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Energy Harvesting And Human Movement

Introduction

Energy is defined as "the ability to do work"- [(1)] while 'Harvesting' which is derived from the word 'Harvest' means "to gather"[(2)]. Everything we do is connected to one form of energy or another and hence the requirement for energy harvesting. Current types of non-renewable energy sources that are heavily reliant on oil and petroleum products, natural gas, coal and also nuclear power will someday have their supply come to an end. A notable method of energy harvesting is trying to generate electrical energy through normal human movements. We are aimed to harvest enough energy from normal human movements to power remote medical monitoring and telemetry systems.

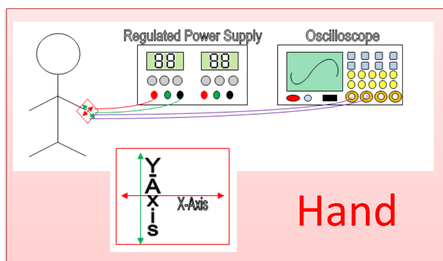
Normal human movements are being "defined" as: walking, sitting around with normal hand gestures, simple movements from the human body that does not have a fixed movement pattern. For example, a walking human will encounter vibration caused by the body's movement and different body parts generate different vibrations during the process of the different movements

Medical applications that will be looked at:
- Electrocardiogram (ECG)
- Blood Pressure
- Oximetry
- Temperature
- Pulse Rate

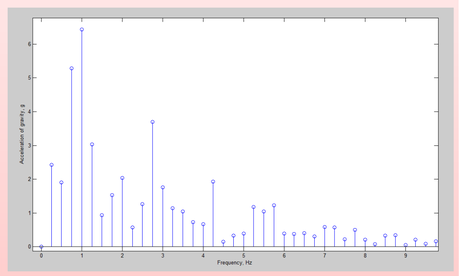
Medical Sensors' Power Requirement

Type	Power Requirement
Electrocardiogram (ECG)	0.2 – 0.3 W
Blood Pressure	3.75 W(Peak / Pump running) 0.2-0.3W (Nominal)
Oximetry with Pulse Monitoring	0.2 – 0.3 W
Temperature	0.05 – 0.075 W

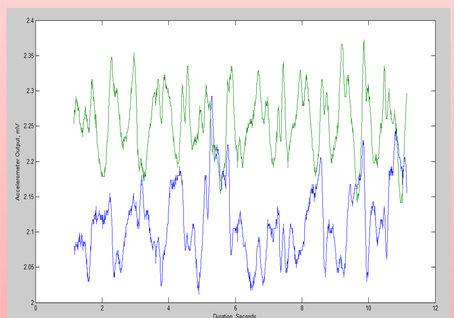
Experiment Results (Hand, Chest, Ankle & Foot)



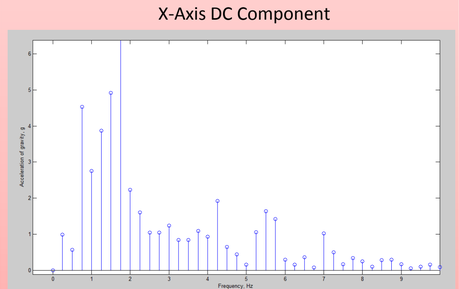
Hand



X-Axis DC Component



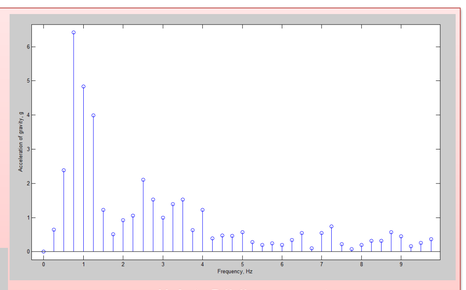
Blue: X-Axis Green: Y-Axis



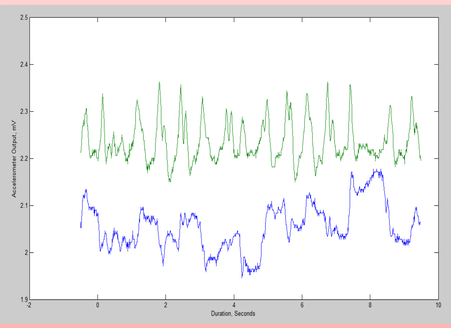
Y-Axis DC Component

- Peak *g* for X-Axis is at 1 Hz while for Y-Axis is at 1.75 Hz.
- The Y-Axis' peaks are almost double of the X-Axis' frequency due to the arm swing motion during the human walk. (To and Fro for each footstep)

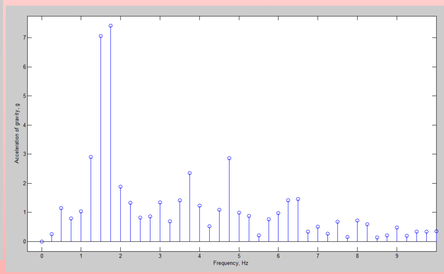
Chest



X-Axis DC Component

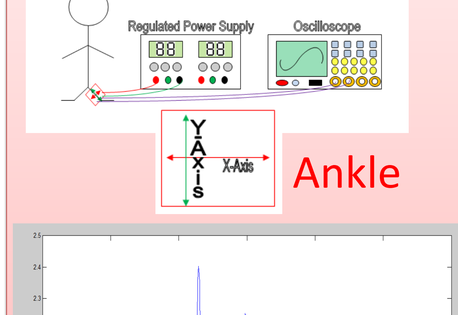


Blue: X-Axis Green: Y-Axis

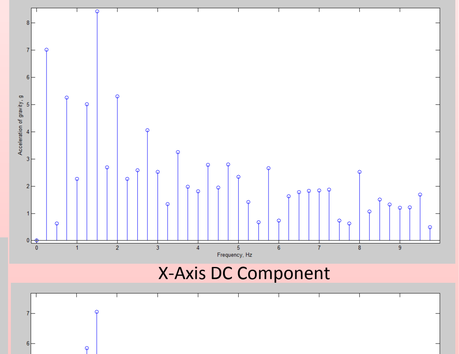


Y-Axis DC Component

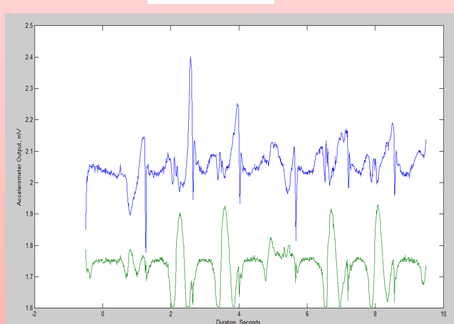
- Peak *g* for X-Axis is at 0.75 Hz while for Y-Axis is at 1.75 Hz.
- The Y-Axis' frequency at 1.75 Hz explains the double foot strike of both feet during walking motion. So the swaying motion captured by the X-Axis should be at about half of the Y-Axis' frequency. Y-Axis has a slightly higher amplitude due to the bounce of the walk.



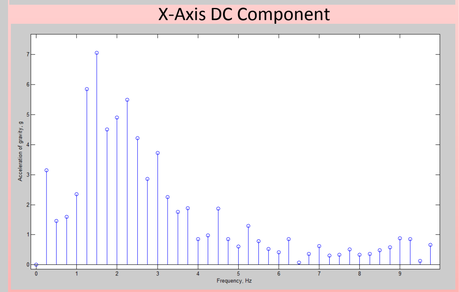
Ankle



X-Axis DC Component

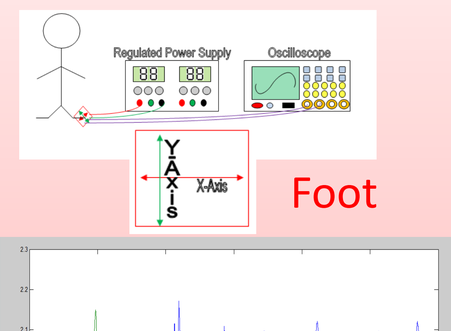


Blue: X-Axis Green: Y-Axis

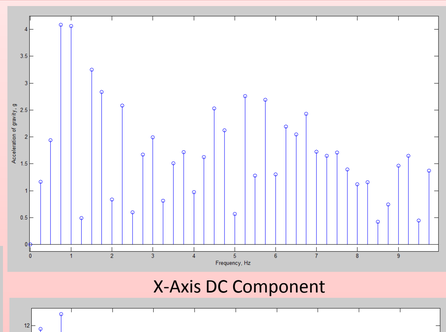


Y-Axis DC Component

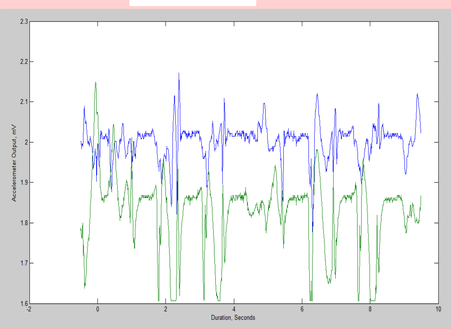
- Peak *g* for X-Axis is at 1.5 Hz while for Y-Axis is at 1.5 Hz.
- Both axis' are of the same frequency because the to and fro motion of the foot is similar with each foot strike. (A set of to and fro movement equals to a foot strike.)
- Also notice the X-Axis has a higher amplitude, this is due to the swing in the foot during the to and fro motion as the accelerometer is placed on the side of the ankle during experiment.



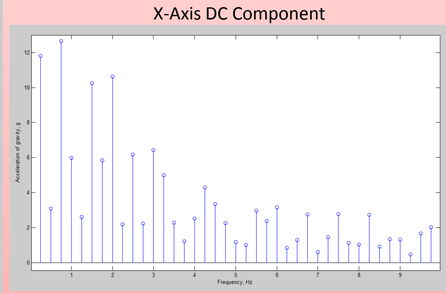
Foot



X-Axis DC Component



Blue: X-Axis Green: Y-Axis



Y-Axis DC Component

- Peak *g* for X-Axis is at 1 Hz while for Y-Axis is at 0.75 Hz.
- Both Axis' are at about the same frequency but notice the Y-Axis' amplitude. It is much higher than the X-Axis due to the heel strike of the foot. And as the foot itself doesn't sway as much, X-Axis' amplitude is considerably less than normal as well.

Vibrations and Human Movements

If compared, "typical" vibrations are easier to manipulate than human movements. Human movement portrays motion of randomness. Vibrations generated from repetitive human actions will not even be the same (graphs attached). However, the vibrations generated from machines for example can be easily manipulated by adjusting the machine's speed and characteristics. Thus the difference between human movements and the "typical" vibration.

Linear and Non-Linear Energy Harvesting

Linear	Non-Linear
Must resonate at a Frequency that is close to the source frequency	Non-resonant systems that can be operated at low frequencies
Narrow bandwidth (High Q-factor)	Wider bandwidth
Can be easily constructed with cantilevers and pendula	Harder to construct compared to linear systems

So why Human Movement with Motion induced Non-Linear Energy Harvesting?

As human motions are unpredictable as well as random, pairing the Non-Linear Energy Harvesting system with it would seem to be a better move compared to a Linear System because:
- Non-Linear Energy Harvester returns a higher power output than its Linear cousin albeit more complex .
- It has a wider bandwidth and is able to work much better in the low frequency environment. (Human walk is about 1 to 3 Hz).
- Does not require as frequent tuning compared to Linear Systems.

Why Human Movement?

Medical patients who need to be monitored are always laden with sensors that will compromise their movement with wires and cables attached to them to provide power to the sensors.

And as the patient still needs to move to "operate", these motions and movements can be used as a power generating tools to help minimize the use of wires attached to them by coming up with a medical sensory box that will have all the above mentioned sensors encased in a wireless case.

The box will then include the medical sensors required as well as the energy harvester to enable power generation while the patient is on the move.

References:
(1) The Energy Story - Introduction: http://www.energyquest.ca.gov/story/index.html#table accessed on the 23rd Oct 2009.
(2) Dictionary (Harvest): http://dictionary.reference.com/browse/harvest accessed on the 15th July 2010.