Reviewing DIY Vibrating Gloves for Parkinsons

Version 1.1, January 2025
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TABLE OF CONTENTS

Foreword

On December 13, 2022, the Today Show aired an amazing story about Dr. Tass's Stanford Gloves for the treatment of Parkinsons. (See, https://www.youtube.com/watch?v=YEEwbxFT4Bc). The gloves worked to relieve many of the symptoms of PD through stimulating the brain non-invasively with gentle vibrational pulses administered in a special sequence to the wearer's fingertips. The story immediately created great excitement and hope for people with Parkinsons and their supporters everywhere.

Given that the availability of Dr. Tass's treatment was projected to be many years into the future, engineers with PD and their supporters around the world began intense local DIY efforts to replicate the Stanford Gloves based on the specifications provided in Dr. Tass's numerous research papers. These DIY developers shared ideas and designs on the web through various PD forums, websites, and YouTube posts. This document is an effort by two of the many developers involved in the DIY PD glove movement to:

1. Suggest a set of standard criteria for reviewing DIY designs.
2. Begin a collection of DIY designs by presenting a few reviews of different types of DIY designs that are currently available.
3. Demonstrate how the vibrational performance of DIY gloves can be bench tested and compared.
4. Suggest a standard format for providing user feedback and provide some initial reviews from vibrating PD glove users.

In presenting this document, we are not advocating for any particular glove design. Likewise, we are not advocating for people with Parrkinsons to use DIY glove therapy. The informed choices of whether to proceed with a DIY glove, and if so what design to choose, should be made by each individual in consideration of their personal circumstances and disposition, and only after consultation with their doctors. This is particularly true for people who have DBS or pacemakers and have to consider special precautions around all electronics.

Please read the disclaimers in this document.

Acknowledgements

Thanks to Dr. Peter Tass for all his dedicated work in inventing and improving his vibrating glove treatment for Parkinsons, to reviewers of initial drafts of this document from Health Unlocked who gave us many helpful suggestions, and to the many PD supporters who have contributed to our communities' efforts to develop DIY versions of vibrating gloves on Health Unlocked, YouTube, Github, and elsewhere.

How to Use This Document

Consult with your doctor before considering DIY therapy.

Content provided here does not replace the relationship between you and doctors or other healthcare professionals nor the advice you receive from them. **People with implanted electrodes from DBS, heart pacemakers, or other internal devices, need to take special precautions around all electronic devices**. https://www.medtronic.com/us-en/healthcare-professionals/therapies-procedures/neurological/deep-brain-stimulation/indications-safety-warnings.html#:~:text=Precautions%3A,their%20physician%20if%20symptoms%20persist.

Check the references.

In this document, we have summarized information on vibrating gloves that we gathered through studying PubMed papers, forum posts, websites, and YouTube videos. We have done our best to be accurate, but we could have made inadvertent errors. Accordingly, we have provided direct references and web links to the actual sources where we obtained the information throughout this document so that readers can easily check out the facts for themselves. Please contact us with any errors or suggestions for future versions.

Read disclaimers before moving forward with building.

If you decide to embark upon your own project to assemble one of the builds reviewed in this document, please start by carefully reading all the disclaimers we have provided.

Save the building hassle and hire a technician.

If you want to try DIY PD gloves, but don't have the ability to get involved in a DIY project of this magnitude, there are lots of people around with electronics experience who could complete all the wiring and/or building for you. Our biggest concern if you are an absolute electronics beginner attempting to build your own gloves is, you may have difficulties troubleshooting what is wrong if things don't initially work when you fire it up the first time. So, if you are a beginner looking to get into DIY gloves for PD, look through the building steps the various developers have provided, and if it all seems too much to get into, consider finding an electronics repairperson who would be willing to put it together for you for some price. *(Note: This is a service we are definitely not interested in fulfilling, so please don't ask).* If you could get a tech person to do it all for the price of the required tools, you would end up breaking even and save yourself a lot of work. But, keep in mind that there will be maintenance to do as the buzzers eventually start wearing out, so there will be some deferred costs down the line if you are not able to change out buzzers for yourself.

Disclaimers

1**. The devices and therapy described here have not been FDA approved**. The research that forms the theoretical basis for the devices described in this document is currently unfinished, and the therapeutic effects (and/or side effects) of such devices are therefore not fully understood. As with any alternative PD treatment that is not FDA approved, if you choose to try some variation of DIY vibrating glove treatment described here, you will be experimenting with your body. Users of this information assume any and all risks related to the use of the information described.

2. **This document is provided freely, solely for personal informational purposes, and does not constitute medical advice**. Users should always seek qualified medical advice when considering medical treatments. While the authors have found the PD vibrating glove approach helpful, we do not claim that these devices will improve anyone's symptoms, nor do we take responsibility for any harm that such DIY devices may inadvertently cause. In providing this document, we are not encouraging anyone to use DIY therapy to treat their PD without the supervision of a neurologist. If you choose to build a device such as this: (a) BEST WISHES and (b) USE IT AT YOUR OWN RISK. **No liability will be assigned to any contributor to this document in the event a user suffers loss as a result of the information.**

3. While the authors of this document have technical backgrounds which give them some level of expertise to test and design various technical aspects of DIY gloves, **neither of the authors have a medical background that would qualify them to provide medical advice**. Our knowledge of PD gloves and their impact on PD is limited to our own experiences and what we have read on the subject. Accordingly, we have taken care in this document to merely summarize and provide references to sources of information we have personally found helpful.

4. **<u>DIY copies of the Stanford gloves may deviate from the official Stanford glove in critical ways that render any guidance from Dr. Tass inapplicable to the DIY design</u>**. At the end of the day, no one can know for sure in advance if any DIY glove design will be worth the investment of time, effort and money, especially given that not all patients have uniform experiences even when using the actual Stanford glove under ideal conditions.

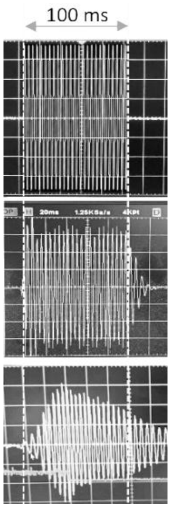
5. While some DIY PD glove designs may come close to reproducing specific aspects of the vibrotactile therapy described in Dr. Tass's papers, none of the DIY designs benefit from the type of medical supervision and technical support provided to research study participants in the papers we reference**. As with any alternative PD treatment that is not FDA approved, if you choose to try some variation of DIY vibrating glove treatment described here, you will be experimenting with your body**. We encourage anyone interested in DIY PD glove therapy to consult with their own doctors to weigh potential benefits and risks.

6. If you decide to move forward with your own glove build, there are many DIY versions on the web you can choose from. **We have only presented a few DIY designs in this document.** It is our hope that other HealthUnlocked forum members will provide their own design reviews to help enlarge our collection.

7. **While every effort has been made to assure accuracy, the contents of this document may contain errors and/or omissions**.

8. **No implied or expressed effectiveness, suitability, or warranty of any DIY Glove design, software or device described in this document is granted or intended, nor should any level of on-going support be expected**. Rights to commercialization of any devices and/or related concepts is not intended, implied or granted. Readers interested in learning more about vCR therapy are encouraged to continually visit updates on the work by Dr. Tass and team at Stanford while exploring your own treatment paths in concert with your doctors.

From our contributing editor:
Given the huge variability of symptoms presented by people with Parkinson's, I strongly believe PWP must travel very different treatment paths to discover their best lives while living with this disease. My 12+ year journey with PD has followed a path with numerous peaks and valleys, and includes therapies involving many combinations of exercise, diet, sleep, several medicines, acupuncture, yoga, multiple DBS implants, and more recently, my own DIY vCR gloves. Our best wishes to you in seeking out your own individual path to find your best life while living with PD.



Part 1: Review Criteria for DIY PD Glove Designs

Reproducibility

In this section, we highlight the fundamental Tass vibrotactile specifications DIYers typically use to evaluate their DIY glove performance. We also suggest a number of additional criteria we have found helpful when comparing different DIY designs. These additional criteria include measures relating to buildability, features, useability, and aesthetics.

As part of the scientific process, scientists routinely report their methods in peer reviewed journals in order that others may reproduce and verify their results. Accordingly, Dr. Tass has carefully documented his methods and device specifications in various prestigious scientific journals. The most helpful papers for people interested in replicating his results can be freely downloaded in full text:

> ***"Coordinated Reset Vibrotactile Stimulation Induces Sustained Cumulative Benefits in Parkinson's Disease"***, 2021, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8055937/ . This paper is referred to as Dr. Tass's "Patterns Paper" in this document. This paper also has a supplementary materials link that has further information about the buzzer design along with patient videos.
>
> ***"Clinical Efficacy and Dosing of Vibrotactile Coordinated Reset Stimulation in Motor and Non-motor Symptoms of Parkinson's Disease: A Study Protocol",*** 2021, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8636796/ . We refer to this paper as Dr. Tass's "Protocol Paper".
>
> ***"Vibrotactile Coordinated Reset Stimulation for the Treatment of Neurological Diseases: Concepts and Device, Specifications",*** 2017, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5624565/ . This paper is referred to as Dr. Tass's "Device Specs Paper" in this document.
>
> A more complete listing of Dr. Tass's publications on vCR can be found here: https://med.stanford.edu/tass-lab/publications.html

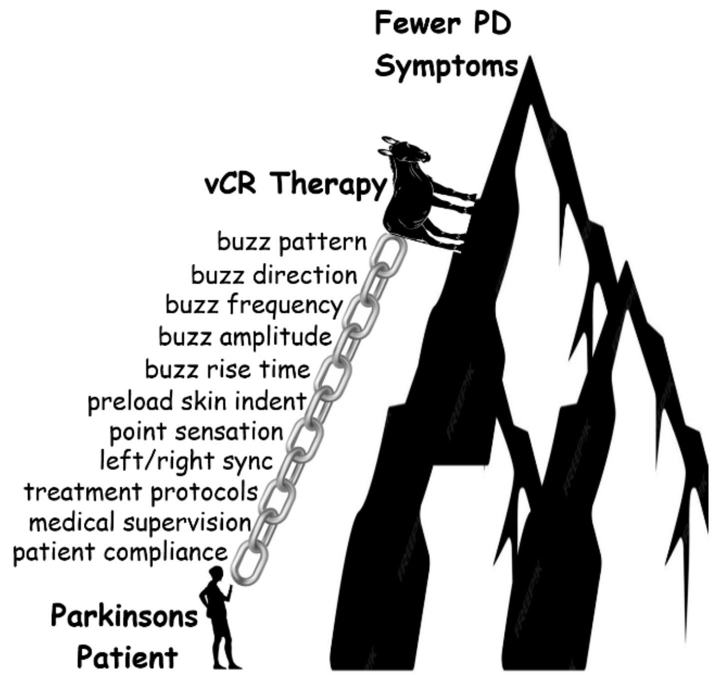
Dr. Tass has also made many presentations on YouTube to publicize his innovative approach. In these presentations, he often provides design details and answers specific questions from participants. See for example:

> ***"Presentation and Q&A with Dr Peter Tass",*** TrainingWheelsOff, Feb 27, 2024, https://www.youtube.com/watch?v=_gmdfrkW2oA&t=3738s

"Questions & Answers with the Doctors", MDFA, June 12, 2023
https://www.youtube.com/watch?v=uDxJkMrYjI0

"The Parkinson's glove & Vibrotactile fingertip stimulation to ease Parkinson's symptoms", NoSilverBullet, Jun 6, 2023*,* https://www.youtube.com/watch?v=XRUOjpm0hKo .

Based on the way replicability works in the scientific process, we assume that any researcher who perfectly replicates Dr. Tass's methods and device specifications set forth in his papers has the theoretical potential to obtain the same sorts of results reported for research study participants. In our reading of Dr. Tass's papers, we identified 11 essential elements to vCR therapy shown in the graphic. The top 8 elements relating to vibrotactile performance constitute the basis for our reviews of online DIY PD glove designs. As we illustrate in the graphic, the chain of elements is only as strong as its weakest link. So, for example, if the buzz amplitude is too high, or too low, the entire therapy is compromised even if all the other elements are perfect.



A big proviso to the reproducibility of results assumption is that Dr. Tass's gloves come with trained neurologists and technicians who work with patients to direct treatment and adjust parameters based on patient responses. Unlike the participants in Dr. Tass's trials, most DIY glove users direct their own treatment. This weak link in the chain could result in a big difference between the Stanford glove and DIY gloves that transcends glove specifications. Note that this document is limited to an analysis of review criteria for the PD vibrating glove design performance. Accordingly, readers are encouraged to study the vCR treatment protocols directly from the original source information provided by Dr. Tass in his publications and presentations.

To date, we are aware of only one formally funded effort that has sought to replicate results from Dr. Tass's vibrotactile studies. The company that is conducting this effort is called Synergic Medical Technologies, Inc., whose web site can be found here, https://synergicmed.com/. Synergic has been granted an "FDA breakthrough device designation" for their VT Touch glove that was patterned according to Dr. Tass's specifications. The announcement can be found online here, https://synergicmed.com/storage/app/media/PDFs/Synergic%20BDDFDA_PR.pdf. In September 2024, Synergic presented positive results that demonstrated significant improvement in bradykinesia in their longitudinal proof-of-concept glove trial (https://www.mdsabstracts.org/abstract/coordinated-reset-vibrotactile-therapy-for-the-treatment-of-bradykinesia-in-parkinsons-disease-patients/). A description of the trial protocol can be found here: https://clinicaltrials.gov/study/NCT05830110 . Notably, **all participants in this study received active therapy alternating with sham therapy at two-month intervals** in order to parse placebo effects out from experimental effect. This was a difficult experimental design for participants since the cumulative gains they would experience from 2 months of real glove therapy would alternately be erased by two months of placebo glove therapy. A participant from this study *(pictured in the Synergic announcement)* described his mostly positive experiences with the VT Touch glove in a series of videos on YouTube here, https://www.youtube.com/@patriddleparkinsonsjourney . Synergic also has a second trial currently underway that is targeted on obtaining full FDA approval for their glove.


Synergic
medical technologies, inc.

PRESS RELEASE

January 04, 2023

SYNERGIC receives FDA's Breakthrough Device Designation

Synergic Medical Technologies announces the receipt of a **Breakthrough Device Designation** from the **US Food and Drug Administration** for the **VT Touch** vibrotactile stimulation glove for treating pathological beta oscillations in Parkinson's disease. Synergic is working with a university medical center to start a randomized clinical trial to test the effectiveness of the **VT Touch** glove with Parkinson's patients. We hope to report on progress with this clinical trial in the near future.

The Weak Link Paradox

As we will see in the following pages, even though DIY gloves have the potential to theoretically reproduce all of the fundamental vibrotactile criteria specified in Dr. Tass's papers, **there are a number of compromises that DIY designers often implement in order to make their DIY gloves more affordable, easier to build, or easier to wear**. As we have illustrated in our chain graphic above, Dr. Tass's vCR therapy depends on each link in the chain. Yet, there are PWP using all types of designs who have happily reported positive therapeutic results despite the vibrotactile shortcomings of the various glove designs. Of particular relevance to this section are the popular easy-to-build designs that use ERM-type buzzers that substantially violate all Tass vibrotactile specifications except left/right sync. Rationales to explain this paradox have been passionately debated by DIYers online and can be summarized into five categories:

1. The Placebo Effect

We are great fans of the placebo effect and we believe that what the world needs is more placebo effect! However, based on a number of factors, we are of the view that placebo cannot explain the depth and persistence of the effects that have been observed with substandard DIY glove designs. In this author's experience, I was not aware there were numerous DIY options to choose from and I started with an ERM design that employed an expensive ERM buzzer that delivered excessive vibrational amplitude. I dutifully administered therapy according to Dr. Tass's protocols for over 4 months, and despite of my very high expectations and confidence that I would experience a positive effect, I experienced no therapeutic effects, placebo or real. I eventually lost my confidence that the therapy. Before completely giving up, I replaced the expensive buzzers with the cheap low-amplitude type many others were using. I started observing various positive effects on my third day of therapy with the low-amplitude buzzers. As I describe in my user review later in this document, the effects became more pronounced over the following months, and in my yearly PD exam 5 months later, my movement-specialist neurologist confirmed my symptoms were indeed less than they had been in my previous year's appointment. So, unless there is a such thing as "reverse-psychology-placebo-effect", where the user obtains the effect only after all confidence in the treatment is lost, I must conclude that the cheap ERM buzzers must have been producing a real effect. *(Note that, two months after I started experiencing benefit, I began researching DIY designs and switched to an LRA-based design reviewed later in this document called the Buzzah Neck Build which has enhanced my level of results with better adherence to the Tass vibrotactile specifications. My experience reviewing DIY designs is what led to the creation of this document).*

In this YouTube presentation, https://www.youtube.com/watch?v=z_t0VmSJm8M, at time starting at 32:34, Dr. Tass points to a number of characteristics of his vibrotactile therapy that are inconsistent with placebo effects. First, placebo effects typically tend to vary in time and tend to be relatively short term. In contrast, the effects of vibrating glove therapy are robust and have been observed to continue over periods longer than 1.5 years. And placebo effects in PD rarely impact tremor. In contrast, all of Dr. Tass's glove patients have benefited from some level of tremor reduction. He goes on in the video to present various before/after patient videos featuring patients who have enjoyed profound reductions in their PD symptoms.

2. Conservatively Biased Specifications

It is common for manufacturers to publish overly conservative specifications of their products to ensure that consumers are not dissatisfied with product performance. Accordingly, some have suggested that Dr. Tass cautiously provided us with overly conservative specifications to 'err on the safe side' to ensure positive effects for others who seek to replicate his results. Some specifications (for example, amplitude, pattern ON/OFF times, and frequency) allow for a range of values that can be adjusted according to individual patient characteristics. Other parameters require strict adherence to specifications that are technically difficult for DIYers to achieve. Consider for example, Dr. Tass's buzzer spec that requires rise time to be less than 2 ms. Should we conclude that a buzzer that gives a 2.1 ms rise time would yield no therapeutic results? What about 2.2 ms? Our view is that, while there is probably some level of conservative bias built into Dr. Tass's strict specifications, this bias cannot possibly account for the positive effects observed from DIY gloves that wildly violate multiple Tass specs. For example, my subsequent bench testing revealed that the rise time of the DIY gloves that gave me my initial positive therapeutic effects was had a rise time of 24 ms. This is 1200% greater than the Tass spec! In total, my early ERM-based DIY design substantially violated 5 out of the 8 fundamental vibrotactile specifications. Surely, the Tass specifications cannot be so conservative that they deviate from the true requirements of vCR therapy by orders of magnitude. We must look then further to answer the weak link paradox.

3. Errors Made in the Scientific Process

Nothing in the scientific process guarantees that scientific conclusions are always correct. Perhaps a decade from now when vCR therapy has been used by millions of PD patients, researchers will find that some of Dr. Tass's rigorous specifications were unnecessary. While this is theoretically possible, we have to consider that Dr. Tass is a highly respected PD researcher with a very long career specializing in Parkinsons research. His peer reviewed work on vCR spans more than a decade, and his work on DBS goes back much further. The vCR specifications he published were developed and validated through a combination of neural simulation experiments, brain imaging, animal trials, and human clinical observations. *S*pecifications are also grounded on well accepted basic neurological research that dates back to the 1980's. While it is always possible Dr. Tass could be wrong about some of minor details of his theory, our view is that it is very unlikely that he could be be off orders of magnitude in numerous fundamental vibrotactile specifications.

4. Some Additional non-vCR Vibrotactile Effect

The therapeutic effect of various types vibrations on PD has been observed in many settings, https://pmc.ncbi.nlm.nih.gov/articles/PMC4100042/ . Some suggest that the efficacy of DIY vibrotactile gloves that do not adhere to the precise Tass specifications may be due to some alternate vibratory effect that is similar to the vCR effect observed by Dr. Tass. This is a compelling explanation of the weak link paradox, and may be part, or all, of the resolution to the paradox. But ultimately, the name of the vibrotactile effect is not nearly so important as the quality of results that are obtained. Our view is that, if a particular DIY design is working to relieve our PD symptoms, it is a great design. We have found the best symptomatic gains with LRA-based gloves that adhere closely to the Tass specifications, but we do not dismiss the possibility that other types of designs might produce similar therapeutic effects through some alternate effect.

5. The Positive DIY Results Could Have Been Even Better

Another argument to settle the weak link paradox is that, while substandard DIY gloves often deliver positive results, their results might have been even better if the glove's vibrotactile performance had been closer to the Tass specs. In our view, this is the most compelling answer to the weak link paradox. This is the rationale that led me to upgrade to a better performing LRA design after I began experiencing positive results with an ERM design.

Availability

When will the Stanford Glove become available to the public? This is the first question on everyone's mind when they see the amazing results Dr. Tass's patients have obtained with the gloves. There is an urgency to this question. Of course, we all hope for a future someday when our children or grandchildren will not have to worry about getting PD, but we also selfishly hope to find some kind of therapy that might help us with the PD we have now. When Dr. Tass is posed with this question in his YouTube talks, it is clear that he feels torn between two competing interests. On one hand, he is obviously a compassionate person who has dedicated his career to helping people with neurological disorders. When he sees someone in need, he sincerely wants to help. He could expedite the approval process by applying to the FDA as a low-risk medical device (similar to a back massager) without making specific claims for helping with PD. However, Dr. Tass explains that this would run counter to his main priority to ultimately provide the most effective therapy to the greatest number of PWP. He believes that the quickest path to this goal is to work for full FDA approval as a medical device for the treatment of PD which will ultimately lead to Medicare reimbursement to patients. When asked if he could try to get limited approval for immediate use by small numbers based on a compassionate exception or a breakthrough FDA designation, Dr. Tass explains that he does not want to risk any possible negative impact on the FDA approval process that could possibly come from a premature release of a preliminary product that has not been thoroughly tested and without the necessary support structure in place. (See, for example, the TrainingWheelsOff video at time, 54:33).

So, what is a realistic timetable to expect the official Stanford glove to be made available to the public? Dr. Tass's research group is now in the process of preparing for a large placebo-controlled study that will almost certainly lead to FDA approval. However, before the large FDA approval study, Dr. Tass explains he must first complete a smaller proof-of-concept study. In the TrainingWheelsOff video at time 1:09:10, Dr. Tass discusses the various studies that were in the planning stage at the time of the presentation in Feb 2024. As we see here, https://clinicaltrials.gov/study/NCT06028477 , the proof-of-concept study is currently estimated to start Jan, 2025 with an estimated completion date of March 2027. However, as we write now in January 2025, the study status is still listed as "Not yet recruiting" (see below).

Not yet recruiting

Vibrotactile Coordinated Reset in Parkinson's Disease - Proof of Concept Study

ClinicalTrials.gov ID NCT06028477

Sponsor Stanford University

Information provided by Vivek P. Buch, Stanford University (Responsible Party)

Last Update Posted 2024-08-19

While the large FDA approval study Dr. Tass refers to is not yet posted on ClinicalTrials.gov at this writing January 2025, we might hope that it could start early in 2026 and run concurrently with the proof-of-concept study. In either case, after the FDA study is completed, there are a number of additional steps that must be completed before the official Stanford glove is available:

Time to analyze and write up results = 6 months?
Average time for journal publication after submission = 6 months
Time for the FDA approval process after submission = 6 months?
Possible delays based on FDA application feedback = ????
Time to ramp up manufacturing of gloves = possibly concurrent with FDA process?
Time to train neurologists with vCR treatment protocol = possibly concurrent with FDA process?

A discussion of the availability timetable can be found here: *https://healthunlocked.com/cure-parkinsons/posts/151165382/stanford-glove-trial* . In his June, 2023 NoSilverBullet interview at time 49:35, Dr. Tass suggested availability might come in 1.5 to 2 years, which would have been around the time we write now in 2025. Of course, with so many factors, it is impossible for anyone to give an exact date. In Dr. Tass's Feb, 2024 TrainingWheelsOff interview at time 1:13:04, he increased his estimate to two or three years. During a Nov, 2023 interview with Kanwar Bhutani https://www.youtube.com/watch?v=tIeLt9nPJrY at time 55:00, he was pressed to give his personal estimate of availability to which he said, *"Things like this it could take two years… Could take three years… Who knows in terms of approvals and if they run into any glitches, or anything along along the way*".

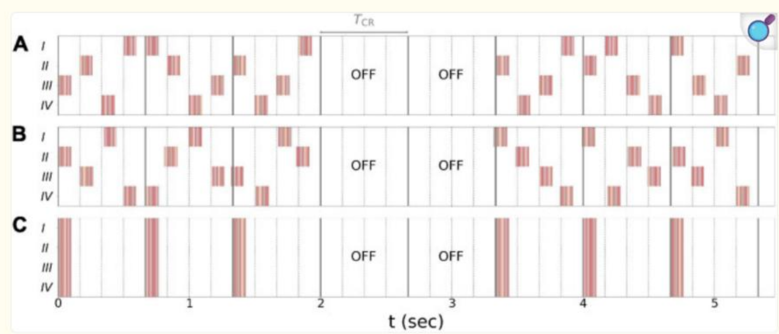
So, however you look at it, at the time of this writing in January 2025, it will clearly be some unknown number years before the Stanford glove is finally available to the public. The authors of this document think that 2028 is a reasonable estimate for the availability of the Stanford Glove given the discussion above. That said, in July 2023, Synergic posted a trial titled "**Vibrotactile Coordinated Reset: A Non-invasive Treatment for Parkinson's Disease 2**", https://clinicaltrials.gov/study/NCT05881460 . The results of this trial, which is currently underway, are hoped to be used to obtain FDA approval for vibrotactile therapy using their VT Touch glove. Assuming results are positive, application for FDA approval could come as early as 2026, leading to the availability of the VT Touch glove as soon as 2026 or 2027.

Buzz Pattern *(Tass Spec)*

Coordinated reset (CR) stimulation is a desynchronizing stimulation technique originally developed for DBS based on timely coordinated phase resets of synchronized neurons, https://pmc.ncbi.nlm.nih.gov/articles/PMC3308339/ . The technique utilizes levels of randomization similar to a related technique called stochastic reset (SR) common in many disciplines. See https://doi.org/10.3389/fphy.2022.789097 for a general discussion of stochastic reset. The difference between CR and SR is that, CR utilizes randomization in a coordinated pattern to achieve a specific desynchronizing effect. Vibrotactile coordinated reset (vCR) was developed by Dr. Tass to be administered through vibratory pulses to fingertips. The Device Specs Paper paper discusses a number of vCR buzz patterns that Dr. Tass has tested in computational neuron models. The two patterns that are available in virtually all DIY designs *(called Regular-vCR and Noisy-vCR)* are detailed in the Patterns Paper. Dr. Tass tested both patterns in a small number of experimental subjects and found no difference in results. Both patterns can be easily reproduced by off-the-shelf microprocessor chips.

As we see in the figure below, both regular vCR and noisy vCR feature a randomized order of pulses to the four fingers (thumb excluded). Each pattern consists of three T_{CR} = 666.8 ms stimulation periods and two T_{CR} = 666.8 ms rest periods, thus the "3:2" ratio we see in the diagram. Each of the three stimulation periods consists of four 166.7 ms vibrational bursts (consisting of ON = 100 ms and OFF = 66.7 ms) that are randomly distributed to the four fingers in such a way so that each finger is stimulated once per period.

The diagram here from the Patterns Paper shows 3 possible stimulation patterns for the 4 fingers on one hand. *(Let's imagine it is the left hand that is represented*). In Regular vCR shown for the left hand as (A) in the diagram, the corresponding right-hand pattern *(not shown)* is not mirrored. In other words, in Regular vCR, each hand receives its own randomized finger pulse order for every 4-pulse sequence. So, for example, the left index finger *(L-I in this diagram)* might be stimulated at the same time as the right pinky finger *(R-IV not shown).* We can then say that Regular vCR has two levels of randomization: randomized finger pulse order, and randomized (non-mirrored) left/right hand pulse pattern.



Open in a new tab

Stimulation patterns used throughout the paper. **(A)** Regular 3:2 ON-OFF coordinated reset with rapidly varying sequence (CR RVS) pattern. **(B)** Noisy 3:2 ON-OFF CR RVS pattern and 23.5% jitter. **(C)** Purely periodic multichannel stimulation. Gray lines indicate multiples of the vibrotactile coordinated reset (vCR) period T_{CR}, and dotted lines indicate multiples of $T_{CR}/4$ during individual CR periods. Roman numerals indicate fingertips on one hand. Stimulation bursts are marked red. Red vertical lines indicate maxima of $f_{vib}(t)$, Eq. (2), during individual bursts. Parameters: f_{CR} = 1.5 Hz ($\frac{T_{CR}}{4}$ = 166.7 ms), burst duration *100* ms, and f_{burst} = 250 Hz.

In Noisy vCR, shown as (B) in the diagram, the stimulation patterns sent to each hand are mirrored, so corresponding fingers on each hand are stimulated simultaneously with the same identical pattern represented in (B). To make up for the losing one level of randomization by mirroring right/left patterns, a random pulse timing jitter is added in Noisy vCR *(as illustrated by small random changes in pulse onset times in (B)).* In jittered timing, the timing of vibratory bursts to fingertips is delayed or advanced randomly by up to ±23.5%/2 of a 166.7 ms ON/OFF burst period. In other words, when jitter is applied to a pulse pattern, each 66.7 ms rest period is randomly modulated within an interval between 66.7-19.6 (47.1 ms) to 66.7+19.6 (86.3 ms). *(Note that jitter is only applied to OFF rest periods in order to keep the 100 ms pulse duration constant for each pulse).* Theoretically, there could be two levels of jitter randomization where each of the eight ON/OFF finger pulses experienced its own randomized (non-mirrored) jitter. However, this would cause left/right hand patterns to become out of sync. Instead, each right-hand finger in Noisy vCR simultaneously receives the same mirrored jittered pulse that the corresponding left-hand finger receives. So, the Noisy vCR pattern features two levels of randomization: finger pulse order (mirrored), and jitter (mirrored).

Dr. Tass has also explored introducing amplitude randomization as another level of randomization (see, https://pubmed.ncbi.nlm.nih.gov/36926109/). Accordingly, many DIY designs feature an option for users to add amplitude randomization to either stimulation pattern. The "range" of amplitude randomization can be adjusted in software setting so that minimum pulse amplitude may be as low as 0% of maximum amplitude, resulting in a range (max-min) of 100%. Alternatively, a user might, for example, set minimum pulse amplitude to 70%, resulting in a range of 30%. The greater the range of amplitude randomization, the more pronounced the effect. Since no standard range setting for amplitude randomization has been specified by Dr. Tass, DIYers who implement amplitude randomization must choose their randomization range by trial-and-error experimentation to determine what range setting provides the best results.

Conservatively minded DIYers choose only between Regular vCR and Noisy vCR to use in their glove software setup since these are the only two patterns that have been thoroughly tested by Dr. Tass in his papers to date. Some may also add amplitude randomization since it was discussed as an alternative by Dr. Tass. However, many DIY designs also offer a hybrid pattern option where users can choose to experiment with multiple levels of randomization in the same pattern. Such a pattern can include randomization in finger pulse order, non-mirrored left/right finger pulse order, mirrored or possibly non-mirrored finger pulse amplitude, and mirrored timing jitter. *(Note that timing jitter must always be mirrored, otherwise left/right hand sync is destroyed and the effects of "bilateral masking" could cause unwanted blurring of the vCR stimulus pattern that is perceived by the brain).* Since each individual user may respond differently to different patterns, some DIYers use trial and error to determine which combination of pattern settings provides the best therapeutic results. That said, no doubt many (if not most) DIYers simply use whatever pattern happens to be set up initially in their developer's glove software.

Left/Right Synchronization *(Tass Spec)*

In Dr. Tass's early papers describing the vCR patterns, he did not explicitly specify a tolerance for the synchronized timing of the vCR pulses administered to the right and left hands. A left/right synchronization specification was probably not included in these early papers because timing is inherently precise in wired glove designs. However, with the advent of the wireless connection that came about in the 2024 Stanford Glove, a synchronization standard became necessary due to the latency and signal propagation delays and clock offset issues that are present in all wireless technologies suitable for this application, such as Wi-Fi and Bluetooth. In a recent internal Stanford publication titled, "**Apparatus and method for efficient wireless synchronization of multi-site non-invasive stimulation for the treatment of disorders of the nervous system**", Dr. Tass discusses the implementation of Bluetooth synchronization and concludes by stipulating a synchronization specification of less than 1 ms,

> *"Precise synchronization, in the sub-millisecond range, is crucial for optimal treatment, especially when employing various excitation patterns that may simultaneously stimulate fingers on separate hands."*

The topic of phase lag between coincident stimuli to different areas of the brain was a focus of numerous research papers in the 1990's, where similar sub-millisecond time lags were measured. (See, for example, https://www.researchgate.net/publication/220499689_How_Precise_is_Neuronal_Synchronization (1995), and Tactile pattern perception by two fingers: temporal interference and response competition (1997)).

Note that wireless Bluetooth synchronization requires additional hardware and complex software. Hence, some wireless DIY designs simply ignore Dr. Tass's synchronization requirement in vCR and implement a variant pattern whereby each glove operates independently with no left/right synchronization.

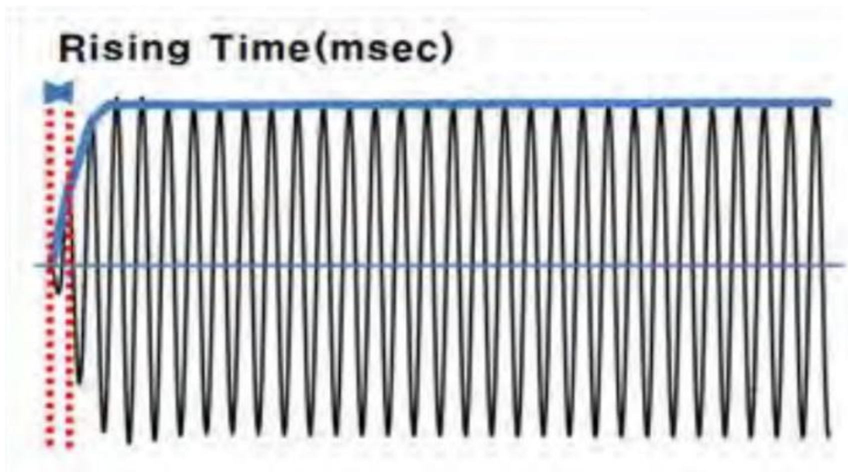
Buzz Frequency *(Tass Spec)*

In the Device Specs Paper , Dr. Tass explains the importance of precise timing of the nerve of impulses coming from fingertip nerve stimulation. There are two types of nerves in the fingertips that are important in vCR: fast acting fast-adapting type I (FA I) units, and fast-adapting type II (FA II) units. Since the nerve impulses from each nerve type travel to the brain at different speeds, vCR therapy must avoid stimulating both types in order to achieve a precise arrival time in the brain. It turns out that vibratory bursts of frequencies 100 to 300 Hz range are optimal to control the timing of the discharges of the FA II units and corresponding thalamic neurons. In contrast, vibratory bursts in the 30 to 60 Hz range are optimal stimuli for FA I units. Dr. Tass then specified a frequency of 250 Hz bursts to be used in vCR therapy to selectively stimulate FA II units, without also stimulating FA I units. Ideally, DIY gloves would utilize the same 250 Hz frequency that

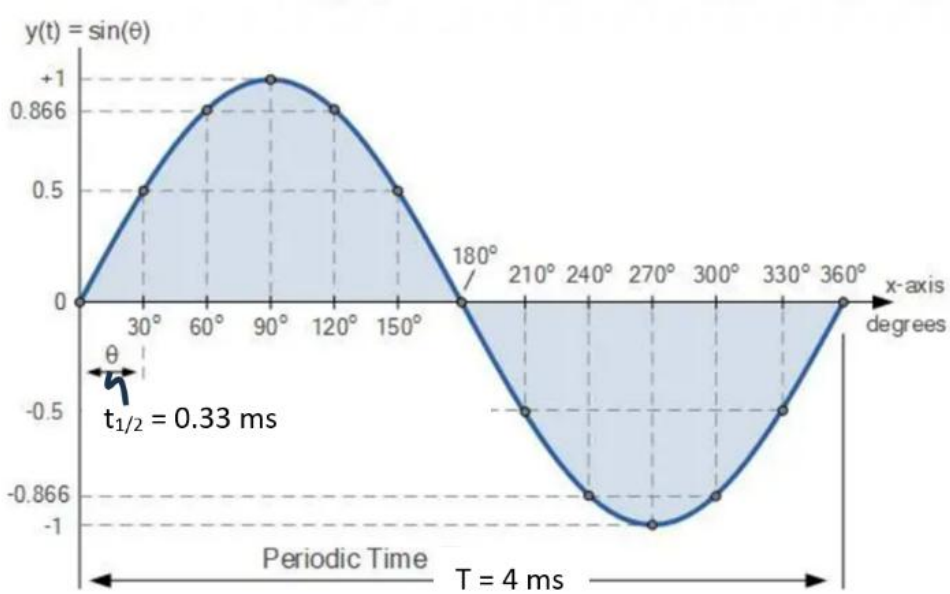
Dr. Tass has specified for his Stanford Glove. However, the popular ERM type DIY buzzers typically vibrate in the range of 150 Hz to 160 Hz. While this frequency is within the optimal range for FA II units, and is out of optimal range for FA I units, it is not as far from the FA I frequency range as with other types of buzzers. The 250 Hz frequency is also preferred because higher frequencies tend to attenuate quickly from the point of contact, therefore minimizing the number of extraneous nerves that are stimulated.

Rise Time *(Tass Spec)*

As we see in the diagram from a Vybronics data sheet, "rise time" is defined by manufacturers to be the time it takes a buzzer to achieve half of its maximum vibrational amplitude. (See https://www.vybronics.com/wp-content/uploads/datasheet-files/Vybronics-VLV101040A-datasheet.pdf). Dr. Tass's buzzer specifications require a rise time of 2 ms or less at a buzzer frequency of 250 Hz.

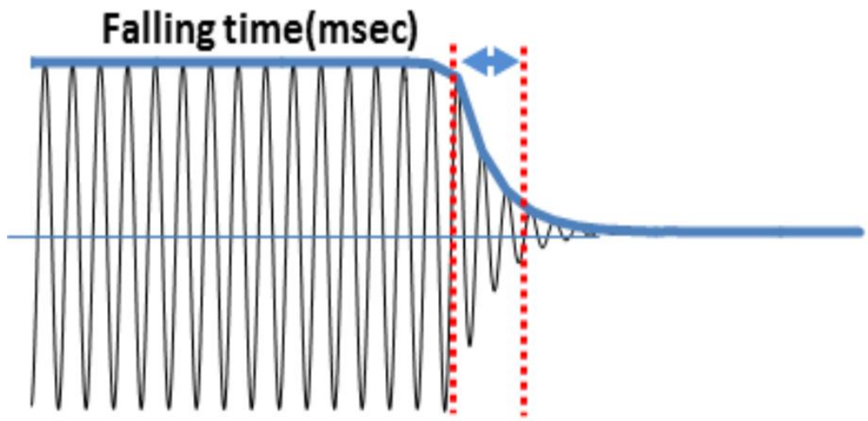


It should be noted that, even a perfect sinusoidal driving signal has a non-zero rise time. As we see in the diagram here, the amplitude of a perfect sine wave reaches half-peak amplitude at $\Theta = 30^o$, which is 1/12th of the wave period. Since the period of a 250 Hz sine wave is 4 ms, we find that the rise time of this perfect sine wave is 1/12 x 4 ms = 0.33 ms. So, even a perfect sinusoidal vibration takes 0.33 ms for its signal to rise to one half peak amplitude. We may infer that a square wave driving signal might generate a faster vibratory rise time because of the vertical leading edge with theoretically zero rise time.



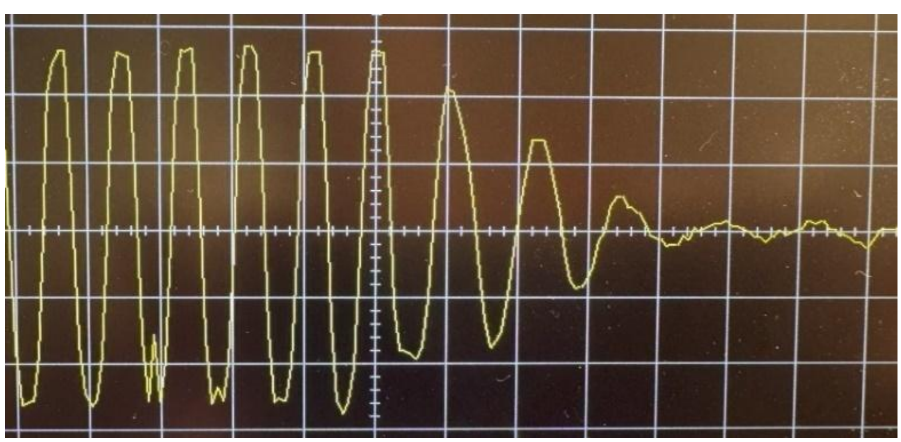
Fall Time

Ideally, when a buzzer is turned off, the vibration would stop instantaneously. However, real haptic actuators have a natural frequency at which they resonate (or ring) for some time after power is cut. As we see in the diagram from the the same Vybronics data sheet referenced above, “fall time” is defined by manufacturers as the time required for the “pulse envelope” of the decaying oscillation (shown in blue) to fall to 10% of the peak vibratory amplitude.

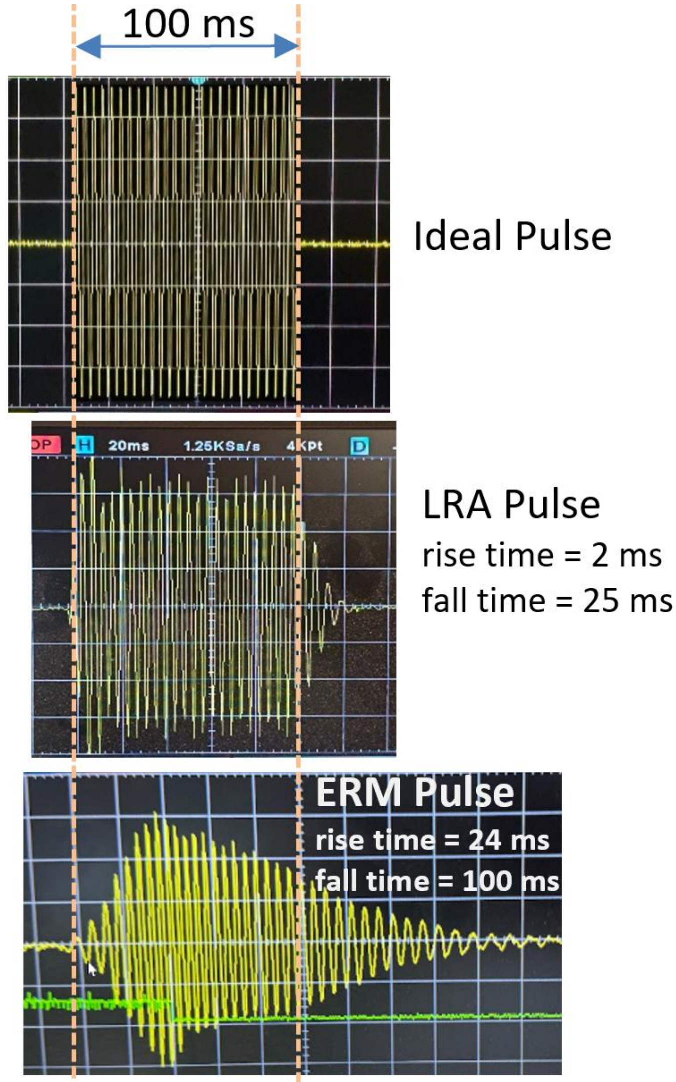


The fact that Dr. Tass does not provide a vCR specification for fall time indicates to us that fall time in vCR therapy is not so nearly as important as rise time. In other words, in order to achieve the desired neuronal reset in vCR, the timing of when the stimulation begins is much more important than when it ends. That said, since the Tass vCR patterns require specific 67 ms OFF stimulation rest periods, we must expect degraded results when buzzer fall times significantly cut into the rest periods. Long fall times are even more problematic in when using the Noisy vCR pattern since jittered rest times may be as short as 47 ms. We might then speculate a maximum ideal fall time could be in the range of 6 ms to 8 ms. In one ERM-type buzzer we bench tested, fall time well exceeded rest time, resulting in overlapping pulses that eliminated the rest periods required by vCR. Some DIYers have sought to compensate for the long buzzer fall times in ERMs by decreasing ON time and increasing OFF time as demonstrated later this document's bench testing section.

Since the natural frequency of LRAs is typically below the 250 Hz driving frequency for vibrating gloves, the ringing we observe after power cut off tends to decrease towards the natural resonant frequency. We clearly see this tendency toward resonant frequency after power cutoff in the LRA vibratory response shown here. When the buzzer is on, it vibrates at 250 Hz. But after only 4 ringing cycles after cutoff, the ringing frequency as dropped to 170 Hz, evidenced by the vibratory peaks getting further apart as the amplitude decreases.



Buzz Pulse Shape



The Device Specs Paper provides us with ideal buzzer pulse shape specifications for each 100 ms pulse, consisting of a perfect 250 Hz sinusoidal pulse that starts and ends sharply, creating a **square shaped pulse envelope** as illustrated in the top image at right. The 250 Hz buzzing frequency was chosen by Dr. Tass in order to excite the desired type of nerve ending in the fingertip without also exciting types of nerves that respond to lower frequencies. It is important to excite only one type of nerve ending since the different types have different propagation times to the brain. In order for vCR to effectively desynchronize pathological neurons firing, the buzz pulses must reach the brain at precise intervals. The 250 Hz frequency is also preferred because higher frequencies tend to attenuate quickly from the point of contact, therefore minimizing the number of extraneous nerves that are stimulated.

Each vCR vibrational 100 ms burst should ideally consist of 25 oscillations. Rise time is usually defined by buzzer manufacturers as the time required to achieve half peak vibrational amplitude. Ideally, we would like to see a very short rise time that creates a sharp onset to the pulse. Since no oscillator in the real world can start or stop oscillating instantaneously, in the supplementary materials to his Patterns Paper , Dr. Tass allows for a 2 ms rise time which can theoretically be tolerated while still meeting the rigorous demands of vCR neurological stimulation.

Since Dr. Tass does not provide us with an actuator tolerance for fall time, we might infer that fall time may not be as important as rise time. Yet, in order for the brain to differentiate between two successive pulses, the fall time must clearly be much less than the 67 ms time between finger pulses. Otherwise, each pulse would bleed into the successive pulse and the brain would not register any relaxation time as we see in the ERM pulse at right. Note that we triggered the ERM in the bottom image with an 80 ms control pulse to prevent excessive pulse overlap due its long fall time. When this ERM received a nominal 100 ms control pulse, it vibrated even longer after shut off. We compare rise and fall times of LRAs and ERMs subjected to two successive pulses in our bench test section to illustrate the issues that arise when fall time is longer than the rest time between pulses.

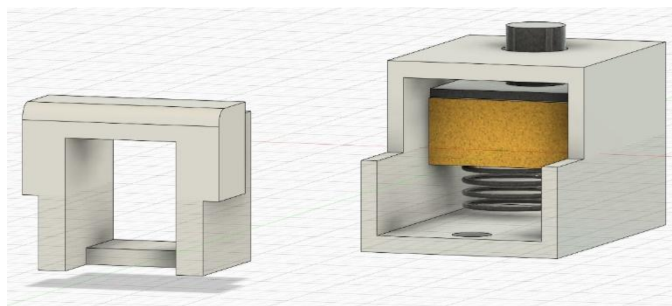
While LRAs clearly have much better vCR characteristics than ERMs, it should be noted that neither is perfect. And, more importantly, many PWP report they have obtained good therapeutic results similar to those observed by Dr. Tass in spite of the limitations of ERMs and LRAs. Our principal author has used both types of systems and has derived similar benefits from each. See the appendix for a much more detailed bench test analysis of several LRAs and ERMs.

Point-like Sensation *(Tass Spec)*

The supplementary materials provided in the Patterns Paper require precise characteristics for the region of contact between the finger and buzzer. Dr. Tass explains that the ideal contract region provides a "***strong, point-like sensation that is easily felt and localized***". The skin contact area is deliberately designed to be very small in order to minimize the overlap between stimulated areas in the brain. As we see in the images, this is accomplished through the use of a "tactor housing" which ideally remains at rest as the buzzer inside pushes perpendicularly up against the fingertip skin.

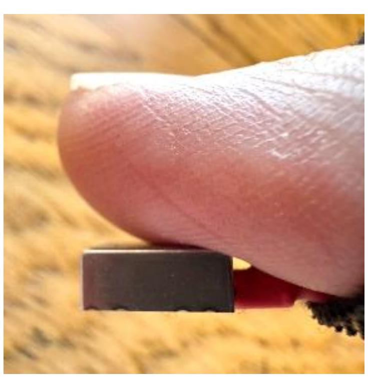
Tactor images of 2021 Stanford Glove from Dr. Tass's Patterns Paper:

Tactor images from the Buzzah Neck Build DIY Design reviewed later in this document:



Unfortunately, tactor housings are clumsy to have strapped on one's fingertips for four hours a day and one needs access to a 3-D printer to fabricate them. Many DIYers instead choose to forgo tactors and simply fix the buzzers under the fingertips inside the glove. This is a significant departure from the Tass guidelines for the fingertip contact region. Below we see images of a VLV101040A LRA buzzer being held against a fingertip to illustrate the region of contact without a tactor housing. While the contact area is not the entire 10mm x 10mm face of the VLV101040A, it is still a much larger area than we see in the Stanford Glove shown above. And, without a stationary housing to shield vibrations, the entire area of the finger is free to vibrate, allowing vibrations to travel away from the contact area and possibly result in overlapping stimulation areas in the brain. In spite of these disadvantages, many users still enjoy good therapeutic results without employing tactor housings. In a study described here, https://pubmed.ncbi.nlm.nih.gov/24908088/ , Parkinsonian mice were effectively treated with vibrations similar to vCR administered to the entire foot area using a vibrating plate.

Using a buzzer without a tactor housing:

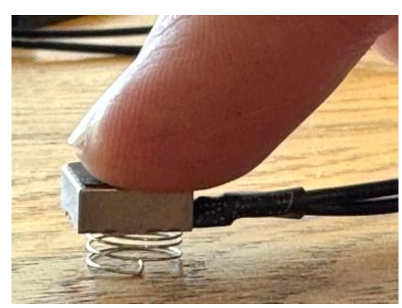


From our principal author about the benefits of tactors:

> *My first pair of vibrating PD gloves utilized buzzers without tactors as shown above. I thought that the LRAs were giving good vibrations to my fingertips and my therapeutic results were good. However, as a consequence of writing this document, I became more aware of the significant technical differences in therapy that might occur in vibrotactile therapy without tactors. I decided to invest in a 3D printer so I could design a tactor to try out. I was very predisposed against using tactors because I was very reluctant to give up the excellent dexterity I enjoyed without using tactors. I fully expected the difference in the feel of my tactorless stimulation to be "close enough" to the buzz feel I received when using tactors.*
>
> *The first thing I did when I built my first tactor glove for my left hand was to compare the buzz feeling to a tactorless glove on my right hand. From the first moment of my trial, it became immediately apparent that there were three factors that made my therapy much improved by the tactor. First, the point-like quality of the vibration as called for by the Tass specifications was much more focused, and clearly point-like, with the tactor. Without a tactor, I could tell my fingertip was diffusely vibrating, but I could not isolate the exact point where the buzzing originated. With a tactor, I clearly sensed the exact point where the vibration was coming from. Second, since the buzzer was backed by an elastic spring, no energy was lost to inelastic interactions with glove fabric, and the intensity of the buzz sensation with the tactor is noticeably stronger. Thirdly, and perhaps most importantly, as I performed activities with my hands during therapy, I noticed that my therapy was often interrupted as I touched objects with my tactorless hand. Without a tactor, the LRA would either get "grounded out" by touching the objects, or it would become displaced from its position on my fingertip. When I touched things with my tactor hand, the tactor case protected the LRA vibration from becoming grounded out. And, when the tactors were jostled by grabbing objects, the spring-loaded button travel would maintain buzzer contact, even if my finger was displaced slightly away from the top surface of the tactor. I estimate that, without a tactor, I was experiencing a loss of vibration to my fingertips for approximately 20% of my therapy time.*
>
> *For these reasons, I have been using tactors for my therapy nearly 100 % of the time. If I need to perform some task during therapy that requires greater dexterity, for example holding on to a dog leash during a neighborhood dog walk, I will either put on a tactorless glove on one hand, or just go with one tactor glove.*

As an interesting sidenote to the topic of tactors, we would mention that, on page 5 of his 2017 Device Specs Paper , Dr. Tass suggests vCR might alternatively be administered on the back side of the finger's middle phalanx as shown here with red dots. If buzzers were placed here, the fingertips would be open and normal activities could be accomplished without loss of dexterity. This is a tantalizing idea that is on my list to try out sometime soon. The best compromise between performance and comfort might be accomplished by having two detachable sets of gloves for use depending on the level of activity one anticipates. During the morning while walking the dog, or typing emails, one could use the glove set with vibrators on the back of the fingers as shown here. And, in the evening when one is sitting down to watch a movie, one could use the normal fingertip mounted tactors since activity is low.

Buzz Direction *(Tass Spec)*



The buzz direction specified by Dr. Tass is perpendicular to the fingertip, also termed the "Z-axis" direction. This direction is chosen to optimize stimulation of the fast-adapting type II (FA II) fingertip nerves, and to minimize collateral stimulation of nearby nerve endings. A perpendicular buzz direction is illustrated by the finger pushing downward on the LRA buzzer shown here that sits atop a spring. When we say "the LRA vibrates along the Z-axis", we mean that the buzzer alternately moves up-towards, and then down-away-from, the fingertip as the buzzer vibrates. As the Z-axis buzzer vibrates in the diagram, it alternatingly compresses and elongates the spring underneath. If the buzzer shown in the diagram was an "X/Y-axis" buzzer as we find in ERM-type buzzers, it would wobble from side to side as it vibrated, never compressing or elongating the spring underneath.

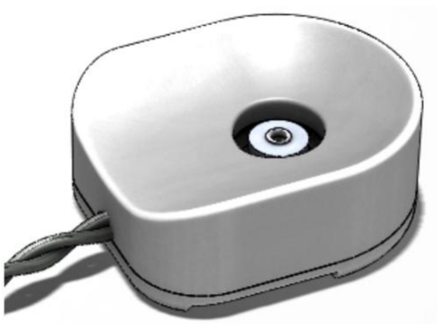
Finger Contact Area

The diameter of the contact area is not specified by Dr. Tass, however, the tactor manufacturer of the 2021 Stanford Glove indicates their 2021 tactors have a contact diameter of 5.1 mm. (See, https://images.hu-production.be/response/460df2ac-7e99-4988-ad8c-cfe50970ad2a.jpg .)

Regarding the shape of the contactor surface, Dr. Tass states in his 2017 Device Specs Paper ,

> *"... to enhance the FA I responses, instead of a flat, spatially homogeneous contactor surface, one could use a contactor surface with a spatially inhomogeneous indentation profile".*

Yet, in both of the tactor images he provides in his 2021 Patterns Paper, we see that there is apparently a deliberately raised indentation profile that would presumably favor the stimulation of FA I units that vCR seeks to avoid. Unfortunately, Dr. Tass does not provide us with an explanation of this apparent inconsistency. In any case, every DIY design we have seen uses flat contact areas of contact for fingertip stimulation.



Preload Skin Indentation *(Tass Spec)*

This tactor contact is specified in the Device Specs Paper to be "preloaded" against the skin causing an initial indentation of 0.50 mm. Since this indentation is much greater than the vibrational amplitude, the buzzer is always pushing up against the skin throughout every part of the vibratory cycle. And, since the housing is designed to remain at rest as the buzzer vibrates, any skin in contact with the housing is effectively held motionless and remains "shielded" from vibrations. This keeps the vibrations from spreading to larger areas of skin. The circular opening in the tactor housing allows a somewhat larger "unshielded" area of skin to vibrate in response to the buzzer oscillations.

Buzz Amplitude *(Tass Spec)*

The 2017 Device Specs Paper specifications call for a buzz peak-to-peak amplitude that can range from 0.03 mm to 0.10 mm (30 - 100 µm), depending on the patient. Unfortunately, there is no ready way we have seen for a DIYer to measure vibrational amplitudes in this very small range. The general guiding principle to vibrational amplitude is to try to keep the amplitude as low as possible to void stimulating a larger fingertip area and can thwart therapy by stimulating overlapping areas of brain stimulation as already discussed in the contact area question. Of course, the amplitude can also be too small to induce therapeutic effect. Most DIYers then simply utilize the nominal amplitude that is delivered by their buzzers and hope that this amplitude is close enough to their optimal setting to provide positive effects. Obviously, this is not an ideal set of circumstances, especially given that all types of DIY buzzers (except ERMs) allow for amplitude adjustment. And even ERM users can crudely adjust their vibrational amplitude by tightening or loosening the Velcro bands holding the buzzers to their fingertips. Dr. Tass has suggested approaches that might be used to calibrate vibrotactile parameters to individual patients in his Protocol Paper which we will explore in an upcoming HealthUnlocked posting.

Buzzer Type

The type of buzzer to be used is the most important choice a DIY glover user makes since each type has its own strengths and weaknesses. As we will see, there are basically four types of buzzers that can be used to implement the vibrational pulses in vCR. The table below summarizes vibrational characteristics for all four types of buzzers.

Buzzer Type Summary	Cost	size	Vibrational Direction	Frequency	Rise Time	Pulse Shape	Operating Voltage
Acoustic Exciter	$10 - $400	**Bulky**	z-axis	250 Hz (variable)	2ms	Square	Low
Piezoelectric Actuator	$20 -$400	Acceptable	z-axis	250 Hz (variable)	1ms	Square	**High**
ERM	$1 - $3	Acceptable	**xy-axis***	**160 Hz (fixed)***	**40ms**	Mound	Low
LRA used in Buzzah	$6	Acceptable	z-axis	250 Hz (variable)	2ms	Square	Low

** Indicates significantly out of spec for DIY*

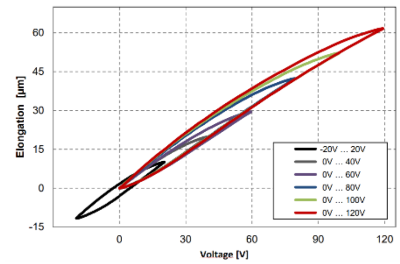
Acoustic Exciter Buzzers

The first type of buzzer we will consider is the Acoustic Exciter. It basically functions in the same way as a musical loudspeaker, where a coil of wire is placed within a strong magnetic field. When current goes through the coil, a force from the magnet moves the coil up and down like the diaphragm of a loudspeaker. This is the type of buzzer used by Dr. Tass in his original 2021 Stanford glove prototype because of its very quick responses to changes in current, having a rise time of less than 2 ms. (See supplementary materials to his Patterns Paper) .

One might think the best buzzer choice for DIYers would be to simply to use this same type of buzzer that Dr. Tass used. However, there are a few problems with this choice. The first problem is that the actual buzzer model he used in his design Engineering Acoustics costs around $3200 per set. The high expense of these buzzers makes them effectively out of reach for most DIY designers. The next problem is that the manufacturer, Engineering Acoustics, does not sell to individuals. So, even if a DIYer has an infinite budget, they cannot purchase these boutique buzzers at any price. There are cheaper audio exciter alternatives from various vendors, including the one shown here from Amazon for only $11, but they are all very bulky and heavy to have mounted to one's fingertips if the user hopes to accomplish household tasks while receiving therapy. And finally, the acoustic exciters require a relatively large input current of approximately 250 ma. This necessitates some kind of external multichannel power amplifier capable of delivering more than 1 Watt of power to each finger.

The only DIY design we have seen utilizing acoustic exciters is documented starting here https://healthunlocked.com/cure-parkinsons/posts/150536169/winnie-the-poos-glove-building-adventure . Hats off to this DIYer who solved all the design challenges with acoustic exciters to obtain a very high level of buzzer performance characteristics.

Piezoelectric Buzzers

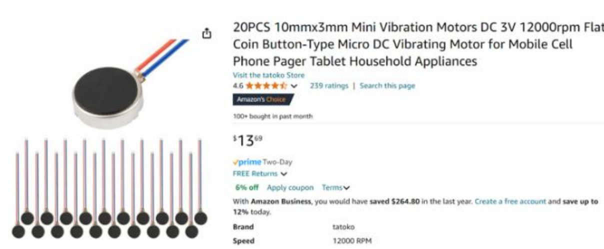


In this YouTube video https://www.youtube.com/watch?v=_gmdfrkW2oA at time 1:08:02, Dr. Tass alludes to a new inexpensive buzzer his team is using in their newest generation gloves. While Dr. Tass does not provide any specifics about the type of buzzer used, we suspect this newest Stanford glove prototype uses piezoelectric buzzers. Given that Dr. Tass also specifically suggests using piezoelectric buzzers in his Device Specs Paper, a logical choice for buzzers would seem to be the piezoelectric buzzer. The performance characteristics of piezoelectric buzzers surpass even that of acoustic exciters, and they are commercially available starting around \$20 each. They can also be very small and lightweight, ideal for fitting to a fingertip. They are even used in iPhones for haptic feedback.

To illustrate why DIYers are not using these buzzers that seem so perfect, let's take a look at this piezoelectric buzzer from Digikey, https://www.digikey.com/en/products/detail/epcos-tdk-electronics/B54102H1020A001/10257750 . We see that this buzzer vibrates at the required frequency of 250 Hz. The maximum displacement of 60 µm is a bit low given Dr. Tass's required displacement range of 60 to 100 µm in the Patterns Paper, but it is in the ballpark. Further, it is quite small and would easily fit on a fingertip, with the cymbal diameter being just 13 mm. But, this type of buzzer presents its own unique issue for the DIY designers. As we see in the displacement graph, this buzzer only attains its maximum displacement at a driving voltage of 120 volts. Typical microprocessor operating voltages employed in glove designs are usually in the range of 3 to 5 volts. Adding 8 additional chips like the Texas Instruments https://www.ti.com/product/DRV8662 would then be necessary to boost driver voltage if this piezoelectric buzzer was used in a DIY design. But, for me, adding the extra electronics is not nearly so problematic as the high voltages that are introduced with piezos. Most sources cite a voltage of 50 volts as being dangerous. In my experience with electronics, we generally start taking special precautions when dealing with any voltage greater than 30 volts. My guess is that, the output is probably not capable of supplying much current, so there is probably little danger to the user unless they have a pacemaker or DBS. That said, high voltage piezoelectric motors are fairly exotic and may require special electronics expertise not possessed my most DIY amateurs. This is probably why we were not able to find any DIY designs that make use of piezoelectric buzzers. If someone who is familiar with working with piezoelectric actuators were to design a glove system using piezos, their design could benefit from small size, relatively low price, and excellent performance characteristics. However, galvanic isolation is typically required at these higher voltages for safety considerations which adds to the cost, complexity, and prolonged safety certification requirements of piezoelectric-based devices. This would be especially true for medical devices. Therefore, piezoelectric actuators are not likely to become widely used in the DIY community.

We will finally note that, there are piezoelectric buzzers that work at lower voltages, but they tend to also vibrate at much higher frequencies and with much lower displacements and lower forces than we require. We read about piezo actuators that use multilayers to increase displacement at lower voltages, in the range of 40 volts, but we have not been able to find any for sale that meet the Tass design criteria.

Eccentric Rotating Mass (ERM) Buzzers

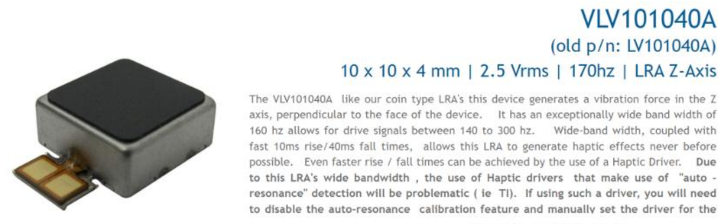


Most of the DIY vibrating glove designs currently found on the web utilize ERM buzzers like the one pictured here. Its design is based on a tiny electric motor that spins an eccentric mass, making the motor wobble. These motors typically cost around \$1-\$3 and provide high levels of vibration. They operate on DC voltage, making them easy to operate with a minimal level of control electronics. And they are fairly robust, putting out a lot of vibrations before they eventually fail.

However, ERMs have three inherent problems for vCR therapy that cause every glove utilizing this type of buzzer to suffer from significant performance issues. First, the frequency of vibration of ERMs is typically fixed at around 160 Hz. This is significantly lower than the 250 Hz frequency which is called for in Tass specs. Second, the direction of the vibration is in the horizontal X/Y plane of the fingertip. So, instead of pushing perpendicularly (in and out) on the fingertip as the Tass specifications stipulate, an ERM wobbles the fingertip in a sideways motion. The combination of the ERM's low fixed frequency and wobbling X/Y motion results in activating large numbers of collateral nerve endings on the skin, something that Tass guidelines stipulate against. And thirdly, ERMs take a lot of time to start spinning when turned on, and even more time to stop spinning when turned off. Dr. Tass calls for rise times to be no greater than 2 ms along with commensurate stopping times. ERMs have rise/stop times typically in the 40 to 70 ms range. As we will see in subsequent questions, this results in poor performance on both pulse pattern and shape. A detailed bench analysis of several ERMs is included as an appendix here.

Linear Resonant Actuator (LRA) Buzzers

The LRA buzzers in the Buzzah Neck Speaker Build come close to meeting all Tass specifications. LRAs work by moving a mass up and down, resulting in the perpendicular type z-axis motion called for in the Tass specifications. The frequency range is usually variable, with many types of LRAs capable of giving strong vibration at 250 Hz. While the rise/stop times are not as good as acoustic exciters and piezoelectric actuators, thanks to software tweaking in Kris Wilk's Buzzah design, they are decent and give acceptable looking pulse shapes as we see in the next question. The downside to LRAs is they need specialized AC electronics (such as a haptic driver chip) as found in the Buzzah design to operate. An excellent DIY tactor housing designed for the VLV101040A LRA can be found here: https://github.com/TactileDesign/DIY-Vibrating-Parkinsons-Glove/ .



Buildability

Buildability criteria relate to how difficult it is to assemble a DIY glove design. These criteria are of paramount importance for PWP who may have limited hand coordination, limited experience with electronics, or simply limited experience in building things. There is one DIY vibrating glove design we present in our designs section that comes ready-made, however, it also scores low on a number of the fundamental Tass specifications discussed in this section. All other DIY designs come with various levels of buildability issues. Our first criterion for buildability is **general build difficulty** which relates to the level of expertise and time required to complete the build. Another criterion is whether **online support** is likely to be available from the designer if a builder encounters questions during the building process. Builders can always seek general advice from other users through various online forums, but it is helpful if the original design creators are available for limited consultation. **User reviews** are helpful to potential builders in anticipating common building challenges of a particular design. The reviews also provide information on how well a particular design works once it is assembled. Quality **documentation**, in the form of pdfs, online instructions, or YouTube videos, is essential for builders of any design. Ideally the documented instructions are presented at a level that beginner builders with minimal expertise can follow. Building **cost** is a central concern of my potential builders. DIY building costs range from $200 to well over $600 depending on the design and tools that are required. The DIY builds with better vibrotactile performance are not necessarily the most expensive. For example, the Blue Buzzah has excellent performance yet it is among the least expensive builds due to its reliance on an electronics PCB that is purchased preassembled from a company in Hong Kong. While soldering is a skill that is easily mastered, many novice builders are concerned about the level of **soldering required** for a DIY build. All but one DIY build we know of requires some soldering, but different designs vary greatly in the amount of soldering required. While most designs require **3D printed parts**, there are many vendors on Itsy who provide economical 3D printing services online. And finally, some designs require **printed circuit boards** (PCBs) that are manufactured overseas. While prefabricated PCBs minimize cost and DIY building time, they also introduce the hassle and complexities of compiling complex online orders, along with additional delays with manufacturing and shipping. Additionally, there is always a concern with errors in online PCB orders since even the tiniest error can result in a PCB that is useless. That said, the PCB ordering process is commonly used by millions of people around the world for all kinds of electronics builds.

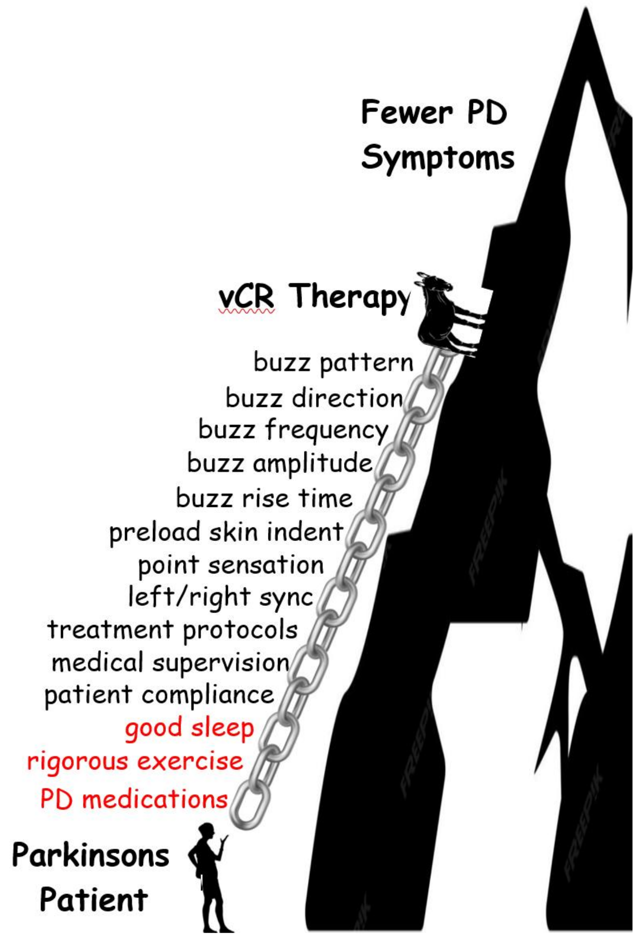
Features

Every DIY build has some number features that enhance the treatment experience. Some DIY users may prefer their **processor location** on the actual gloves. Other users don't like the extra weight and bulk added to their gloves and prefer their processor to be mounted in a fanny pack. The Buzzah Neck Build design we have put forth mounts the processor on a **Bluetooth speaker** that can be paired with the user's smartphone. Various designs deal with **cable routing** in different ways. Fanny pack designs have cables from the processor to the hands that hang down around user's knees. The Buzzah Neck Build minimizes cable issues by running cables from the neck-mounted processor to the hands. Some designs use Bluetooth synchronization to eliminate the need for cables but introduce new challenges to meet the Tass 1 ms synchronization specification as we discussed earlier. Other designs simply ignore the Tass synchronization requirement and eliminate cabling by mounting unsynchronized processors on both gloves, letting their glove operate independently of one another. Finally, Dr. Tass has suggested that it might be possible to administer one-sided stimulation therapy as is commonly done with traditional deep brain stimulation (See, the MDFA video at time 31:24). Some gloves designers then feature an option for **one-handed therapy** for users who want to have one hand free during treatment. It should be noted that Dr. Tass expects one-sided therapy to be less effective than synchronized two-handed therapy.

Useability

Useability relates to how well a patient may carry on the normal activities of daily life while receiving glove treatment. Various glove designs will score differently in the various useability criteria. There are no useability criteria explicitly provided in the Tass specifications, however, it is clear usability principles were taken into account in the design of the Stanford glove. A glove design with high level of usability will first have a high level of **portability**, allowing the patient to moving freely to attend to normal activities. While we find this criterion absolutely essential, many DIYers are content with designs that require the user to be sitting deskbound for the entire treatment time. Another usability criterion is finger **dexterity**, which relates to how well a patient is able to use their hands during treatment. All glove designs will impose compromised finger dexterity, however, designs with tactors are particularly restrictive. Gloves that are high in useability should also be high in **on/off easability**, so that gloves would be easy to quickly take off and put on for trips to the bathroom, tying shoelaces, and other immediate tasks that come up during therapy. And finally, gloves high in useability will also have minimal **wire tangle** to navigate when moving around. Obviously, Bluetooth designs avoid all wire tangle issues, but also introduce a new concern with left/right Bluetooth time synchronization accuracy as discussed previously.

Three Foundational Links to the Chain

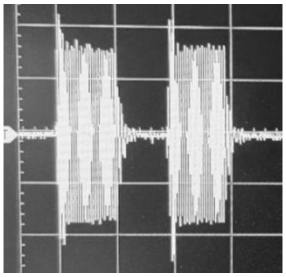


To end our discussion of PD glove criteria, we would like to revisit our original graphic to add three supplementary aspects of therapy that are often left unstated.

Improved sleep is usually considered one of the outcomes to vCR therapy. Paradoxically, **good sleep** is also considered a prerequisite to any therapy that relies on the bodies inherent power to heal itself, https://pmc.ncbi.nlm.nih.gov/articles/PMC1443671/ . DIYers might then consider ways to improve their sleep quality as a means to boost the efficacy of their DIY vCR therapy.

Ample PD research has demonstrated the power of **rigorous exercise** to ease PD symptoms and possibly alter PD progression, https://pmc.ncbi.nlm.nih.gov/articles/PMC4122088/. Kanwar Bhutani, Dr. Tass's patient from early trials who may be the most improved vCR PD patient, went further to put his rigorous exercise regime on par with his vCR therapy in this YouTube interview: https://www.youtube.com/watch?v=tIeLt9nPJrY when he stated at time 51:48, *"Don't expect this to be the end all solution. I don't want to get your hopes up and say, 'Well you wear the gloves and, all of a sudden, it's going to be miracles'. I had to do some life changes as well. I have to exercise regularly. Fifty percent of the battle is exercise! I bike about 20 miles on the weekends, and about eight miles a day. And I walk for about three miles a day, every day."*

While a lessened reliance on **PD medications** is a common outcome reported by vCR patients, Dr. Tass does not recommend moving forward with vCR without the benefit of PD medications. See for example, https://www.youtube.com/watch?v=uDxJkMrYjI0 at time 35:00, where he talks about the positive "*collaborative effort between medication and glove*" to improve patient well-being. Therefore, doctor prescribed PD medications may play an important role in effective vCR therapy. Dr. Tass likewise notes in the above clip that his PD gloves may enhance the efficacy of some PD medications. *(Note that, as we have stated in our disclaimers, DIYers should always consult their doctors before instigating any alternate therapy for their PD, especially when considering any kind of change in medications).*



Part 2: Bench Testing Buzzer Performance

How were vibratory responses captured?

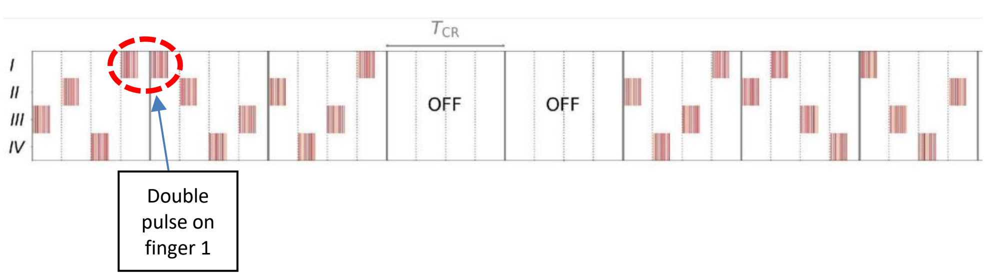
To test the vibrational characteristics of a buzzer, we held it firmly against an audio microphone which was connected to my oscilloscope through a preamp buffer as shown. The settings on the preamp were identical for each test. Testing was limited by the fact that the only buzzer that was tested within a tactor housing was the square shaped VLV101040A. That said, while the localized feel and perceived vibratory amplitude of this buzzer was enhanced by the tactor, the rise and fall times remained essentially identical.

When do double pulses occur in a vCR sequence?

A series of buzzer pulses for fingers I-IV on a single hand is depicted in the figure below from Dr. Tass's paper. Each 100 ms pulse is separated from the next pulse by a 67 ms rest period. A double pulse (circled) happens occasionally on a single buzzer when the same finger is buzzed at the end of one 4-pulse sequence, and then again at the beginning of the next 4-pulse sequence.

Why were double pulses observed?

A double pulse is the most challenging situation for a buzzer to perform since the buzzer receives a new pulse immediately after receiving the prior pulse, leaving the buzzer minimal time to equilibrate between pulses. By observing double pulses, we may observe any glitches in performance that might arise in a single buzzer when its equilibration time is shortened. <u>We are also able to easily visualize whether there is a clear 67 ms rest period separating pulses as called for in the Tass buzz pattern criteria</u>. To capture a double pulse, we would monitor a single finger buzzer for several seconds during normal operation until a double pulse happened, at which time we would initiate a screen capture.



How do rise and fall times compare for LRAs vs ERMs?

Going to the Vybronics web site https://www.vybronics.com/products/coin-vibration-motors and sorting by rise time, we see that all of the buzzers with shortest rise times are all LRAs. We tested the three highest vibrational amplitude models of z-axis LRAs available from Digikey. The manufacturer specifications for the three LRA buzzers and two ERMs we tested are shown in the table below.

Manufacturer Buzzer Specifications Compared to Bench Observation

Buzzer Model	Size (mm)	Spec Rise Time (ms)	*Obs Rise Time (ms)*	Spec Fall Time (ms)	*Obs Fall Time (ms)*	Vibe Force (Grms)	Freq (Hz)	Envelope Shape
VG832022D LRA	8x3.25 disk	50	***20***	80	***120***	1.0	adjustable	Mound
VG1040003D LRA	10x4 disk	10	***4***	50	***20***	2.0	adjustable	Square
VLV101040A LRA	10x10x4 square	10	***2.2***	40	***26***	2.75	adjustable	Square
Typical ERM	10x3 disk	40-80	--	50-100	--	<1.0	160 fixed	Mound
Tatoko ERM	9.9x3 disk	No Spec	***24***	No Spec	***100***	≈2.0	160 fixed	Mound
Toothbrush ERM	7x25 Cyl	No Spec	***16***	No Spec	***50***	>5	160 fixed	Mound

Why are observed LRA rise and fall times so much better than manufacture specs?

We speculate that there are three reasons why observed LRA performance is so much better than manufacturer specs:

1. Manufacturers are overly conservative in their advertised specs so as to allow for possible worst-case variation in the manufacturing process.

2. When Vybronics tested their LRA performance, they were using driving signals with frequencies well below resonance, whereas we tested our LRAs well above resonance. We would clearly expect to see much faster rise times with higher driving signal frequencies.

3. The LRAs in our tests may also derived some benefit from the fact that our 2506L haptic driver chips output a PWM driving signal which may yield better starting specs than a analog sinusoidal driving signal.

What were our test conditions for the LRA bench tests

In the following pages, three different LRA models were tested according to the procedure described above. All LRAs were driven using Kris Wilk's Buzzah system with voltage set at 2.5 V, amplitude at 100%. The testing frequencies are provided with the results. While the details of the measurements are shown for the VLV101040A, the measurement techniques were identical for all buzzers.

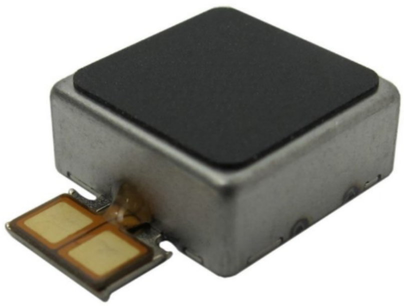
What were our test conditions for the ERM bench tests

All ERMs were driven using an Arduino Nano based processor and Darlington pair transistors to buffer the Arduino and to provide a more robust power source to drive the buzzer motors. Note that the driving voltage from the Darlington pairs was set at approximately 1 volt above the nominal voltage rating of the ERMs to get just a bit higher amplitude and frequency for my therapy. This higher driving voltage may have worsened the stuttering we observed on double pulses. Somewhat better performance may have been observed if the driving voltage had been set within manufacturer limits. Since the frequency of oscillation of ERMs is fixed, we sorted samples of ERMs based on frequency to find the highest frequencies in the batch. The DC driving pulses for the ERMs were set at 80 ms instead of the standard 100 ms in an effort to compensate for the long ERM fall times which effectively lengthen pulse duration. Rest time between pulses was correspondingly lengthened in settings from 67 ms to 87 ms.

VLV101040A

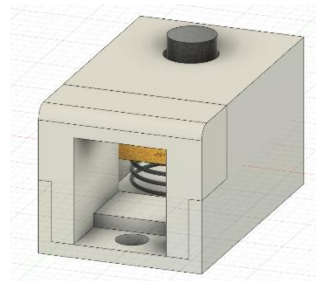
(old p/n: LV101040A)

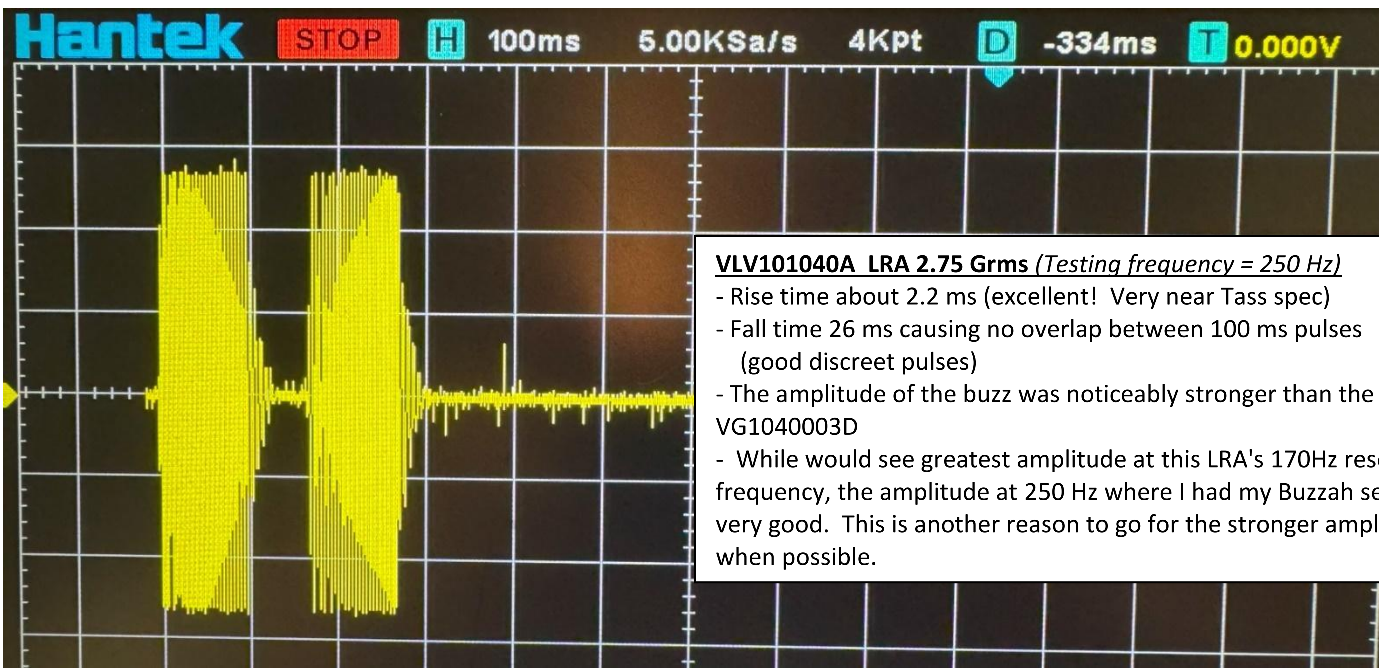
10 x 10 x 4 mm | 2.5 Vrms | 170hz | LRA Z-Axis



The VLV101040A like our coin type LRA's this device generates a vibration force in the Z axis, perpendicular to the face of the device. It has an exceptionally wide band width of 160 hz allows for drive signals between 140 to 300 hz. Wide-band width, coupled with fast 10ms rise/40ms fall times, allows this LRA to generate haptic effects never before possible. Even faster rise / fall times can be achieved by the use of a Haptic Driver. **Due to this LRA's wide bandwidth , the use of Haptic drivers that make use of "auto - resonance" detection will be problematic (ie TI). If using such a driver, you will need to disable the auto-resonance calibration feature and manually set the driver for the**

NOTE: This buzzer was tested inside a spring tactor as shown here:





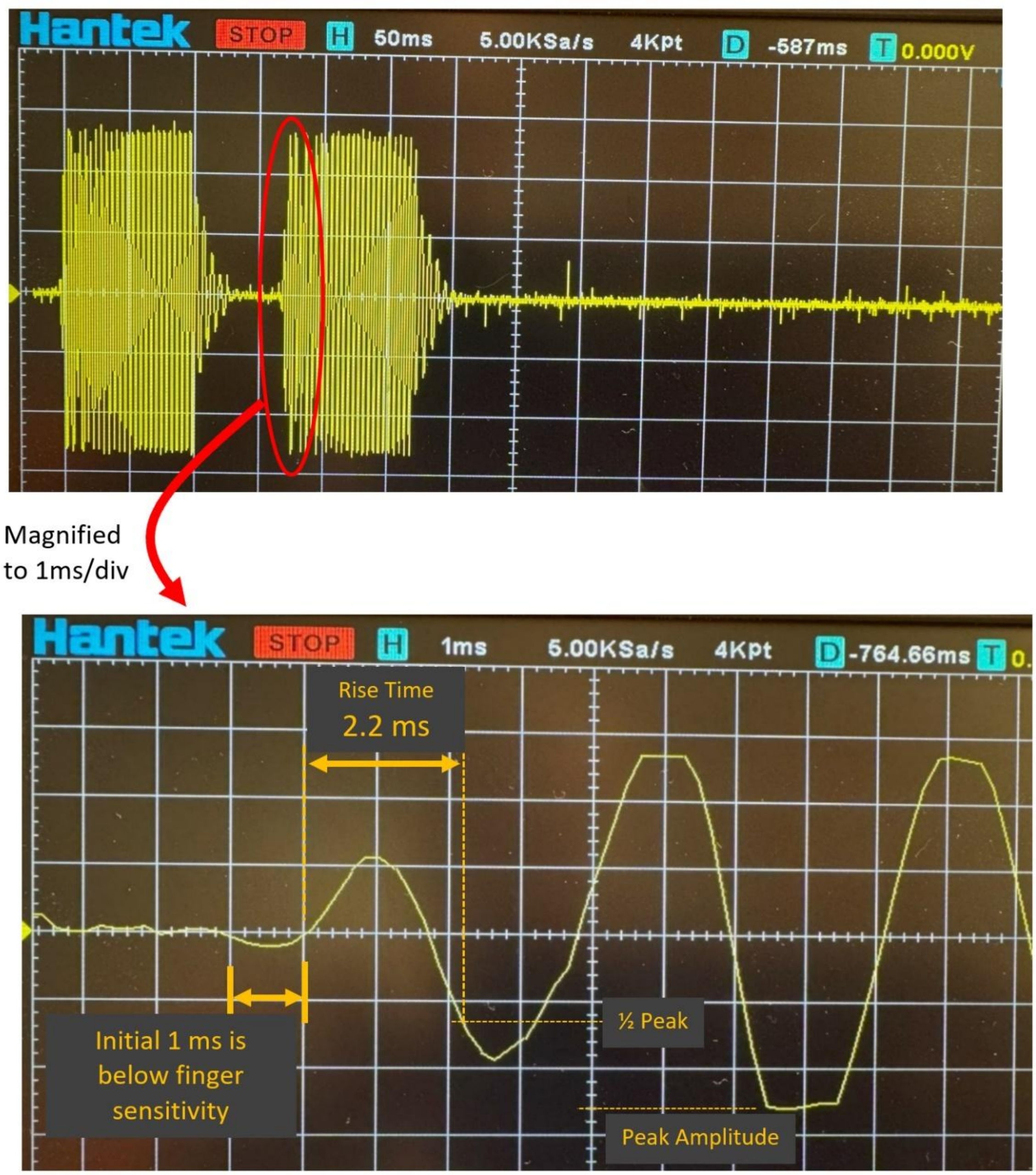
<u>**VLV101040A LRA 2.75 Grms** *(Testing frequency = 250 Hz)*</u>
- Rise time about 2.2 ms (excellent! Very near Tass spec)
- Fall time 26 ms causing no overlap between 100 ms pulses (good discreet pulses)
- The amplitude of the buzz was noticeably stronger than the VG1040003D
- While would see greatest amplitude at this LRA's 170Hz resonant frequency, the amplitude at 250 Hz where I had my Buzzah set is still very good. This is another reason to go for the stronger amplitude when possible.

Conclusion: If the goal is to most accurately reproduce Dr. Tass's vibratory pattern, the VLV101040A is the winner in our opinion and that is the model we used in our designs. It has the shortest rise/fall times and highest <u>maximum</u> vibration amplitude of all LRAs tested. Having the extra amplitude is great since we are driving the buzzer at a higher frequency than its resonance. You can easily adjust the level down using a setting in the software if you find that you are getting too much stimulation. If you use the VG0832022D and you want more amplitude, you will be out of luck. The VG1040003D is also very good and, if you wanted a small disk-shaped buzzer, that would be the one to go with…

Measuring Rise Time on the VLV101040A

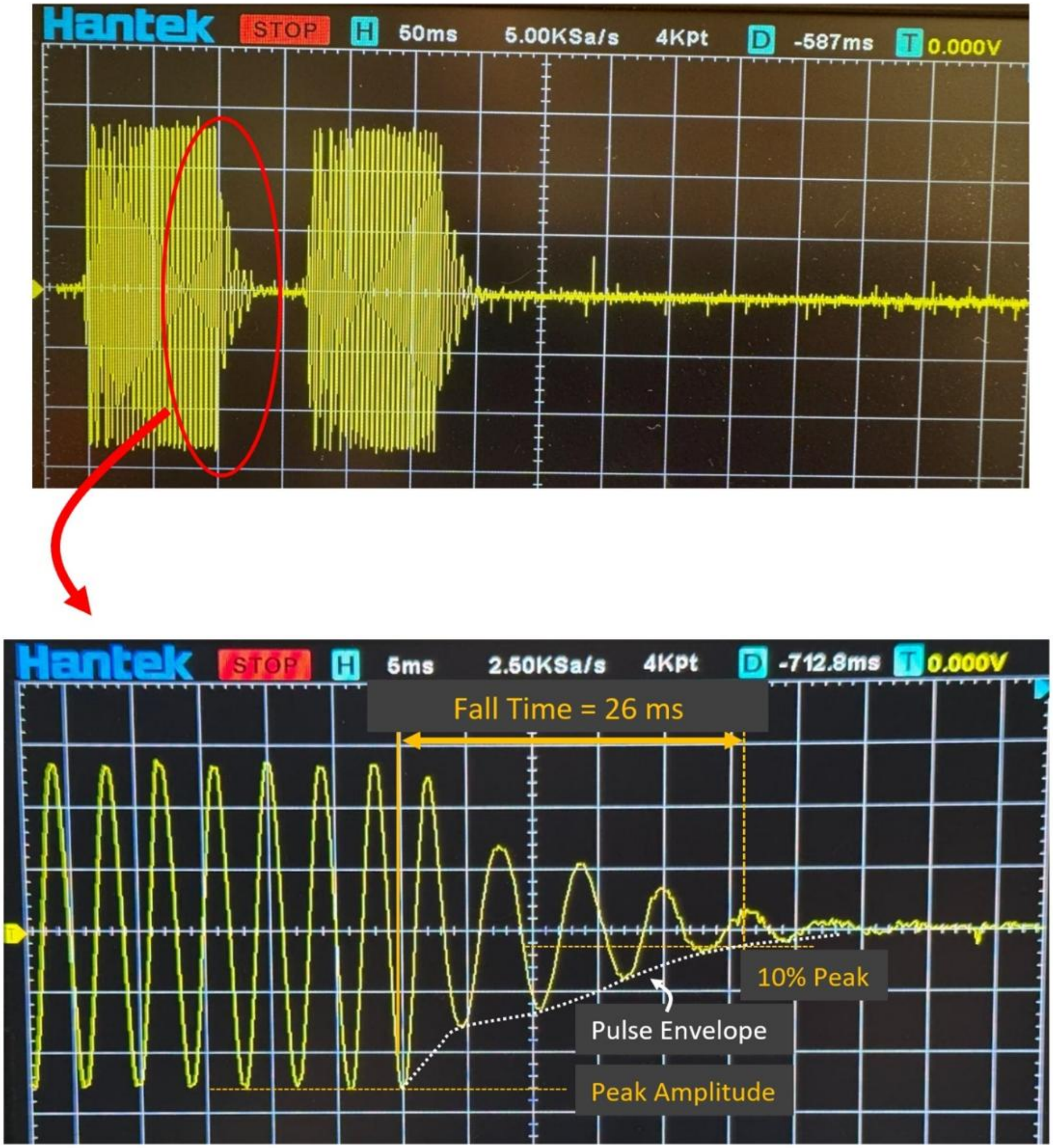
Below we see an expanded view of the startup behavior of the VLV101040A LRA. Each box in the magnified lower view represents 1 millisecond. The vertical amplitude divisions are arbitrary and depend on the gain of the microphone used to acquire the signal. We see that the amplitude of the resulting vibratory waveform is 2.6 divisions. The observed rise time of 2.2 ms is the time it takes the vibration to reach one half of its peak amplitude (1.3 divisions). We may ignore initial 1 ms of the LRA vibratory response that of the same order as the background noise, and is thus below the finger's threshold of sensation.

Interestingly, the observed 2.2 ms rise time for this LRA is significantly (4X) better than the manufacturers specification of 10 ms and was consistent across several LRAs we measured.



Measuring Fall Time on the VLV101040A

Below we see an expanded view of the cutoff behavior of the VLV101040A LRA. Each box in the magnified lower view represents 5 milliseconds. The peak amplitude of the resulting vibratory waveform is 2.6 divisions. The fall time of 26 ms is the time it takes the pulse envelope to fall to 10% of its peak amplitude (0.26 divisions).



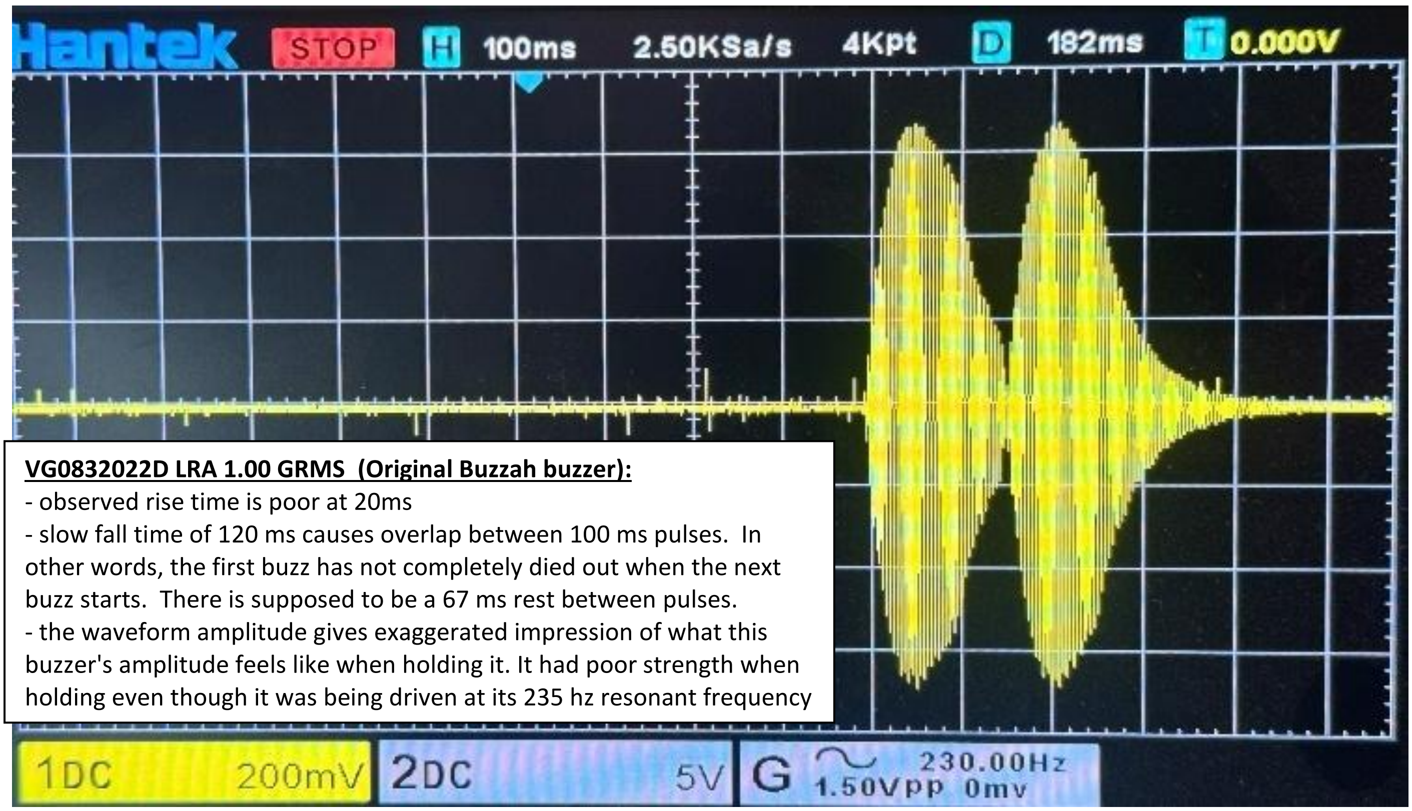
Model Number:

VG0832022D

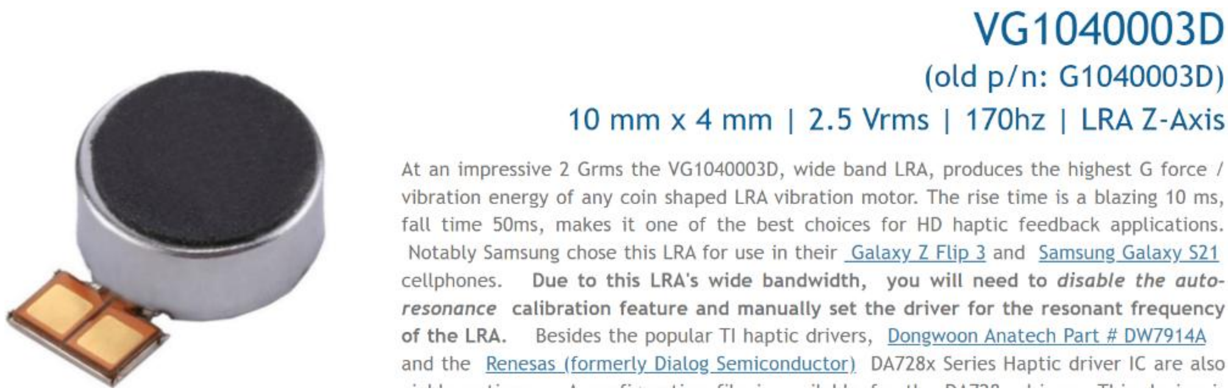
(old p/n: G0832022D)

8 mm x 3.2 mm | 1.8 Vrms | 235hz | LRA Z axis

The VG0832022D LRA coin vibration motor is identical to the VG0832013D, except that is longer 100 mm wire leads. It vibrates in the Z axis, which is perpendicular to the face of the vibration motor. As seen from the table below, it draws only 19 ma @ 0.6 V while producing a G force of 0.55, making it ideal for battery powered wearables. Rubber Poron foam pads, connectors and custom lead wire lengths are available. Custom FPC are also available for minimum orders of 10K pcs. Tooling fees apply



Conclusion: It would have been great to use this LRA because it is so small - offering the least bulk on one's fingertip and its 8 mm diameter coming closest to Dr. Tass's nominal 5 mm contact area. Unfortunately, the amplitude of this LRA was insufficient to make a significant therapeutic buzz I could feel on my fingertip. The buzz pattern is also less than ideal in that there is overlap of pulses due to long fall time.

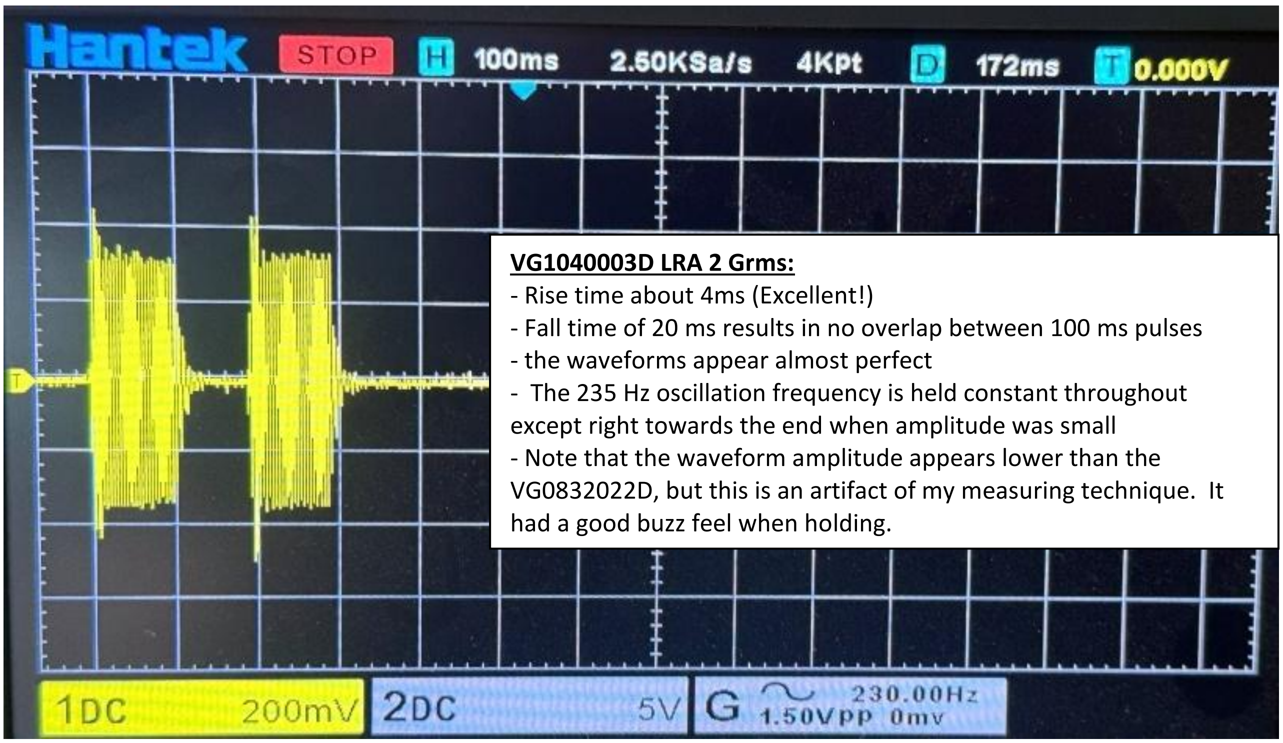


VG1040003D

(old p/n: G1040003D)

10 mm x 4 mm | 2.5 Vrms | 170hz | LRA Z-Axis

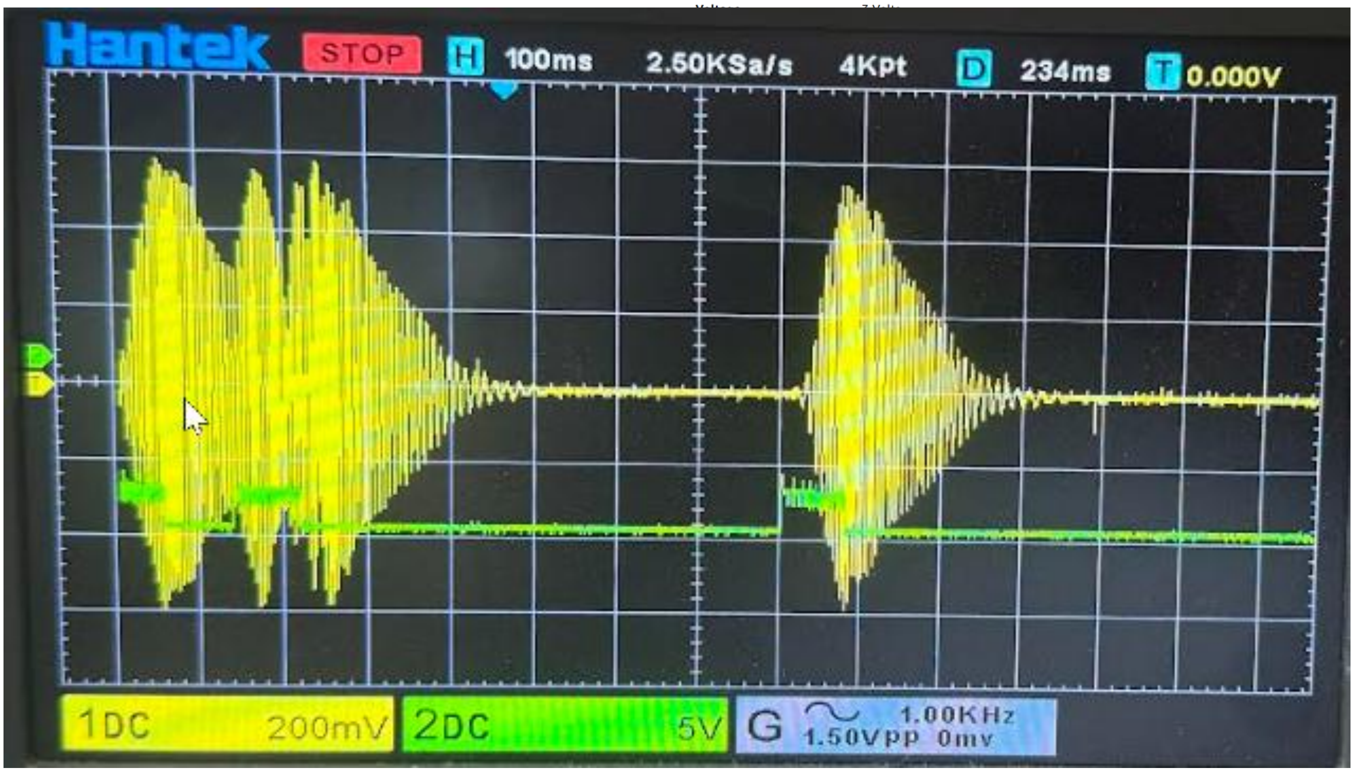
At an impressive 2 Grms the VG1040003D, wide band LRA, produces the highest G force / vibration energy of any coin shaped LRA vibration motor. The rise time is a blazing 10 ms, fall time 50ms, makes it one of the best choices for HD haptic feedback applications. Notably Samsung chose this LRA for use in their Galaxy Z Flip 3 and Samsung Galaxy S21 cellphones. **Due to this LRA's wide bandwidth, you will need to *disable the auto-resonance* calibration feature and manually set the driver for the resonant frequency of the LRA.** Besides the popular TI haptic drivers, Dongwoon Anatech Part # DW7914A and the Renesas (formerly Dialog Semiconductor) DA728x Series Haptic driver IC are also



Conclusion: This LRA has a nice crisp pattern and enough buzz. It would be acceptable to use. The scope waveform is smaller than the VG0832022D, but this is an artifact of my measuring technique. The feel of this 2.0 Grms buzzer felt significantly stronger than the 1.0 Grms VG0832022D.

Tatoko ERM

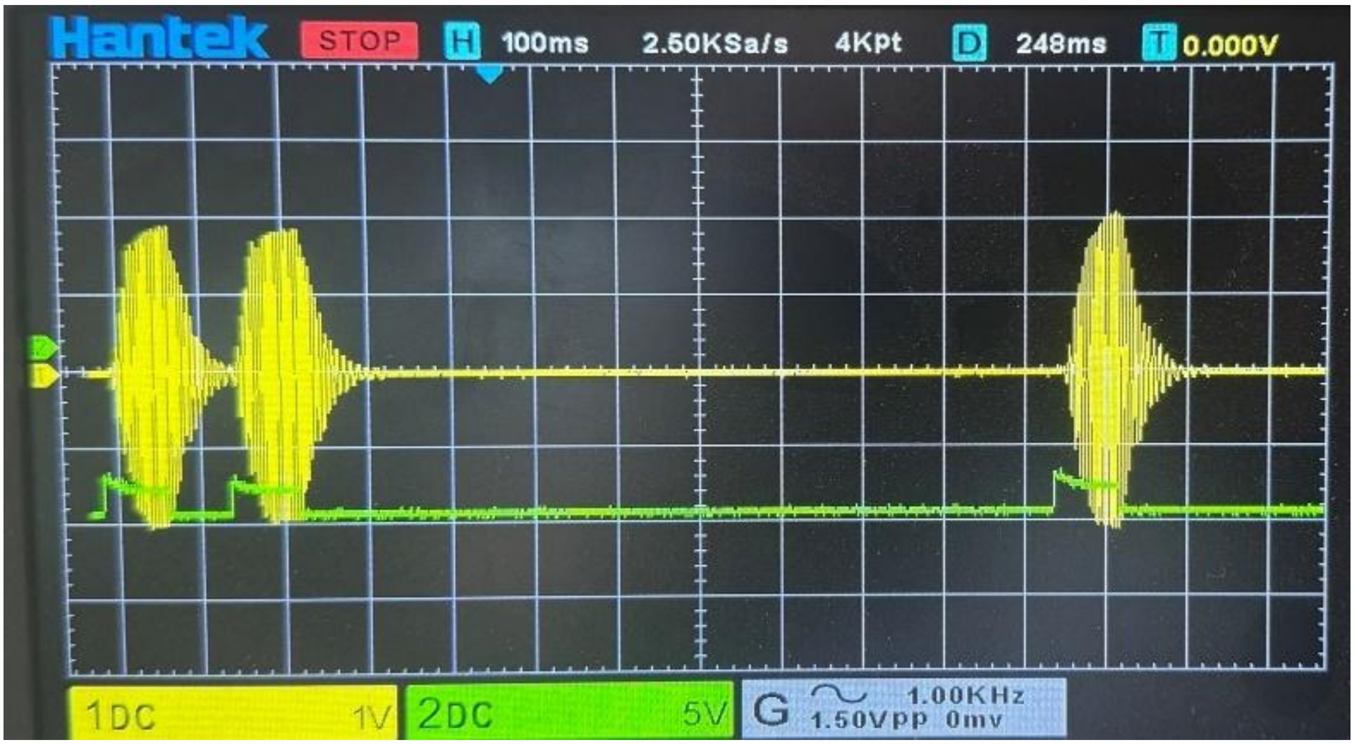
Below is a double pulse from a coin type ERM vibrator I used in my glove prototype II. Note that the big blob at the beginning of this capture is supposed to be <u>two</u> 100 ms pulses separated by 67 ms of rest. This coin type ERM is like a church bell, once vibrating and it takes a long time to stop. When I first observed this response, I thought my driver chip might be stuttering when producing two successive pulses, accidentally sending out three pulses instead of two. To check this, I hooked up my second scope input and looked simultaneously at the output of the driver to the buzzer *(green trace).* As you can see, there were only two pulses going into the buzzer:



<u>Tatoko ERM Mini Vibration Motors from Amazon (ERM) Amazon ASIN : B07Q1ZV4MJ</u>
- Rise time of 24 ms (Not good)
- Fall time about 100 ms causing significant overlap between 100 ms pulses. The two 100 ms pulses at the beginning of the capture effectively merge into one ugly 400 ms blob pulse.
- Double pulse caused glitching in start of second pulse
- Even though trigger pulse was only 80 ms, resulting pulse ended up being essentially 300 ms in length due to long fall time
- The amplitude is strong but the frequency is around 160 HZ, 36% lower that the recommended frequency of 250 Hz from Dr. Tass's

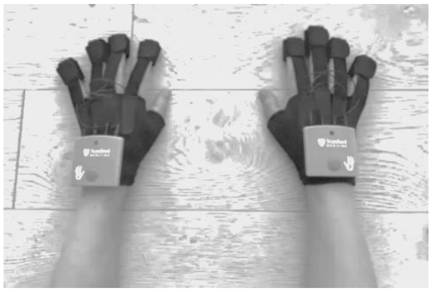
Toothbrush ERM

The large cylindrical toothbrush ERMs I used in my original Prototype I glove set gave much better vibrational characteristics as shown below, but their therapeutic value for me was near zero. I think this was because the buzz amplitude was too high.



<u>7x25mm Waterproof Micro Vibrating Toothbrush Motors (ERM)</u>
<u>Amazon ASIN: B0CY2KLH2P</u>

- Rise time is not great at 16 ms
- Fall time is unacceptable at around 50 ms resulting in slight overlap of successive pulses but with no glitching
- While the amplitude seems about the same as the others, note that the voltage scale is set a 1V/div. So, the amplitude of this ERM is enormous, almost 5 times the Tatoko. I think this was giving too much buzz for me which resulted in no therapeutic value.



Part 3: Comparing Online DIY Glove Designs

In this section, we compare five DIY glove builds from the web to the Stanford glove. Each glove is reviewed according to over 30 criteria. Topics include buzzer vibration performance, user convenience features, building requirements, and miscellaneous related issues.

<u>Keep in mind that the builds described here represent only a very small sampling of DIY designs that are available</u>. Unfortunately, there is no single place online you can go to explore all the various designs that are available. Perhaps, someday someone will compile a comprehensive list for us! You can find more designs by:

1. Search YouTube for any of the following:
   DIY Parkinsons Gloves
   Vibrating Gloves for Parkinsons
   Vibrotactile Gloves
   Vibrotactile
   Vibrotactile Parkinsons
   Vibration Parkinsons
   Gloves Parkinsons
   Tass Gloves
   The Stanford Glove

2. Search HealthUnlocked for any of the above

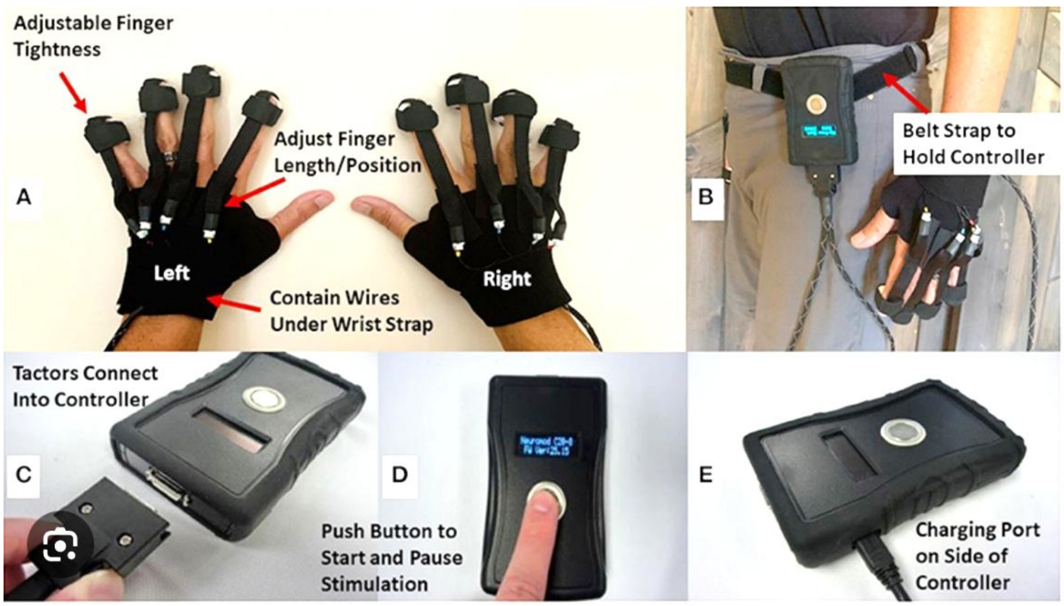
3. Search Github for any of the above

4. Search Google or Facebook for any of the above

The 2024 Stanford Glove

The Stanford Glove is not a DIY design. We are including Dr. Tass's official Stanford Glove in the list here for comparison purposes. Below, we see the 2021 version of the Stanford Glove compared to the most recent 2024 version of Dr. Tass's Stanford glove described here: https://www.youtube.com/watch?v=_gmdfrkW2oA&t=3738s at time 46:10. In the 2024 version, the central control box has been replaced with two small compartments on the back of the gloves. The gloves are synchronized wirelessly, eliminating the need for wires. The size of the tactors mounted on fingertips also appears to be reduced.

2021 Stanford Glove



2024 Stanford Glove

The 2024 Stanford Glove		
Web Link		https://med.stanford.edu/tass-lab.html
Buzzer Type	Piezoelectric probably	The 2021 Stanford Glove used acoustic exciters. We speculate that they switched to piezos in 2024 based on the smaller apparent size of the tactors and a previous statement about piezos made by Dr. Tass.
FDA Approved for Treatment of PD?	No, but...	Stanford group is waiting to apply until their upcoming placebo-controlled study is completed. However, the vibrating PD glove version from Synergic called the VT Touch has been granted breakthrough device designation from FDA, see https://synergicmed.com/storage/app/media/PDFs/SynergicNewsletter_2024_Jan.pdf
Expected Availability to Public	2028	
Tass Vibration Specs		
vCR Buzz Pattern	Yes	
Z-axis Buzz Direction	Yes	
Buzzer 2 ms Rise Time	Excellent	
Buzzer Fall Time	<6 ms? (unspecified)	Dr. Tass does not provide fall time specs, however, we may assume that the desired fall time must be small compared to the OFF time 67 ms rest period for vCR.
Tactor – Point like Vibration	Excellent	
5.1 mm Contact Area	Yes	
0.5 mm Preload Indentation Adjustment	Yes	
250 Hz Pulse Frequency	Yes	
Pulse Amplitude Adjustment	Yes	
Left/right Synchronization	< 1 ms delay	This is quite a challenge for wireless designs
Build Considerations		
Build Difficulty	N/A	Of course, this is not a design that is available to DIY builders. While specifications are well documented, the proprietary electronics and tactor designs have not been published.
Online Support Available	N/A	
User Reviews Available	Yes	Early patient outcomes are well documented by research neurologists and study participants. This system has also been formally reviewed by numerous neurological journals through the scientific peer review process.
Documentation	PubMed	Many papers from Dr. Tass regarding specifications and performance. Details of electronics are not published.
Approximate Cost	N/A	Currently unavailable to the public
Soldering Required	N/A	
3D Print Required	N/A	
Printed Circuit Board Required	N/A	
Features		
Processor Location	Hands	
Cable Routing	Wireless	
BT Speakerphone/Music Player	No	
Gloves Detachable from Processor	No	
One Hand Therapy Option	Yes?	We assume gloves can work independently
Useability		
Portability	High	Very small and sleek processor housing
Finger Dexterity	Low	Tactors limit dexterity
Glove On/Off Easability	High	
Aesthetics: Could it pass for regular glove?	No	Open fingers
Aesthetics: Does it have a professional look	Yes	The gloves look very nice! A team of several full-time engineers have been developing this model over the course of a decade.
Possible Issues	Availability	An optimistic estimate of availability for this glove is sometime in the year 2028. Unforeseen delays could push the delivery date even farther out.
Overall Impression		Without doubt, this is the gold standard by which all DIY glove designs are measured.

The Buzzah Neck Speaker Build (LRA)

This is the design our principal author uses and has provided building instructions in a separate document.

Advantages of this DIY Build

1. Buzzah uses LRA buzzers which allow for adjustment of frequency, amplitude and other characteristics of buzz. This is a big deal because this allows the user to adjust treatment individually depending on what settings get the most therapeutic effect.
2. Most connections do not require soldering.
3. Setup of the Buzzah microprocessor code is VERY easy and does not require special software.
4. Neck speaker positioning of electronics eliminates need for fanny pack and uses minimal wire lengths.
5. Bluetooth music speaker and speakerphone is handy to have available when needed and can be operated with thumbs.
6. Minimal in-glove tactor design allows for relatively comfortable use of fingers during treatment.
7. In-glove tactor design makes putting on and taking off very quick.
8. Gloves are detachable for transport or for swapping out different types of buzzer designs. This is handy if the user wants to implement one-handed therapy or swap in a single tactorless glove for greater dexterity when performing special tasks.

Areas for Possible Improvement

1. There are downsides of having the tactors inside the glove, including the fact that the design relies on an ideal glove fit that is hard to achieve without trying out many gloves for fit. The glove fingers have to be loose enough to have room for the tactor boxes, but not so tight that the button gets completely depressed, resulting in a preload displacement greater than 0.50 mm. To help gauge the proper preload button height, I made 3D-prints of tactors with various button heights to aid users in choosing the ideal glove size.
2. A user may get around the finger/tactor fit challenge by simply employing Velcro tighteners on the fingertips of oversized glove. However, when Velcro is added to the glove fingertips, the gloves become clumsier and more difficult to put on.
3. There is a rarely occurring glitch in the Buzzah electronics that happens occasionally where the software stops running the buzz pattern, and all buzzers turn on at once. This has happened during treatment for me three times in 6 months. When this happened, I simply turned the gloves off and back on, and everything was fine. This rare glitch might be eliminated by a simple adjustment to the Buzzah software by Kris to run the buss at a slightly slower speed, but all things considered, we don't view it as much of a problem.

The Buzzah Neck Speaker Build		
Web Link		https://github.com/TactileDesign/DIY-Vibrating-Parkinsons-Glove
Buzzer Type	LRA	
FDA Approved for Treatment of PD?	No	No DIY glove is FDA approved for treating PD
Expected Availability	Now	
Tass Vibration Specs		
vCR Buzz Pattern	Yes	
Z-axis Buzz Direction	Yes	
Buzzer 2 ms Rise Time	Excellent	Measured rise time is 2.2 ms
Buzzer Fall Time	Acceptable	As described in the Bench Testing section, there is a 25 ms fall time to the LRA I use that makes the buzz pulse to have a small tail. Plans are underway to shorten fall time using phase cancellation in the code
Tactor – Point like Vibration	Excellent	Relies on glove finger tightness to hold tactors in place. Adjustment is occasionally needed during treatment.
5.1 mm Contact Area	Yes	5.1 mm button with 5.5 mm hole
0.5 mm Preload Indentation Adjustment	Yes	Adjustable by spring stiffness and glove finger tightness
250 Hz Pulse Frequency	Yes	
Pulse Amplitude Adjustment	Yes	
< 1ms left/right pulse timing lag	Yes	Not a problem for wired designs
Build Considerations		
Build Difficulty	Fairly Difficult	The gloves have a lot of steps because design adapts regular gloves
Online Support Available	Yes	Through Github site
User Reviews Available	Yes	This system is reviewed here in this document. There are also many users on Kris Wilk's Github site who have posted their experiences with various Buzzah designs
Documentation	Github	Supporting documentation about the Buzzah brain is also found on Kris Wilk's Buzzah GitHub site.
Approximate Cost	$380	
Soldering Required	Minimal	
3D Print Required	Yes	For tactors and 3 platforms
Printed Circuit Board Required	No	
Features		
Processor Location	Neck Speaker	
Cable Routing	Hanging from neck speaker	Wires hanging from neck speaker are not intrusive. I wear a neck speaker even when not having treatment and I am never even aware it is on.
BT Speakerphone/Music Player	Yes	I take and make calls on the speakerphone almost every day
Gloves Detachable from Processor	Yes	
One Hand Therapy Option	Yes	
Useability		
Portability	High	This is a big feature for me that I could not get by without.
Finger Dexterity	Medium	Small tactors limit dexterity, but not as much as larger tactors mounted outside of glove.
Glove On/Off Easability	High	As good as it gets when using tactors
Aesthetics: Could it pass for regular glove?	Yes	I use my gloves every morning while walking my dog. I often encounter people on the trail and, I have only had one person take notice of my gloves. They noticed the buzzing sound while we were talking.
Aesthetics: Does it have a professional look	Maybe	From a distance, it just looks like I am wearing a neck speaker with regular gloves – especially when I run my cables through sleeves of jacket
Possible Issues	Glove Finger Fit	To take full useability advantage of having small tactors mounted inside the glove fingers, the user has to take care to use a glove that gives just the right tightness in the fingers without being too tight. If the glove fingers are too loose, the user will need to use Velcro tighteners on the glove fingertips.
Overall Impression		I have been using this system for a couple months and I am very pleased with the results. The build process is straightforward, but allow for at least 30 hours of build time to get a set put together.

The Blue Buzzah 2.0 (LRA)

A new wireless LRA design that will be available soon is the Blue Buzzah. It is based on the Buzzah electronics design from Kris Wilk. The developer currently has a working prototype he has been using for some months (v1.0). He expects to have his open source vers. 2.0 design with a smaller electronics box ready to post on GitHub sometime in February, 2025.

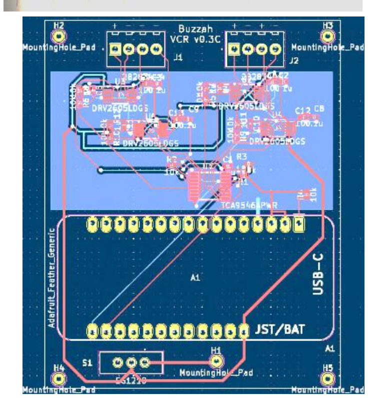
Since the Blue Buzzah and OEDK design teams shared design/software and other aspects during their parallel developments, the hardware architectures are very similar. However, the new Blue Buzzah code includes additional features leading to a number of important treatment enhancements for DIYers to consider.

Advantages of the Blue Buzzah:

1. The Blue Buzzah incorporates optional vCR pattern variations recently alluded to by Dr. Tass.
2. Several user-accessible settings are coming in the Blue Buzzah 2.0 (see below).
3. The developer of the Blue Buzzah is very active in making improvements, with plans to potentially make use of Apple watch/IPhone based biofeedback to calibrate patient-specific stimulation and possibly neurofeedback settings to individual users. **<u>This will be a huge step forward for the DIY PD glove world!</u>**
4. While the size of the Blue Buzzah 1.0 electronics box shown here is larger than that of the 2024 Stanford glove, version 2.0 will be roughly 35% smaller in footprint.

Features coming in the Feb 25 release of 2.0:

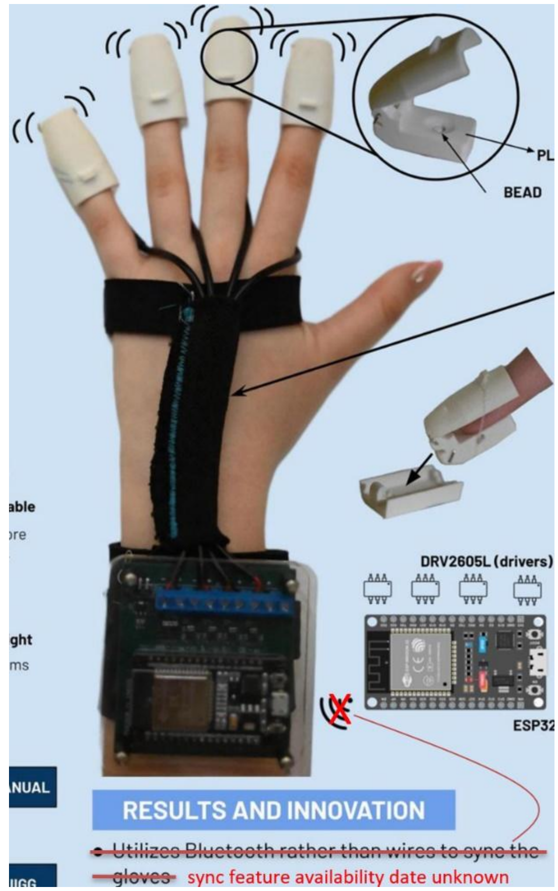
- Wireless design eliminates Ethernet cables often used to connect the electronics to each glove
- Version 1.0 uses fingertip-mounted tactors with open cell foam for decoupling vibration (Compatible with Buzzah Neck Speaker spring tactors)
- Can be operated with the two gloves synchronized or independently
- Simple architecture: A Bluetooth LE MCU + TI I2C mux + TI Haptic driver ICs
- Uses Adafruit's nRF52840 Feather Express module built on Nordic's very low power nRF52840 BT LE MCU
- Integrated Li-Po battery charging and monitoring
- Micro USB port for optional software updating / configuring and battery charging
- Comprehensive hardware and software support from Adafruit for the Feather module, in an industry standard footprint & pinout used by several module suppliers
- Uses low cost, 2-layer custom PCB manufactured by JLCPCB (same supplier as Rice's OEDK supplier) to minimize soldering
- Version 2.0 supports the same stimulation configurability as other Buzzah designs, plus:
  - Session datalogging
  - User-defined stimulation patterns
  - Double randomization: time (jitter) + amplitude (intensity)
  - Triple randomization: time (jitter) + amplitude (intensity) + frequency
- Identical to the other Buzzah and Rice OEDK designs which use LRAs to allow for adjustment of frequency, amplitude and other characteristics of stimulation. This is a big deal because this allows the user to adjust treatment individually depending on what settings achieve the most therapeutic benefits
- Setup of the Buzzah MCU code (in Circuit Python) is simple
- Foam decoupling used with v1.0 prototype features in-glove tactor design that allows for relatively comfortable use of fingers during treatment
- In-glove tactor design makes putting on and taking off easy
- Electronics and software can support use w/ other glove+tactor designs without major changes



V1.0 PCB

The Blue Buzzah		
Web Link		Posting date target Feb 2025 for version 2.0 which is smaller than v1 pictured above
Buzzer Type	LRA	Vybronics VLV10104A
FDA Approved for Treatment of PD?	No	No DIY glove is FDA approved for treating PD
Expected Availability	Feb 2025	
Tass Vibration Specs		
vCR Buzz Pattern	Yes	
Z-axis Buzz Direction	Yes	
Buzzer 2 ms Rise Time	Excellent	Same as for Buzzah Neck Build
Buzzer Fall Time	Acceptable	As described in the Bench Testing section, there is a 25 ms fall time to the LRA I use that makes the buzz pulse to have a small tail. Plans are underway to shorten fall time using phase cancellation in the code
Tactor – Point like Vibration	Excellent	When used with v2.0 spring-based glove/tactor design
5.1 mm Contact Area	Yes	
0.5 mm Preload Indentation Adjustment	Yes	V1.0 uses a foam cushion. Foam tactor holder means that contact area is not as well defined as called for in Tass. Open source v2.0 will take advantage of spring based tactors.
250 Hz Pulse Frequency	Yes	User-config. from 170 to 250 Hz. Has option to “frequency hop” to enable “triple randomization” option
Pulse Amplitude Adjustment	Yes	
< 1ms left/right pulse timing lag	Unknown	Will be characterized soon after release of 2.0
Build Considerations		
Build Difficulty	Easy	
Online Support Available	Yes	Support will be through GitHub user community as with original Buzzah
User Reviews Available	Not yet	Developer has experienced mild to moderate improvement in symptoms with v1.0
Documentation	Yes	When design is posted on GitHub
Approximate Cost	$200 approx.	For a glove set
Soldering Required	Nearly zero	No significant soldering: most of the electronics’ brain comes already assembled from China on 2-layer custom PCB
3D Print Required	Yes	For spring-based tactors and electronics case
Printed Circuit Board Required	Yes	The Github site will include all the files necessary to submit the order for the two PCBs that are required.
< 1ms left/right pulse timing lag	Very good	Version 1 already has Bluetooth synchronization implemented with typical timing lag of ~10 to 50 ms. New versions (v2.1) will have tighter synchronization
Features		
Processor Location	Back of glove	Future version will be miniaturized
Processor to Glove Cable	NA	Wireless
Cable Routing	wireless	No cables
BT Speakerphone/Music Player	no	
One Hand Therapy Option	Yes	Gloves can operate in synchronized and non-synchronized modes
Useability		
Portability	High	
Finger Dexterity	Medium	Small tactors limit dexterity, but not as much as larger tactors mounted outside of glove.
Glove On/Off Easability	High	
Aesthetics: Could it pass for regular glove?	Moderate	Only wrist electronics box is exposed, but next revision will reduce box size significantly
Aesthetics: Does it have a professional look	Yes	Next revision with smaller box will improve aesthetics
Possible Issues	China board	Design depends on trade with China not becoming disrupted
Overall Impression		The current revision provides a complete, low power, wireless platform; When paired with the latest spring-based tactor assembly and glove from the Buzzah Neck Speaker design with its compelling stimulation fidelity, Blue Buzzah will become a go-to solution for VCR therapy DIYers

The Rice University OEDK Glove (LRA)



Definitely worthy of mention is the preliminary OEDK glove design that is currently posted on their GitHub site. When the code is updated, this will become the second DIY PD glove available with wireless synchronization. However, <u>the current code departs significantly from the Tass specifications in that it does not have right-left hand synchronization implemented at the time of this writing</u>.

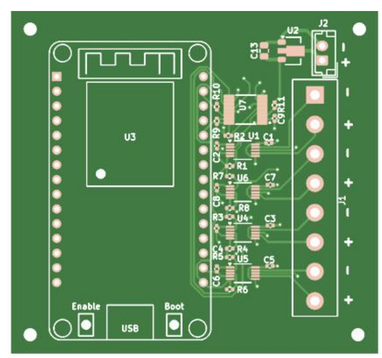
While this design looks very different than the Blue Buzzah, the design teams shared design/software and other aspects during their parallel developments, and thus the hardware architectures are very similar.
Here is a list of similarities and differences:

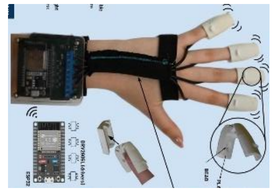
Similarities with the Blue Buzzah

1. Both use the same LRA buzzer model
2. Both use the same DRV2605L driver chips that get better performance out of the LRA buzzers. Very nice!
3. The OEDK and Blue Buzzah both are very easy to build because most components of the glove mounted processors are assembled on a multi-layer PCB board in China at JLCPCB as per a complex online ordering process.
4. Since both designs use surface mount ICs, they are relatively inexpensive to build.

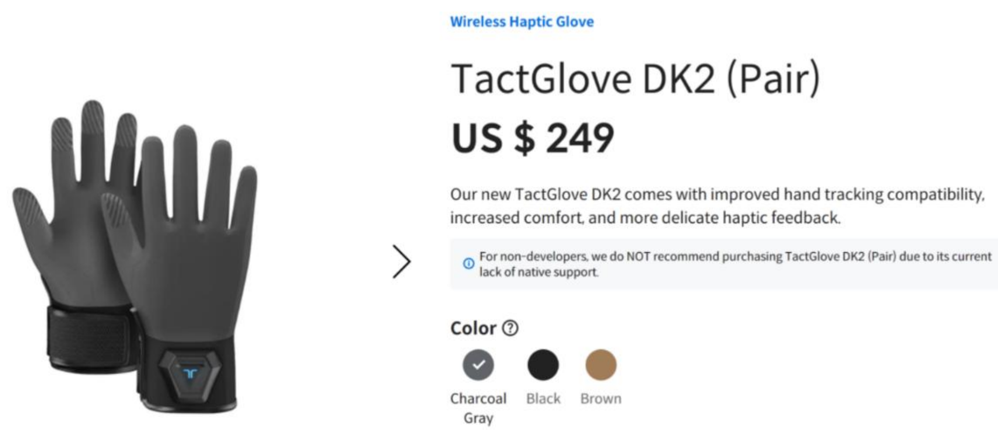
Differences with the Blue Buzzah

1. The biggest difference is that the Blue Buzzah has left/right glove synchronization implemented, whereas the OEDK design has yet to post publicly their synchronization scheme and software.
2. There is a cadre of builders online at Kris Wilk's Github site who have actually assembled Buzzahs and are currently using them. I have helped two other PWP assemble their own Buzzah Neck Speaker Builds, so I know the Buzzah design works. In contrast, I searched Google, Github, YouTube, Facebook, and HealthUnlocked, and I could not find anyone talking about this design despite the fact it has been up on Github for 7 months.
3. The OEDK tactor design uses foam to decouple buzzer vibrations from the tactor housing. In contrast, the Blue Buzzah uses springs. Using foam instead of springs makes the tactors easier to build and saves about $15 in parts cost. However, foam does not work as well as springs, resulting in less buzz amplitude. That said, since both designs use the same LRA model, <u>one could easily adapt the Buzzah gloves described in this document to work wirelessly using the OEDK forearm mounted processors</u>.
4. The OEDK tactor/glove design appears much easier to build than the tactor/glove design in the Buzzah.
5. The finger contact area of the OEDK tactors is significantly smaller than the 5.1 mm called for in the Tass specifications. We tested small contact areas similar to this in developing the Buzzah tactor and found that the vibration sensation becomes less distinct when the diameter is less than around 4 mm.



The Rice University OEDK Glove		
Web Link		https://oedk.wildapricot.org/Treatment-Glove https://github.com/RiceU-VibrotactileGlove/Manual
Buzzer Type	LRA	
FDA Approved for Treatment of PD?	No	No DIY glove is FDA approved for treating PD
Expected Availability	Now	
Tass Vibration Specs		
vCR Buzz Pattern	Yes	
Z-axis Buzz Direction	Yes	
Buzzer 2 ms Rise Time	Excellent	Should be same as for Buzzah
Buzzer Fall Time	Acceptable	Should be same as for Buzzah
Tactor – Point like Vibration	Good	Since foam is used instead of springs and finger contact area is small, I would expect that amplitude of vibration suffers.
5.1 mm Contact Area	Too small	The contact area appears significantly smaller than the 5.1 mm Tass spec. I tested small contact areas similar to this in developing the Buzzah tactor and found that the vibration sensation becomes less distinct when the diameter is less than around 4mm.
0.5 mm Preload Indentation Adjustment	No	
250 Hz Pulse Frequency	Yes	
Pulse Amplitude Adjustment	Yes	I assume this is available in the software settings
< 1ms left/right pulse timing lag	**No Sync**	**Left/right hands are not synchronized in current version of their code**
Build Considerations		
Build Difficulty	Easy	Building ease doesn't get any better than this! Almost no soldering and most of the brain comes already assembled from China.
Online Support Available	Yes	Through email link provided on website. I contacted them with questions and received a detailed and cheerful reply in less than 24 hours.
User Reviews Available	None Found	The OEDK design appears to be a fantastic student project that has not yet been tested by any PWP. If there were just a few reviews from people who had successfully built and used this system, I would feel much more comfortable giving this design a try.
Documentation	Website and Github	
Approximate Cost	$200	
Soldering Required	Almost none	
3D Print Required	Yes	For tactors and possibly the forearm boxes
Printed Circuit Board Required	Yes	The Github site includes all the files necessary to submit the order for the two PCBs that are required. The complex ordering process is well documented on the ODEK website.
Features		
Processor Location	Forearms	
Cable Routing	No Sync	**NOTE: Wireless synchronization is not implemented in current version**
BT Speakerphone/Music Player	No	
Gloves Detachable from Processor	No	
One Hand Therapy Option	Yes	I assume one glove can operate independently of having a second glove present.
Useability		
Portability	High	
Finger Dexterity	Low	Fingers are encased in shells.
Glove On/Off Easability	Low	
Aesthetics: Could it pass for regular glove?	No	Conspicuous
Aesthetics: Does it have a professional look	Yes	
Possible Issues	No L/R sync between gloves, No User Reviews, Use of foam instead of springs	**The current version of this glove does not implement wireless synchronization**. See previous page for detailed descriptions of other possible issues.
Overall Impression		This is really a fantastic design that will become a top DIY design when the designers implement Bluetooth synchronization between gloves. We also need to see at least a couple of user reviews to increase confidence in this build. The forearm boxes can be made a bit smaller and relocated to the back of a regular work glove to increase useability.

The bHaptics TactGlove DK2 (LRA)



This system uses new glove for virtual reality and gaming from a company called bHaptics. <u>This glove is not approved by bHaptics to be used for treating PD</u>, but it can nonetheless be programmed to provide the randomized Tass buzz patterns. This is the only DIY PD glove version running the Tass vibration patterns that one can purchase already assembled and almost ready to go.

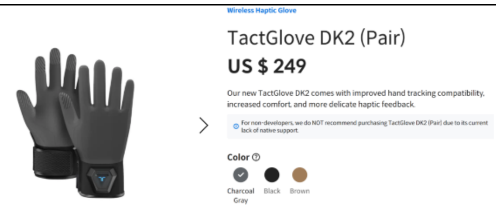
Pros for the bHaptics gloves:

- Cost is only $250
- Gloves are ready made – so you would not need to construct your gloves
- Both gloves are wireless!
- Without wires and tactors, the gloves appear like normal gloves aesthetically
- The bHaptics brain is in an iPhone or PC app that controls the gloves wirelessly
- The glove has the ability to stimulate your thumb also
- There are about 10 people on HealthUnlocked who have used this system for PD and their reviews are generally positive

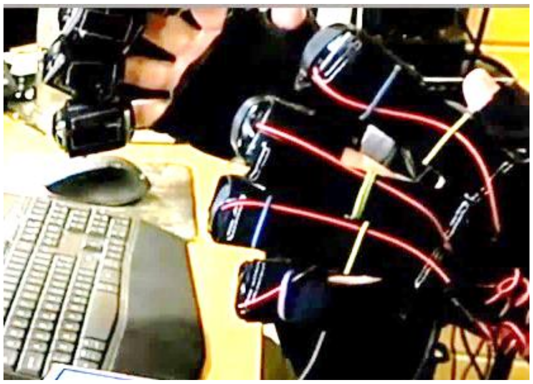
Cons for the Bhaptics gloves

- Gloves are very new and currently only recommended for professional game developers
- <u>bHaptics does not support their product to be used for PD therapy</u>
- You have to download a special beta version of the app from one of two people on HealthUnlocked
- Both PC and iPhone apps need to be open and running the app with screen on near the gloves
- You can't use your phone/PC while receiving therapy
- The app is coded in html – very complicated.
- Big - The frequency the Bhaptics gloves operate on is limited by bHaptics to be 170 Hz. Dr. Tass's specifications call for 250 Hz – this is a pretty big difference and would probably make the bHaptics not give as good results as the Buzzah which also uses 250 Hz. That said, if this was your only alternative, vibrating at 170Hz would be way better than nothing!
- VERY BIG - The company that makes the Bhaptics gloves does not allow users to replace their own buzzers. The way we use our PD gloves, constantly starting and stopping buzzers for 4 hours a day, puts a heavy load on the buzzers and they need to be replaced occasionally. I have had three buzzers I needed to replace in the 5 months since I have been using the Buzzah system. I would have had to send these gloves back to bHaptics three times – taking lots of time out of my therapy….
- THE BIGGEST DRAWBACK – bHaptics does not use tactors. There is a significant difference in the feel of the buzzes when you have tactors – the buzzes are more focused on your fingertips and there is not as much collateral buzzing of your bones – more intensity on a smaller area. So, the buzzing in these does not meet the Tass specifications. That said, there are a lot of people who use buzzers without tactors and still report good therapeutic results.

So, my conclusion is that there are definitely options that are superior to the bHaptics in achieving the Tass specifications and maximizing the potential for therapeutic results. But the Bhaptics could be a good alternative for some people with Parkinson's who don't have the ability (or inclination) to construct their own set of vibrating gloves.

The bHaptics TactGlove DK2		
Web Link		https://healthunlocked.com/cure-parkinsons/posts/150029715/tass-style-glove-iphone-app-hardware https://www.bhaptics.com/en/shop/tactglove/
Buzzer Type	LRA	
FDA Approved for Treatment of PD?	No	No DIY glove is FDA approved for treating PD
Expected Availability	Now	
<u>Tass Vibration Specs</u>		
vCR Buzz Pattern	Yes	Not tested, but I assume this is OK
Z-axis Buzz Direction	Yes	
Buzzer 2 ms Rise Time	Unknown	Should be OK since it has an LRA
Buzzer Fall Time	Unknown	Should be OK since it has an LRA
Tactor – Point like Vibration	Poor	No tactors means that contact area is not well defined as called for in Tass specifications. Finger sits on LRA
5.1 mm Contact Area	Poor	No tactor. Contact area too large and not well defined.
0.5 mm Preload Indentation Adjustment	No	No tactor
250 Hz Pulse Frequency	No	Frequency restricted to 170 Hz
Pulse Amplitude Adjustment	Yes	I assume this is available in the software settings. Amplitude delivered by LRAs reduced without a tactor.
< 1ms left/right pulse timing lag	Unknown	No information was available at this time. The DK2 ad specifies “Bluetooth connectivity”, but does not explicitly say anything about timing synchronization.
<u>Build Considerations</u>		
Build Difficulty	Comes Assembled	
Online Support Available	Yes	HealthUnlocked has several users of this system who respond to posts quickly
User Reviews Available	Yes	Many on HealthUnlocked
Documentation	HealthUnlocked	Software/app must be sent from developers on HealthUnlocked.
Approximate Cost	$250	
Soldering Required	None	
3D Print Required	No	
Printed Circuit Board Required	No	
<u>Features</u>		
Processor Location	Gloves	
Cable Routing	Wireless	
BT Speakerphone/Music Player	No	
Gloves Detachable from Processor	No	
One Hand Therapy Option	Yes	I assume one glove can operate independently of having a second glove present.
<u>Useability</u>		
Portability	High	
Finger Dexterity	High	No tactors means greater dexterity.
Glove On/Off Easability	High	
Aesthetics: Could it pass for regular glove?	Yes	Looks like a nice lightweight glove.
Aesthetics: Does it have a professional look	Yes	Very nice look
<u>Possible Issues</u>	Many	See previous page for detailed descriptions of issues.
<u>Overall Impression</u>		There are definitely options that are superior to the bHaptics in achieving the Tass specifications and maximizing the potential for therapeutic results. But the bHaptics could be a good secondary alternative for some people with Parkinson’s who don’t have the ability (or inclination) to construct their own set of vibrating gloves.

The Winnie-the-Poo Glove (Acc. Exciter)



This is the only glove system we have seen that uses an acoustic exciter buzzer like the one used in the 2021 version of the Stanford glove. An updated version due in early 2025 will be more compact and robust.

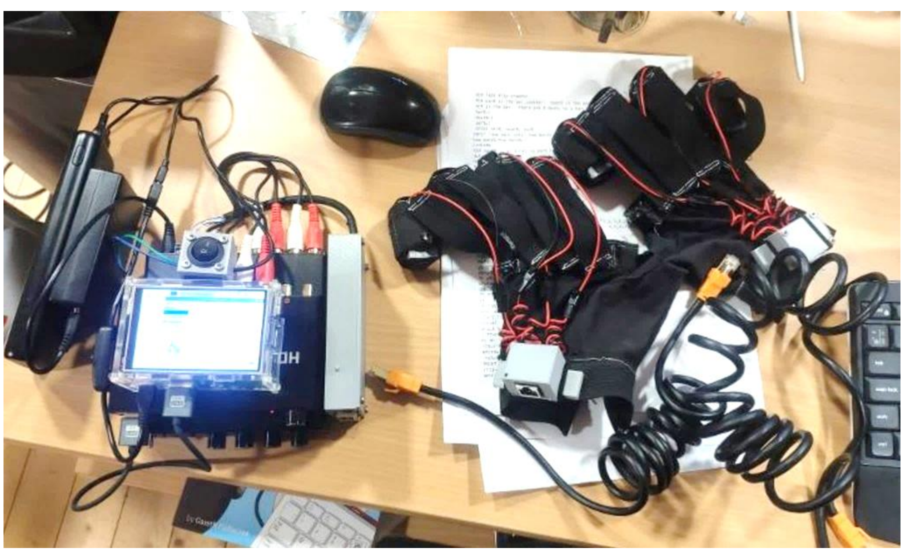
Pros for the Pooh gloves:

- The best reproduction of the Tass vibration specs of all DIY designs
- Great online support on HealthUnlocked from Winnie-the-Poo
- Many enthusiastic users on HealthUnlocked

Cons for the Pooh gloves

- Gloves are more expensive that most DIY designs
- Very bulky to carry
- Gloves are very bulky due to large size of acoustic exciters

Note: A new, more portable version of this design will be out soon!



The Winnie-the-Poo Glove		
Web Link		https://healthunlocked.com/cure-parkinsons/posts/150536169/winnie-the-poo-s-glove-building-adventure https://www.curepd2.com/
Buzzer Type	Acoustic Exciter	
FDA Approved for Treatment of PD?	No	No DIY glove is FDA approved for treating PD
Expected Availability	Now	Smaller update coming Feb 2025
Tass Vibration Specs		
vCR Buzz Pattern	Yes	
Z-axis Buzz Direction	Yes	
Buzzer 2 ms Rise Time	Excellent	Should be as good as 2021 Standford glove
Buzzer Fall Time	Unknown	Should be as good as 2021 Standford glove
Tactor – Point like Vibration	Good	Larger contact area leads to less point-like sensation
5.1 mm Contact Area	Too Large	Diameter is given at 7 mm instead of 5.1 mm as in the 2021 Stanford glove. This leads to almost twice as much contact area as in the 2021 Stanford Glove.
0.5 mm Preload Indentation Adjustment	Yes	Preloading is adjusted during glove build
250 Hz Pulse Frequency	Yes	
Pulse Amplitude Adjustment	Yes	
< 1ms left/right pulse timing lag	Yes	Not a problem with wired designs.
Build Considerations		
Build Difficulty	Very Difficult	
Online Support Available	Yes	Winnie-the-Pooh is very active on HealthUnlocked and has assisted many builders to replicate his excellent design
User Reviews Available	Yes	Many on HealthUnlocked
Documentation	HealthUnlocked, Website videos	There are numerous videos documenting the build on the website.
Approximate Cost	$690	From the website and converted to dollars from euros. Includes tools.
Soldering Required	Yes	
3D Print Required	Yes	
Printed Circuit Board Required	No	This design could be made portable with PCB mounted components
Features		
Processor Location	Tabletop	
Cable Routing	Wireless	
BT Speakerphone/Music Player	No	
Gloves Detachable from Processor	Yes	
One Hand Therapy Option	Yes	
Useability		
Portability	Barely	Uses large discrete components that are difficult to transport. Winnie is currently working on a new version that is smaller.
Finger Dexterity	Low	Gloves are very large due to the large size of the acoustic exciters. New version will be smaller.
Glove On/Off Easability	Low	
Aesthetics: Could it pass for regular glove?	No	
Aesthetics: Does it have a professional look	No	
Possible Issues	Portability	Uses desktop components so users must be sitting near tabletop for 4 hours per day.
Overall Impression		This DIY version is the best I have found in reproducing the Tass vibration patterns. This high level of performance requires compromises in useability. That said, the new 2025 version will be significantly smaller.

The PD Buzzboard Gloves (ERM)

When I got started, this was the only DIY design that I could find. As far as I know, this was the first DIY design ever posted on YouTube. I am forever grateful to the Buzzboard designer for his early help in getting me started in my first DIY glove build. I originally used his Nano design with more powerful toothbrush buzzers (bench tested in in this document) and essentially got zero results. I used the toothbrush buzzers because I thought the Buzzboard buzzers were too weak and had poor rise/fall times. After several months of getting no results with the toothbrush buzzers, I had decided to give up. But, the fact that so many people had posted positive results with this design caused me to make one last try with the exact Buzzboard glove system. I started to obtain the positive results on my third day of using the original Buzzboard buzzers. Two months later, I upgraded to the Buzzah LRA design with tactors to get buzzer performance closer to the Tass guidelines.

From the Buzzboard website:

The PD Buzzboard project has a few variations:

- The "PD Buzzboard" itself, which is a board which sits in your lap, and has vibrating motors on each finger. Users can put this in their lap, place their fingers on the motors, and get vibration on their fingers. This is easiest to build, but users must stay stationary while using.
- The "PD Buzzboard Gloves with One Controller". This variation has a central controller running the vibration program, typically used in a fanny pack, and wires running from the fanny pack to the gloves. This is more mobile than the Buzzboard, as users can walk and move around, but there are some central cables which can get caught on things.
- The "PD Buzzboard Gloves with Separate Controllers". This variation has separate controllers on each hand. This is the hardest to build, but has the most mobility.

Pros for the Buzzboard gloves:

- The largest cohort of users online
- Many users have provided positive feedback
- Excellent video documentation by the designer
- Email support from the designer
- They are cheaper than most other builds
- Easier to build than many other builds because gloves don't employ tactors
- The Nano processor version is very small and can be mounted on the back of a glove

Cons for the Buzzboard gloves

- Uses ERMs which don't reproduce the Tass specs as well as other designs
- Without tactors, fingertip stimulation is not as focused and point-like as called for in Tass specs
- Their frequency is fixed at 160 Hz, significantly lower than Tass spec of 250 Hz
- Not as many adjustable buzz parameters compared to other designs

PDBuzzboard Gloves		
Web Link		https://github.com/pdbuzzboard/pdbuzzboard https://www.youtube.com/watch?v=1PfsVjnPAuQ&t=1456s
Buzzer Type	ERM	The designer specifically calls for this model of ERM sold by Digikey: https://www.digikey.com/en/products/detail/vybronics-inc/VW0625AB001G/9974285
FDA Approved for Treatment of PD?	No	No DIY glove is FDA approved for treating PD
Expected Availability	Now	
Tass Vibration Specs		
vCR Buzz Pattern	Yes	Updated versions of software are correct. Check to see that you are using the most updated software since some early versions for the Arduino Uno employed initial settings that were out of Tass pattern specs.
Z-axis Buzz Direction	No	ERMs wobble instead of pushing in and out as per Tass specs
Buzzer 2 ms Rise Time	Poor	We have not bench tested the ERM in this design, but ERMs typically have very poor rise times
Buzzer Fall Time	Poor	We have not bench tested the ERM in this design, but ERMs typically have very poor fall times, some of which are longer than the 67 ms rest period
Tactor – Point like Vibration	Poor	No tactor is used
5.1 mm Contact Area	Poor	Diameter is 10 mm instead of 5.1 mm as in the 2021 Stanford glove – resulting in 4 times the fingertip contact area
0.5 mm Preload Indentation Adjustment	No	
250 Hz Pulse Frequency	No	Frequency is fixed around 160 Hz.
< 1ms left/right pulse timing lag	Yes/No	Excellent synchronization is achieved in wired version. The wireless version does not synchronize left/right hands.
Build Considerations		
Build Difficulty	Moderate	
Online Support Available	Yes	pdbuzzboard@gmail.com This designer is very helpful and responsive to emails
User Reviews Available	Yes	Many on various platforms
Documentation	HealthUnlocked, YouTube videos, Github	There are numerous videos documenting the build on the website.
Approximate Cost	$200	
Soldering Required	Yes	
3D Print Required	No	
Printed Circuit Board Required	No	
Features		
Processor Location	Tabletop, Fanny Pack or Gloves	
Cable Routing	From waist or Wireless option	There is a version where each hand has its own processor – so no wires. However, the two hands are synchronized as in the Stanford designs
BT Speakerphone/Music Player	No	
Gloves Detachable from Processor	No	
One Hand Therapy Option	No	
Useability		
Portability	Excellent	Nano versions are very small and portable, but not original Buzzboard
Finger Dexterity	High	Since this design doesn't use tactors, there are only the buzzers on fingertips – no tactor boxes
Glove On/Off Easability	Good	
Aesthetics: Could it pass for regular glove?	No	
Aesthetics: Does it have a professional look	No	
Possible Issues	Poor buzzer specs	ERMs don't perform well according to Tass specs, but many users (including myself) have nevertheless obtained excellent therapeutic results with this design.
Overall Impression	I obtained great results with this design.	At the time I started, I don't think there were any LRA designs available. I recently upgraded to the Buzzah LRA design with tactors to get buzzer performance closer to the Tass guidelines. If you are just starting, you might consider choosing a design that matches Tass specs more closely.

Part 4: Feedback from Vibrating PD Glove Users

This section presents first hand anecdotal accounts from a small number of people with Parkinsons (or PD caregivers) detailing their experiences using some version of vibrating gloves. In some instances, the accounts were collected through direct email communication with the authors. In other cases, we simply provide internet references where people have extemporaneously shared their experiences in some kind of online public forum. No effort has been made to comprehensively represent the wide range of people who have tried this type of therapy. Keep in mind that the type of glove, duration of treatment, compliance with treatment dosing, and prior duration and severity of PD varies between users.

From Anonymous Caregiver

1. How long have you been using Vibrating PD gloves?

    Started using gloves in late March 2024. *(8 months)*

2. How long did you have PD before starting with gloves?

    Diagnosed in February 2021. *(3 years)*

3. What version of vibrating glove are you using?

    Started with Buzzah system using Vybronics VLV101040A LRAs, using that from March 2024 to mid-October 2024, then switched to WTP *(Winnie-the-Poo)* ***system and using that since.***

4. What version of the vCR pattern does your glove use?

    Tass pattern, mirrored, with Jitter. Tried a few different frequencies (225, 235, 175) with the Buzzah system. Now at 250 Hz with the WTP system

5. How often and how long do you use your gloves?

    This is the main problem, very inconsistent. Mostly daily use with occasional days without. At most 3 hours per day, with one 2-hour session and another 1-hour session. But these happen at most once or twice per week. Some days it's as little as 40 to 50 minutes. If it's going to end up being less than that I don't even bother. Doing an average of all days since we began, the average daily use comes out to 106 minutes per day = far short of the recommended 240 minutes

6. What PD symptoms, if any, have improved as a result of the gloves?

    The improvements are something I as caregiver notice - improved voice, much reduced masking, more presence/energy - she just seems more herself when she gets several days in a row of at least 2 hours per day. Possibly some improvement in bradykinesia and rigidity at the upper end of use, but hard to say.

7. What PD symptoms, if any, have not been helped by the gloves?

    No reduction active tremor, constipation. Not sure about bradykinesia and rigidity

8. What problems, side effects, or challenges have you encountered with glove treatment?

    Just using them as recommended. There's not a lot you can do with them on. I've inserted a stylus on the index finger so she can do some computer work but it makes doing that very slow. Other than that she can't really do anything with her hands while wearing them, which is what makes it so difficult to use them the required amount.

9. What is your overall assessment of your experience with vibrating glove treatment?

    I think they could have much bigger impact if they were worn the recommended amount of time.

10. Is there anything above using the gloves that you wish you had known before you started?

    I knew it was going to be a challenge to get her to wear them the recommended amount, but the 4 hours a day is a very real, very significant challenge. If you're too busy to get that in each day, lower your expectations. Maybe still consider building them and trying them, just lower your expectations on what they'll do.

From PWPInnovate898 on HealthUnlocked

1. How long have you been using vibrating PD gloves?

    As a DIY glove developer and collaborator, as well as a PwP with bilateral DBS since 2017, I have been using several iterations of various glove designs beginning in Feb. 2023.

2. How long did you have PD before starting with gloves?

    11 years.

3. What version of the vibrating glove are you using?

    Currently using v1.0 prototype of the "Blue Buzzah" DIY design.

4. What version of the vCR pattern does your glove use?

    I mostly use the "noisy VCR" w/ RVS (rapidly varying sequence). I have used other similar patterns but only for limited therapy sessions.

5. How often and how long do you use your gloves?

    3 to 4 times per week for 1 to 2 sessions per day, and 30 min --> 90 min/session.

6. What PD symptoms, if any, have improved as a result of the gloves?

    Sleep quality has improved considerably (much less frequent waking between ~2 to 3 AM
    Voice projection is moderately improved
    Rx changes:
    - ***Reduced C/L IR intake from 2 to 3 tablets of 25/100mg per day to 1/2 to 1 tablets/day***
    - ***No changes to 25/100 C/L ER and Neupro (3mg)***
    - ***Added 1 tab/day amantadine (100mg)***
    - ***DBS: no changes***

7. What PD symptoms, if any, have not been helped by the gloves?

    Balance sometimes improves but very mildly, and only if I have more consistent therapy sessions with the Gloves.
    Little to no improvements to gait, which is my most prevalent and frustrating PD symptom.

8. What problems, side effects, or challenges have you encountered with glove treatment?

    Challenges:
    - ***Time commitment: 4 hour /day over several months is a huge time sink!***
    - ***Frustration & anxiety: knowing the desired neuroplastic changes can take months to reveal themselves, as noted by Dr. Tass.***
    - ***Disappointment: realizing the optimal stimulation parameters are extremely patient specific and difficult to "get right" when there is no direct feedback in current designs to tune the settings for my conditions.***

    Side effects: More frequent dyskinesia.

    Problems: Frequent design changes for the overall system, especially the tactor housings.

9. What is your overall assessment of your experience with vibrating glove treatment?

"Cautiously optimistic":

- ***Based on the mild improvements to just two of my symptoms (sleep, voice).***
- ***Despite the many innovative ideas from the large number of DIY glove development teams, all designs include at least some important deviations to the specifications outlined in the publicly available research.***

10. Is there anything above using the gloves that you wish you had known before you started?

How long the therapy would take before symptomatic improvements would reveal themselves.
The critical importance in tuning the stimulation parameters to each patient.

--

From Winnie the Poo On HealthUnlocked

1. How long have you been using Vibrating PD gloves?

    Two years

2. How long did you have PD before starting with gloves?

    I was diagnosed with the PD at the start of 2018, so four years

3. What version of vibrating glove are you using?

    The Winnie-the-Poo glove

4. What version of the vCR pattern does your glove use?

    Noisy 3:2 ON-OFF CR RVS mirrored pattern with 23.5% jitter.

5. How often and how long do you use your gloves?

    I used the gloves for 2 hours twice a day for six months, and now use them for 2 hours a day most days

6. What PD symptoms, if any, have improved as a result of the gloves?

    I could say bradykinesia or rigidity. I think tremor is helped too. But really its PD. That feeling. When I am able to maintain regular therapy compliance with the gloves, most of the time throughout the day I don't feel like I have Parkinsons disease. And when I miss using the gloves I feel shit. Most essential – dystonia.

7. What PD symptoms, if any, have not been helped by the gloves?

    I'm not sure. Constipation, smell, fatigue, sleep. But maybe they are improved.

8. What problems, side effects, or challenges have you encountered with glove treatment?

    4 hours a day is very difficult to find. The gloves are very restrictive. And mine are bulky, at best luggable, but not really portal. They have also been too delicate and break frequently. Because my wife now won't let me travel without them I also travel with an aluminum attaché case with soldering iron solder wire snips and a full tool kit. I have nearly completed a substantial redesign which uses much smaller tactors, much less delicate construction, virtually no soldering and a large touchscreen. The only soldering is the wires connecting to the exciter terminals. Eight exciter 16 joints. The only tools that I travel with now are wire strippers and an electrical screwdriver.

9. What is your overall assessment of your experience with vibrating glove treatment?

    My wife won't let me travel without them. I don't think I would be skiing black runs. Or even walking round the ski resort.

10. Is there anything above using the gloves that you wish you had known before you started?

    I think the gloves are by a large margin, the most important element in managing my PD. I hold to the belief that exercise is important and probably the 2nd most important factor for me. I am encouraged by the pace at which things like the sub-cutaneous pump, stem cell grafts, and disease modifying medications are developing, and "holding on" for better in the future. And I think we all go through the process of rejecting conventional, experimenting with all manner of supplements and alternative ideas, and eventually wise up and understand the cynicism of the experienced long-haulers. I think a positive attitude, and not obsessing about the disease help too.

From TactileDesign on Github

1. How long have you been using vibrating PD gloves?

    Six months with positive effect. (I don't count my first 6 months when I was using toothbrush ERMs that were too energetic and resulted in no effect)

2. How long did you have PD before starting with gloves?

    3 years.

3. What version of the vibrating glove are you using?

    Buzzah Neck Speaker Build. <u>I just started using tactors with this system 3 months ago</u>.

4. What version of the vCR pattern does your glove use?

    Noisy vCR without mirroring hybrid.

5. How often and how long do you use your gloves?

    Twice per day --> 2hr per session. (I only missed 2.5 sessions in the last 6 months – very difficult to maintain such compliance, but it is worth it for me.)

6. What PD symptoms, if any, have improved as a result of the gloves?

    Gradually lowered medication need from 4 C/L to zero in just over a month. *(Note: I lowered my C/L dosing in consultation with my doctor. For information about complications that may result from lowering C/L dose, consult your doctor.)* ***Balance, stiffness, voice, posture, energy, cognition, balance, and facial masking all improved – took away 1yr or more of my PD progression.***

7. What PD symptoms, if any, have not been helped by the gloves?

    My tremor initially improved to zero with the gloves <u>while I was still taking C/L</u>. But once I gradually stopped C/L, my tremor eventually became a bit worse than it was a year ago. I am currently working to adjust my vibration settings to see if I can get better results for my tremor.

8. What problems, side effects, or challenges have you encountered with glove treatment?

    The buzzing slightly aggravates my tendency toward tendonitis.

9. What is your overall assessment of your experience with vibrating glove treatment?

    Before using the gloves, I had pronounced stiffness, masking, slumped/stiff posture, and the beginning of balance issues. All these symptoms are now better than they were a year ago with improvements confirmed in my yearly neurologist appointment. My tremor is a bit worse than a year ago. If I had known a year ago how much the gloves would help my PD, I would have felt very encouraged. Now, while I remain <u>very thankful to have glove therapy</u>, I have become used to my "new normal" with less PD symptoms, and I sometimes feel impatient that my tremor is not improving as quickly (since I stopped taking C/L) along with my other symptoms.

10. Is there anything above using the gloves that you wish you had known before you started?

    I wish I had not doggedly kept treating myself with the same set of ERM gloves with excessively strong buzzers that were not helping with my PD symptoms for my first 6 months.

From David's Life with Parkinsons Podcast on YouTube

David has a at least 10 videos on his YouTube channel about his experience with his DIY PD gloves. They can all be found here:
https://www.youtube.com/results?search_query=david+life+with+parkinsons+gloves

Here is a sampling of his glove videos:

https://www.youtube.com/watch?v=GdY_22PdWlw

Labour Day weekend PD Glove rebuild

1.1K views • 1 year ago

https://www.youtube.com/watch?v=ul_XuK8Kuok

Final glove update - You don't want to miss it!

1.2K views • 2 months ago

https://www.youtube.com/watch?v=WQwFuEtFUcM

David initially enjoyed positive therapeutic effects from his PDBuzzboard ERM based DIY gloves. However, he eventually developed side effects from the buzzing that he attributed to overstimulation. Here are David's comments he provided us in response to our invitation for him to contribute to this handbook:

> ***"I was diagnosed with Parkinson's Disease in May of 2017. I became aware of the Vibrating PD gloves through a FB message from another viewer. I was going through a rough time, and was having a very difficult time managing my symptoms. I was pointed towards the PD Buzzboard setup and began developing a set of gloves for myself with the help of a friend. I soon developed a love/hate relationship with the gloves as they initially helped, but constant repairs and overstimulation symptoms began to wear me down. My friend and I continually evolved my setup a number of times to address the problems, but were unable to achieve long term success. Each evolution followed the same pattern; initial success followed by over stimulation problems. I don't have an issue with the gloves at all, I just feel I fall into the niche of being over sensitive to the vibrations. I had to abandon the quest as the over stimulation symptoms became debilitating. I wish success to anyone who does their own build, as I feel there is a lot of potential in this technology. I have found something similar that is helping me a lot, and does not initiate over stimulation."***

Update to David's review: A few weeks after David submitted his review, he contacted me to see if I could help him modify his gloves to create a DIY version of The Beech Band. In the process of repurposing his gloves, we discovered that he was using an old version of the software in his Buzzboard Uno glove build that came with initial settings that were out of Tass specs for pattern. The software settings he had been using were producing a buzz pattern with excessively long ON times. This may be the reason he was getting problems with overstimulation.

From Participants in PD Glove Research Studies

The links provided below feature publicly posted information from former research study participants sharing their experiences with the gloves.

Pat Riddle participated in the Synergic longitudinal study

Episode 3 Parkinson's Gloves 5-week mark https://www.youtube.com/watch?v=F0mXCxEq0J4
February 21, 2023 https://www.youtube.com/watch?v=r6Dk1D-YZCo
Episode 5 Parkinson's Gloves - information correction https://www.youtube.com/watch?v=GNTUIq2Qb4k
Episode 6 Twitching Women IV Dr Tass https://www.youtube.com/watch?v=0Gm2LcwKR1E
Episode 7 Ancient Remedies & Essential Oils https://www.youtube.com/watch?v=A-ecXQoaykw
Episode 8: 6 months use of Glove: https://www.youtubes.com/watch?v=jq5f-oalRBQ
Episode 9 Glove update https://www.youtube.com/watch?v=7yDkcXkhsT4
Episode 10. Cutting back on gloves/medication https://www.youtube.com/watch?v=AOeXkDyB5s0
Additional videos here: https://www.youtube.com/@patriddleparkinsonsjourney/videos?view=0&sort=dd&shelf_id=2

Kanwar Bhutani participated in an early Stanford Glove trial

Mr. Bhutani describes his amazing experience with glove therapy in this YouTube interview: https://www.youtube.com/watch?v=tIeLt9nPJrY

He was also careful to temper the expectations of participants at time 51:48, saying, *"Don't expect this to be the end all solution. I don't want to get your hopes up and say, 'Well you wear the gloves and, all of a sudden, it's going to be miracles'. I had to do some life changes as well. I have to exercise regularly. Fifty percent of the battle is exercise! I bike about 20 miles on the weekends, and about eight miles a day. And I walk for about three miles a day, every day."*

Before/after Images from Dr. Tass's supplement in, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8055937/

Jimmy Choi is a famous PWP inspirational speaker who was a competitive contestant on American Ninja in spite of his young onset PD.

Mr. Choi documented his experience as a Stanford Glove research study participant starting with this July-2019 post: https://www.facebook.com/jcfoxninja/posts/so-whats-this-clinical-trial-i-am-doing-research-has-suggested-that-using-low-fr/599615847234047/

In this subsequent Oct-2019 post: https://www.facebook.com/jcfoxninja/videos/633518073843710/, Jimmy explains that his off-med MDS-UPDRS score amazingly went from 63 to 42 in just 3 months of treatment with the Stanford gloves.

Before After

In this Dec, 2020 interview, https://www.youtube.com/watch?v=2UDmXkmTiM4 at time 45:30, Jimmy explains that, while the glove treatment allowed him to delay his DBS surgery, he was again planning to have DBS.

Prompts for Submitting Your Own User Review on HealthUnlocked

1. How long have you been using vibrating PD gloves?

2. How long did you have PD before starting with gloves?

3. What version of the vibrating glove are you using?

4. What version of the vCR pattern does your glove use?

5. How often and how long do you use your gloves?

6. What PD symptoms, if any, have improved as a result of the gloves?

7. What PD symptoms, if any, have not been helped by the gloves?

8. What problems, side effects, or challenges have you encountered with glove treatment?

9. What is your overall assessment of your experience with vibrating glove treatment?

10. Is there anything above using the gloves that you wish you had known before you started?

Form for Submitting Your Own Design Review on HealthUnlocked

Web Link		
Buzzer Type		
FDA Approved for Treatment of PD?		
Expected Availability		
Tass Vibration Specs		
vCR Buzz Pattern		
Z-axis Buzz Direction		
Buzzer 2 ms Rise Time		
Buzzer Fall Time		
Tactor – Point like Vibration		
5.1 mm Contact Area		
0.5 mm Preload Indentation Adjustment		
250 Hz Pulse Frequency		
Pulse Amplitude Adjustment		
< 1ms left/right pulse timing lag		
Build Considerations		
Build Difficulty		
Online Support Available		
User Reviews Available		
Documentation		
Approximate Cost		
Soldering Required		
3D Print Required		
Printed Circuit Board Required		
Features		
Processor Location		
Cable Routing		
BT Speakerphone/Music Player		
Gloves Detachable from Processor		
One Hand Therapy Option		
Useability		
Portability		
Finger Dexterity		
Glove On/Off Easability		
Aesthetics: Could it pass for regular glove?		
Aesthetics: Does it have a professional look		
Possible Issues		
Overall Impression		