Electronic Tuning Fork

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Introduction

I. Clinical Problem

- Diabetic peripheral neuropathy (DPN) is the most common complications of diabetes (1,2).
- In 2015, about 9.4% of the US population or 30.3 million people has diabetes. Approximately 60 to 70 percent of patients with diabetes suffer the disease.
- The mechanism of the disease is not thoroughly understood
- The earliest symptom is the loss of vibratory sensation in the most peripheral extremities.
- Current diagnosis tools fail short to measure the degree of severity (3).

II. Current Tools to Diagnose DPN

www.toolsforwellness.com

www.tylerfootclinic.com

www.obimed.com/etf128

III. The Gap

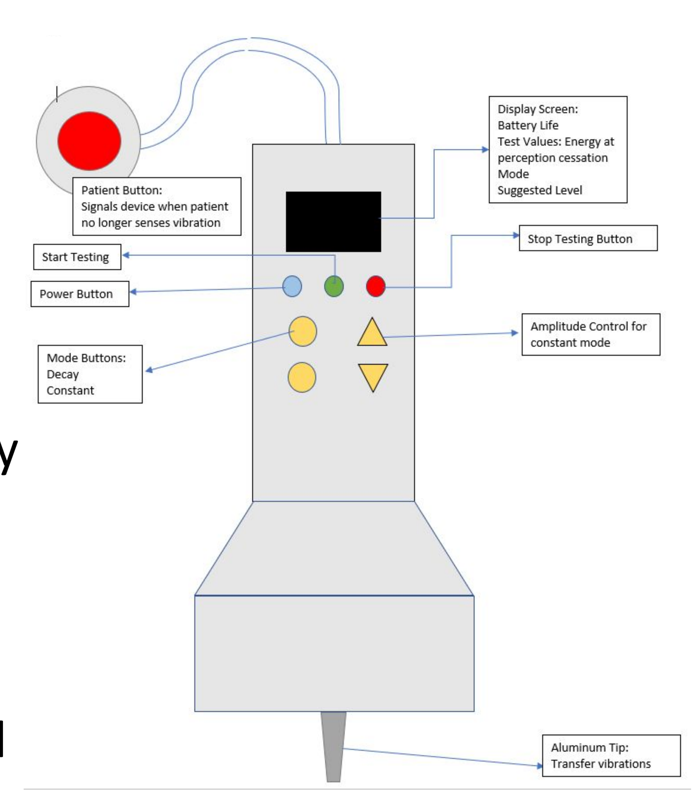
- Traditional tuning fork: Prone to human error, not quantifiable, only qualitative results.
- Monofilament: Again qualitative, no range in sensations. The monofilaments tested were neither precise nor accurate (4)
- ETF128: Expensive, still does not quantify extent of neuropathy
- Procedure needs to be operated and result interpreted by physician.

IV. Problem Statement

We saw a need for a device which gives quantifiable data regarding the onset and extent of peripheral neuropathy in diabetic patients; can be operated with little human error, and offers suggestive interpretation of results.

Proposed Solution

- **Vibration:** at 128Hz, created by electrical motor. Frequency and amplitude can be controlled independently.
- **Quantitative measurements**:
  - duration of vibration perception.
- **Ease of use**: provide a simple and user-friendly interface
- **Ease of interpretation:** interpret energy and/ or timing data to return suggestive results about the onset and extent of DPN in patient.
- **Little human errors:** reduce human error in use with automated timing and use of a patient response button.



Design Iterations and Rationales

I. **First Prototype:** Solenoid electric motor whose amplitude and frequency can be controlled independently using an Arduino.

1. Rationale: Solenoid vibrations transferred through metal tip to patient. Easily powered and cheap.

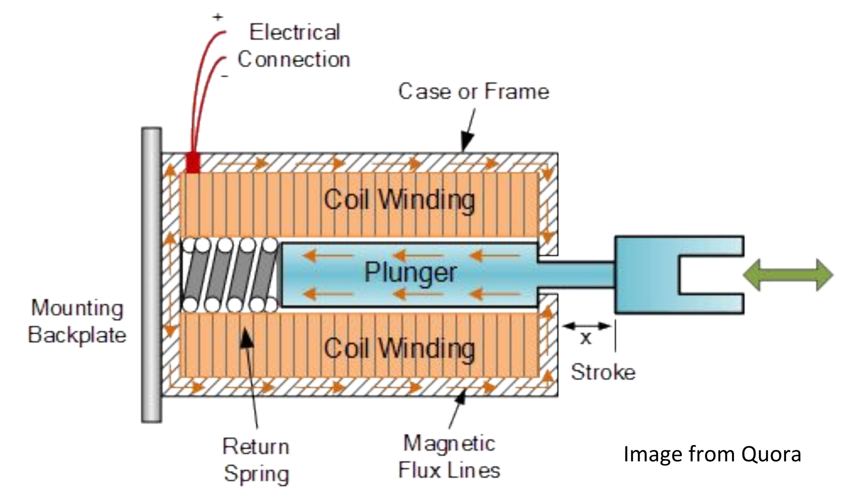
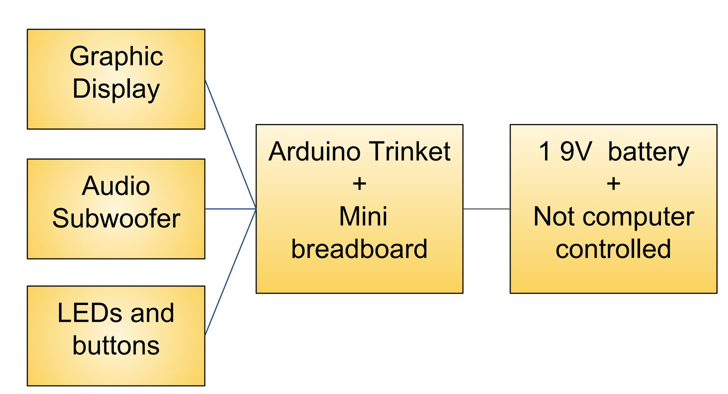


Image from Quora

2. Idea Scrapped: Plunger motion created chattering. Created non-sinusoidal waveforms of inconsistent amplitude and frequency. Fine controls would be necessary to use this mode of vibration. Conclusion: Another mode of vibration will have to be used to generate more consistent vibration patterns.

II. Second Prototype:

1. Schematics:



Tang Band W2-1625SA 2" Neodymium Subwoofer

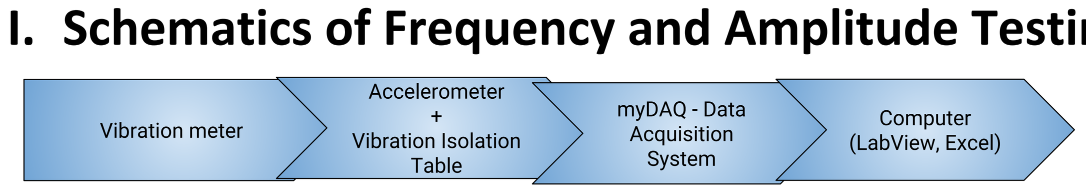
2. Rationales:

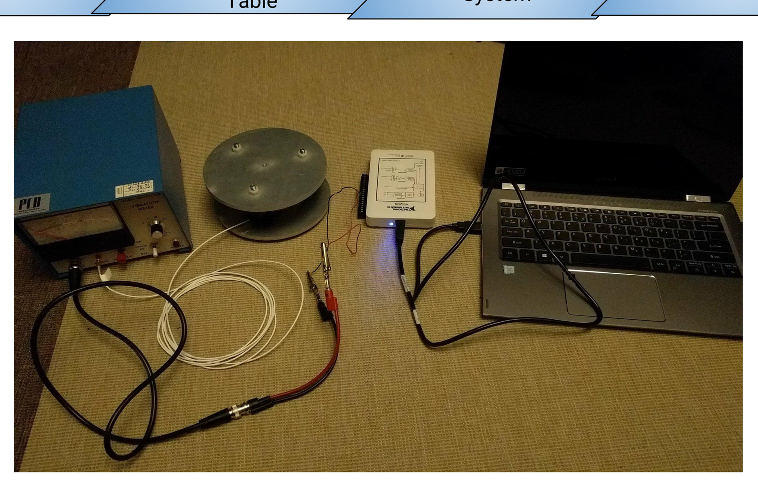
Driving subwoofer (vibratory mechanism) at 128Hz, relatively cheap but powerful. Analog output results in even waveforms. Control essentially by volume controls.

3. Further Changes: Successful vibration generation allowed for future iterations to focus on amplitude, decay profile, mobility, and validation.

Studies and Results

I. Schematics of Frequency and Amplitude Testing

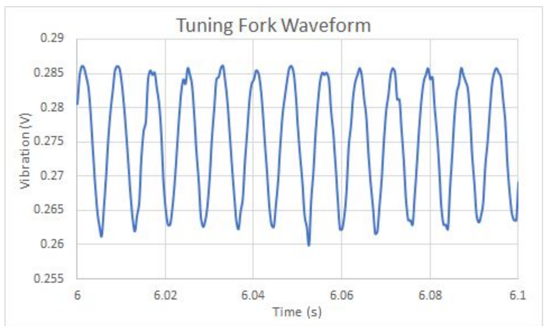


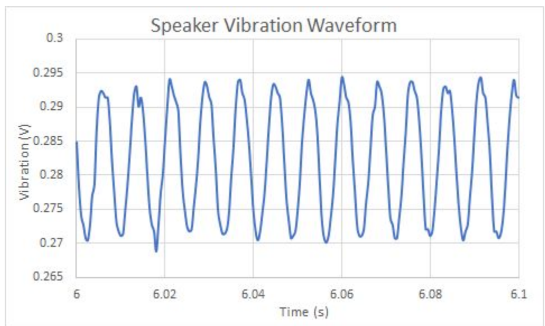


Vibration meter uses a handmade isolation table combined with an accelerometer to detect vibrations. Data is gathered on Labview after processing through a DAQ device. Further processing of data was completed on Microsoft Excel. No documentation for device was found. Testing would be done by simply placing vibrating device on isolation table.

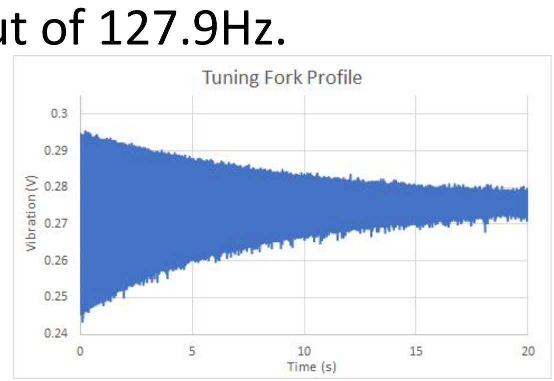
Results (cont.)

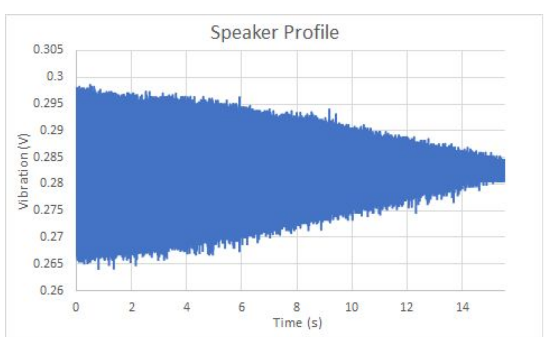
II. Results





Objective: Matching the Tuning Fork Waveform
Status: Accomplished, produced a sinusoidal waveform output to match that of the tuning fork. Frequency of 128.2Hz matches the tuning fork output of 127.9Hz.





Objective: Producing a Vibration Profile
Status: Accomplished, the profile attempted was linear such that a better measurement could be made. The decaying profile of the tuning fork is fast at first before slowing down. Linear profile allows intermediate values to be more accurate. Starting amplitudes matched at 0.05V p-p.
Note: Vibration outputs reported in Volts due to the unknown calibration between voltage and vibration meter units (G's). A newer or more modern vibration meter may be able to be calibrated for actual output in G's to be reported by device.

Objective: Side by Side Testing
Status: Not Accomplished, prototype only recently functional, next steps.

Conclusions

- Overall functionality of device has been achieved. The device can output a sinusoidal waveform with the similar amplitude and frequency to the tuning fork.
- Device outputs the time interval from when the physician presses on the Start/Stop button to when the patient responds.
- The device is intuitive and has the potential to reduce human errors
- Future iterations of the device include:
  + Miniaturize the device to have a small footprint
  + Validate the device calibration profile with respect to the tuning fork
  + Introduce the device to the clinical setting

References

1) Diabetes Control and Complications Trial Research Group (DCCT)
2) Ramsey SD, Newton K, Blough D, et al. Incidence, outcomes, and cost of foot ulcers in patients with diabetes.
3) Rith-Najarian SJ, Stolusky T, Gohdes DM. Identifying diabetic patients at high risk for lower extremity amputation in a primary health care setting. A prospective evaluation of simple screening criteria. Diabetes Care 1992;15: 1386–9.