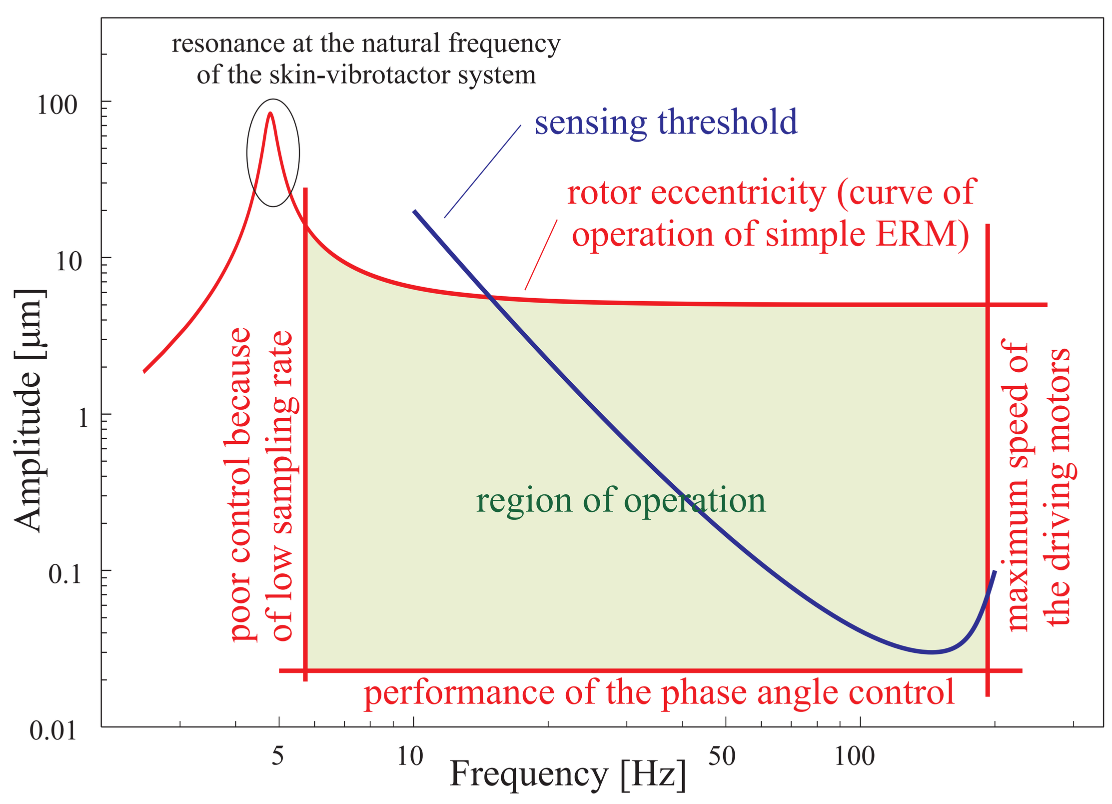
Prototype device

## Region of operation

In case of a single- or dual-rotor ERM vibrotactor attached to human skin, the steady state amplitudes of the vibration can be obtained by

$$A = a\frac{\lambda^2\cos(\delta)}{\sqrt{(1-\lambda^2)^2+4\zeta^2\lambda^2}},$$

where $\lambda$ and $\zeta$ are the frequency ratio and the relative damping of the skin-vibrotactor system, $\delta$ is the half of the phase angle between the rotors and $a = em_0/m$ is the distance of the eccentric mass moment of the rotors divided by the overall mass. The necessary parameters of the skin can be obtained e.g. from [5], so the natural frequency of such system can be 3–10 Hz and the relative damping 0.03–0.07. With these parameters and the eccentricity of the rotors we get for simple ERM vibrotactors a "curve of operation". For dual-rotor vibrotactor we can reach amplitudes below that curve with the change of the phase angle $\delta$. The region of operation is limited by lines resulting from the control performance, but it is possible to push them further if needed.



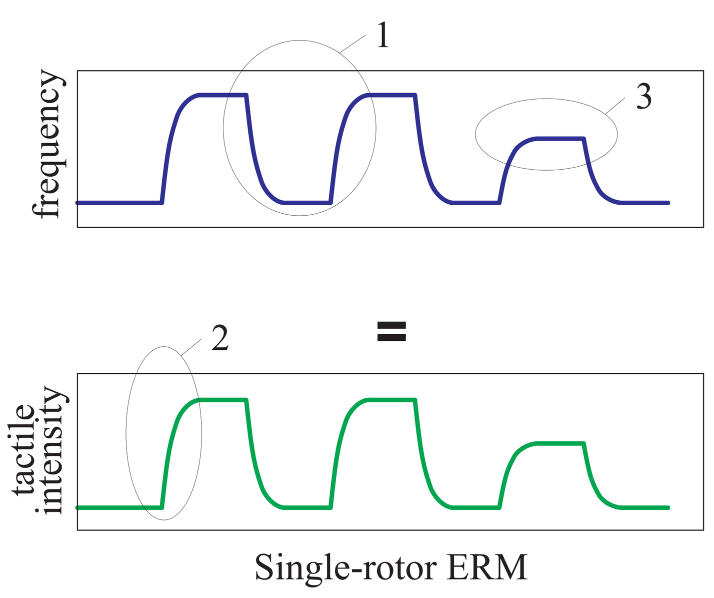

## Changing vibration intensity

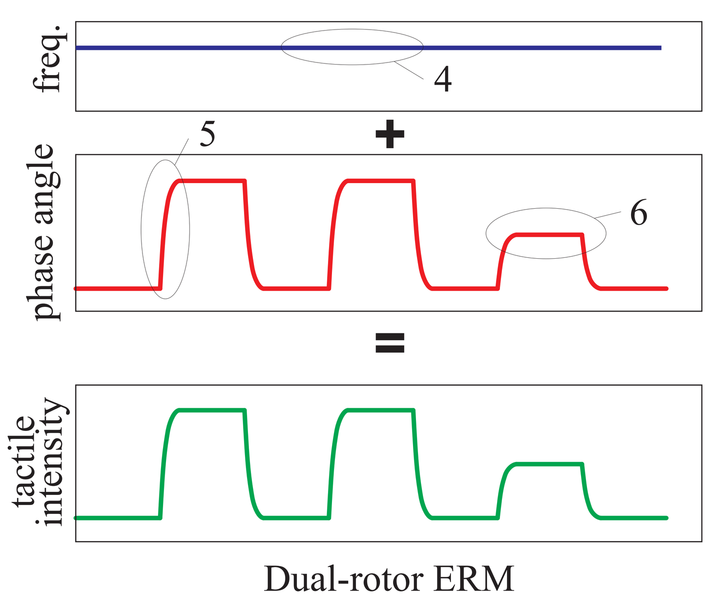
With single-rotor vibrotactor

1. To change the intensity we have to slow down and speed up the rotor,
2. The change of the intensity is relative slow because of the inertia of the rotor,
3. Lower intensity means lower frequency, thus optimal tactile parameters cannot be set.

With dual-rotor vibrotactor

4. The change of the intensity can be done at constant frequency,
5. Changing the phase angle takes much less time as slowing down the rotors,
6. Every intensity level can be reached at the desired frequency.

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## References

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[1]Ákos Miklós (miklosa@mm.bme.hu), MTA-BME, Research Group on Dynamics of Machines and Vehicles, Budapest, Hungary

[2]Zsolt Szabó (szazs@mm.bme.hu), Department of Applied Mechanics, Budapest University of Technology and Economics, Budapest, Hungary