

# **The “Stop-It” Anti-fidgeting Device**

By

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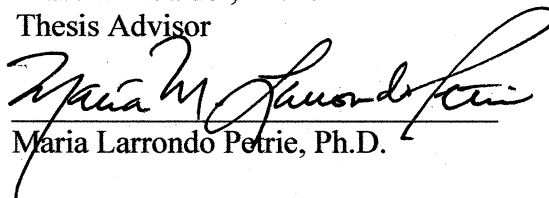
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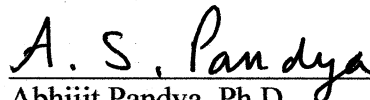


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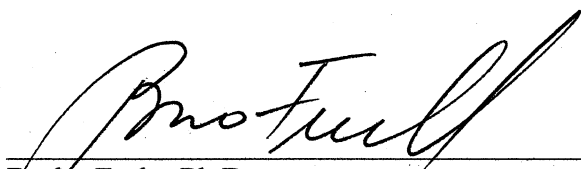
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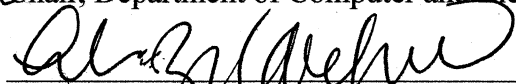


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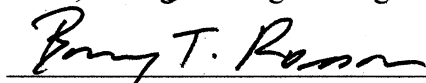
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## **Abstract**

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Fidgeting and otherwise constant movements in individuals can be beneficial in those who suffer from Attention Deficit/Hyperactivity Disorder or Generalized Anxiety Disorder as well as others. However this constant movement can also be a distraction to others as well as protrude an air of no self confidence. It is the drawbacks from these actions that we wish to address. By developing an intelligent system that can detect these motions and alert the user, it will allow the wearer of the device to self correct. It is in this self control that one may exhibit more confidence or simply reduce the level of irritation experienced by those in the immediate vicinity. We have designed and built a low cost, mobile, lightweight, untethered, wearable prototype device. It will detect these actions and deliver user selectable biofeedback through a light emitting diode, buzzer, vibromotor or an electric shock to allow for self control.

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# **Chapter 1: Introduction**

## **1.0 Overview**

Various types of limb movements are the result of very different conditions. It has been said that some of these actions are helpful whereas others have been described as a rude distraction to people. Still some see them as nothing more than the formation of a bad habit. Therefore we have made it our responsibility to investigate the reasons for such activity and design a device to allow the individual to become aware and control these movements.

## **1.1 Problem Statement**

Fidgeting and self-stimulation are two common examples of such limb movements and can be beneficial for individuals with certain conditions. They can help to alleviate discomfort [Yoa2006, Wil1996, NIH2001, All2003, Sle2007], decrease stress [Eva2008], retard weight gain [Min1999, Wik2009a], counteract boredom [Say2009] or allow an individual to escape to a more comfortable reality [Mas2008, Nic2001]. Unfortunately there are times when such actions are frowned upon and should be suppressed even if only temporarily. It is our intention to introduce a solution to allow an individual to control themselves when a time of excessive movement may be seen as inappropriate.

## **1.2 Background**

Those with Restless Legs Syndrome (RLS) will move their legs about as a relief of discomfort [Yoa2006, Wil1996, NIH2001, All2003, Sle2007] and people with Periodic Limb Movement Disorder (PLMD) will experience involuntary limb convulsions [Gal2007a, And2005, Sle2006, Sle2007]. Those who suffer from Attention Deficit Hyperactivity Disorder (ADHD) will fidget to help with concentration when working memory is needed [Clo2009, Edg2009, Upi2009] and it helps those suffering from Generalized Anxiety Disorder (GAD) to alleviate the anxiety that accompanies day-to-day living [Eva2008]. Individuals with autism will perform self-stimulation, or stimming, to heighten or lessen the senses when they feel it necessary [Mas2008, Nic2001].

## **1.3 Motivation**

Whatever reason one has to fidget, self-stimulate or move about restlessly, there are times when it is inappropriate. Giving a presentation to a group of people to whom one is trying to sell a product or idea is our first example. SlideShare is an online community available for individuals and companies to upload and view presentations as well as other documents for others to review [Cru2009]. According to them, number four on their list of bad habits to have during a presentation is fidgeting. It reflects nervousness and insecurity and does not merit comfort from the audience [Sli2009].

Presentations are ways of communicating ideas effectively to a group. The characteristic that separates presentations from another communiqué such as a report is that the presentation carries the speaker's personality with it. One of the most valuable

tools available to a speaker, after their voice, is their body language and control. People normally not only listen to the presentation but they also watch the presenter. Fidgeting reflects nervousness or insecurity. These habits inspire no confidence in the speaker and good posture tells the audience that one knows what they are doing and that they care deeply for the topic [Cla2007].

The same holds true for job interviews. Carmine Gallo is a communications skills coach who has worked with the top professionals at companies such as IBM, Intel, Home Depot and others. He writes a weekly leadership and communications column for BusinessWeek.com and is an expert in public speaking, presentation skills and communications skills [Gal2009]. In one of his articles he pointed to an informal interview with Sergeant Matt Eversmann of the United States Army. The troops that he commanded needed to believe that their leader was strong and confident in times of uncertainty and Mr. Gallo related this to the corporate world. Potential employers need to know that the top candidate for employment will be able to stand like an oak and be a leader. Fidgeting only makes one look unsure, nervous and unprepared. [Gal2007b].

Fidgeting can have one removed from a sporting event as well. This is the case for the St. Louis Chess Club and Scholastic Center. Where being quiet is a prime directive for spectators at a chess tournament, much like golf, it is outlined in an etiquette card that is handed out at the beginning. The usual suspects are highlighted such as talking, cell phones, food wrappers as well as fidgeting. We have stated that fidgeting can be a distraction to others, in the rules here it can get you removed. If a player feels that a spectators presence is a disturbance to their game then they can have the tournament director require that the spectator be moved away from the game [Hol2009]. This trend

could easily spread to other chess clubs and maybe to other sports. So much for our obligation to heckle the opponents at the next baseball game.

The sight of someone fidgeting or stimming can be distracting in times of formality. Weddings for example can be overly formal and ceremonious. The guests however must adhere to the rules of etiquette the same as those who are footing the bill. It is the host's job to deliver speeches they may not want to give and it is the guest's job to be patient and listen. "There is nothing ruder than a person who is constantly fidgeting in plain view when the speeches are being given" [Git2007].

At the collegiate level more students are entering college ill-prepared, unmotivated and without an understanding of basic classroom civility and etiquette. In most cases the students are not intentionally rude, but can be immature, annoying and disruptive. An instructor at Villanova University issues a formal class document for expected classroom behavior. On the list of negative test taking activities in which to refrain is knee bouncing, a form of fidgeting, as this can be a distraction to others. Exams are stressful enough that the students need not be bothered with that as well. Even if it is tolerated during regular class time [Wil2007].

There are also times when it is less tolerated during class time. Fidgeting can be most distracting in situations where it is felt more than seen. In a common classroom setting, chairs can be connected to desks that are meant for more than one person. Knee bouncing and foot wriggling in a situation such as this will generate movement in the entire table. It is at a time such as this that fidgeting suppression is most appreciated [Sla2006].

## **1.4 Approach**

Fidgeting and self-stimulation due to the various disorders and syndromes at times can be less than acceptable. It is in these times that an individual should have the ability to maintain some sense of control. If they are unable to handle such a task on their own then outside help may be a plausible alternative. This alternative can be in the form of another person who helps to maintain stability in someone who may lack the necessary self discipline. It can also be that of a device that will serve as a reminder to those that do have the will power but just find themselves forgetting.

We propose a solution to end these fidgeting movements in inappropriate times by developing a system that will detect these actions. The device will pick up the movements for a specified amount of time before turning on an indicator. This reminder will inform the proper person so that said action can be stopped before it goes on for too long. In some cases the person to inform might be the individual wearing the device, and in other cases, such as stimming motions in the autistic, someone else might have the partial responsibility of suppressing the actions of another. This will be the difference in internal and external indicators as we will see later.

The device that is being proposed will be a system on a single board and small enough to be worn comfortably in the area of the most activity. The strap to be used will be a simple hook and latch system such as Velcro as this gives a fair amount of flexibility in handling different sizes of the problematic areas. If the fidgeting is more persistent in the ankle such as in persons who are more prevalent to foot wriggling then it will be able to be worn around the ankle. If knee or leg bouncing is more common then wearing it above the knee will be a more efficient placement of the device. An individual with



autism might implement hand flapping as their means of stimming. In this situation, placement of the device on the wrist would be more appropriate.

## **1.5 Organization of the Thesis**

The remaining sections of the thesis will continue as follows. Chapter two will be a literature review of the problem. It will be an examination of the history of the conditions that result in these repetitive behaviors.

Chapter three is a comparison of products, patents and academic reviews that relate to repetitive limb movement. Some offer solutions to the underlying conditions while others may use a technique that is of interest to our research.

Chapter four will be a detailed explanation of our solution. It will relate to the hardware as well as the software and how they will work together. It is in this solution that one can suppress their own actions.

Chapter five will cover our conclusions and recommended research. This will be our final remarks and suggested directions for future solutions. It is here that one will find our references for further review.

## **Chapter 2: Literature Search**

### **2.0 Overview**

The following literature looks at different aspects of limb movements. We will look at different reasons one might feel the need to move their legs or whether it is an involuntary act. It is our higher understanding of the underlying problem that we might better be able to derive a solution.

### **2.1 History and Causes**

The following sections relate to the history and background of several relevant conditions that cause voluntary or involuntary leg movements. Some of these conditions can have serious consequences whereas some may be no more than a mild distraction. Yet another is an affliction that is active most times unbeknownst to the individual.

#### **2.1.1 Restless Legs Syndrome**

A common medicinal reason for constant movement in the lower legs is known as Restless Legs Syndrome (RLS). RLS is a term coined by Karl-Axel Ekbom, Figure 2.1, a professor of neurology from Gothenburg, Sweden, circa 1944. He called it “Asthenia crurum paraesthetica” which translated to “irritable legs”. It was in 1945 with the publication of “Restless Legs” by Ekbom that described the disease and introduced eight actual cases. Hence the disorder is also known as “Ekbom’s disease”. The word

syndrome was added later to indicate the diagnosis was due to symptoms rather than a pathological system. Ekbom described the feelings as weakness or cold sensations in the legs causing irritation and the need for constant resituating in order to find a more comfortable position [Rls].



Figure 2.1 Karl-Axel Ekbom from [Rls]



Figure 2.2 Thomas Willis from [Rls]

Whereas Ekbom gave RLS its official name, the disease was actually first described several hundred years earlier. In the mid 1600's an English physician by the name of Thomas Willis, Figure 2.2, with a specialty of the nervous system, wrote about a case in which the symptoms that he described in London Practice of Physik were the same as those for RLS by today's standards [Rls]. He called it the Watching Evil, which was insomnia due to discomfort of the arms or legs. Willis believed that a spinal cord irritation may cause this discomfort in the limbs. Although the cause of RLS is idiopathic [Yoa2006], or unknown, some research has identified a connection between the cerebrospinal fluid and lower levels of dopamine or iron-deficiency [Wik2009c]. Willis also suggested that a cure for the Watching Evil be blood letting [Rls]. The relevance being that iron deficiency anemia happens to be a blood disorder [Iro2007].

Over 12 million Americans are diagnosed as having RLS. The number of Americans that actually suffer from the symptoms of RLS is expected to be around 40

million. The underdiagnosis is a result of people believing that they cannot be helped or have symptoms too mild to pursue medically [Yoa2006, NIH2001].

What is Restless Legs Syndrome? RLS is a neurological disorder characterized by unpleasant sensations in the legs and an uncontrollable urge to move when at rest in an effort to relieve these feelings [NIH2001]. The range of metaphors used in an attempt to describe these feelings made it difficult for doctors to diagnose patients with RLS. It's these creepy crawly sensations that one gets in the deep regions of the lower legs when relaxing that cause unrest. Some of the descriptions of these feelings are as follows: "A toothache in my legs...with Pepsi-cola in my veins", tickling pain, rats crawling on legs [Wil1996], the list of imagery is lengthy. A person with RLS may not be able to portray these feelings to someone who does not have RLS, however, someone with RLS would understand completely the sensations that are being depicted and would yet relate differently to what they feel [Wik2009c]. It is these sensations that denies an individual the ability to remain at ease. This discomfort is only alleviated by motion of the affected extremities [Yoa2006, Wil1996, NIH2001, All2003, Iro2007, Wik2009c]. This motion can be as simple as a rapid wiggling of the foot or bouncing of a knee up and down [All2003]. But the most often used form of relief comes in the form of walking. Because the symptoms happen mostly at night, sufferers find themselves walking throughout the night to relieve the discomfort. This has caused sufferers of RLS to be given the nickname of Nightwalkers [Yoa2006].

Since this syndrome is primarily a nighttime affliction it has been categorized as a sleep disorder [Wil1996]. The sensations in the legs of sufferers inhibit the ability to go to sleep at night. Therefore, the results are too many nights of not enough sleep or even

no sleep [Yoa2006]. The consequences can range from just being tired the next day, to inability to focus on your job, to extreme exhaustion [NIH2001]. Some have lost jobs, been ridiculed by family, and even gone so far as to consider self-mutilation and suicide [Yoa2006]. One author mentioned her personal experiences. “Often I fell asleep trying to eat and my head fell face-down into my filled plate... sat in armchairs to keep me from falling sideways onto the floor. I took a walk one morning and I fell asleep and crashed to the sidewalk”. Falling asleep at the wheel is another common occurrence as a result of RLS [Wil1996]. That is as real as it gets.

There are some links that might help scientists eventually find the causes of Primary Restless Legs Syndrome (when there are no underlying conditions). Women are more likely to suffer from RLS as men [Yoa2006]. Caucasians are more likely to be diagnosed with RLS over African-Americans [Wik2009c]. And there has been evidence of a familial connection in approximately 50% of the cases [All2003]. Whereas the symptoms of RLS usually do not begin to appear in an individual until they reach their forties or even later, it is these genetic cases that will show signs in the younger ages [NIH2001]. Therefore heredity is an apparent concern. There are also connections between lower levels of dopamine or iron deficiency and RLS. Since these iron and dopamine deficiencies are usually the result of an underlying condition, they result in Secondary RLS. There has been a significant amount of success with pharmaceutical treatments of RLS aimed at increasing these levels or treating the catalyst condition [NIH2001]. The administration of levodopa (L-Dopa), which the body turns into dopamine, is a treatment for Parkinson’s Disease and has shown to greatly reduce the

symptoms of RLS [NIH2001]. Improving the iron levels in the body has shown a decrease in the symptoms of Restless Legs Syndrome as well [NIH2001].

### **2.1.2 Periodic Limb Movements Disorder**

Another disorder common to leg movement is known as Periodic Limb Movements (PLM). Periodic Limb Movement is when someone experiences episodes of simple repetitive muscle movements in the legs and sometimes the arms as well. While this primarily occurs during sleep (Periodic Limb Movement during Sleep or PLMS), there are more severe cases that do happen while a person is awake (Periodic Limb Movement while aWake or PLMW). If these periodic movements fulfill a minimum criteria then it will be classified as Periodic Limb Movement Disorder (PLMD) [Sle2006]. Of those that are diagnosed with RLS, 80% are also diagnosed with Periodic Limb Movement Disorder [NIH2001]. This is not inversely true with PLMD [And2005]. In contrast to RLS, Periodic Limb Movement Disorder (also known as nocturnal myoclonus) is involuntary movement and will at least allow a person to fall asleep. Whereas RLS is voluntary movement due to discomfort and not allowing any sleep.

Periodic Limb Movement Disorder was also being described by Sir Thomas Willis in “...Physik” as a “leapings and contractions of the arms and legs”. We notice in Willis’ description that he mentions arms [Yoa2006]. A small percentage of people with PLMD experience it in the arms as well, this is why Limb is used in the name in lieu of Leg even though a large majority of people with this disorder are affected in the legs only [Yoa2006]. It was formally described in the 1950’s and in the 70’s was listed as a potential cause of insomnia. It was in 1979, though, that the Association of Sleep Disorder Centers set the official parameters for determining the presence of PLMD. “A

formal diagnosis of nocturnal myoclonus requires three periods during the night, lasting from a few minutes to an hour or more, each containing at least 30 movements followed by partial arousal or awakening” [Sle2007].

When breaking down the name of the disorder, Periodic, implies that the movement during sleep is regular. When an episode occurs these movements fall in the range of between twenty and forty seconds apart [And2005]. Even though the convulsive movements are usually confined to the legs, they do sometimes include the arms as well. Therefore Limb is used in lieu of Legs [Yoa2006] and Movement is descriptive of the minor slow convulsion that takes place.

The causes of Primary PLMD, like that of Restless Legs Syndrome, are unknown [And2005] although they both share some of the same links such as hereditary connections, or lower dopamine levels [Gal2007a]. Secondary PLMD is a by-product of other conditions such as diabetes, a spinal cord tumor or injury, narcolepsy and iron deficiency. The symptoms of PLMD are not leg movements, but poor sleep and daytime sleepiness and not knowing why. This is due to the fact that most PLMD sufferers do not know that they have it unless a “bed partner” informs them [And2005]. This is in contrast to those with RLS, who know why their sleep is hindered. The biggest problem comes for those with RLS who also have PLMD. RLS denies one of the quantity of sleep and PLMD will deny them of the quality of sleep [Yoa2006].

Where there are no tests that can be done to detect PLMD [Yoa2006], a physician can perform bloodwork to see if any of the underlying conditions are met that result in PLMD [And2005]. However, one can have themselves monitored for Primary PLMD using a polysomnography. This will detect and record the convulsions during sleep and if

they follow a certain, fairly strict criteria then PLMD can be confirmed [Yoa2006]. These criteria as mentioned before are, “three periods during the night, lasting from a few minutes to an hour or more, each containing at least 30 movements followed by partial arousal or awakening.” If another opinion is desired then a referral to a neurologist can rule out all other possibilities to solidify the results of the polysomnography [And2005].

There is no current cure for PLMD [Sle2007]. However, to treat it a physician can prescribe various medications to help the sleep process. Dopamine is a neurological messenger that regulates muscle movement, therefore L-Dopa is a common prescription used to boost dopamine production. Various anticonvulsants can be used to reduce muscle contractions. And baclofen is a prescription often given to inhibit the neurotransmitters that enhance muscle contraction [And2005].

### **2.1.3 Autism**

Next we include autism and its sensorimotor issues. The word autism has been around for about 100 years and is from the Greek “autos” meaning self. Swiss psychiatrist Eugen Bleuler, Figure 2.3, first used the term, which translated to “escape from reality”, in 1911 “to refer to one group of symptoms of schizophrenia”. Austrian psychiatrist Leo Kanner, Figure 2.4, Johns Hopkins University, eventually adopted the term in the 1940’s to describe the withdrawn behavior of some of the children whom he had been studying [WebMD2008]. He recorded a pattern of symptoms in children that would have normally been called emotionally disturbed or mentally retarded. But because Kanner saw capabilities in these children and they were in fact not mentally disturbed he needed a new category, he called it Early Infantile Autism (Kanner’s Syndrome) [Wob2009].



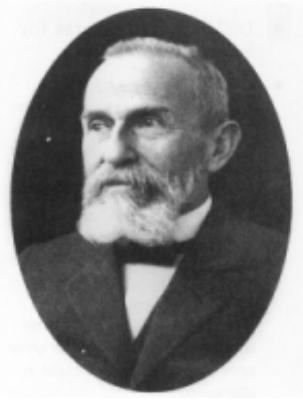


Figure 2.3 Eugene Bleuler from [Wik2009g]



Figure 2.4 Leo Kanner from [Wik2009d]

Autism and schizophrenia were considered linked until the 1960's when researchers were able to differentiate between the two in children. After a while psychiatrists were able to develop a way of describing autism and related conditions. As a whole these conditions were categorized as Pervasive Development Disorder (PDD). Within PDD is the Autism Spectrum Disorder (ASD) [WebMD2008]. This is the generalized category of disorders that have similar features yet one person might have mild symptoms while another could have a more severe case. But both have an autism spectrum disorder.

Earlier treatments for autism included medications such as LSD, electric shock and behavior change techniques that include pain and punishment. It is these behaviors that we will be focusing on here. One of the symptoms of autism is repetitive behaviors, stereotypic behaviors, such as rocking, head-rolling, arm waving and other such movements [Ede2007, Wik2009b]. When autism is accompanied with more severe mental retardation, these stereotypic movements become more frequent [Hue2001]. Behavioral therapies try to reinforce positive behaviors and reduce the unwanted behaviors usually implemented using Applied Behavioral Analysis (ABA) [Nih2008].

ABA is the use of behavior analytic methods and research findings to change socially important behaviors in meaningful ways [Cam].

These repetitive movements are referred to as self-stimulation, or stimming, and is used for sensory stimulation. It is a common autistic symptom. These repetitive behaviors are used to stimulate the senses as well as allow them to retreat to something familiar in an unfamiliar setting [Eva2008]. The list of stimming practices include those which are pleasurable to each of the senses [Nic2001]. These can be touch, smell, hearing and sight. An autistic person might stare at a light or repeatedly blink their eyes because it pleases the sense of sight. They have been known to snap their fingers or make noises to stimulate their sense of hearing. Vestibular movements stimulate the sense of equilibrium and are common in the autistic. Examples include rocking and neck-rolling [Ede2007].

Self-stimulating behavior is not confined only to the autistic community. Ordinary individuals will engage in hair twirling, pencil biting or other activity to counteract boredom or stress. So most people need these stimulations, however the autistic need it at a higher level [Say2009]. A lot of these “leisure activities” are nothing more than stimming behaviors that provide a particular type of sensory input and became highly ritualized over time and made socially acceptable [Mos1993].

Stimming has several purposes. If the surroundings are too exciting for someone autistic they might perform what is to them a calming action. Sometimes referred to as zoning out [Mas2008]. Staring at a crumbled-up piece of string is a good example. This is not listed as an official stim, but because no two autistic children are the same, if it is used as a calming effect to an autistic child then it is a stim nonetheless. By contrast if the

surroundings are too boring they will do something that is to them more stimulating [Ede2007]. This is where the more inappropriate stims have a better chance of being acted upon such as waving the arms, running around or moving the legs about erratically.

If a stim is deemed inappropriate then controlling when and where it is used might be more productive than trying to get rid of it altogether. What if it is replaced by another even more improper stimming action [Mas2008]? Because stims are a necessary outlet for the autistic, it might be more beneficial for the guardian to encourage the less popular stims be done at home or in an otherwise more manageable environment. Sometimes these bad behaviors can simply go unnoticed by the autistic child and if they are reminded that they need to stop then that is what they will do. Another way of responding to the more destructive stimming is to join in with them. Not the too destructive actions anyway. If the child is doing something that is only mildly inappropriate, the article used ripping paper as an example, then this would not look good in public, yet at home this could be an opportunity to interact with the child [Mas2008].

#### **2.1.4 Generalized Anxiety Disorder**

In our examination of overactive limb movements, anxiety and its many levels presented itself as a probable source. About 18% of American adults experience anxiety of one form or another as well as some children [Nih2007]. As a primary emotion, anxiety has long been viewed as an adaptive means in preparing for threat and danger and is believed to be experienced by everyone at some time and at some level. The differences in the levels could be characterized by whether the anxiety is reliably cued by an event or if it is a spontaneous occurrence. This in addition to how the anxiety is handled, whether that event is avoided or if a person will perform certain rituals or safety

behaviors for protection [McL2001]. Here we briefly examine some of the primary disorders at the differing levels.

A *panic disorder* is uncued and unexpected, meaning that you do not see it coming, it just happens for no apparent reason. It is a feeling of intense anxiety that may last a few minutes or a few hours. With it comes a rapid heartbeat, shortness of breath, sweating and clammy hands. There is a domineering thought of a catastrophic occurrence [McL2001]. *Specific Phobia*, on the other hand, one can see it coming. Like the name suggests it is a fear of something specific and can be avoided in most circumstances. If someone has a fear of parking meters then it can be fairly easy to avoid them. However, the authors suggest, that if one has a fear of bridges then don't live in Stockholm [McL2001]. *Social Phobia* is generally a fear of a negative evaluation from others triggered by social interactions. It is mostly like Specific Phobia in that these interactions can be avoided but can also be like Panic Disorder in which a social interaction can be unforeseen. A person with Social Phobia can in fact be socially competent under normal circumstances, meeting with friends, but start to feel nervous under special circumstances such as public speaking [McL2001].

Individuals with *Obsessive Compulsive Disorder* will engage in seemingly excessive or illogical activities in order to neutralize the anxiety they feel after an intrusive thought or action. Some examples include constantly checking under the car because the person was afraid that they had hit someone. Continually turning the outside hose on and off because they are not sure it is really off, or a child that needs to arrange and then rearrange items in their bedroom until they are just right [McL2001]. *Generalized Anxiety Disorder* is a persistent uncontrollable worry about the same

problems that anybody with any kind of responsibility would have to confront on a daily basis. These are such things as finances, relationships, school and are accompanied by muscle tension, irritation, and insomnia [McL2001, Spe2009]. *Posttraumatic Stress Disorder* is associated with exposure to a situation in which there was a serious threat of injury or death. It can be triggered by a sound, smell, taste or anything that was a reminder of said situation [McL2001].

We will be looking at Generalized Anxiety Disorder, GAD, more closely for the purposes of this paper. People with GAD will worry excessively about things that are unlikely to happen. They will also worry about the small issues that everyone else does. Minor things like relationships, work, money and health for instance with the exception that they will be more frequent and taken to a higher level. A simple comment about a bad economy and a person with GAD will start to have snowballing visions of an impending pink slip [Smi2008a] that leads to foreclosure on your home and then a divorce. Because this worry can go on all day long it will take a physical toll on the body. The body aches, you can't sleep and are exhausted all the time [Smi2008a].

Rather than letting this anxiety take over and control one's life there are ways of handling it. Some self help remedies that can help an individual accept the nervousness and in some cases increase relaxation can be attempted, such as accepting uncertainty. One problem for people with GAD is that they worry about what they do not know. Since it is impossible to know and predict everything, these individuals need to try and release themselves from that burden. Another direction is to set aside a worry period. Set a time of the day that you are allowed to worry, the rest of the day is "worry-free". This

technique helps to at least reduce that amount of time during the day where anxiety is a problem, giving that person more control over their life [Smi2008b].

Jumping to worst case scenario is a common characteristic of those with GAD. Challenging these cognitive distortions can also be effective. Essentially this is really thinking about the situation that is bothersome and considering the chances that such an event will actually take place as compared to the chance that it will not happen. Forcing oneself to slow down and think about whether worrying will actually do any good.

Finally, simply taking care of oneself. A proper diet of complex carbohydrates can stabilize blood sugar, which when low can cause irritability and anxiousness, as well as increase levels of serotonin which can have a calming affect on the nervous system. Exercising relieves tension and stress and boosts physical and mental energy. And just as important, enhances well being by releasing endorphins, the brain's feel-good chemical [Smi2008b].

Some of the symptoms of GAD are fatigue, muscle tension, aches, nausea, fidgeting, hot flashes and irritability [Spe2009, Wik2009a]. It is the fidgeting that we are concerned with here along with its good and bad points. Fidgeting is the act of moving about restlessly and may be a result of nervousness, agitation or boredom and can often be an unconscious act. Bouncing one's leg repeatedly is one act and so is playing with a ring on a finger [Wik2009a]. While parents often consider fidgeting to be bad, research is being done to support the idea that fidgeting in some cases can be beneficial [Clo2009, Edg2009, Upi2009, Min1999, Wik2009a]. As in the case of weight loss, people who fidget are generally slimmer and find it harder to put on weight. Fidgeting is now being

considered a nonexercise activity that can burn as much as 800 calories in a day [Min1999].

### **2.1.5 Attention Deficit/Hyperactivity Disorder**

The last condition we will be focusing on for this paper is Attention Deficit/Hyperactivity Disorder (ADHD). ADHD is one of the most common childhood disorders that can continue through adolescence and adulthood. Scientists are still unsure of what really causes ADHD however some studies do suggest that genes may play a role. And like many other illnesses ADHD may actually be a combination of other factors such as brain injuries, nutrition and environment.

Children with a particular version of a gene had thinner brain tissue in the areas of the brain associated with attention. As the children with this gene grew, their brain developed to a normal thickness level and the symptoms of ADHD improved as well. In addition, if a woman was in contact with cigarette smoke or alcohol during pregnancy then those environmental hazards have shown a potential link to ADHD. So has post-natal children exposed to high levels of lead, like that which can be found in plumbing fixtures or the paint of older buildings. Children who have experienced non-traumatic brain injuries have also shown an increase in ADHD behavioral symptoms. And although it is a popular belief that sugar enhances the symptoms of Attention Deficit/Hyperactivity Disorder, more research is discounting this theory.

There are three subtypes of ADHD. Predominantly hyperactive-impulsive, predominantly inattentive, and a combination of both. In order to determine which disorder a child might have is dependent on the symptoms that they display. These symptoms are split into two categories relating to inattentiveness or hyperactivity. The

inattentive symptoms relate to children who seem more like daydreamers. Whereas those with hyperactivity seem to be overly stimulated. If a child exhibits six or more symptoms in one of these categories for a period of six months then they can be diagnosed as having one or the other. Those children that exhibit symptoms in both classes can be classified as having the combination of inattentiveness and hyperactivity [Nim2008].

Some of the symptoms in the hyperactivity category is fidgeting and squirminess. They might talk nonstop, have difficulty doing quiet tasks, dash around and generally be in constant motion. This is what brings us to ADHD and its connection with Generalized Anxiety Disorder. Fidgeting is a common symptom for both. Where GAD and ADHD can both be treated with medications we want to look at more of a behavioral approach.

One of the symptoms for children with Attention Deficit Hyperactivity Disorder is a tendency to fidget more than those who do not suffer from ADHD. At first many parents would try to get them to stop assuming that, if they could, the kids might be able to concentrate a little more [Clo2009]. However, studies performed at the University of Central Florida has shown that fidgeting allows ADHD sufferers to keep their minds and bodies active since their brains do not produce enough dopamine to maintain alertness [Upi2009].

The study showed that children with ADHD had a hard time with their short-term memory because they lacked adequate cortical arousal [Clo2009], this is the firing patterns in the cerebral cortex [CBS2004]. Their squirms and fidgets helped to stimulate that arousal in order to help them concentrate on tasks that would require a stronger working memory. However, when these same kids were allowed to watch a scene from a



movie that required no working memory even the ADHD kids were sitting still in their seats [Clo2009].

Fidgeting is not only used as a stimulation during a need for concentration. If an ADHD mind gets bored it starts to get sluggish. Brain scans of people with ADHD show that during boring repetitive tasks the pre-frontal cortex of the brain slows down and the mindless activity of fidgeting helps to self-regulate and stay focused [Edg2009].

Fidgeting is something that everyone does to some degree or another. If done right then those with ADHD can manage their symptoms unnoticeable to others. Fidgeting should be kept respectable, no clicking pens during a meeting or bouncing a knee up and down or wiggling your foot while sitting in a row of chairs with others. And it is good practice to not allow these movements to interfere with primary tasks. So overall fidgeting can be beneficial as long as it is kept where it belongs, away from others and out of sight. It is this fidgeting and stimming as a distraction that will be addressed in this paper.

## **Chapter 3: Current Solutions**

### **3.0 Survey of Devices and Methods**

Actigraphy, a method of monitoring human activity, and motion detection has been used in many studies and products. They range in systems as large as desktop computers to much smaller devices composed almost entirely of a thin film of plastic less than a foot long. Some are used for extensive testing and will maintain many hours worth of data whereas others will simply use counters incremented by sensor inputs. This chapter will look at previous works by companies and individuals relating to this problem. We will investigate current products available for purchase as well as patents and patent applications that are relevant to the problem. In our search we located several theses and dissertations that used devices or procedures relative to our research.

### **3.1 Products**

The following subsections relate to several products on the market that address, in some form or another, limb movement. Some are for the purpose of detection and others are for the relief of symptoms. However all are available for purchase either for personal reasons or for company use.

### 3.1.1 Leg-Wrap

Magnopulse is a company based in Bristol, England and established in 1996 whose specialty is the development of magnetic therapy products [Mag2009]. Magnetotherapy, also known as magnotherapy [Wik2009e], is an alternative to conventional medicines that uses magnetism, either static or pulsed, to treat an ailment [Ihl2006]. It is suggested that magnotherapy can help improve your circulation by stimulating blood flow and moving more essential nutrients and oxygen to your vital organs, muscles and joints [Magb]. However there is not enough documentation to suggest that this is true but there are testimonials to its success [Mag2009, Ihl2006].

Using this idea, Magnopulse created a band that is used to alleviate the discomfort associated with Restless Legs Syndrome that they call the Leg-wrap, Figure 3.1. This wrap is simply a velcroed band that is worn under the knee and just above the calf and incorporates several magnets sewn within the band to help with circulation [Mag2009]. Although this product is available and for sale there is no documented proof that Magnetotherapy is anything more than a placebo [Wik2009e]. Pharmaceutical solutions still appear to be the most recommended solution to the treatment of RLS. Where a solution such as this is feasible for the relief of discomfort in the limbs it does not achieve the detection of limb movement and biofeedback.



Figure 3.1 Leg Wrap from [Mag2009a]

### **3.1.2 Alpha-Trace**

The detection method used to diagnose Periodic Limb Movement Disorder is called polysomnography. The term derives from Greek, where “poly” means many, “somno” meaning sleep and “graph” meaning to write. Therefore, the polysomnography is used to perform multiple tests on someone sleeping to determine possible sleep disorders. Any mechanism used to perform polysomnography measures and records several physiologies that include heart rate, breathing, eye movement, chest movement, oxygen saturation and yes leg movements [Wik2009f]. One is connected to so many wires as to make them feel like a marionette.

B.E.S.T. Medical Systems is a company out of Vienna, Austria and has been developing computer based diagnostic equipment for Neurophysiology and Sleep Labs over the past 20 years. Their Alpha-Trace line of products employ what they call the “Graphic Working Plan” which is software that coordinates the system database, Figure 3.2 is a depiction of the interface. The Graphic Working Plan is an intuitive interface and makes available up-to-date information on all networked Alpha-Trace products. A single click can give the user information on a patient for the current session as well as previous sessions for comparison. The Alpha-Trace Digital Sleep, shown in Figure 3.3, is equipped with its own monitor, keyboard, mouse and hard drive. Because this system is so extensive with the amount of hardware that accompanies it that mobility is less of an option. However it can be rolled into a room or even attached to a bed or table [Bes2004]. The Alpha-Trace is more than sufficient for the detection of limb movements however does not give instant biofeedback and is not a system designed to be worn by an individual.



Figure 3.2 Graphic Working Plan from [Bes2004]



Figure 3.3 Alpha-Trace Digital Sleep from [Bes2004]

### 3.1.3 Trackit

On the other hand Lifelines LMT, out of the United Kingdom, provides a home version called the Trackit™ Sleep walker [Lif2006], several views are shown in Figure 3.4 below. Whereas the Alpha-Trace Sleep is the size of a computer workstation, desk included [Bes2004], the Trackit's largest dimension is 5.5 inches and weighs less than 400 grams, battery included. It can be worn across the chest in conjunction with built in sensors while sleeping to allow for a no cables approach to the diagnosis. Unfortunately not all the measurements are supported this way. Sensor inputs are provided to monitor and record PLMD activity as well as several others. Only with the addition of this extra sensor transmitting to the main unit will limb movements be recorded. The standard battery will provide up to 13 hours of continuous operation to be recorded onto a compact flash card and optional Bluetooth will allow direct communication to a computer for operational management and recording as well [Lif2006]. This system does allow for more portability, however, it would still be somewhat cumbersome for everyday wear. This product is excellent for a polysomnography with more freedom of motion, however

it only outputs to another device for analyzation. Our device will be designed to provide a more immediate delivery of biofeedback.



Figure 3.4 Trackit from [Lif2006]

### 3.1.4 Pro-Tech

Where both of the previous polysomnography devices record and monitor, one thing that they do not provide is the actual sensor for detecting Periodic Limb Movements during Sleep. They only provide the inputs for them and the software needed to translate the data. Therefore a product such as the ones provided by Pro-Tech® Services, a global leader in manufacturing sleep diagnostic sensors, based in Washington will be needed as well. They offer a series of Periodic Limb Movement Sensors, shown in Figure 3.5, that employ an accelerometer using moving coil/permanent magnet sensor technology. Velcro is used to strap the sensor to the patients arm or leg and a wire connects to the system performing the polysomnography. This device receives its power through the wire to that connection therefore does not require additional batteries [Pro]. Although it is wearable and does pick up limb movements, unfortunately it is not a device that can operate without the use of a computer or other data capture and analyzation system. Our implementation will be completely self contained with no wires or cables necessary for the utilization of the device.



Figure 3.5 Pro-Tech from [Pro]



Figure 3.6 KickStrip from [Kic2003]

### 3.1.5 KickStrip

Next we introduce the disposable PLMD sensor the KickStrip<sup>®</sup>, Figure 3.6, developed by SLP Ltd. out of Israel [Kic2003]. This less accurate system can be used by a physician when there are suspicions that the patient might be suffering from Periodic Limb Movements during sleep. The KickStrip<sup>®</sup> is to be attached to the front of the leg, running from the just above the ankle to the top of the foot. It uses a flex movement sensor, or a strain gauge, for detection of movement and a CPU, software, LED, battery and display in an encasing in the head of the strip to count the movements in real-time. To activate the sensor one must place the strip on the leg and attach an activation sticker. The LED indicates that installation of the sticker was done properly. Deactivation upon waking is accomplished by removing the sensor and cutting the long sensor tail with scissors. The chemical display looks like a single digit seven segment display where all areas are a silver gray. After the CPU calculates the severity of the PLMs it will black out some of the segments permanently. It is suggested to wait at least one hour after removal before reading the results [Slp, Kic2003]. This is an inexpensive and less accurate detection method of possible limb movements but will give the user an indication

whether or not further testing may be required. However it does not relay instant biofeedback for immediate correction and that is the goal of our research.

### **3.1.6 Products Conclusion**

There are several products available for purchase that can detect general activity. As previously mentioned various motion and movement sensors will detect these movements and then send a signal to an additional device which in turn may record the signal. After a period of recording, the data may then be analyzed by yet another system or person for the determination of what the signal is implying. However there is yet a product available that will detect unnecessary limb movements and return immediate biofeedback for the purpose of self correction. Therefore we were unable to directly compare current products with that of our proposed solution

## **3.2 Patents**

The next section looks to the patent office to discover patents and patent applications that might have an impact on our research. Some of the patents look to correct the problems associated with limb movements while others simply offer another form of detection. They vary in complexity from the use of straps to the implementation of laser technology.

### **3.2.1 Nonexercise Activity Thermogenesis**

One patent application number 10/938,890, an artists depiction is shown in figure 3.7, in relation to fidgeting describes an activity monitoring device. Where our intention is to control fidgeting due to the annoyance to others, this device encourages fidgeting to



promote weight loss. It uses a three-axis tilt and vibration sensor to detect when the individual wearing the device is not fidgeting and alerts them. The casing has a display that can be used as the indicator to the user about the lack of motion or to change menu options with the scroll buttons. The suggested device incorporates either a speaker or a vibration motor as possible indicators whereas our proposed implementation will incorporate a Light Emitting Diode and an electric shock option as well [Pal2006].

The use of a 3-axis accelerometer is not specifically determined for the patent application in this comparison even though that will be our sensor of choice. However the capability to vary the sensitivity of said movement sensor is suggested and that will be the case with the development of our device as well. The difference is in how the devices will vary their sensitivities. This weight management system will use scroll buttons interacting with a display for the user to select the sensitivity and ours will use a potentiometer that is constantly being read by an analog to digital converter.

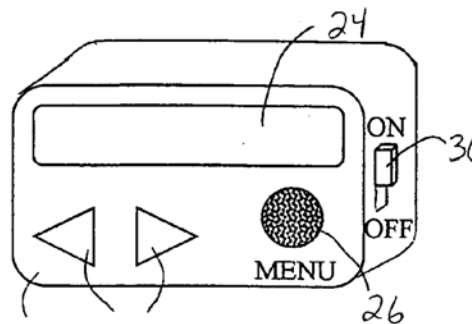


Figure 3.7 Nonexercise Activity Thermogenesis from [Pal2006]

The weight management method does give the user the ability to change the time intervals used for the measurement of inactivity which is in contrast to our design. It is our intention to detect fidgeting right away by measuring the sensor continuously, also through the analog to digital converter, for a small period of time and quickly give the

user biofeedback therefore the time interval will remain the same. And lastly the primary difference resides in the algorithm. Both devices use a movement sensor to send a signal to a microcontroller which processes and sends a signal to the desired indicators. Their algorithm will send a signal to the correct output when the movement sensor does not detect enough movement and our device will send a signal to the output when too much activity has been detected.

### 3.2.2 Foot Exercise

According to the National Institute of Neurological Disorders and Stroke (NINDS) excessive exercise has a tendency to aggravate the symptoms of RLS however a program of regular moderate exercise helps to alleviate the symptoms. An apparatus defined in patent application number US2008/0039303, and depicted in Figure 3.8, by Mr. Rodney Edward Wilcocks of Australia will allow the user to perform a minor amount of exercise while sitting and at rest by providing a force against the foot of one of the legs.

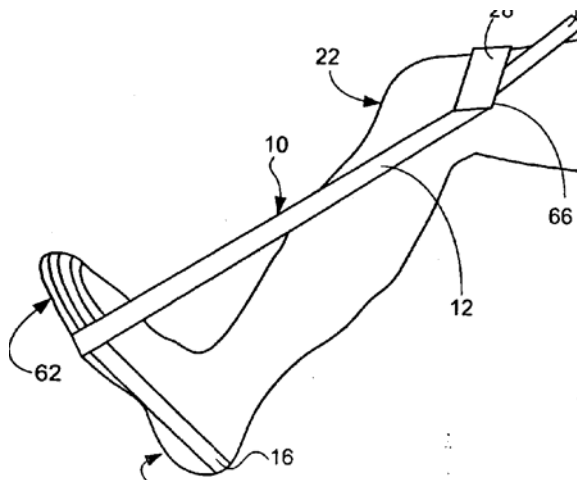


Figure 3.8 Foot Exercise from [Wil2008]

The device retards movement in the downward position of the foot allowing mild exercise of the lower leg. This system is secured on the foot by the elastic strap across the ball of the foot and an additional strap that goes around the back of the ankle. However, at the knee, the elastic strap is not secured by another traversing the circumference of the lower thigh. Instead, the system has a single strap that connects the elastic strap on either side just above the knee. As an extension of the elastic strap a handle allows the user to pull and readjust the device as necessary.

Because the device is not secured completely at the knee then the user should use the device while sitting. Or if comfortably sitting is not feasible at the time then lying while the knee is bent upwards will do. With the knee bent then the elastic strap will pull against the top of the knee with enough friction as to reduce possible slippage.

Once the contraption is in place and the user is comfortably sitting the device is ready for use. The system will provide just enough resistance that simply moving the foot up and down or in a circular motion will give the muscles a little workout to help alleviate the discomfort that comes when someone suffering from Restless Legs Syndrome is at rest [Wil2008]. Where this contraption is designed for the temporary relief of the discomfort associated with RLS it does not promote the self suppression of leg movements.

### **3.2.3 VNUS Closure Procedure**

Where the previous treatment of RLS utilized moderate exercise this treatment of RLS attacks a different issue, the veins of the legs themselves. Venous reflux develops when the valves in the veins that prevent the blood from flowing backwards become diseased and no longer function as one-way valves. A procedure known as VNUS

Closure procedure will close the problematic veins to eliminate blood reflux that is causing discomfort.

The system, as described in patent application number US 2008/0071333 A1, a pictorial of the procedure is shown in Figure 3.9 below, used to perform this procedure avoids complicated surgery by inserting a catheter below the affected area. An introducer is used at the point of entry of the vein. A laser fiber will pass through the introducer into the vein providing heat to the problematic area. Once the laser fiber is in place and warmed up with a wavelength of between 1.2 and 2.7  $\mu\text{m}$ , a pull back device that is attached to the laser fiber catheter will slowly pull the catheter backwards, closing the vein as it does.

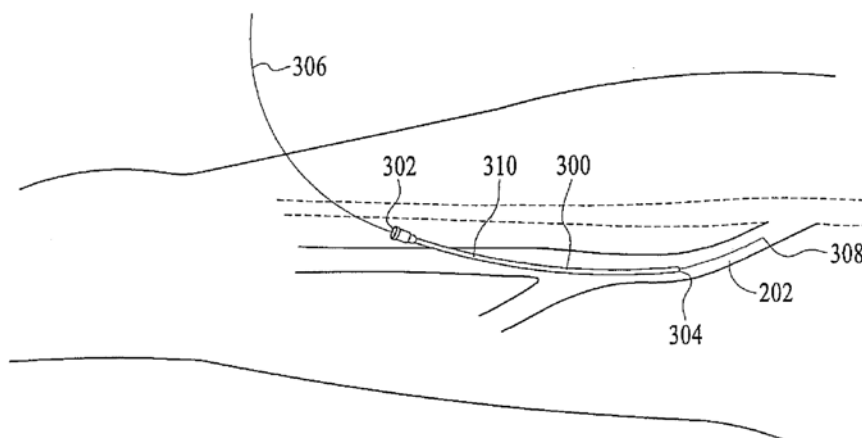


Figure 3.9 VNUS Closure Procedure from [Hay2008]

Whereas this treatment does not cure RLS, it is a solution to one of the underlying conditions that leads to the symptoms of RLS [Hay2008]. As previously mentioned this device does avoid complicated surgery, however it is not something that a user can use on their own. Because this system needs to be inserted into a vein and incorporates laser technology used to heat these veins, it is recommended that the proper technicians be

present. This system may reduce the discomfort associated with RLS which in turn would reduce the necessary fidgeting. However this system does not detect these movements as they are happening for the purpose of self correction.

### **3.2.4 Electrodes**

One invention found, patent number 5,368,042, uses yet another method to determine muscle contraction with biofeedback. For their case the purpose was for swing evaluation and improvement in various sports such as golf or baseball. Where the detection method is different, the detection of movement is the same nonetheless. Their system is a band that can be worn like a wristwatch on the arm or the leg and uses an onboard indicator such as a Liquid Crystal Display (LCD) screen or an audio device or both.

The detection of movement is accomplished by using electrodes, shown in Figure 3.10 by the two circles in close proximity, under the band and pressed against the skin. These electrodes should be silver or silver-plated to avoid corrosion from body perspiration. When the electrodes pick up a signal, such as the contraction of a group of muscles, it is sent to an amplifier to boost the signal. This amplifier should be high gain as the impulses from the muscles are likely to be minute. The output signal from the amplifier would then be directed to an output device as aforementioned or to another input device such as that for recording [ONe1994].

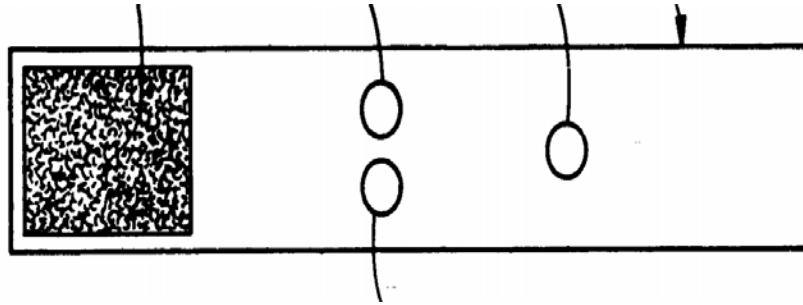


Figure 3.10 Electrodes from [One1994]

It is our belief that such a mechanism, when placed on the legs, can be used to alert at all muscle contractions and movements. If an individual is suspected as suffering from PLMD this device can be used to record those mid-sleep movements. If the individual is a fidgeter then this device could act as an alert. This method was brought to our attention as a possibility even though we have decided on another direction. The use of the electrodes on the other hand will still be implemented in our design with the use of the electric shock indicator. Rather than the electrodes detecting a small signal they will be delivering a somewhat larger signal.

### 3.2.5 Hyperactivity Detection

Individuals with Attention Deficit/Hyperactivity Disorder, especially in children, have a knack for wanting to constantly be in motion. What was suggested in patent number 4,112,926 is a device that can record the number of times that a child exceeds the acceptable level of activity based on a given threshold. This device uses mercury switches affixed to a plane parallel to the ground and  $120^\circ$  to each other to detect movement in any direction. The switch is activated when movement sends the mercury in the containment unit to one side away from its contact leads essentially opening the circuit. This opening allows an electric current to pass from a positive voltage source to

an internal device to begin the counting process. The closure of the switch normally allows current to pass from the voltage source to ground, as can be seen in Figure 3.11.

Each time one of these switches is opened two onboard counters are incremented. One counter measures the total number of times that the mercury switches were opened while the second records these openings for a specified amount of time. At the end of this epoch the second counter is reset. However, if a set number of switch openings is recorded in this counter before the expiration of time then this is considered hyperactivity and a third counter is incremented and an external indicator will be activated. An indicator to use would be an audio device or a mini light in the case of someone with a hearing disability. The mentioned third counter tallies the amount of times that hyperactivity was attained during evaluation of the monitoring system

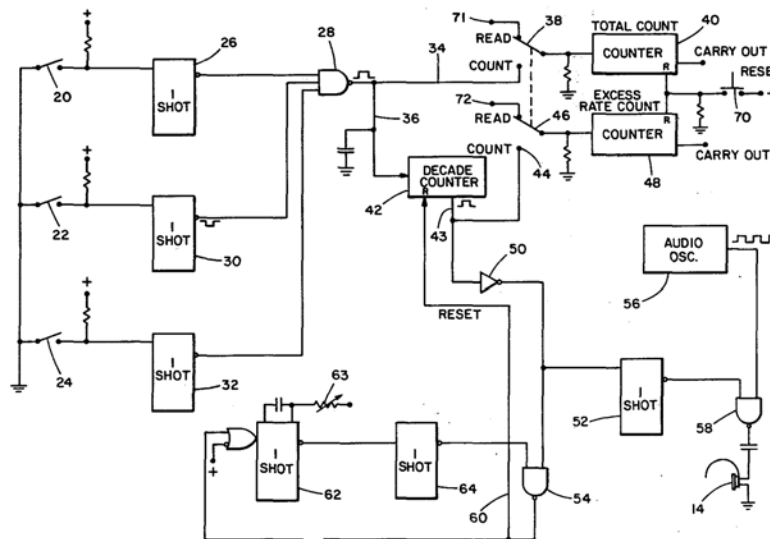


Figure 3.11 Hyperactivity Detection from [Sch1978]

The unfortunate part of this system is that it did not allow for on-the-fly adjustment or readings. Meaning, the only indication of hyperactivity was when the chosen output device was activated. In order for the counters to be read the system had to

be removed from the individual and plugged into a read out display for evaluation. Or when the threshold of hyperactivity should be raised such as when a child is at play the system needed to be removed and adjusted [Sch1978]. Our device will instead use an accelerometer for movement detection. It will, however, still allow the wearer to receive instant biofeedback as well as utilize on-the-fly adjustment.

### 3.2.6 Hyperactivity Biofeedback

Using patent number 6,582,380 B2, depicted in Figure 3.12, an individual with ADHD will continue to be alerted to hyperactivity by an indicator, a vibromotor here. However, additional circuitry is implemented to determine the level of hyperactivity. If an upper threshold is reached then the vibration indicator will go from a vibration of less than a second to one of five seconds. If the person being monitored wants instant feedback based on their performance for a particular session (hour, class period, day) then they can get it at the push of a button. LEDs are used as silent, visual indicators to relate how well an individual is doing during a current session.

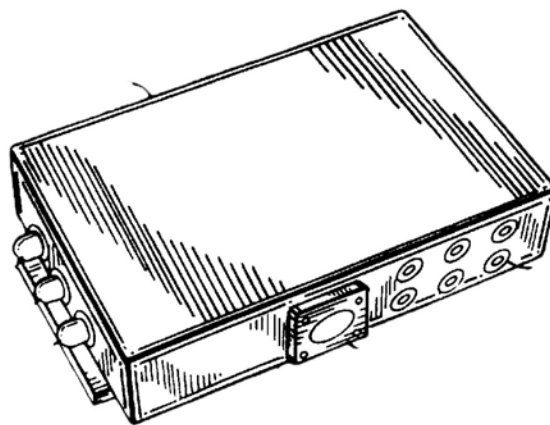


Figure 3.12 Hyperactivity Biofeedback from [Kaz2003]



In communication to an individual ADHD actimeter, the patent suggests a Desktop Transceiver (DTR). This DTR can be wired directly into each actimeter for results and calibration or the individual devices could go wireless. A short range radio frequency (RF) protocol such as Bluetooth could allow communication to the DTR in small areas like a single room. Whereas a longer range protocol could be used to allow a wider freedom of roaming and still maintain two-way communication. Communications like these do make the design of the logic and battery system more complex. However, depending on the design of the DTR, internet communication is also possible [Kaz2003]. This device will allow for instant feedback but only at the request of the user and calibration still needs to be accomplished by another unit. The difference with our solution is that various forms of biofeedback is delivered and the sensitivity can be adjusted without additional equipment.

### **3.2.7 Low Energy Emission**

The brain has shown to not only serve as a communication link and thought process organ but also a source of significant chemical activity. Research shows that neurotransmitter compounds that are involved in the regulation of sleep and wake cycles in the body are secreted during electrical or chemical stimuli. A group in the 1970's demonstrated that weak electromagnetic fields at low frequencies could modify the release of these neurotransmitters in the brain. These low energy emissions were found to be effective in Central Nervous System (CNS) disorders like that of GAD and panic disorders as well.

United States Patent number 5,634,939, Figure 3.13, is the design of a low energy emission therapy system to treat CNS disorders. The system involves the application of

low energy radio frequency (RF) electromagnetic waves for the treatment of the underlying conditions. The device sends the signal through a coaxial cable to a probe that may be inserted into a variety of orifices, the closer to the brain the better, for delivery of the electromagnetic field. No sensory components are used in the design, only the electromagnetic emitter that can be programmed to apply the desired amount of energy emission therapy. [Kus1997]. Since GAD is a condition that is a major contributor to the need for fidgeting we felt it to be appropriate to include this method of relief in our research. However, this method does not detect and allow for self correction, it merely delivers the electromagnetic waves for a biochemical approach to the relief of GAD which in turn should dampen the resulting fidgeting.

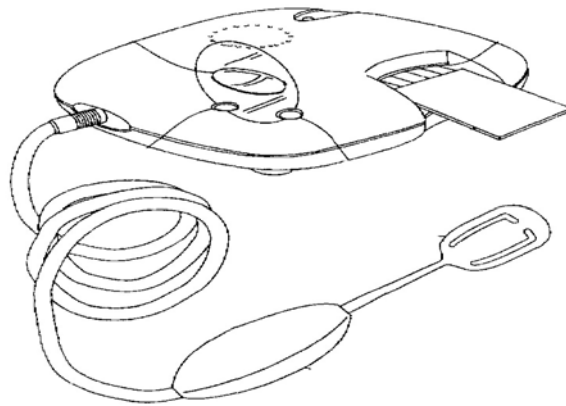


Figure 3.13 Low Energy Emission from [Kus1997]

### **3.3 Thesis and Dissertations**

This section looks at various theses and dissertations that have used either a device or a procedure in their study that relates to our research. A lot of study has been done in the medical field with Restless Legs Syndrome, Periodic Limb Movement Disorder and Attention Deficit Hyperactivity Disorder especially. However most of them

are for the use of pharmaceuticals. The following were studies done to detect and record the activities of the subjects and not their medicated responses.

### **3.3.1 Use of Actigraphy**

Dissertation [Boo2006] was a clinical study into the various aspects of ADHD in adults. According to this study many authors see the symptoms of ADHD as the consequence of disturbances in executive functioning (EF). This is defined by the references of this study as “the ability to maintain an appropriate problem solving set for attainment of a future goal”. Some of the domains of EF relate to basic problem solving skills such as the generation of different solutions, planning that solution through and the working memory needed to perform said solution.

The study used several forms of testing including neuropsychological testing, placebo controlled testing and sleep study testing. It is the sleep study testing that we are interested in for the purpose of this paper. They used an Actiwatch Activity Monitoring System that recorded activity during periods of sleep. An epoch of one minute was used before the samples were saved and counters set back to zero. The results could then be downloaded and analyzed with sleep analysis software to determine sleep and wakefulness. The Actiwatch is similar to the size and shape that we wish to achieve in our proposed system. This device only records for a time for later retrieval and analysis whereas our device will give instant feedback dependent on the amount of activity detected.

Dissertation [Ist2002] was an attempt to validate the use of actigraphy as a way of objectively measuring activity caused by RLS. The actigraphy would provide a new and more practical way of detecting the motor symptoms associated with Restless Legs

Syndrome at the onset of sleep. An Actitrac actigraph was used in the experiments alongside an electromyography (EMG), which detects and records potential muscle activity. The actigraph in this case proved to be not as effective in detecting and differentiating between movement with relation to RLS and typical movements. It was also suggested that the Actitrac did have a timing issue with the software involved in the studies. Again the main difference is that the use of biofeedback is not implemented. This device will detect and record for later analysis. Our intention is to deliver near instantaneous feedback for the purpose of self suppression.

The study in [Pan2004] looked at the activity patterns of youth who fall into the Autism Spectrum Disorder (ASD). Physical Activity (PA) among children is usually because of social interaction with their peers. Youth with ASD have problems with socializations, therefore this limits their opportunities for interaction with their peers and subsequently will suffer from a reduced level of PA. Studies have shown that reduced activity levels have a connection to higher health risks.

In order to study the activity levels of different groups of youths with disabilities (those with ASD and those without), the author used an MTI accelerometer to record their activities. This accelerometer was to be worn in a nylon pouch at the right hip for at least eight hours a day and for at least four out of the seven days to which they were assigned the device. It was suggested that the case be worn during the height of the most likelihood of activity (not during sleep hours) and not to be worn while bathing or for water activities. At the end of the collection of the data the information in the accelerometer was downloaded into the proper software and analyzed according to which group the child belonged. This study used an accelerometer for the detection of general

activity in a child and for later analysis. Where the purpose of our device is to detect the purposeful movements of a single limb for the immediate suppression of such motions.

The master's thesis written by Lt. Leonard E. Haynes [Hay2007] of the United States Navy used actigraphy devices worn on the wrists of sailors aboard the USS CHUNG-HOON (DDG-93). His research was for the purposes of comparing the Navy Standard Work Week to that of the actual activity of the United States Navy sailor. By having the subjects of this study wearing a Wrist Activity Monitor (WAM) AMI model MicroMini Motionlogger Actigraph, the study was able to record their activity level for an 18 day period. The subjects were also to keep a record of daily activities at the same time for comparison of the data at the end of the test time.

The results of the study showed that the average sailor was on Available Time, the time that is for the ship, almost 17 hours more than what is recommended by the Navy's definition of the Navy Standard Workweek. These extra hours on duty have to come from somewhere and unfortunately they come from the Non-Available Time allotted to each sailor, essentially affecting their predicted effectiveness. It was the conclusion then that the Navy's Standard Workweek was not sufficiently representative of the actual activities of the sailor. This study used an actigraph for the monitoring of sailors for a period of 18 days without any instant biofeedback. It is our intention to deliver instant feedback to the user without recording any data.

### **3.3.2 Use of an accelerometer**

A study by Hans Moller [Mol1988] of Florida Atlantic University utilized an accelerometer in conjunction with Electromyogram (EMG) to help stroke sufferers to regain mobility. Previous work has shown that if a patient engages in motor rehabilitation

within the first six months following a stroke then the chance of at least a partial recovery is increased. Since paralysis caused by a stroke is from damage to the brain then what the author wanted to experiment with was bypassing the brain to continue this rehabilitation.

By using an EMG to detect potential electrical signals provided by muscles then these signals can be fed into a computer and then output to the corresponding muscle on the paralyzed side. He was allowing patients to move a good arm or leg and that motion would move the other arm or leg. The accelerometer was attached to the wrist in this experiment to indicate the beginning of movement and that the signals from the EMG need to be read and converted. Here the author used the signal from the accelerometer to trigger the application of another system. Our device is similar in that we wish to deliver immediate signals to various outputs based on the detection of the accelerometer.

### **3.3.3 Use of Home Polysomnography**

For the diagnosis of sleep disorders the gold standard is a full polysomnography in a certified sleep clinic. Using a home device as an alternative is becoming an increasingly popular one. A study done by Dorthée Maria Moss [Mos2006] is to determine the feasibility of performing an unattended sleep study at home on school-age children by implementing a home polysomnographic device, shown below being worn by a child in Figure 3.14, that can be easily attached to the children with a soft belt. Various sensors are attached that allow for the recording of breathing, oxygenation of the blood, pulse, body position, body movement as well as others.

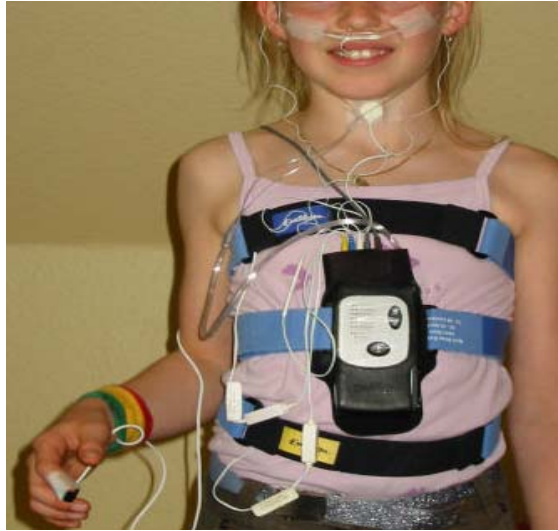


Figure 3.14 Home Polysomnography Device from [Mos2006]

After a night of recording, the data would be downloaded and analyzed with statistical software. This analyzed data is presented to various investigators with as much as 18 years of experience in the field. It is determined by the study that a portable home polysomnography device would be sufficient for the determination sleep disorders in a large percentage of children. The device generated valid information and was well accepted by nearly all of the study participants. The relevance of this study to our research is that RLS and PLMD are indeed sleep disorders, and in the case of PLMD can only be detected with a polysomnography. However it is our intention to develop a device that can help an individual contain themselves from limb movements while they are awake.

## **Chapter 4: The “Stop-it” New Proposed System**

### **4.0 Overview**

Discussed in this chapter is the development of a device that will act as a detection and alert system to these limb movements. It is this device that will allow an individual to become aware of this distraction in order to self-correct or allow another individual to step in and help correct. The use of a microcontroller that utilizes an acceleration sensor for movement detection and several selectable output methods will be implemented for user alert. The selected alert can be external or internal according to the current venue or situation.

### **4.1 System Requirements**

As with any system or device in development, the system requirements are a description of the minimums that the device must meet. This can include the minimums or maximums in the size or weight of the device as well as current and power restrictions based on the used components. Ours will include the type of inputs that need to be used as well as the required outputs. The following subsections are a brief description of what is desired and what is to be expected from the intended system and what makes it unique as well. They will include portability, weight, size, inputs, outputs and electrical limitations.



### **4.1.1 Self Contained**

The intention of the system is that it may be used in areas where improper limb movement may be a distraction to others. For this to be feasible the device must be functional in all or at least most places. Therefore the device must be a self contained unit. In order to achieve this it must be a stand alone product that is capable of detection and alert without an umbilical to a computer or other control device. To achieve this our intention is to utilize an embedded platform that will have all power as well as input and output components on board and in close proximity to each other. A strap that implements a hook and latch system like that of Velcro will be used for flexibility of limb placement.

### **4.1.2 Weight**

Where portability means that the system can be used anywhere it will not make a difference if the device is too heavy to be worn. One of the concepts behind the system is to detect limb movement and allow an individual to self-correct. If the device is too heavy then it might just weigh the individual down to retard improper movement. It would seem to have a similar effect as strapping the person to a chair. It is not our goal to introduce a forced suppression system. It is however our intention to develop a system that can be comfortably worn on the leg or arm that will allow for self-suppression.

### **4.1.3 Size**

The final requirement indicative of the physical properties of the system is in regards to the overall size of the device. The footprint of the system as a whole will be such that it can be worn by a user without much interference with other motions that may

be necessary for daily activities. Sitting at a desk while in class or standing at a podium while giving an important presentation fall into this category.

Where the square inches of the footprint is important so is the overall height of the device. For example if the system has a footprint of 12 square inches but rises too high off of the surface then this will prove to be too cumbersome to the individual wearing the device. By keeping the device relatively flat it would seem less burdensome to the person wearing the apparatus. The intended design of the device should be the approximate size of a wrist watch. The prototype, however, will be a little bulky and unpleasant.

#### **4.1.4 Movement Detection**

The purpose of the device is to detect limb movements that are rude or distracting based on location and/or time. Therefore the device will detect leg or arm movement over an epoch that will determine whether the movements are considered inappropriate. However these movements need to be substantial in that the device is not picking up every minor muscle twitch or counting a single movement as an inappropriate action. It will count the movements over a small period of time and if a user selectable level is reached then the proper person is notified by internal or external indicators.

#### **4.1.5 Indicators**

Once extensive improper movement is detected the device will activate the appropriate outputs. Various indicators are used to alert the proper person as to the activity, whether that person is the one wearing the device or someone else in the

vicinity. Therefore the system will have the ability to change the type of indicator used for the notification.

An internal indicator is an output that is utilized to inform only the person wearing the device of their actions so that they may act to control their own movements. This indicator must go completely or almost completely unnoticed by others. However an external indicator will be the one to use when a person other than the individual wearing the device needs to be notified of such activity. This would be the correct choice when an individual does not have the proper self control as in someone with autism. This may also be the output of choice for a parent simply trying to break a child of what they see as a bad habit.

#### **4.1.6 Power**

For a product to be portable as suggested in system requirements section 4.1.1 it will need to have a portable power source, and therefore a battery will be necessary. Since the size of the device as suggested in section 4.1.3 is a consideration it will need a small battery like those used in most portable electronics. It is the opinion of the author of this document that the battery should be of the type already easily available in most corner stores and markets.

### **4.2 Theory of Operation**

The next few subsections will give the reader a brief description of what to expect from the intended device. By using the system requirements as a guideline we have developed a system that can be used freely in almost any location and by anyone with the exception of maybe the smallest children. It will be lightweight, portable and above all

have the ability to allow the user to adapt the system to meet what is expected for the venue. The overall system operation is depicted in the flowchart of Figure 4.1.

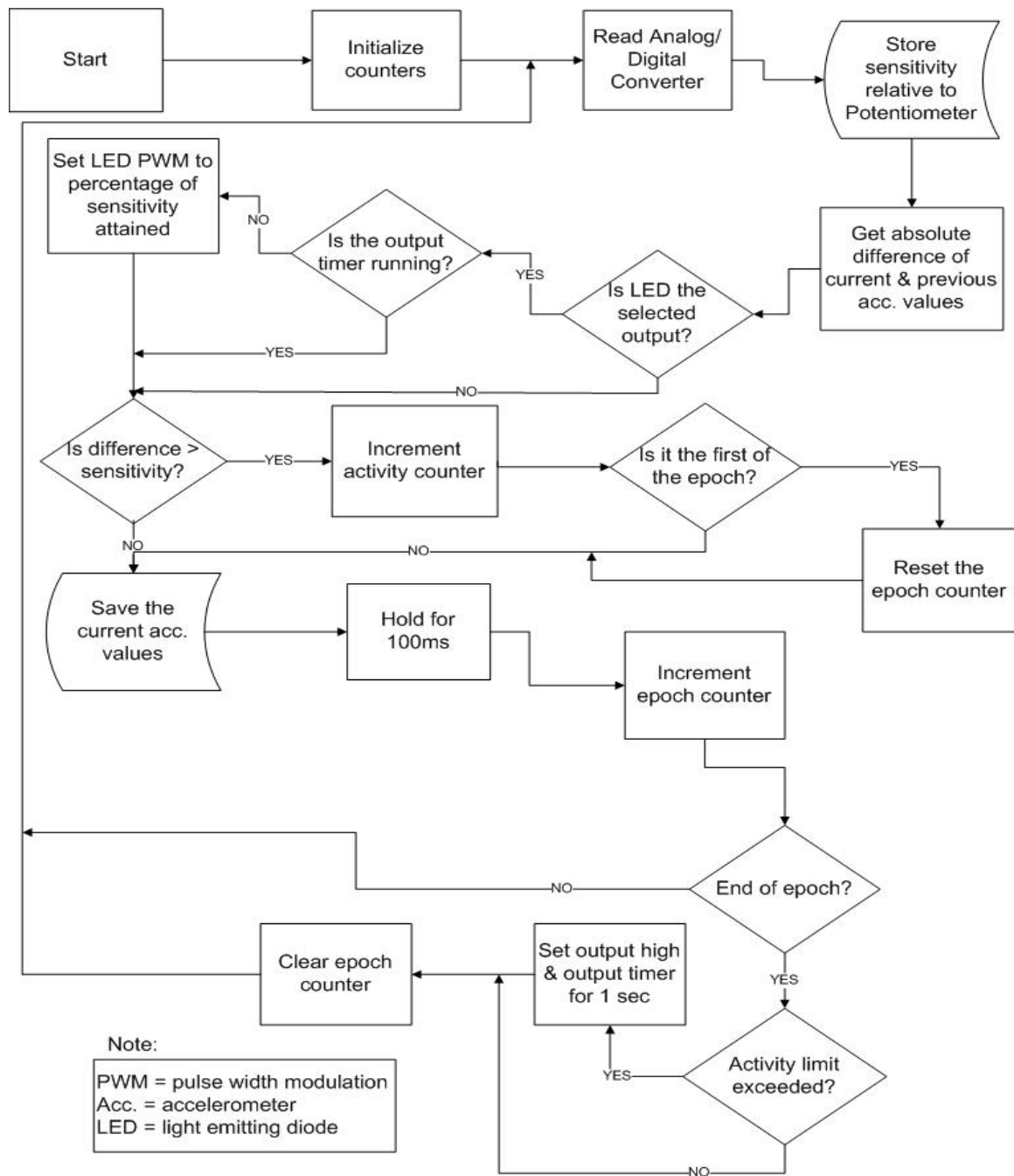


Figure 4.1 System Flowchart

### **4.2.1 Signal Processing**

The intended device, as with a large majority of electronic systems, will implement the use of a microcontroller. This microprocessor will read several inputs delivered to it by several components of the system and, depending on the values of these inputs, will determine what action, if any, will be taken. To be more clear, if the signals sent to the processor by the movement sensors are within the parameters to necessitate a response then this controller will send a time constrained signal to one of several outputs. The user of the device will have the ability to change the indicator type with the push of a button which will tell the processor where to send the signal.

### **4.2.2 Movement Sensing**

The device will be capable of detecting movement on any axis. Therefore, physiological placement of the system will not affect its movement sensing reliability. Whether the placement of the device is face-up, face-down or on its side, this will not disrupt the operation of the device.

### **4.2.3 Output Indication**

Once the movement sensors are in place and operating properly the system will need to output a signal for indication to the user. The individual wearing the device or monitoring the person wearing the device can change the medium of indication with the push of a button. For a simple audible indicator a small buzzer will be utilized as one option. If someone favors the more inaudible indicators then a vibromotor is one option as well as a light emitting diode (LED) for a completely silent option. Another alternative

while still providing a silent indicator, with the exception of a possible outburst from the person wearing the device, is an output that delivers an electric shock.

## **4.3 Prototype Implementation**

This section will give more insight to the individual components themselves and how they will work and communicate with each other. Knowing how each piece of the puzzle fits is vital to the proper utilization of the components and of the system. The device consists of an embedded microcontroller that receives three signals from an accelerometer as the instrument of measurement. The processor will then control four different output devices dependent on its user defined settings.

### **4.3.1 The Embedded Platform**

The most complex piece of our system is the evaluation board from Freescale, the Coldfire model MCF52233DEMO [Cola], the overall block diagram of which is shown in Figure 4.2. Contained within is three of the components necessary for the function of the device as well as some other functionality that can be implemented for ease of use. The Demo board can utilize four different methods of communication namely a Universal Serial Bus (USB), an Ethernet connection, an RS232 connection and a background debugging mode(BDM).

Hardwired to the evaluation board is the most important, a microcontroller, a 3 axis acceleration sensor, and a voltage regulator. In addition, the demonstration board provides a reset button and a push button switch that will be implemented in our design as well.

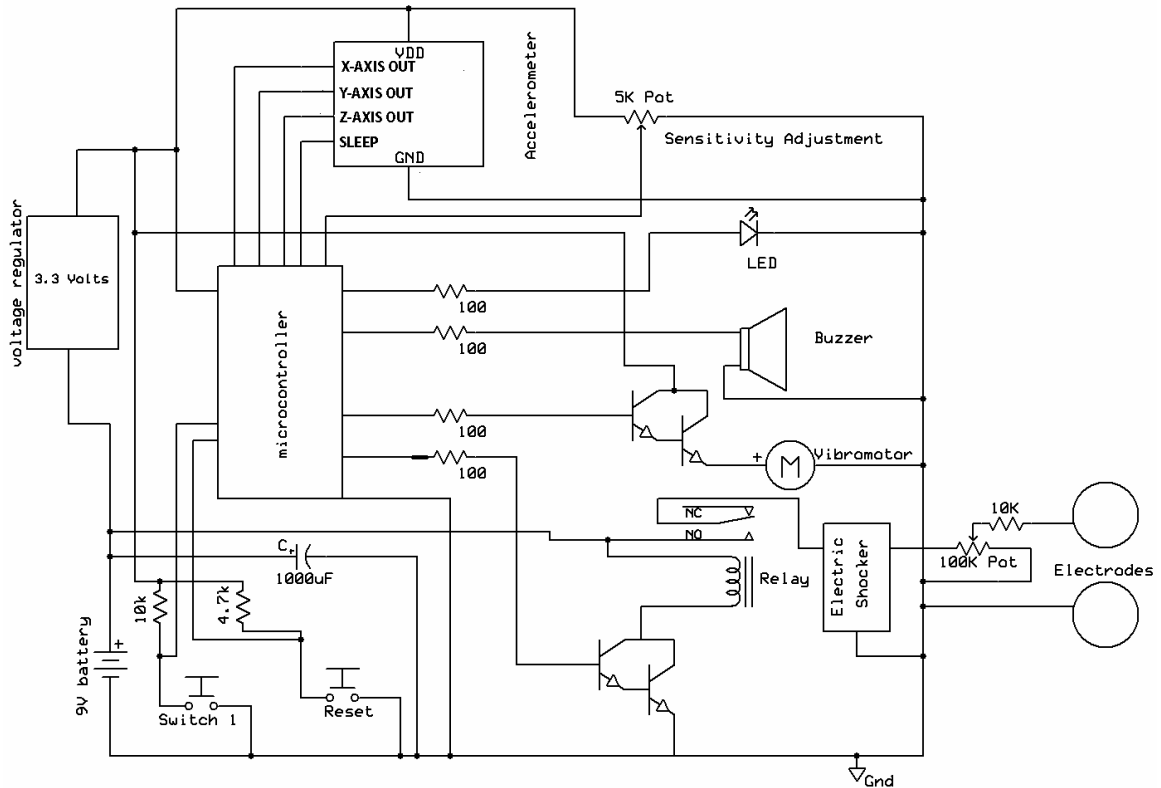


Figure 4.2 Overall Block Diagram

#### 4.3.1.1 The Coldfire Microcontroller

The microcontroller hardwired to the M52233DEMO board is the Coldfire MCF52233CAF60 microprocessor developed by Freescale Semiconductor [Colb]. This is an 80-pin 32-bit microprocessor that operates at 3.3 Volts with a clock speed as high as 60 MHz. Where this chip is extensive in what it offers we will only delve into the components within the chip that are relevant to the purpose of our design. The full extent of this chip's functionality will be used in the future to add more intelligent features to the device.

The processor utilizes a single Analog/Digital Converter (ADC) however this ADC can measure eight different incoming analog signals and save their values for later

use. When the microprocessor calls for a read on one of the analog channels the value is read as a 12-bit value, however the value is stored as a 16-bit value in the most significant bits in memory. The controller does implement two types of memory for storage of the applications, 256KB of Flash memory and of 32KB RAM memory. Flash is a non-volatile memory that retains its values even when the systems power has been turned off. Whereas the RAM memory will only retain its data while power is being supplied to the chip. In order for our device to retain its operational abilities upon power-up or resetting the system without the need of a computer attached by an umbilical then Flash memory is a must.

Additionally the controller has the benefit of various timers. These timers will be used to spread out the sampling rate as well as increment the epoch counters. These timers cause an interrupt in which the application is halted and will not resume until the interrupt vector has finished running its code.

#### **4.3.1.2 Accelerometer**

As aforementioned the demonstration board comes equipped with acceleration sensor Coldfire model A7260 [Colc] also developed by Freescale Semiconductor. It is a 16-pin square chip that only utilizes 8 pins. This component has an operational voltage supply maximum of 3.3 Volts however it can go as high as 3.6 Volts without experiencing any permanent damage. When the acceleration sensor has a power supply then the internal G-sensor unit will output a voltage between 0.85 Volts when a negative acceleration is detected and 2.45 Volts with a positive acceleration. These outputs are on three different lines that are directed into analog inputs 4, 5 and 6 of the microcontroller.



When the ADC of the controller is reading the inputs from the accelerometer, it is on these three inputs.

The resolution on the accelerometer can be changed as well. The sensor has three of its own inputs with the exception of the pin with the supply voltage. They are g-Select1, g-Select2 and Sleep Mode. The Sleep mode is for the conservation of power and as this device is not intended for 24 hour a day use we will not be bothering with it here. The g-Selects are logic inputs that can change the resolution from 800mV/g which is a higher sensitivity to as low as 200mV/g. This is a lower sensitivity, however it allows the user of the accelerometer to implement it for a greater range possible applications.

#### **4.3.1.3 Power Supply**

The supply voltage can be delivered to the board via three different ways. The first one is through the USB cable, Figure 4.3a. The USB will deliver 5 Volts which is then sent through the voltage regulator to bring the working voltage down to the necessary 3.3 Volts. The second is a power jack, seen in Figure 4.3b. This is a barrel connector 2.1mm wide and center positive. Any connection to this connector should have a supply voltage of between +5 and +15 Volts as it will still be regulated through the voltage regulator. And lastly the board is equipped with a battery terminal, pointed out in Figure 4.3c, in which a battery casing's wire can be inserted and screwed down to supply the voltage. This method is not recommended as the battery voltages are not brought down by the voltage regulator and one risks the possibility of applying too much power to the system and causing damage. For the purposes of programming and debugging the USB cable will be implemented during the design phase. The final operating power supply for the device will use the power jack. We intend to do this by soldering a 9-Volt

battery connector directly to the daughter board to supply extra voltage to the electric shocker and then to a center positive 2.1mm power jack. It is in this way that the system can be completely mobile with the use of a standard easy-to-get battery and prevent the carelessness of adding too much power.

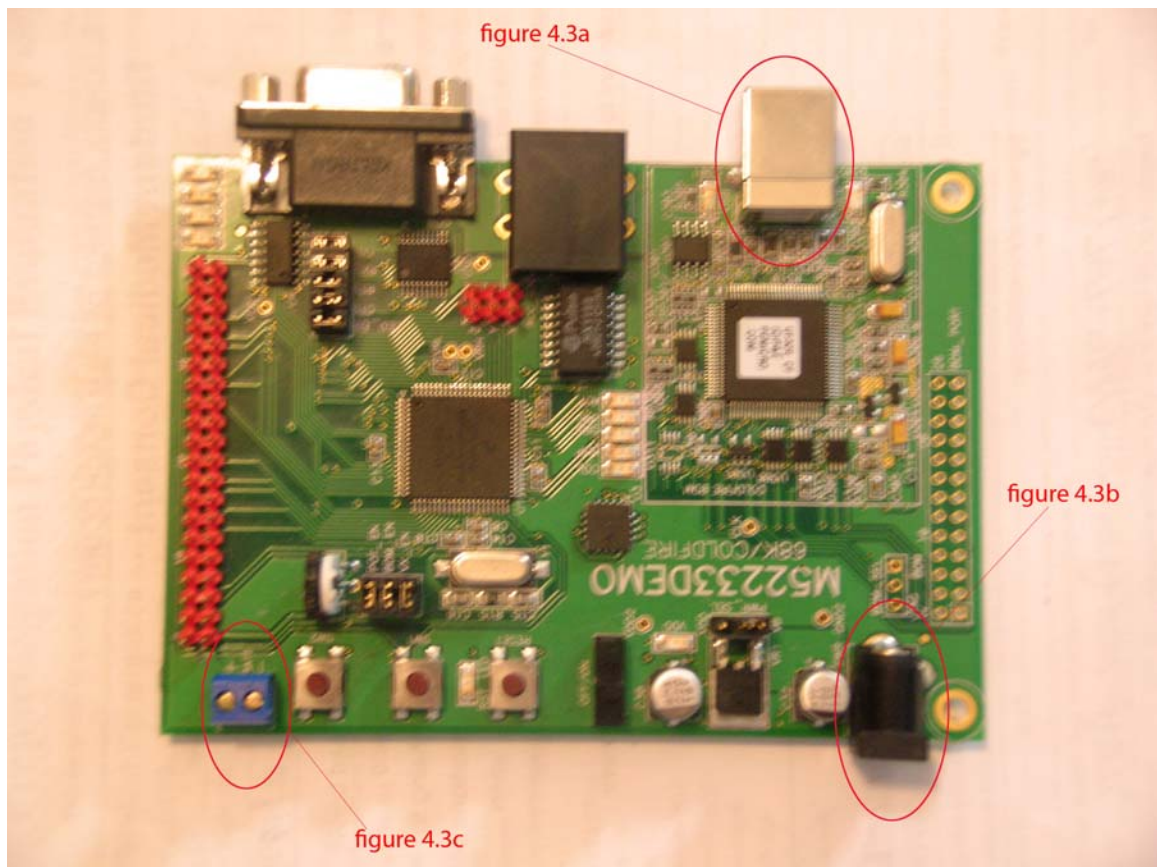


Figure 4.3 Evaluation Board Power Supplies

### 4.3.2 Indicators

The hardware system connected to the platform is shown in the schematics of Figure 4.2. The indicators are the components of the system that return biofeedback to the user. When the microprocessor determines that the acceleration sensor has picked up enough movement to take action it is through one of these indicators that a signal is sent. The user will have the capability to change the indicator based on the needs of the time.

The different indicators are an LED (Figure 4.4a), a buzzer (Figure 4.4b), a vibromotor (Figure 4.4c) and a device that will deliver an electric shock to the wearer (Figure 4.4d) all shown in Figure 4.4

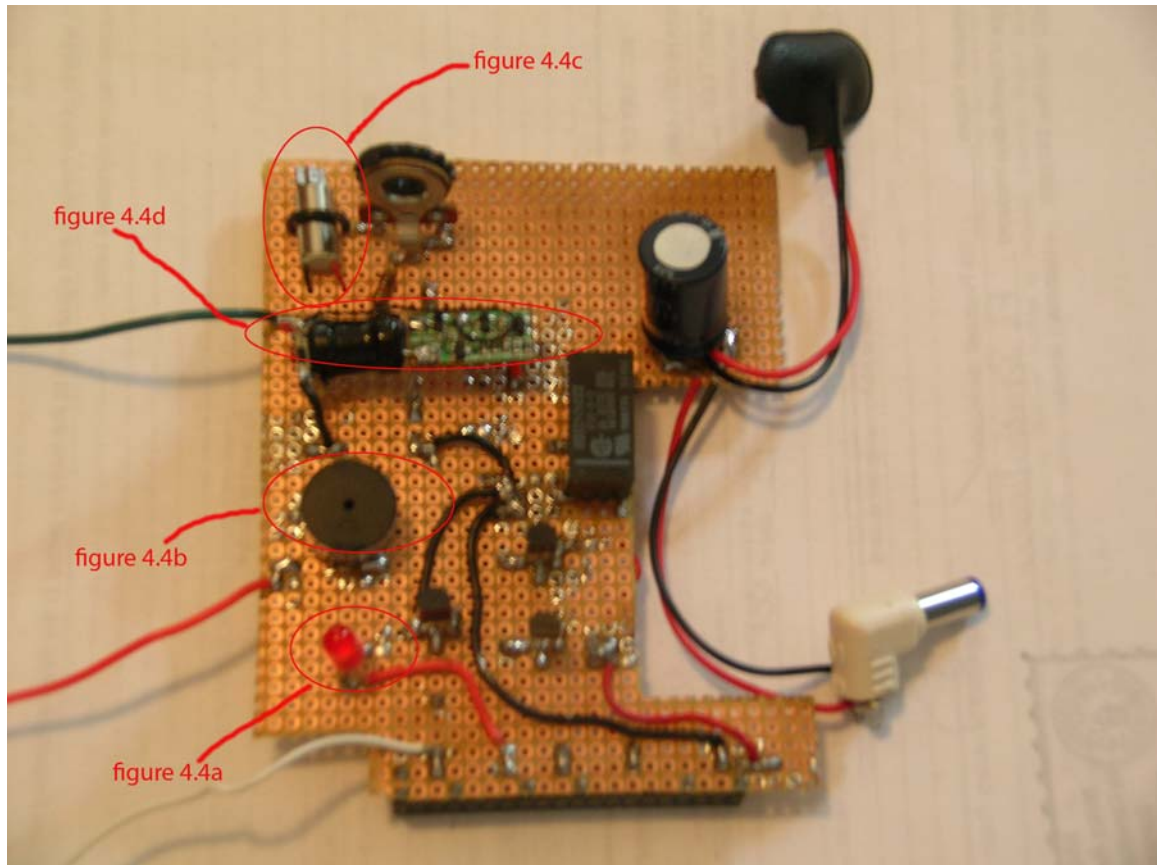


Figure 4.4 Daughter Board Indicators

#### 4.3.2.1 Light Emitting Diode

A diode is an electronic component that allows electrical current to flow in only one direction. A light emitting diode will emit a luminescence when a current is flowing in the proper direction and the amplitude of that luminosity can be controlled by turning the current on and off quickly using a pulse width modulator or PWM. For our purposes the LED will reflect the intensity of the movement from 0 – 100% where 100% means

the threshold to activate the output has been reached. Any generic LED will work fine for this project.

#### **4.3.2.2 Buzzer**

The only strictly audible device as part of the indicators is the implementation of a buzzer. Whereas the LED transferred current into a visible light the piezoelectric buzzer turns the current into sound waves. If the microcontroller output for the buzzer has been selected by the user, then when action is decided, the processor will send a high signal to the appropriate pin which will raise the voltage on the positive side of the buzzer. This voltage difference across a crystal inside the piezoelectric buzzer causes a vibration. It is this vibration that results in sound waves whose amplitude is determined by the voltage difference. For our purposes we chose to use a RadioShack 12VDC 70 dB Piezo Buzzer part number 273-074 [Rada].

#### **4.3.2.3 Vibromotor**

The vibration motor, vibromotor, is a small motor that will spin in either direction depending on the direction of the current driving it. Unfortunately the current from the microcontroller output was not enough to run the motor. It was therefore necessary to build a Darlington Stage Transistor by implementing two Bipolar Junction Transistors (BJT) in series. If the current applied is flowing from the positive terminal of the component to the negative terminal then the rotation of the device is clockwise. However if the current applied to the device flows from the negative terminal to the positive terminal then the rotation is counter-clockwise. What makes this component different from an ordinary motor is the weighted end. The rotating end has a weight placed off

center so that the device will have the feeling of shaking or vibrating at high speeds. This project will implement a RadioShack 3VDC micro vibration motor part number 273-107 [Radb] capable of delivering a speed of 13000 revolutions per minute.

#### **4.3.2.4 Electric Shock**

To deliver an electric shock to the wearer of the device we extracted a working mechanism from a store bought gag gift. This gag gift is a fake pen that when “clicked” closed a circuit between two leads allowing a current to flow through the person holding the pen. Since the current of the output signal from the microcontroller was too small, the signal was not enough to trigger a relay part number RSB-5-S [Rsb], Figure 4.5a. Therefore the microcontroller output was used to turn on a Darlington Transistor to pull the negative side of the relay to ground and allow a current to traverse through the coil of the relay. This action pulled the relay switch to the desired pole and closed a circuit that ran from the Vdd of the 9 volt battery to the Vdd of the shock mechanism. Since the relay drew its power directly from the 9V battery, whenever the microcontroller triggered the relay the voltage potential dropped below 3.3 Volts. This is the threshold for the operation of the microcontroller and would hence reset the entire board. Therefore a 1000uF capacitor is placed across the terminals of the battery allowing the voltage to remain around the desired 9 Volts. Now that power is being delivered to the electric shock mechanism a current can be delivered between the output and ground. The higher potential output is fed through a potentiometer so that the applied voltage can be varied. The output from the potentiometer is run through an additional 10K $\Omega$  resistor to reduce the maximum allowable current to pass through to ground. This output is then fed to a lead that is made of a wire and an ordinary penny. We have utilized an additional lead

made of another wire and penny as well connected to ground and both of these leads are held in close proximity together by a fabric. This fabric will be placed on the skin underneath the device and as current passes from one lead to the other it will be felt as a mild to moderate shock by the wearer of the device.

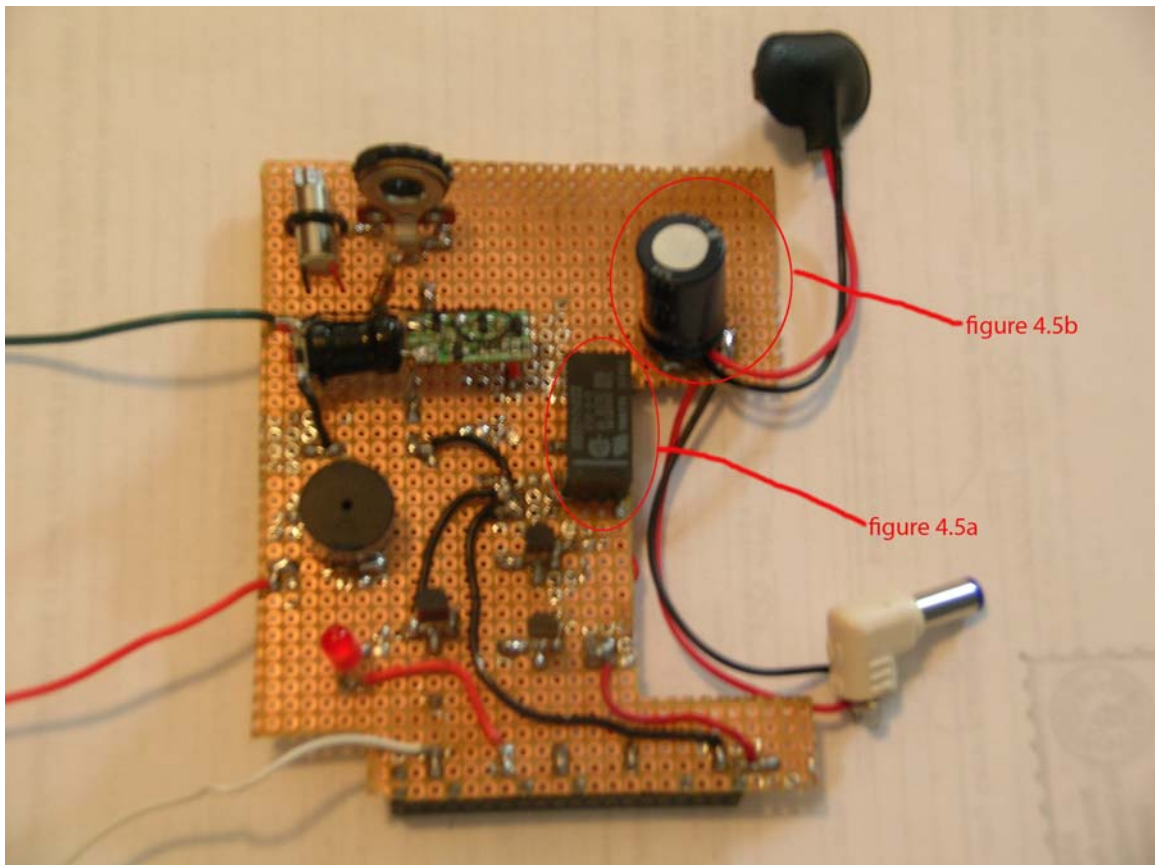


Figure 4.5 Shock Relay and Capacitor

#### 4.4 Parts and Cost

Below is a list of the parts necessary to complete the prototype of our design and the cost associated with its development. As the cost of the evaluation board required for the construction of this device exceeds practicality, it will not be included in the final cost. However an estimate of the components from the evaluation board that were necessary will be assumed and integrated into the final cost.

Table 4.1 Parts and Cost

Part Name	Quantity	Unit Cost	Total Cost
PCB Board	1	\$3.99	\$3.99
9V Battery	1	\$4.49	\$4.49
9V Battery Connector	1	\$1.99	\$1.99
3.3 Volt Regulator	1	\$1.25	\$1.25
Microcontroller	1	\$8.86	\$8.86
Accelerometer	1	\$4.68	\$4.68
Darlington Transistor	2	\$1.59	\$3.18
Potentiometer	2	\$1.49	\$2.98
1000uF capacitor	1	\$2.59	\$2.59
Relay	1	\$2.49	\$2.49
Electrodes	2	\$0.01	\$0.02
Push button switch	2	\$1.50	\$3.00
LED	1	\$1.49	\$1.49
Buzzer	1	\$3.49	\$3.49
Vibromotor	1	\$3.99	\$3.99
Electric Shock Device (pen)	1	\$5.99	\$5.99
“Stop-It” prototype total cost			\$54.48

## **4.5 Software**

This software contains a series of instructions and conditions as well as the handles of needed variables. This will then be saved in the non-volatile Flash memory of the Coldfire microcontroller so that it will not need to be reinstalled when the device is powered on or reset.

### **4.5.1 Integrated Development Environment**

The Integrated Development Environment, commonly called an IDE is the development software that allows programmers to write applications for various products. The IDE that we will be using is CodeWarrior, also developed by Freescale, mainly because it is capable of compiling applications for all of the Freescale microcontrollers. CodeWarrior uses a system for component development called beans that helps keep the development process more organized and can reduce the amount of work required by the programmer significantly. After the necessary beans are inserted into the project and the proper functions enabled then only the code for the needed functions will be in the project. By inserting a bean into the IDE project we can drag-n-drop only the functions that are necessary for our purposes.

Part of the IDE includes what is called the bean inspector. This is a window that has all the information that one would need to use a particular bean. If our purpose was to insert a bean that utilized an interrupt timer, then the bean inspector will let us view and change the settings of the timer. These settings can and do include the length of the timer interval as well as the interrupt priority and the interrupt vector that will be invoked. It is



also in the inspector that we can choose which methods to include in the compilation and which input pin that the timer will use.

CodeWarrior IDE keeps the files necessary for application development organized as well. Whenever a bean is inserted into the project the header files are added to the project as well and will be visible from the project solutions window. This is important if the programmer needs to change something in the code or simply add to it. We never recommend removing any items from the code because it is then that disaster can and will strike. Figure 4.6 is a screenshot of the IDE and some of the vital working windows for development such as the bean inspector, bean selector, target CPU pin depiction, working C file and the important solution window.

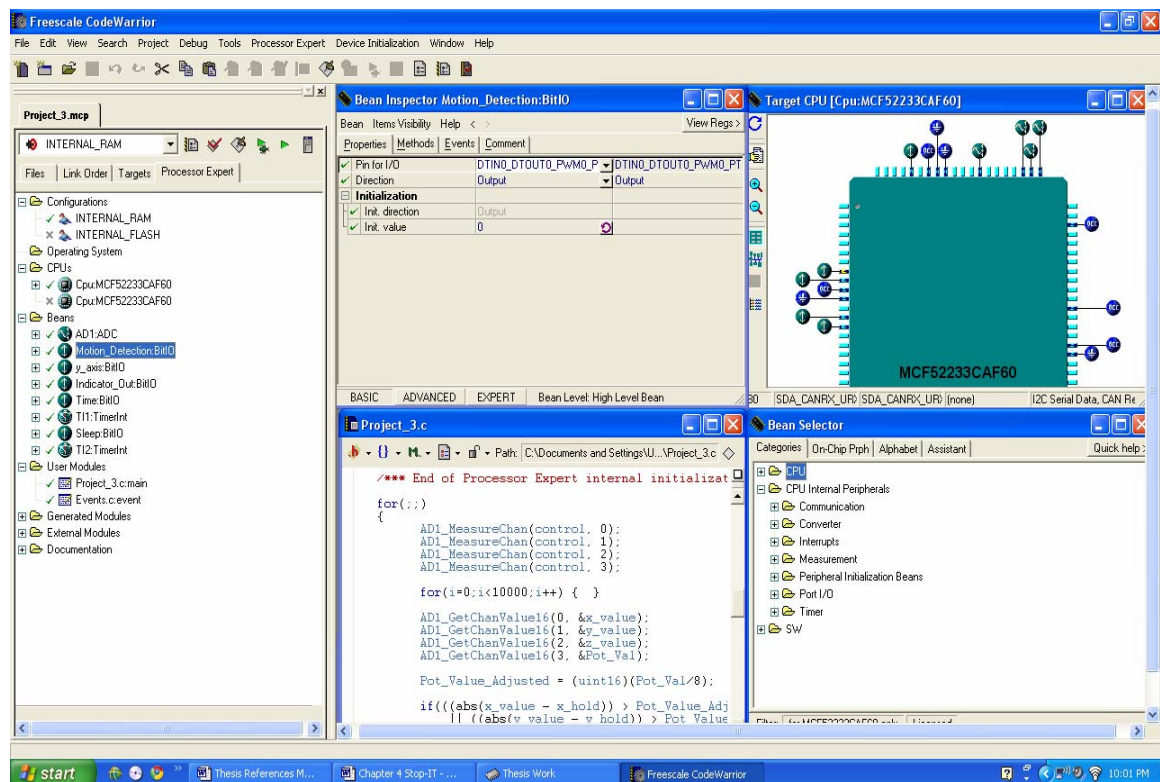


Figure 4.6 Integrated Development Environment Screenshot

## 4.5.2 The Code

Our code is written in the C language and consists of exactly two C Source code files and they are the main file and the events file, this is the file that handles all of the interrupts from the project. There are more files that the IDE generates when the project is compiled but they need not be seen by the programmer, which helps to reduce the confusion when developing larger applications.

There are two important areas when writing code for application development. One I will categorize entirely under syntax mainly because they are the small items that can easily be missed. These are the punctuation, library inclusion, capitalization, consistency within the code as well as a multitude of others. The second area is the algorithm itself which is the step by step process that determines how well the application will do its job. This was shown in the previous Figure 4.1 however what is to follow is the code itself. This is the main C source code file followed immediately by the events C source code.

```
#include "Cpu.h"
#include "Events.h"
#include "AD1.h"
#include "LED.h"
#include "Buzzer.h"
#include "Vibromotor.h"
#include "Shocker.h"
#include "LED_led.h"
#include "Buzzer_led.h"
#include "Vibro_led.h"
#include "Shock_led.h"
#include "TI1.h"
#include "Sleep.h"
#include "TI2.h"
#include "Switch_Outputs.h"
#include <stdlib.h>

#include "PE_Types.h"
#include "PE_Error.h"
#include "PE_Const.h"
#include "IO_Map.h"

uint16 x_value=0;

uint16 y_value=0;
uint16 z_value=0;
uint16 x_hold=0;
uint16 y_hold=0;
uint16 z_hold=0;
uint16 x_diff=0;
uint16 y_diff=0;
uint16 z_diff=0;
uint16 x_ratio=0;
uint16 y_ratio=0;
uint16 z_ratio=0;
uint32 high_ratio=0;
uint16 Pot_Val=0;
uint16 count=0;
uint16 count2=0;
uint16 count3=0;
uint16 Pot_Value_Adjusted=0;
uint16 out_put=0;
uint16 L_Timer=0;
uint16 L_Timer2=0;

uint16 i = 0;
bool control = TRUE;
extern bool check;
```

```

void main(void)
{
    PE_low_level_init();
    LED_SetRatio16(32760);

    for(;;)
    {
        while(TRUE)
        {
            AD1_MeasureChan(control, 0);
            AD1_MeasureChan(control, 1);
            AD1_MeasureChan(control, 2);
            AD1_MeasureChan(control, 3);

            for(i=0;i<10000;i++) {

                AD1_GetChanValue16(0, &x_value);
                AD1_GetChanValue16(1, &y_value);
                AD1_GetChanValue16(2, &z_value);
                AD1_GetChanValue16(3, &Pot_Val);

                Pot_Value_Adjusted = (uint16)((Pot_Val/3)+1);

                x_diff=(uint16)(abs(x_value - x_hold));
                y_diff=(uint16)(abs(y_value - y_hold));
                z_diff=(uint16)(abs(z_value - z_hold));

                x_ratio=(uint16)((x_diff*100)/Pot_Value_Adjusted)/2);
                y_ratio=(uint16)((y_diff*100)/Pot_Value_Adjusted)/2);
                z_ratio=(uint16)((z_diff*100)/Pot_Value_Adjusted)/2);

                high_ratio=x_ratio;
                if(high_ratio>y_ratio)
                {
                    high_ratio=y_ratio;
                }
                if(high_ratio>z_ratio)
                {
                    high_ratio=z_ratio;
                }
                if((out_put==0)&&(check!=TRUE))
                {
                    if(high_ratio>1)
                    {
                        LED_SetRatio16((uint16)(high_ratio*65535/100)
                );
                    }
                    else
                    {
                        LED_SetRatio16(1);
                    }
                }

                if(((x_diff) > Pot_Value_Adjusted)
                    || ((y_diff) > Pot_Value_Adjusted)
                    || ((z_diff) > Pot_Value_Adjusted))
                {
                    if(check==FALSE)
                    {
                        count++;
                        if(count==1)
                        {
                            count2=0;
                        }
                    }
                    else
                    {
                        if(check==FALSE)
                        {
                            Buzzer_ClrVal();
                            Vibromotor_ClrVal();
                            Shocker_ClrVal();
                        }
                    }
                    x_hold = x_value;
                    y_hold = y_value;
                    z_hold = z_value;
                    control=FALSE;
                    TI1_Enable();
                    do
                    {
                        // Holding
                    }while(control==FALSE);
                    TI1_Disable();
                    count2++;
                    if(count2==10)
                    {
                        if(count>= 6)
                        {
                            if(out_put==0)
                            {
                                LED_SetRatio16(65535);
                            }

                            else if(out_put==1)
                            {
                                Buzzer_PutVal(TRUE);
                            }
                            else if(out_put==2)
                            {
                                Vibromotor_PutVal(TRUE);
                            }
                            else if(out_put==3)
                            {
                                Shocker_PutVal(TRUE);
                            }
                        }
                        TI2_Enable();
                        count=0;
                        check=TRUE;
                    }
                    else
                    {
                        count=0;
                    }
                    count2=0;
                }
            }
        }
    }
}

if(((check==FALSE)&&(out_put==2))||(out_put!=2))

```

## The following is the Events C source file

```
#include "Cpu.h"
#include "Events.h"
#include <stdlib.h>

uint16 counter=0;
uint16 counter2=0;
uint16 l=0;

bool check = FALSE;

extern bool control;
extern uint16 Pot_Value_Adjusted;
extern uint16 out_put;

void AD1_OnEnd(void)
{
    /* Write your code here ... */
}

void Cpu_OnCoreWatchdogINT(void)
{
    /* Write your code here ... */
}

void TI1_OnInterrupt(void)
{
    counter++;
    if(counter == 2)
    {
        counter = 0;
        control = TRUE;
    }
}

void TI2_OnInterrupt(void)
{
    counter2++;
    if(counter2==15)
    {
        TI2_Disable();
        check=FALSE;
        counter2=0;
        if(out_put==2)
        {
            Vibromotor_ClrVal();
        }
    }
}

void Switch_Outputs_OnInterrupt(void)
{
    for(l=0;l<60000;l++) {}

    if(out_put<3)
    {
        out_put++;
    }
    else
    {
        out_put=0;
    }
}
```

```
if(out_put==0)
{
    LED_led_PutVal(TRUE);
    Buzzer_led_ClrVal();
    Vibro_led_ClrVal();
    Shock_led_ClrVal();
}

else if(out_put==1)
{
    LED_led_ClrVal();
    Buzzer_led_PutVal(TRUE);
    Vibro_led_ClrVal();
    Shock_led_ClrVal();
}

else if(out_put==2)
{
    LED_led_ClrVal();
    Buzzer_led_ClrVal();
    Vibro_led_PutVal(TRUE);
    Shock_led_ClrVal();
}

else if(out_put==3)
{
    LED_led_ClrVal();
    Buzzer_led_ClrVal();
    Vibro_led_ClrVal();
    Shock_led_PutVal(TRUE);
}

while(Switch_Outputs_GetVal()==FALSE)
{
    // No Code - holding pattern
}
```

## **Chapter 5: Conclusion and Future Research**

### **5.1 Summary**

As we have shown, fidgeting and limb movements can have benefits and drawbacks. Those with Attention Deficit/Hyperactivity Disorder will fidget and utilize some form of movement when concentration and working memory are needed. Individuals who suffer from Generalized Anxiety Disorder will fidget in times of accelerated nervousness to help alleviate the stress. For the people with Restless Legs Syndrome fidgeting is a means to relieve discomfort in the legs and the autistic may use fidgeting or self-stimulation to retreat mentally to a more comfortable place. It has even been seen as a way for the less physically active to burn calories and retard weight gain.

However as with many afflictions there are times when such actions are deemed inappropriate. It is in these times that we have seen a need for the development of a tool that can help an individual suppress their own actions or the actions of another. With the use of our fidgeting suppression system a person will have the ability to intervene on the actions that can be a disturbance to others. The attachment of this device on the knee or ankle will detect knee bouncing and foot wiggling or it may be attached to the wrist in the autistic for the detection of hand flapping, a common autistic self-stimulation technique. As we have shown the internal accelerometer will detect the level of movement performed by the wearer of the system by delivering a varied output based on the intensity of the motions. The algorithm in the software determines if the movements are

enough to denote a distraction and relates this information to the wearer with the use of indicators. These indicators will be selectable by the user and can be visual, audible or realized by the sense of touch depending on the need and the venue.

In order for the device to be completely self contained it utilizes battery power even though the board is capable of providing power through the USB port. The software on the system is stored in Flash memory for non-volatile storage therefore powering down the system will not require the reinstallation of the program.

For our development team to provide the readers of this paper a proper comparison of previous solutions to that of our own, we have inserted Table 5.1. For simplicity we have left out a comparison of the devices used in the thesis and dissertations sections for they were merely used in study and not for the design themselves. However the products discussed as well as the patents and patent applications are included in the table.

Table 5.1 Comparison of Products and Methods

Product or methodology name	Discomfort Relief	Movement Detection	Long-term data acquisition	Wearable	Self-contained	Accurate	LED biofeedback	Buzzer biofeedback	Vibromotor biofeedback	Shock biofeedback	Adjustable sensitivity	Low cost
Leg-Wrap	✓			✓	✓							✓
Alpha-Trace			✓		✓	✓						
Trackit		✓	✓	✓		✓						
Pro-Tech		✓		✓		✓						✓
KickStrip		✓	✓	✓	✓							✓
Nonexercise Activity Thermo		✓		✓	✓	✓	✓	✓			✓	
Foot Exercise	✓			✓	✓							✓
VNUS Closure Procedure	✓											
Electrodes		✓		✓	✓							✓
Hyperactivity detection		✓	✓	✓		✓		✓			✓	
Hyperactivity biofeedback		✓	✓	✓		✓	✓		✓		✓	
Low Energy Emission	✓			✓	✓						✓	
“Stop-It” Anti-fidget device		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓

## 5.2 Future Research

Our implementation is a solution to inappropriate fidgeting however there is room for improvement. The prototype that we have built use an evaluation board with a footprint of 12.75 inches squared (3in. x 4.25in). It would be a step forward to reduce this area significantly for the purpose of increased concealment and portability. Since we have chosen to use an evaluation board for the purpose of this thesis there is more functionality available than what is needed. By utilizing only the components necessary for the job this footprint can be significantly reduced. Since we are utilizing a 9 volt battery which is a little bulky, by reducing to a flat battery, such as those found in watches, the area that is occupied by the device can continue to be reduced. Furthermore printed circuit boards (PCBs) are stiff and not very flexible. If the system were to utilize a “circuit board” that is as flexible as fabric then the components can actually wrap around the limb. This would allow the development of a device that can be worn like a sweat band.

As we have applied the capability to vary the input sensitivity of the accelerometer it may also be an improvement to vary the amplitude or frequency of the outputs as well. The electric shock applied to the individual can be changed based on the severity or length of movements as can the frequency applied to the audible device. Most microcontrollers have Pulse Width Modulation that can be used to alter the brightness of the LED or the speed of the vibromotor which may be indicative of the level of activity due to fidgeting. For those who can see the advantages of a device such as this and the improvements that can be made to make it a better product we invite them to explore and expand.



Next it would be a giant step forward to implement a system that was capable of sensitivity adjustment based on other non-activity related sensors. With the simultaneous use of other sensors that monitor temperature, perspiration, heart rate, and breathing then the system would essentially turn with the onset of strenuous activity. Extending this idea even further would be to implement wireless communication to a device that, in some cases could help control or alert to fidgeting, and in other more medically related situations contact the proper medical personnel.

Finally the device should be tested on human subjects to fine-tune the suggested settings and document its medical and psychological benefits. Individuals of various age, gender and physiology should be used in this testing to determine if any ergonomical factors need to be considered. These tests can determine the optimal placement based on the condition that an individual suffers from as well as the particular style of movement that they favor. Lastly, it would be interesting to experiment with tethered placement of the sensors, removing them from a position of permanence for displaced monitoring.

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