Social Defense Mechanisms: Tools for Reclaiming our Personal Space

by

Limor Fried

Submitted to the Department of Electrical Engineering and Computer Science
in Partial Fulfillment of the Requirements for the Degrees of
Bachelor of Science in Electrical Engineering
and Master of Engineering in Electrical Engineering and Computer Science
at the Massachusetts Institute of Technology
January 28, 2005
Copyright 2005 Limor Fried All rights reserved.

The author hereby grants to M.I.T. permission to reproduce and
distribute publicly paper and electronic copies of this thesis
and to grant others the right to do so.

Author ____

Department of Electrical Engineering and Computer Science
January 28, 2005

Certified by ____

Chris Csikszentmihalyi
Thesis Supervisor

Accepted by____

Arthur C. Smith
Chairman, Department Committee on Graduate Theses

Social Defense Mechanisms:
Tools for Reclaiming Our Personal Space

by
Limor Fried

Submitted to the
Department of Electrical Engineering and Computer Science

January 28, 2005

In Partial Fulfillment of the Requirements for the Degree of
Bachelor of Science in Electrical Engineering
and Master of Engineering in Electrical Engineering and Computer Science

ABSTRACT

In contemporary Western society, electronic devices are becoming so prevalent that many people find themselves surrounded by technologies they find frustrating or annoying. The electronics industry has little incentive to address this complaint; I designed two counter-technologies to help people defend their personal space from unwanted electronic intrusion. Both devices were designed and prototyped with reference to the culture-jamming "Design Noir" philosophy. The first is a pair of glasses that darken whenever a television is in view. The second is low-power RF jammer capable of preventing cell phones or similarly intrusive wireless devices from operating within a user's personal space. By building functional prototypes that reflect equal consideration of technical and social issues, I identify three attributes of Noir products: Personal empowerment, participation in a critical discourse, and subversion.

Thesis Supervisor: Chris Csikszentmihalyi
Title: Director, Computing Culture Group at the MIT Media Lab

Table of Contents

Introduction

The Media Lab focuses on pioneering advances in media and technology, often with the aim of improving human-machine interaction. Much of this work has been in new sensor designs, innovative interfaces, and unconventional integrations of existing technologies. While the Computing Culture group contributes to this body of work, its main focus is to investigate “how artists can refigure technology to address the full range of human experiences,” primarily from a social and cultural perspective. For example, many universities have research groups that study how wearable computers can be used to better manage our time, but Kelly Dobson explores how wearables can help us better manage our emotional needs. The work in the group ranges from queries into combative user interfaces, to full-scale implementations of software that helps citizens ‘keep tabs’ on their elected officials, to PDA software that assists users in mapping out walking routes in NYC that avoid security cameras.

The charter for the Computing Culture Group at MIT includes the question “What do technologists miss?” The research I have engaged takes this question and extends it to ask “What do people want technologists to develop?” Many engineers aim to design a technology (or sensor design, or interface) and then try to create an application for that technology, effectively building an answer and then inventing a need. In contrast, my research aims to identify a lived, experienced human need, and then determine how technology can address that need. Out of the “full range of human experiences,” I chose to focus on human-machine experiences and, in particular, our dislike of certain common electronic devices. Last year, a research group polled more than 2,000 Americans, asking them “What technologies do you hate the most, yet cannot live without?” In examining two of the top three answers, televisions and cell phones, I sought to determine why is it that we hate these devices. My investigation included trying to find a common theme in their modes of operation from a social/interface standpoint. To do so, I investigated their use of “Hertzian space,” an architecture of human/device interaction previously defined and explored by the designers Anthony Dunne and Fiona Raby. By characterizing how electronic devices and humans intersect in the Hertzian aether, I theorized that we find these devices frustrating to use because they invade our personal space via distraction. For example, cell phones and their users may be distracting because they are often impolitely loud. Televisions, on the other hand, are distracting in the sense that they have a ‘hypnotic’ quality to them that makes it difficult for many people to avoid staring at one if it is in the area.

Manufacturers of these cellphones are aware of our frustration with these devices. In fact, cell phone companies now include a section of etiquette advice in their user manuals. However, there is little incentive for them to support an active censorship scheme, such as cell phone bans in places such as hospitals, theaters and places of worship. Just as tobacco corporations lobby against smoking bans, cell phone manufacturers instead push for “voluntary action.” Likewise, broadcasting companies have no incentive to make television less distracting because the addictive qualities of television are the same ones that bring high ratings and thus large advertising revenues. The corporate solution, consumer self-enforcement, is basically, “try to be polite.” The problem is that this technique is barely effective, to which nearly anyone can attest.

Since we cannot depend on others to respect our personal space, I have decided to instead focus on how we can defend it ourselves, using special electronic devices specifically designed to combat wireless communication technologies and televisions. Having defined the problem, I set out to design two “counter-technologies,” a set of portable electronic devices that enable the user to defend their personal space from intrusion. For protection from unwanted wireless communication such as cell phones, I designed and built a personal cell phone jammer, named *Wave Bubble*, which creates a small ‘bubble’ of wireless-free space. To help people who find themselves distracted by televisions, I designed and built a pair of electronic spectacles, named *Media-Sensitive Glasses*, that darken whenever the wearer stares at a television for too long. These "counter-technologies" bridge art and engineering; the prototypes masquerade as something that could be mass-produced and sold, and yet function as a statement about us and how we interact with popular technologies. This form of product design takes part in a tradition of culture-jamming industrial design that has been coined "Design Noir" (Dunne and Raby 2001). Much of "Noir" product design aims to use consumer electronics as social commentary, tracking how such devices can be used to address those 'real human needs.'

Having built the two devices, I also attempt to categorize why we may find them interesting. I compare them to other related projects and art pieces constructed in the "Design Noir" style, such as those recently created by Steve Mann. I find that there exist common themes for all these pieces: control, personal space, and subversion, and that these themes are essential to their categorization as "Noir." Finally, I detail the engineering and construction of both *Wave Bubble* and the *Media-Sensitive Glasses*, so that interested parties may experiment in building their own 'social defense mechanisms.'

1

Background

Hertzian Space

All of the electronic devices that are produced and sold to us, by their very existence, participate in our culture. Many of them are designed to be interactive, and we engage with them on a daily basis. Some of these devices, such as computers, video games and personal digital assistants, are explicit in their interactivity. However, even devices like electric coffee pots, remote controls and radios are interactive, in the sense that we use them and they affect us. In Hertzian Tales, author Anthony Dunne extends the physical interactivity between device and person into an architecture he calls "Hertzian Space." This space encompasses not only the form and function of a device, but also how people react and relate to it. In a sense, Hertzian space is a holistic view of the electronic device and its cultural interactions. Dunne and Raby describe this "electro-climate," inhabited by humans and electronic machines, as the interface between electromagnetic waves and human experiences: "Hertzian space describes what happens in front of the screen, outside of the object, it is part of the space our bodies inhabit, even though our senses detect only a tiny part of it" (Dunne and Raby 2001, pg. 12). Visible lights are part of Hertzian space, as are radios, medical X-rays, televisions and UV tanning lamps. Although we cannot sense much of this space (other than visible light of course), the authors claim that we are affected by it, both physically and psychologically. Machines that otherwise seem to be contained in their plastic shells can escape their boundaries and 'bleed' into this space, affecting all who are in it. Taking this idea to an extreme, the authors cite research into 'electrosensitives,' people who are literally allergic to electromagnetic radiation. Of course, there are less pathological examples of how people respond to Hertzian space, such as fears that cell phone radiation causes brain cancer, or how some find more comfort in cassette tapes than CDs because they think the sound 'feels' different.

Design Practices of Hertzian Space

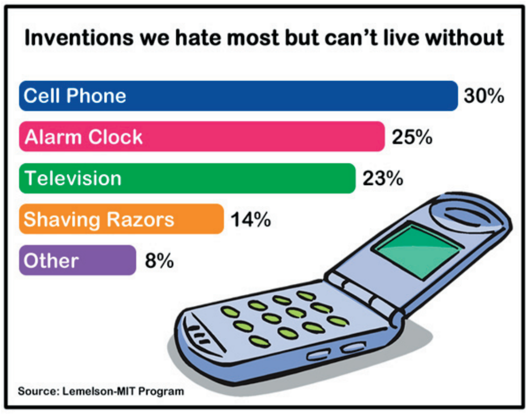
Dunne and Raby believe that increased awareness of Hertzian space will assist our design practices. They believe that we are only beginning to understand its effects and consequences, and that "it is an environment that must be fully understood if it is to be made habitable" (Dunne and Raby 2001, pg. 12). Unfortunately, many manufacturers of electronic products do not consider Hertzian space as an important element in their design process compared to, say, the technical specifications or manufacture costs. As a result, the environment enclosing both device and user is unbalanced. Media theorist Marshall McLuhan describes this cause and effect specifically in regards to electronic media[2] that have been forced into a social system without any regard for social convention:

"The new media and technologies by which we amplify and extend ourselves constitute huge collective surgery carried out on the social body with complete disregard for antiseptics. If the operations are needed, the inevitability of infecting the whole system during the operation has to be considered. For in operating on society with a new technology, it is not the incised area that is most affected. ...It is the entire system that is changed" (McLuhan 1964, pg. 70)

We see clear examples of such 'surgeries' and 'infections' all the time, when new technologies are introduced at the pace of engineering without full consideration for their possible effects on society. The Lemelson-MIT Program, an organization for researching issues related to inventions and inventors, organizes an annual study for gauging popular view on invention technology called the "Invention Index." In 2004, the Program asked Americans "what inventions they hate the most but cannot live without." The cell phone placed first with 30% of the votes. When the Program also asked in a related study whether such inventions have improved American's quality of life, 95% of respondents said "yes" (Lemelson 2004).

In a press release discussing these results, the director of the program commented with his interpretation: "Cell phones have clearly been beneficial in terms of increasing worker productivity and connecting people with family and friends. However, the Invention Index results show that the

2. While Dunne and Raby use 'Hertzian Space' to talk about technology, McLuhan focuses specifically on media. However, McLuhan's idea of media is inexorably tied to the medium device itself and in that sense, I feel that both are essentially discussing the same thing, but from different perspectives



The results of the 2004 'Invention Index' show that Americans hate some electronic devices more than ingrown hairs.

benefits of an invention sometimes come with a societal cost" (Lemelson 2004). Essentially, he is restating what McLuhan observed in 40 years prior.

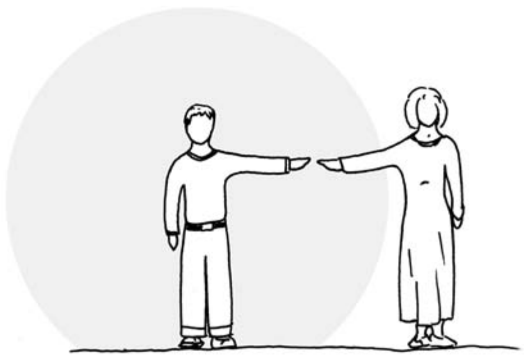
What is interesting to note is that, along with the cell phone, the third "most hated/necessary" device in the survey is the television. The fact that both of these devices are disruptive may explain why they are so disliked. (Contrast their mode of operation to that of say, a microwave oven, or even a PDA.) Dunne and Raby's assertion that devices must peacefully inhabit Hertzian Space if they are to coexist with people seems to fit these devices in particular: they 'leak' heavily into their surroundings, blasting anyone in the area with noise and light. Cell phones and televisions are so prevalent in modern societies that it is increasingly difficult for us to avoid them. Couple this prevalence with the aforementioned devices' antisocial use of Hertzian space, and one finds symptoms of the 'infection' McLuhan has described. By using these devices in public (for example, placing a call on a cell phone while on the train, or turning on a TV in a restaurant) everyone in the area is affected, without any say in the matter.

It is my theory that we dislike these two devices because they invade our personal space, and we feel as if we are unable to protect ourselves. More specifically, both cell phones and cell phone users can be distractingly loud and since we cannot 'turn off our ears,' we have no way to keep ourselves from listening. Televisions are visually distracting; even with the sound off, we find it difficult to keep from staring at the screen if it is in sight despite the fact that we may not be particularly interested in watching television. These devices can be physically distant, but their Hertzian presence (in the form of sound and light) enters our personal space uninvited.

Personal Space

The concept of "personal space" was first studied by Edward T. Hall and published in The Hidden Dimension (Hall 1966). By doing ethnographic studies relating physical distances and psychological comfort, Hall determined that people have well-defined 'bubbles' of space that surround them. For each person there are multiple nested bubbles, each one corresponding to a space that becomes more innately "personal" as the diameter decreases. The largest bubble which we still consider personal space (the 'far phase') extends 2.5-4 feet beyond the body. Hall theorized that this distance is not arbitrary, but that it is directly related to the distance at which others could successfully control us: "Far enough for two people to touch hands, this is the limit of physical domination in the very real sense. Beyond it, a person cannot easily 'get his hands on' someone else" (Hall 1966, pg 113). When unknown or untrusted people enter this space, one may become uncomfortable and aggressive. Hall called the study of personal space "proxemics" because it discusses the social effects of physical proximity, but there are other ways in which we may find our personal space inhabited. For example, by visual, aural and other "Hertzian" encroachments. Just as we become uncomfortable when people enter our personal space, so too may we become uncomfortable when unfamiliar electronic devices do the same.

Indeed, while our culture finds physically invading one's proximal personal space abhorrent, other methods are regarded as merely good advertising techniques. In Being Digital, Nicholas Negroponte explains that "the economic models of media today are based almost exclusively on 'pushing' the information and entertainment out into the public" (Negroponte 1996). Indeed, one of the metrics by which advertising value is counted is by



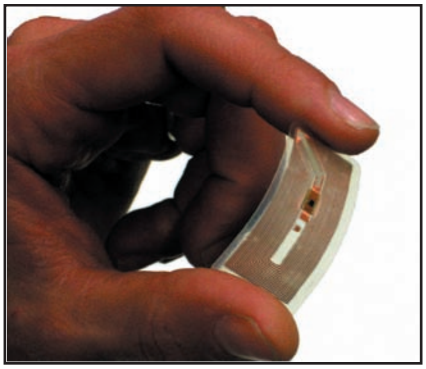
The personal space bubble extends up to 4' beyond the body, far enough to guarantee physical safety.

The effects of electronic devices, however, can easily extend into this space

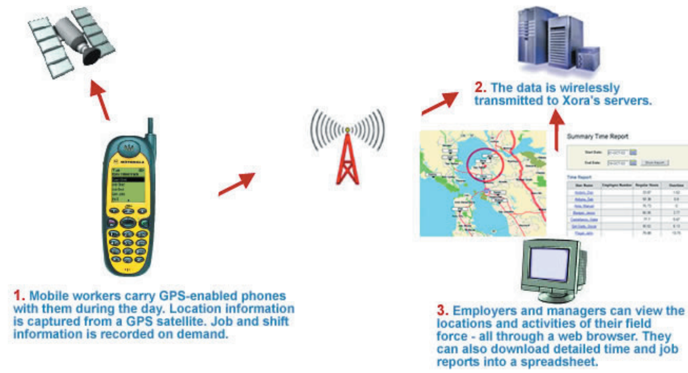
'eyeballs': how many people are watching, and how much attention can you garner from them. While it is true that billboards have been distracting us for a hundred years, electronic devices such as the television and cell phone are a bigger nuisance because they invite interaction. That is to say, we find phones and televisions more distracting because they are, as McLuhan puts it, "cool". As described in greater detail in Understanding Media, the "cold" adjective implies that the technology requires the viewer or listener to "complete" the content. McLuhan thought that phones 'demanded' to be picked up; his argument for television's attraction was that the low-resolution 'mosaic' of video required the viewer to 'fill' in the missing information.[1]

Electronic devices can also invade our personal space by betraying our privacy. The introduction of RFID tags has prompted privacy-protection groups such as the Center for Democracy & Technology and the ACLU to call attention to how such technologies can impact people and their personal space. In a statement to the Senate Committee on Energy and Commerce, the CDT states that while "RFID devices hold possibilities for consumers, businesses and government" they are a privacy risk for consumers because the tags communicate information without notifying the user (CDT 2004). This is because the tags are so small, they can be embedded, unnoticed, into everything from clothing to soda cans, and they can be scanned merely by pointing an RFID reader at the person from a

1. Although the need for visual 'completion' may contribute to television's entrancing nature, recent studies have determined that a physiological response accounts for much of the effect, as discussed in section 4.



RFID tags are small, flexible, and can uniquely identify just about everything.



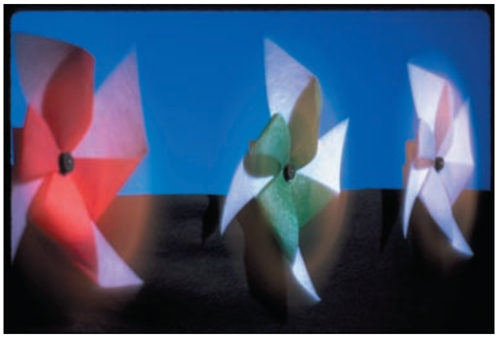
Xora, a GPS tracking company, demonstrates the effortmless way to track employees (Source: Xora website)

few meters away. Thus, someone with an RFID reader could, surreptitiously, determine where you bought your clothes, and how much you paid for them, essentially tracking your purchase history without your knowledge or consent.

There are similar privacy issues with Global Positioning Service (GPS) receivers. Since the commercial introduction of GPS to consumers in the mid 1980s, the service has been used for everything from geographic surveying to automobile navigation systems. Since then, GPS receiver modules have become inexpensive enough that they can be built into cell phones and cars. As a result, multiple companies have begun offering tracking services: employers can track their employees, parents can track their children, and car rental companies can track their customers. Of course, the receivers are discrete enough that they may easily be hidden, and the tracker may decide not to inform the tracked of its existence. As a result, an unaware user may not realize that their car or phone is broadcasting their every move to any interested party.

Proposed Solutions

While it has taken some time, many designers are starting to realize that the technologies they help bring to market can bring about social discomfort through use, i.e. they are adversely affecting Hertzian space. As a result, there have been calls to design new products with such issues in mind, in



Pinwheels*, a project by Andrew Dahley from the Tangible Media Group, uses a benign method of communicating information. The direction and speed of the pinwheels corollates to network traffic.*

the hopes that it is possible to create electronic devices that can peacefully coexist with us. Following his earlier observation that media is ‘pushing’ data onto us, Negroponte rallied technologists and designers to redesign existing media and implement ‘pulling’ mechanisms. His theory is that if technologies require our permission before they disrupt us, we will have balanced the human/device ecosystem back in our favour.

Other designers have decided that instead of trying to redesign the entire infrastructure of information transmission, it might be wiser to fix the modes of interaction. The Tangible Media Group at the Media Lab, led by Hiroshi Ishii, attempts to soften the methods by which electronic devices interact with people. Ishii’s theory is that if designers make the ‘pushing’ of information more subliminal, we will not mind the intrusion. In another group at the Media Lab, the Speech Interface Group, director Chris Schmandt believes that the devices should be made more intelligent. If technologies know more about the user and their preferences, the device will know how not to be annoying. For example, one’s cell phone should know if it’s in a movie theater and automatically turn off the ringer so as not to disturb others. In consideration of the RFID privacy concerns, the Auto-ID group (which is helping to define the RFID standards) has added a “kill switch” capability to the electronic tags. In theory, a store could have a ‘zapper’ after the checkout station, so that customers can disable the tags after the product has been purchased.

What all these solutions have in common is that, essentially, technologists and designers are trying to convince the electronic device industry that they are responsible for repairing device/human interaction. Such attempts to debug and fix the system are laudable, but it seems likely that consumers will have to wait many years before the industry follows these suggestions, if at all. Until these changes come into effect, I propose that designers, technologists and artists should explore the realm of human/device interaction and come up with new ideas for how the consumer may defend his or her personal space from unwanted electronic intrusion.

My approach to helping people cope with intrusive technologies is to develop counter-technologies. After investigating common complaints regarding how certain electronic devices invade our personal space, I analyzed the complaints and devised an 'antidote,' a technique that can nullify the invasion. I then engineered a new device that provides that protection, either through control or avoidance.

The first complaint I addressed is two-fold: first, people are frustrated that cell phones ring at inopportune moments and that their users are not well versed in cell phone etiquette. Second, embedded radio devices like GPS and RFID raise serious privacy concerns. In response, the new device I designed, named *Wave Bubble*, is intended to defend the user's personal space from unwanted wireless communication by creating a personal "cold spot" bubble where RF devices such as those mentioned do not function.

The second complaint I addressed is the over-prevalence of televisions which, coupled with their 'hypnotic' nature, makes it difficult for us to turn away, even when we are not enjoying the experience. The new device, named *Media-Sensitive Glasses*, is intended to help the user protect him or herself from unwanted television media by blocking out televisions when they are in view.

McLuhan noticed that, with the creation of new technologies, there is also a trend towards developing methods to nullify them: "What we seek today is either a means of controlling these shifts in the sense-ratios of the psychic and social outlook, or a means of avoiding them altogether" (McLuhan 1964). Likewise, Dunne and Raby noted that, as electronic devices enter the collective Hertzian space, "other objects [will] evolve to provide shelter from it, filter it, furnish views and allow for privacy" (Dunne 2001). My research realizes their predictions by creating that shelter and providing the methods for control or avoidance. Utilizing the counter-technologies I have designed, we may defend our personal space by either directly controlling nearby devices or creating an environment whereby it is easy avoid them, thereby disabling their power to intrude.

Although the counter-technologies I have designed are functional, they are meant to be more of a proof-of-concept than a product that will appear at the mall. These devices are new members of the electronic/social ecosystem discussed by McLuhan and Dunne, acting as buffers between people and the technologies that annoy them. By creating a viable product and presenting the prototype, I am highlighting the Hertzian conflicts we live with as well as our distress when we are incapable of 'fixing' the problem. The pieces are also intended to demonstrate unorthodox methods of addressing such issues, in the expectation that others may ask themselves whether they are willing to use those methods. All of these issues are meant to fit into a greater dialogue about how electronic devices are designed with regard to interactivity and personal space, and how such Hertzian issues affect us, even when we have become accustomed to these disturbances.

Design Noir

The tradition of designing and using electronic devices as social commentary is known as "Design Noir." Dunne and Raby coined the term in their book, Design Noir to describe the history of culture-jamming product design. They define Design Noir products as part of the 'hidden underbelly' of 'real human needs,' acting as elements in a "narrative space

The film noir genre offers dark and seedy characters with hidden agendas and secret lives. Design Noir offers a look at the 'hidden underbelly' of 'real human needs.' (Still from Hidden Desire*)*

entered by using and misusing a simple electronic product" that challenges "the conformity of everyday life by short-circuiting our emotions and states of mind" (Dunne and Raby 2001, pg. 10). The authors note that much of product design is produced and marketed like a Disney movie — universally acceptable and squeaky clean. Not all fims are Disney, however: there are many other genres available. Their use of the adjective 'noir' connotes the dark and mysterious 'Film Noir' genre, with stock characters like the beautiful dame who ends up being the killer, or the protagonist with a mysterious past. Likewise, there are many electronic products that aren't all they seem either; the cell-phone jammer that is meant to look like just a cell phone[3], or a $10 CD of 'background noise' that can be used to trick people on the phone into thinking you are at a party or stuck in traffic.

Dunne and Raby describe the emotional power of Noir design as being split between the object itself (fulfilling the 'real human need') and the narrative (in describing what that need is). For example, the CD of background music is, in and of itself, a product that is quite boring. There need not be much creativity or craft involved in its production. However, once that product is purchased and used by someone to lie about their whereabouts, it becomes very interesting. The $10 CD has become an electronic alibi, an accomplice to someone's crime. Did the user intend to make himself seem more social by being at a party when they were really just at home, or to excuse a missed appointment when they had really just overslept? Did the CD ease their conscious? Did it make the act easier to go through

3. Sold by Global Gadget UK (http://www.globalgadgetuk.com/)

The electro-draught excluder, a foam briefcase that is meant to block harmful radiation, is shown protecting its owner. The excluder is not actually functional, but still serves to demonstate how many of us are concerned about the health risks associated with electromagnetic radiation. (Source: Design Noir)

with? Were they ashamed of using the device or were they using the device because they were ashamed? These sorts of questions are implicitly introduced whenever we encounter such devices.

Although the background music CD is an example of a product that has been marketed and sold, there are also many examples of art projects intended to incite the same discussion. Not surprisingly, many of them deal with issues of controlling private space. For example, Dunne and Raby's Placebo project includes a piece titled "electro-draught excluder," a portable, briefcase-like device meant to block invisible electromagnetic radiations, thereby protecting the user from harm. Another example is the *No Contact* jacket, a project from the Interrogative Design Group (part of the Center for Advanced Visual Studies at MIT). It is a women's jacket with high-voltage wires sewn into the outside and a rubber shielding layer on the inside. If the wearer feels physically threatened, a switch in the cuff sends a shock through the fabric, temporarily stunning any aggressors. Not intended to be manufactured and sold commercially, it nevertheless highlights women's fear of being attacked and the prevalence of aggressive behavior against solitary women in the urban environment.

Control

A common element in many projects that may be classified as Design Noir style is that of control. That element is particularly obvious in the *No Contact* jacket: the item is designed to explicitly make it difficult for an

The No Contact jacket, created by Adam Whiton and Yolita Nugent, highlights a common fear of being attacked. When activated, the electrified jacket will stun anyone who touches the wearer. (Source: No Contact Jacket website)

attacker to control the wearer. Many Noir devices are more subtle in the methods by which they impart control. For example, Dunne and Raby cite the Sony Walkman as a seminal Noir electronic device, primarily because it allowed people to control and customize their environment through music: "When the Sony Walkman was introduced in the early 1980's, it offered people a new kind of relationship to urban space. It allowed the wearer to create their own portable micro-environment... It functioned as an urban interface" (Dunne 2001, pg. 45).

The devices I have created function in a similar fashion. The portable music player allows the user to filter out their surroundings by drowning out external sounds. Likewise, Wave Bubble allows the user to filter cell-phones out of their surroundings by disabling their use, while the Media-Sensitive Glasses filters out televisions by blocking their user's line of sight.

One of the reasons that may explain the overwhelming success of the Walkman (and other portable music devices) is that by giving us more control over our environment, the Walkman has liberated us. In his essay, "The Digital Renaissance," media commentator Douglas Rushkoff writes about how the most revolutionary electronic devices are those that free us from the constraints of our environment. He claims that the first liberating technology was the remote control. Whereas his generation would often sit through television commercials, annoyed, a “14-year old today, watching a commercial and feeling the first signs that he’s being put into an imposed state of tension...with the .0001 calories that it takes to press a button, he’s out of tension and out of the arc of that story” (Leach 2002, pg. 18). The simple remote control is liberating because it allows the user to easily filter the television-watching experience, ostensibly giving the viewer increased control over their television watching experience.

Rushkoff believes that giving people more control over their environments is the promise of the “digital renaissance.” In his view, electronic devices have great potential as tools for “reality programming.”[4] Such devices are inevitable, he says, because we are starting to realize that “much of reality is open source, and that the ‘codes’ by which we organize our experiences are more accessible than we generally assume” (Leach 2002, pg. 17). While Rushkoff’s statements are close to the Design Noir philosophy, they fall short because the devices he mentions in respect to “reality programming” give a sense of control without actually addressing the issue at stake. The remote control, for example, makes it easier to change channels but does not actually let the viewer ‘escape,’ since all broadcast stations play advertisements at the same time. As a result, the remote control has not initiated a dialog about televsion, advertising and consumer’s desires. The introduction of Digital Video Recorders (e.g. TiVo), on the other hand, has opened the debates between viewers and broadcasters. DVRs can be easily programmed to allow the viewer to skip commercials of recorded shows simply by pressing a button on the remote; some can even skip them automatically.[5]

4. While Rushkoff uses the term “reality programming,” a more appropriate term for the sorts of devices I discuss might be “reality hacking.” Where ‘hacking’ connotes the feelings of subversiveness and unauthorized control that I discuss later.

5. Ironically, a popular way to detect commercials is to watch for audio level changes; most commercials are louder than the programming in order to “grab your attention.”

Subversion

The ongoing clashes between consumers who buy technologies to help them avoid advertisements and the corporations that try to find new ways to add commercials leads us to a second common element in Design Noir: subversiveness. Part of why television viewers love remotes and DVRs is that they make it easy for them to watch a show without having to sit through the ads, essentially tricking the broadcaster and subverting their economic model. The CD of background sounds is another example, a product whose whole basis is tricking someone on the phone. Even the *No Contact* jacket is a little subversive. The jacket itself does not look particularly different from most and there is nothing that may alert an attacker that their victim is wearing an electrified coat. It could even be used to shock non-agressors.

Both of my devices are subversive in their nature, and that subversiveness is an important element of their use. *Wave Bubble* is made to be small yet powerful enough that it can be kept in a pocket or bag while it is activated. Since there are many situations in which wireless devices cannot communicate properly, it is not inherently obvious that a discrete jammer has been used against them. For example, jammed RFID scanners will simply not get any responses from tags, and assume that there are none in the area. Also, there are many RF “cold spots” where architectural elements make it difficult for GPS to communicate with the coordinate satellites. If the device is used in a café, cell-phone users will stay away from the affected area but will not be able to pinpoint why they aren’t receiving any signal.

The *Media-Sensitive Glasses* are also subversive, albeit in a more subtle way. As discussed in detail in section 4, much of the “mesmerizing” effect of televisions is due to the flicker of jump cuts and quick action. This effect is why televisions are so hard to ignore when in the room, as well as the reason for people watching television for much longer than they intended, even when they are not particularly enjoying the experience. Of course, the longer one watches TV, the higher the network’s ratings. Higher ratings translate directly into increased advertising revenues. By darkening the lens whenever the wearer looks at a television, the glasses reduce the hypnotic power, making it easier for the viewer to disengage from the set. Therefore, using the glasses subverts the broadcasting and advertising companies' attempts to make money by hooking viewers.

Portability was a crucial design element when drafting the *Wave Bubble* and *Media-Sensitive Glasses*. Both devices are intended to be small enough to fit in a pocket, lightweight enough to carry with the user at all times, and simple enough to be usable by anyone (the glasses automatically turn on when necessary, the *Wave Bubble* has a single button). My intention was that by successfully designing both devices with these characteristics in mind, they will be considered 'wearables.' The main benefit of having a wearable device is that because the device is with the user all the time, it becomes an electronic 'prosthesis' which extends the wearer's realm of control. Having the device on the person and constantly performing the mediation or filtration desired gives the user an automatic sense of agency. Eventually, the user may not even realize that the device is actively mediating their reality. If the device can actually maintain functionality for the entire day, it may become an element of the "reality programming" that Rushkoff mentioned.

At the moment, when one thinks of wearable devices, gadgets such as PDAs and cell phones come to mind. Such devices are prosthetic in the sense that they extend the capability of our memory (in the case of PDAs) or our ability to communicate (such as with cell phones or pagers). Researchers such as Steve Mann, a professor at University of Toronto, believes that while such uses are highly desirable, there is a greater future for wearable technology in the realm of personalized reality mediation, particularly in controlling personal space. His research and art may be said to use the Design Noir technique[6] of creating prototype electronics to inspire dialog in the realm of personal space and personal mediation through the use of prosthetic-like wearable computers.

6. Mann actually calls his work "Existential Technology" (EXISTtech), and the pieces are categorized as "in(ter)ventions," patented devices that also act as interventions.

While a student at MIT, Mann designed a wearable computer intended to fully mediate his visual reality. His full-fledged system was comprised of a

By using the EyeTap mediated-reality system, the wearer can protect his personal space from offensive advertisements (such as the one on the left) by automatically replacing them with more calming images (such as the one on the right). (Source: Personal Imaging Laboratory)

helmet with a video camera mounted so that it pointed at his field of view. The video was sent via radio link to a set of high-power video processing servers back at his MIT lab. The video processing servers would then apply a programmed filtration or modification and transmit the video back so that it would be displayed on his glasses.[7] After years of revising the system, he shifted his work from the purely technical realm of how to design and build fully functional wearable systems to what such systems can do for people in a social context. One of the first applications for the wearable system was to detect and block advertisements (e.g. billboards) in his field of view. In his view, corporations invade personal space by bombarding people with their advertisements and other "visual detritus" and since they are unlikely to stop, "in(ter)vensionist" (as he calls them) technologies must be developed to protect the wearer.

It is no coincidence that many of his "in(ter)ventions" are wearable devices (e.g. *WearCam, EyeTap, Please Wait*, etc.). Mann's work relies heavily on his view that wearable computers/technologies' primary use should be to provide people with control over their environment: "The most fundamental issue in wearable computing is no doubt that of personal empowerment, through its ability to equip the individual with a personalized, customizable information space, owned, operated, and controlled by the wearer" (Mann/ISWC 1998). Mann's work differs from mine in that he focuses more

7. After decades of revision and technological advancement, the Eyetap system is smaller, lighter, and doesn't require a rack of computers: it is an augmented/mediated-reality system in the form of electronic glasses coupled with a lightweight wearable computer.The glasses redirect any light that is directed towards the eye through a system of mirrors and lenses to a miniature video camera tucked in the frame, so that the computer can analyze the visual content, overlay extra information or selectively censor, and project the augmented vision back into the eye via a micro LCD and more mirrors.

examining the ties between organizational responsibility and empowerment (particularly with surveillance), but his methods for granting that empowerment — through electronic devices that are kept close to the user — is the same.

Conclusion

As manufacturing costs drop, and markets increase, electronic devices become more and more common, to the point where we will soon be constantly surrounded by them. Engineering and industrial practices have, for a long time, driven the creation of new technologies and their introduction is often preceded by market studies, but not studies of social effects. It is not that the technologies are flawed; many of them, like the cell phone and television, are well-liked and have found tremendous success. However, when the social impact of electronic devices is poorly gauged, the use of the device can result in what McLuhan calls an "infection." In particular, I have examined how the introduction of cell phones and televisions into social contexts has left many of us unhappy. In particular, I believe that a strong component of the frustration we feel with these devices is related to how they interact with personal space.

While there have been slow but steady improvements in electronic interface design, consumers will have to depend on the foresight of large corporations to create devices that respect our personal space. Until that time, I have decided to design and build customized tools that not only help consumers defend their personal space, but also highlight these issues. My work is a combination of electrical engineering and culture-jamming; these portable electronic device were created with the sole functional purpose of disabling other common devices, transducing the promise of electronic convergence into the possibilities electronic dissent.

When introducing my work to corporate sponsors visiting the Media Lab, I noticed that even though my work subverts their business model, employees would still express a desire to own and use it. After watching the Wave Bubble jam a cell phone, representatives from both Motorola and Nokia admitted that even though the technology was illegal, they would certainly buy a jammer if they could.[1]

These reactions are precisely the sort of dialog that Design Noir is meant to inspire. Part of what makes "Design Noir" objects so intriguing is the alternative they give to the consumer: an illicit love affair, a 'dangerous' and 'complex human pleasure' (Dunne 2001, pg 6). These designs are not crafted to make us buy more, or to encourage our slavish loyalty, but to begin a more 'life-like' relationship with electronics. One in which we are attracted and repelled, where we feel jealousy and doubt, where we dominate and relinquish. Design Noir electronics are the "complex reality hidden beneath the slick surface of electronic consumerism."

I once presented both Wave Bubble and the Media-Sensitive Glasses to a visiting industrial designer from IBM Watson R&D. He was familiar with Design Noir, and had studied with Dunne and Raby at the Royal College of Art. After my demonstration, we engaged in the following exchange:

> Designer: "So, do these things work?"
> Me: "Err, yes."
> Designer: "I mean, do they really work?"
> Me: "Well, of course they work."
> Designer: "You're wasting your time. Conceptual pieces would be just as effective!"

While his point is valid — many Design Noir pieces don't actually work in the technical sense — I disagree with his assertion that building functional devices is a waste. First, taking the time and effort to build full prototypes of these devices lends credence to the notion that Design Noir is a valid approach to solving common problems. Second, I believe that the sense of 'liberation' that comes from using Noir devices is diminished when there is no actual control. Clearly, telling someone that it is possible to remotely disconnect a cell phone is not nearly as interesting subversive as having them do it themselves.

1. One employee from Samsung asked (sincerely, it seems) if it were possible to incorporate Wave Bubble 'technology' into a cell phone so that only the user could make calls, and all others in the area would be blocked.

Perhaps one of the reasons for the mostly conceptual nature of Design Noir pieces is that there are few engineers contributing to the body of work. This is unfortunate, as Design Noir electronics can be both technically advanced as well as evocative. It is my hope that by designing, building and documenting these two projects as part of an engineering thesis, I encourage more engineers to explore this genre. This view comes partially from my belief that the "Design Noir" philosophy can be enlightening (particularly for those who could end up designing next year's "technology we hate but can't live without), but more so because I believe that there should be more hybrids of art and engineering. Many of my friends who are engineers have told me "what you do is art, not engineering" and a few artists have told me "this is engineering, but not art." To them I would like to present this work with confidence that it engages both communities.

Wave Bubble

The *Wave Bubble* device is a small, low-power RF jamming device. Although it can be easily tuned to disrupt RFID, GPS, WiFi or any other RF communications system, it was designed with cell-phone blocking in mind. Currently, almost 160 million Americans carry cell phones (CTIA 2002) and almost all of us have felt the frustration of having a conversation interrupted because the other person received a call, or overhearing an obnoxious cell phone user while trying to eat at a restaurant. Cyberculture writer and researcher Sadie Plant describes the mobile phone as frustration to all those in its vicinity in her report “On the Mobile”:

“All ringing phones are disruptive, even arresting. As Marshal McLuhan observed in Understanding Media, an incoming call provokes a sense of expectation, even urgency, which is why we usually feel compelled to answer a ringing phone, even when they know the call is not for them. Like a calling bird, a ringing phone demands a response. Public uses of the mobile spread this tension to all those within earshot while leaving them powerless to intervene: only the person to whom the call is made is in a position to respond” (Plant 2002)

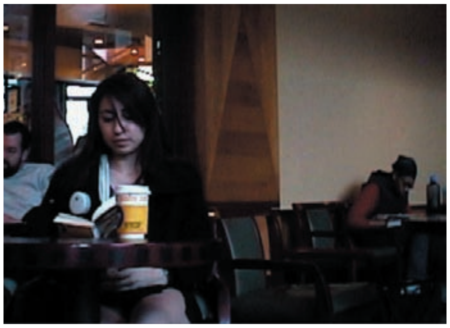
Indeed, while the oft-inappropriate ringing, and unreasonably loud conversations can be annoying, the sense of powerless, or lack of control increase the frustration. As a result, there have been some attempts to control cell phone use, to create ‘safe zones’ of Hertzian space. In some cities, trains and trolleys (most notably, Amtrak) have designated “quiet cars," for people who prefer no cell usage. Some (usually high-scale) restaurants request that the patrons leave their cell phones at the front desk during their meal so as not to disturb other diners. The easiest and most common technique to curbing cell use is requesting courtesy for others. While this, coupled with increased social pressure on cell-phone users, may prove to be effective the long term, the pace will be gradual and is certainly prone to failure.

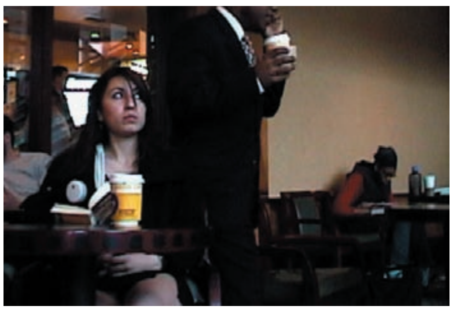
Some businesses and places of worship have decided that they would, rather than request polite cell-use, simply disable all cell phones from being used. Companies have been formed solely for the purpose of developing high-power 'cell phone jammers' for courtrooms, meeting rooms, lecture halls, etc. These devices almost invariably send high power bursts of noise in the radio frequency bands used by cell phones. Most phones, unable to maintain contact with the cell tower, usually report that there is no signal available and are thereby disabled. Unfortunately for consumers in the US, they cannot purchase or use these devices without incurring heavy fines. The FCC has declared it illegal to electronically impede other people's communications[1] because the radio frequencies have been 'sold' to an entity which has sole right to transmit on that band. As a result of this ruling, and due to the high demand for blocking wireless devices, there has been an increasing amount of research and development into passive 'RF blocking' devices, such as wallpapers and windows (reference). Such devices, since they are not electronic and do not "actively" impede communication, do not fall under the FCC regulations.

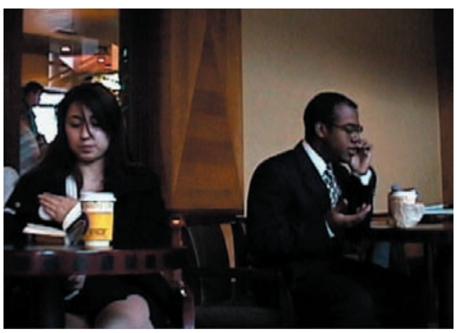
Since cell phone companies have not come up with an effective solution to the 'social infection' of inappropriate cell phone use in public,[2] and businesses are afraid of using large-scale jammers for fear of excessive fines, I have decided to design a low power RF jammer for personal use. Manufacture and use of *Wave Bubble* is not exempt from the FCC regulations. However, there is no legal constraint on dissemination of

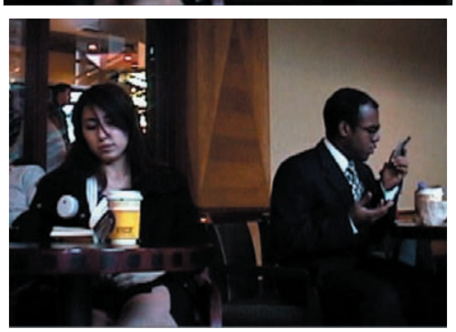
1. The operation of transmitters designed to jam or block wireless communications is a violation of the Communications Act of 1934, as amended ("Act"). See 47 U.S.C. Sections 301, 302a, 333. The Act prohibits any person from willfully or maliciously interfering with the radio communications of any station licensed or authorized under the Act or operated by the U.S. government. 47 U.S.C. Section 333. The manufacture, importation, sale or offer for sale, including advertising, of devices designed to block or jam wireless transmissions is prohibited. 47 U.S.C. Section 302a(b). Parties in violation of these provisions may be subject to the penalties set out in 47 U.S.C. Sections 501-510. Fines for a first offense can range as high as $11,000 for each violation or imprisonment for up to one year, and the device used may also be seized and forfeited to the U.S. government

2. Well, Nokia has declared a "Cell Phone Courtesy Week" to gently inform people it may not be nice to use their phones in churches or libraries.









information pertaining to jamming in the FCC regulations, and I have fully documented the process by which one may build a Wave Bubble for personal use. Anyone who decides to build and use it is performing an act of civil disobedience (a fact which may add to the subversive feel of the device). Hopefully, with social or technological advancement, such a device will cease to be useful.

Media-Sensitive Glasses

The *Media-Sensitive Glasses* device is a pair of electronically-enhanced sunglasses, specifically designed to darken whenever the wearer has watched too much television. They are designed to be worn throughout the day by people who find that they are easily distracted by televisions and feel as if they are ‘unable’ to turn away from the screen. The glasses may also be worn by people who are concerned they may encounter unpleasant television media or want to cut down on their television-viewing habits. The name of this project originates from the fictional “Peril-Sensitive Sunglasses” used by one of the characters in Douglas Adams’ sci-fi series The Hitchhiker’s Guide to the Galaxy (Adams 1979). The glasses would darken whenever the wearer was in a dangerous situation, the theory being that they would relieve any stress that could be triggered by peril, allowing the wearer to maintain their cool and casual attitude in the face of danger. Likewise, the *Media-Sensitive Glasses* can relieve the stress and despondency associated with heavy television viewing.

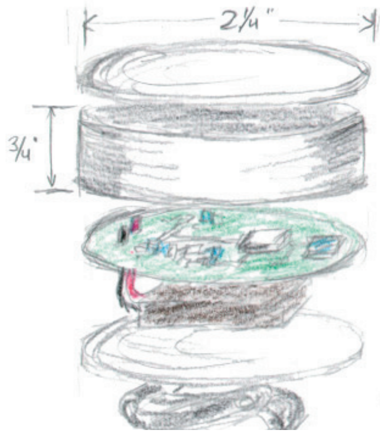
Television is addictive, and as anyone can tell you, it is difficult to turn off or look away from a television that is already on. McLuhan theorized that this is because the low-resolution “mosaic” of television light invites completion from the viewer. The viewer is thus engaged with the television in a way he would not find himself involved with different media such as radio or movies. However, recent scientific research into the response of the human brain to watching television points more to a more physiological reason.

One possible explanation for the extremely distracting nature of televisions is that quick edits and bright flashes that are common to television programming activate the ‘Orienting Response’ (OR), an innate reflex that Ivan Pavlov characterized in his famous “classical conditioning” research. He found that an animal “turns its sensors to the source of stimulation” when encountering novel experiences (Pavlov 1927). Television’s highly colorful and active video mosaic triggers our orienting response, as shown by measuring the EEGs of television watchers, making it difficult for us to look away (Thorson 1986). In a study of children’s television viewing habits, Dorothy Singer observed that ``The TV set, and particularly commercial television with its clever use of constantly changing short sequences, holds our attention by a constant sensory bombardment that maximizes orienting responses... We are constantly drawn back to the set and to processing each new sequence of information as it is presented...The set trains us to watch it” (Singer, pg. 289-303).

Unfortunately, the more television we watch, the unhappier we become by watching it. By performing studies on television watchers and their habits, Kubey and Csikszentmihalyi found that the watcher’s affect decreased as the amount of television watched increased. ``It is easy for our eyes to remain transfixed on the screen even though we concentrate less and derive less satisfaction from the experience... In general, the more people view the less they appear to enjoy it” (Csikszentmihalyi, ch. 5). In addition, when watchers initially turn on the television, they report an immediate surge of relaxation and, conversely, turning off the television often results in quick drop (Csikszentmihalyi, 2002). As a result, television viewers may find it easy to turn on the set, but feel discouraged from turning it off.

My theory is that by reducing the effect of television as a novel visual element that elicits an OR, the wearer can break the ‘hypnotizing’ power of television. The glasses are configurable to either go completely dark when the user looks at a TV or to gradually darken with an adjustable timer.

While initially intended to specifically target situations where people find themselves surrounded and distracted by televisions that they cannot turn off (such as in lobbies, restaurants, etc.), the Glasses may also be used as a ‘quitting aid.’ By slowly adjusting the timer on the glasses, starting with perhaps 4 hours per day and slowly work their way down to 1 hour or less, the wearer can gradually wean themselves from TV (quitting TV cold turkey can sometimes lead to irritability and mood-swings (Csikszentmihalyi pg. 190).) While currently configured to detect and block out television, the Glasses can also easily be adjusted to work with the common computer CRT, as part of a therapy system to aid those who compulsively browse the web or check email.



An early sketch of Wave Bubble packaging


A dual-band GSM Wave Bubble, displayed in Beijing

Design and Implementation of Wave Bubble

Introduction: Jamming techniques

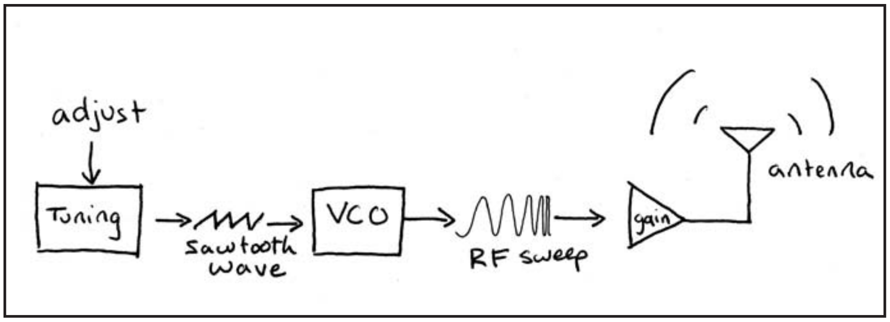
There are multiple ways to incapacitate or 'jam' an RF device. The three most common techniques can be categorized as 'spoofing,' 'denial of service,' and 'shielding' attacks. The first technique basically involves tricking the device into disabling itself or turning itself off. For example, GPS receivers determine their location by listening for satellite-transmitted time codes and performing a triangulation-like calculation. If one could send conflicting time code messages to a GPS receiver, it may compute an incorrect coordinate or malfunction in some other way. One could also construct a device that mimics a cell phone tower. Any cell phone in the area would transmit cell messages to the tower, which the tower would simply 'throw away.' The second technique, 'denial of service' (often referred to as DoS), is more of a 'brute force' method. In this attack the jammer overwhelms the radio band with junk signal, so that any real signals will be drowned out. The third, traditionally known as TEMPEST or EMF shielding, is passive, and basically requires enclosing the area in a faraday cage made of conductive mesh. Any devices inside the cage (which can be as large as a building) will not be able to transmit or receive RF signal outside of it.

The Faraday Chair is an effective (although not quite portable) way of shielding a person from RF. (Source: Design Noir)

All three have advantages and drawbacks. The first technique, 'spoofing,' is much more sophisticated, requiring specialized technology that is customized to each application. It is harder to detect than the other techniques because the jammer is effectively indistiguishable from what it is immitating. The second technique, DoS, is fairly simple, but can be hard to control, (i.e. it is not selective at all, wiping out all devices operating on a certain RF band) and requires a lot of power as it must be many times more powerful than any of the devices being jammed. The third technique, 'shielding,' is the simplest, and is also the only one that complies with FCC regulations. It also requires no power. However, shielding techniques are constrained to a certain location and cannot be used selectively. A faraday shied is always 'on' and tends to affect multiple RF bands.[1] Since the *Wave Bubble* device is meant to be low cost, portable, and adjustable for multiple bands, the most reasonable design would be based on the second technique.

Implementing a DoS attack on RF in hardware is fairly straight forward, the design is essentially the same as that of what is being blocked except much noiser. The main components of a jammer are a voltage controlled oscillator (VCO), a tuning circuit for controlling the VCO so as to transmit into the desired RF band, a 'noise' source which may be built into the tuning circuit, an RF amplification circuit (otherwise known as a 'gain stage'), and an appropriate antenna. All of these components are now mass-manufactured

1. Recently, there has been more research in how frequency selective surfaces (Munk 2000) can be tuned to block specific RF bands. (Register 2002)



The simplest method of building a RF jammer does not include a feedback loop

as solid-state devices, are low cost (totalling under $50), and can be packaged into a portable device.

VCO Selection

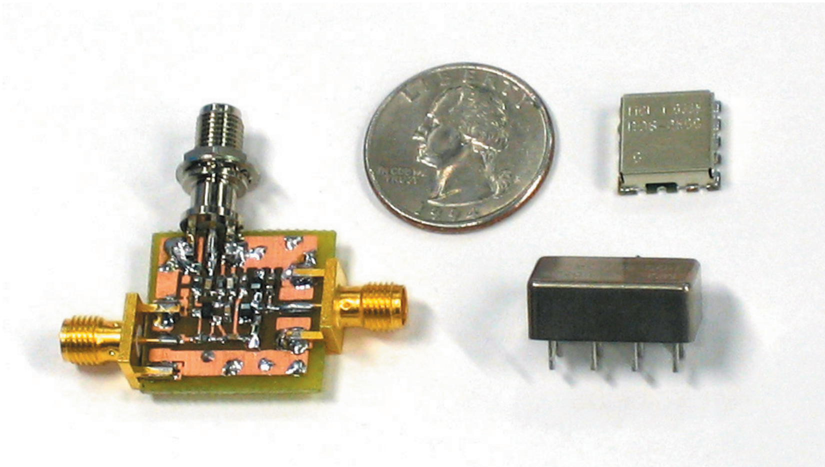
At the heart of the RF jammer is a VCO, the device that generates the RF signal which will interfere with the cellphone, GPS receiver, etc. There are three selection criteria for selecting a VCO for this application. Most importantly it should cover the most popular bands that a user may want to defend him or herself from. These are the mobile phone AMPS (800MHz), PCS (800MHz, 1800MHz, and 1900MHz), and GSM (900MHz, 1800MHz and 1900MHz) networks, GPS (1227MHz and 1575MHz), WiFi (2.4GHz) and the most popular RFID spectrums which include 14MHz, 400MHz, 800MHz, and 2.45GHz. Secondly, it should be readily available at low cost and in small quantities. Third, it should be in small enough a package to allow portabilization. Lastly, it is preferable for the device to have reasonable power requirements. That is, it should run at low control voltages and with low power consumption.

Low frequency VCOs (under 1MHz) are somewhat simple to build using op-amps, and are often implemented as RC relaxation circuits. High frequency VCOs (above 10MHz) are more complicated in their design, and are often based on Clapp or Colpitts oscillators. Since we are concerned with RF in the range of 800MHz up to 2.5GHz, a wide-band, high-frequency VCO is desired. Inquiries into various VCO technologies have resulted in a three viable options: building a VCO from 'scratch,' purchasing a 'encased' VCO from an RF parts supplier, or using a VCO with built-in phase-locked loop (PLL, basically a feedback-driven tuning circuit) such as those available from Analog Devices.

Building a VCO from scratch is not particularly difficult, as there are only a dozen parts required, but involves a great deal of consideration over component selection to acheive proper functionality. The benefits of constructing the VCO include extremely low cost (on the order of a dollar or two), versatility (the VCO can be designed with a custom range) and availability (since it uses only a few transistors, and readily available passive components). Unfortunatly, the actual construction is very difficult to debug without proper equipment or expertise.

Prefabricated VCOs (the second option) are essentially the same topologicaly as hand-made ones, except that the fabrication and testing work is done by a company. These VCOs are often just small circuit boards with Clapp/Colpitts oscillators built onto them, then hermetically sealed into a metal case. The main benefit of going with this option is a guarantee of functionality, although at the loss of RF band-selection and at an increased price. The third option is a fairly new technology—only recently have IC manufacturers begun combining VCOs into their PLL chips. The benefits of such a device include having a high quality tuning circuit built in, which saves costs and eases some parts of the fabrication process. However, it also means that there must be a microcontroller included into the design to control the embedded digital PLL (the other two options use a simple voltage tuning circuit). Also, such chips tend to have much narrower bandwidths, roughly 100MHz.

At the time of development, Analog Device was the only company with combined VCO/PLL synthesizer chips, produced under the ADF4360 series name. While these chips are fairly inexpensive and low power,



Three VCOs, clockwise: surface mount MiniCircuits ROS, plug type MiniCircuits POS, and hand-built.

they also have low output power and low bandwidth. To cover the desired RF spectrum, three chips would be necessary. The ADF4360-7 (350-1800MHz) covers the GPS bands and lower cell bands, the ADF4360-3 (1600-1950MHz) covers the upper cell bands, and the ADF4360-1 (2040-2450MHz) covers the WiFi and BlueTooth bands. Many of the chips were not yet in wide-spread production and were difficult to obtain during the design and specification phase of this project. Therefore, they were not fully explored as a viable option.

I then decided to explore constructing and designing my own VCOs, so that I could customize the RF band output. A wideband 1-2GHz design based on a colpitts/varactor VCO was built and tested. While the design seemed sound, I could not get the VCO to oscillate past 1.5 GHz, much lower than expected or desired. Lacking suitable equipment and expertise to fully debug the circuit, I opted to pass on working further on this topic, noting that if I were designing RF jammers for sum 1.5GHz signals, hand-built VCOs are a viable option.

Finally, I decided to go with prefabricated VCOs. Although they are more expensive than the rest of the options, they are guaranteed to work and are not prohibitively expensive. There are easily a dozen companies producing fabricated VCOs, but the two companies whose products I found to be the

MODEL NO.	FREQ. (MHz) Min. Max.	POWER OUTPUT (dBm) Typ.	TUNE VOLTAGE (V) Min.	Max.	PHASE NOISE (dBc/Hz) SSB@ offset frequencies: Typ. 1 kHz	10 kHz	100 kHz	1 MHz	PULLING (MHz) pk-pk @12 dBr Typ.	PUSHING (MHz/V) Typ.	TUNING SENSITIVITY (MHz/V) Typ.	HARMONICS (dBc) Typ.	Max.	3 dB MOD. BANDWIDTH (kHz) Typ.	POWER SUPPLY Voltage (V) Nom.	Current (mA) Max.
ROS-100	50-100	+8.3	0.5	17	-75	-105	-125	-145	0.6	0.3	3.0-5.0	-30	-20	100	12	20
ROS-150	75-150	+9.5	1.0	18	-80	-103	-127	-144	0.8	0.3	4.0-6.8	-23	-16	100	12	20
ROS-200	100-200	+10.0	1.0	17	-80	-105	-125	-145	0.6	0.3	6-11	-30	-20	100	12	20
ROS-300	150-280	+9.0	1.0	16	-80	-102	-122	-142	0.5	0.3	7-17	-28	-18	100	12	20
ROS-400	200-380	+9.5	0.5	17	-80	-100	-120	-140	0.2	0.3	9-22	-24	-18	100	12	20
ROS-535	300-525	+6.0	1.0	17	-75	-98	-118	-138	0.5	0.4	9-27	-20	-15	100	12	20
ROS-765	485-765	+6.0	1.0	16	-74	-95	-115	-135	2.0	0.5	10-40	-27	-14	100	12	22
ROS-1000V	900-1000	+0.0	0.5	12	-74	-102	-122	-140	1.0	0.4	12-16	-30	-20	8000	5	25
ROS-1100V	1000-1100	+0.0	0.5	12	-80	-103	-123	-142	1.5	1.5	12-16	-26	-20	8000	5	25
ROS-1121V	1060-1121	+2.5	1.0	11	-88	-111	-131	-149	0.7	0.7	8-13	-11	--	10000	5	30
ROS-1410	850-1410	+7.0	0.5	11	-73	-99	-119	-138	15.0	1.0	50-80	-8	--	1000	12	25
ROS-1500	1000-1500	+5.0	0.5	20	-79	-104	-124	-144	10.0	1.2	16-40	-13	--	100000	12	26
ROS-1720	1500-1720	+7.0	0.5	12	-73	-101	-121	-141	11.0	1.3	28-34	-17	-10	18000	12	25
ROS-1900	1450-1900	+7.0	0.5	20	-80	-106	-126	-146	7.0	0.7	22-34	-15	-10	100000	10	25
ROS-1900V	1450-1900	+8.0	0.5	20	-78	-104	-124	-144	7.0	0.7	22-34	-18	-10	100000	5	28
ROS-2000	1350-2000	+7.0	0.5	20	-75	-100	-120	-140	8.0	1.5	30-50	-11	--	2000	12	26
ROS-2500	1600-2500	+6.5	0.5	14	-66	-90	-113	-133	18.0	5.0	30-180	-14	-8	6000	12	25
ROS-2650	2165-2650	+6.0	0.5	10	-75	-101	-121	-141	8.0	1.0	27-36	-12	--	6000	12	25
ROS-3000V	2400-3000	+9.0	0.5	22	-70	-96	-116	-136	30.0	1.5	20-60	-18	--	20000	5	40

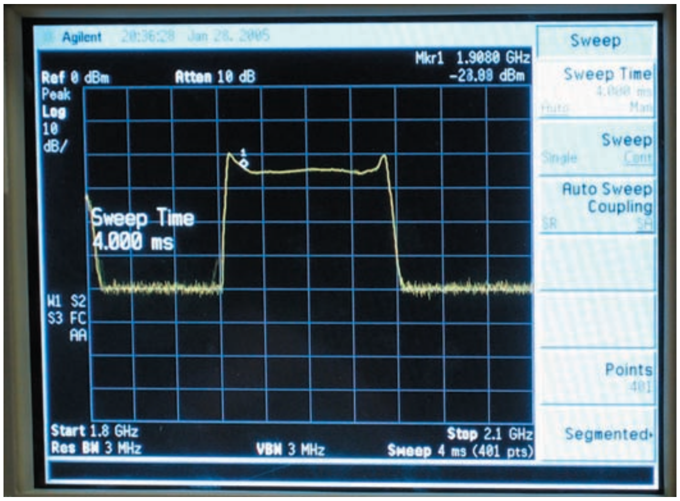
The VCOs Available from MiniCircuits in the ROS package outline cover all the bands we are interested in

most available were Micronetics and MiniCircuits. Micronetics makes high quality parts, and an early version of the Wave Bubble uses one of their VCOs. However, I found MiniCircuits to provide an much wider range of VCOs at lower prices. I chose the ROS line of VCOs, as that line seemed to cover a good wide range of RF bands covered with reasonable power requirements, in a small but managable package. In particular, I intended to use the ROS-2500, with a frequency range of 1.5GHz to 2.5GHz, and the ROS-1410, with a frequency range of 800MHz to 1.4GHz. Combined, these two VCOs cover all but the low RFID frequency ranges. The RF power output of this range of VCOs is on the order of +7dBm. The power requirements are modest, around 25mA at 12V. The output frequency is programmed via an analog input voltage, ranging from 0 to as high as 25V.

Tuning Circuitry

The tuning section of the RF jammer sweeps the VCO through the desired range of frequencies. There are two commonly used types of tuners: open-loop and feedback. The first kind of tuner is very simple, and requires only a few op-amps and passive components. Basically, it is just a triangle or sawtooth-wave generator, offset the proper amount so as to sweep the VCO from the minimum desired frequency to a maximum.[2] Often, because VCOs drift with power supply, and because lots can have tuning variations,

2. The first revision of Wave Bubble is based off of the multiple schematics available from Green Bay Professional Packet Radio www.gbppr.org



The Wave Bubble's output is measured using a spectrum analyzer. As seen here, it is currently tuned to sweep between 1.9GHz-2GHz, otherwise known as the PCS band

a frequency-counter or spectrum analyzer is necessary to get the correct bandwidth. The second type of tuner uses a PLL to constantly adjust the VCO to keep it at the right frequency. For such high frequencies, a programmable PLL must be used, whereby the PLL divides down the RF frequency by a 32-bit number *n* and then compares it to a 'quality' (i.e. high precision) reference frequency from a crystal running at, say, 10MHz. If the VCO's output frequency is too high, the output pin of the PLL drops low, and vice versa.To program in *n*, a microcontroller must be used. Since most RF projects have the VCO tuned to a single frequency, the divider, *n*, is often programmed once and connected more or less directly to the VCO in a feedback loop. Since this is not the situation for us — we would like to sweep the frequencies — the VCO/PLL stage requires a more complicated setup involving a microcontroller and possibly digital potentiometers. For this revision, only a simple tuner was implemented, with the intention that future revisions will include self-tuning/PLL circuits.

Gain Stage and Antenna Selection

In order for Wave Bubble to protect its user's personal space, it must effectively disable RF communication in a fairly large area. The target radius of the Bubble's jamming area is on the order of 2m, which corollates to the size of the average American's personal space 'bubble.' Once the VCO has been chosen, the output power of the jammer (which is proportional to the effective area) can be increased by adding amplification stages before the antenna. Each gain stage increases the output power (up to a certain maximum defined by the maximum capable by the gain stage) at the cost of battery life.

For the gain stage, I chose the AG-603 InGaP gain block, an easily available, general purpose RF buffer amplifier. In general, the AG603 has an f_t at 6GHz, and provides about +17dBm gain or more up to 2GHz which suits us well. The IC is linearly biased from a 6V rail through a resistor, and draws 75mA, consuming a little less than half a Watt. The maximum output power of this particular device is a little more than 20dBm which means that, given our VCO output power of +7dBm, using one gain stage if fine but that it is not possible to cascade two or more. If more output power is desired, a second, higher-power amplification device will be required. Early prototypes using a single gain stage proved to be successful in disabling cell phones at 2m distance, and so a higher powered gain stage was not investigated.

A proper antenna is necessary to propagate the jamming signal. In order to have optimal power transfer, the antenna system must be matched to the transmition system. Matching the antenna is usually just a matter of picking an antenna with little return loss, usually described as the VSWR. A well-tuned antenna, one that has a VSWR of 3 or less at the transmitted frequencies, is highly desirable. For the first few revisions of the *Wave Bubble*, all of which operated in the PCS or GSM bands, a GSM patch antenna was used. Such antennas are soldered directly to the PCB and are quite small. Unfortunatly, patch antennas come in various sizes and mounting patterns and are not, in general, interchangable. Since the *Wave Bubble* is intended to be tunable to any frequency, the patch antenna was later replaced with an RP-SMA PCB edge-launch connector so that a variety of antennas may be attached depending on what frequency band the device is tuned for.

Power Supply

For *Wave Bubble* to be an effective portable RF jammer for daily use, it must have enough power to jam RF in the vicinity of the user, and go without recharging for at least a day or two. All RF jammers require a lot of power as, by definition, they must substantially overpower all nearby devices to disable them. Therefore, the most important specification of the *Wave Bubble* power supply was that it would provide the almost 2W of power required, for at least 2 hours of use (enough to last through an entire movie, or meal at restaurant) at a fairly low cost and in a reasonable amount of space.

Unfortunatly, the *Wave Bubble* requires three different voltages to run, two of which draw a fair amount of current. These requirements make the power supply design particularly complex. Depending on what model is used, the VCO may require up to 40mA at 12V. (The two particular VCOs chosen for this design both ran at 12V at 25mA each.) Each RF gain stage requires 6V at 75mA, with at least one stage required per VCO. The VCO tuning circuit runs mostly at 6V, at a few mA, but also requires up to 30V to tune the VCO over its entire range.

Since the device is intended to be used on a daily basis it must run either on a rechargable battery pack or disposable batteries, both of which usually average 3-5VDC at a few Ah. Therefore, DC-DC step-up converters must be used to provide the high voltages necessary to run the device. The two options for such converters are inductor-based boost regulators and switched-capacitor voltage doublers. Switched-capacitor converters are fairly simple and reasonably effecient, but are not regulated (that is, if you want 5V from 3V you have to double to 6 and then use an LDO regulator to get 5V). Boost converters are always regulated, but cost a little more, and are more complex to get working, requiring careful specification of the external components to acheive high efficiency.

The first design of the *Wave Bubble* power supply utilized a dual boost regulator, the LT1944 from Linear, to generate +-12V and 6V. Although this solution was functional, it operated at the edge of the converter's capabilites. Another issue that cropped up was that, depending on the PCB layout, RF noise would couple into the inductors, saturating the cores and causing the boost regulator to fail intermittantly. A second power supply was designed, using only switched-capacitor DC-DC converters. Such converters would be immune to failure inductor saturation. A three-voltage (+6, +12 and +24V) switched-capacitor power supply was designed for Wave Bubble.

Unfortunatly, there are many drawbacks to using switched-capacitor converters. First, they are often configurable only as voltage doublers or inverters which means that three cascaded converters are necessary. Secondly, they are often not regulated and have fairly high output impedance, which means that a separate voltage regulator is needed for each voltage output stage. What this amounts to is that the cost of the power supply is quite high and many components are necessary. However, unless a proper shielding system is built, this type of supply is the only one that can provide guaranteed performance.

To power *Wave Bubble*, a fairly powerful battery source is needed. Two viable sources are 2-4 standard AA alkaline batteries, or a medium-sized (3.7V at 1Ah) lithium ion battery. Either will suffice to run Wave Bubble for multiple hours.

Conclusion

The *Wave Bubble* was designed and built during the spring term of 2004. Multiple revisions were tested against different cell phones with reasonable success. Older (2nd generation) cell-phones were easier to jam, likely because their output power is lower, and their receiving front-end less sensitive than those of current phones. Depending on the cell phone model, the effective zone of the bubble ranges from 1 to 2m. While the design is successful, there is a lot of work that needs to be put into *Wave Bubble* before it can be considered completed.

Improvements

There are many possible improvements that can make *Wave Bubble* more effective and reliable. The most important is the design and implementation of a simple power supply, a task that is not difficult as much as tedious. It seems likely that a fully switched-capacitor power supply would be best, to minimize failure due to a poorly shielded board. Unfortunatly, there are multiple versions of switched-capacitor chip, each with different loads and capacities. It seems that, considering the large number needed to run *Wave Bubble*, it might be best to implement all of the DC-DC converters using a 3-channel PWM chip. Particularly if it is possible to hand-build a charge-pump converter that can supply more than 200mA, a bottle-neck in the current revision.

There is also an obvious need for a feedback tuning circuit; few people have RF frequency analyzers for tuning the jammer by hand. A good candidate for a PLL is the LMX23xx seriers of high frequency, programmable PLLs. This chip would have to be programmed every time the device is turned on, likely by a microcontroller. Instead of a passive feedback loop, the microcontroller could use programmable resistors to set the bandwidth and offset. Such a setup would make it easy to change the configuration of the jammer on the fly, i.e. have a switch for selecting which band the user would like to disable.

Design and Implementation of Media-Sensitive Glasses

Introduction

The *Media-Sensitive Glasses* are a pair of eyeglasses that, when worn, detect when the wearer is watching television and subsequently darken, so as to 'protect' the wearer from television's 'hypnotic' effect. The glasses are intended to be part of a therapy system for people who find themselves surrounded by televisions on a day-to-day basis and find it difficult to look away from a television set even if they are not enjoying the viewing experience. To be effective, the glasses must correctly determine when the wearer is watching television and darken the lenses or otherwise render the television's image difficult to see as well as be comfortable and safe to wear. This section details the design and implementation of the *Media-Sensitive Glasses*.

Television Detection

Photo detection circuit

The first important requirement of the *Media-Sensitive Glasses* is that they be able to detect when the wearer is looking at a television with few errors. The simplest method for doing so seemed to be detection of the characteristic flicker from a television, nominally 59.94Hz in the US.[1]

1. NTSC standard for color video transmission, PAL standard is 50Hz.

A photo sensor is used to detect when a television is in view. Most photo sensors, such as photo diodes and photo transistors, are PN junctions whose packaging has been designed so that the junction is exposed to ambient light. They are available in many substrates and configurations which affect what wavelengths the sensors respond to, as well as light sensitivity and dynamic range. Because the majority of light emitted from televisions is in the visible range, and often with a bluish tinge, the photo sensor must be sensitive in the visible-light range (i.e. peak wavelength detection should be around 500nm). The two most popular and available photo detection substrates are silicon (Si) with peak wavelengths around 550nm (visible) and gallium-arsenide (GaAs) with peak wavelengths around 800nm (IR). Therefore, a Si-substrate photo sensor was chosen for use in the circuit

When selecting a photo sensor, there are two major options for how the PN junction is packaged. Such detectors are available in both photodiode (just exposed PN junction) or phototransistor (NPN with exposed base) configurations. Phototransistors have an 'built-in' gain of 100 or more, and are therefore more sensitive. Photodiodes have faster response times, but require extra active-biasing circuitry, buffers and signal-amplification. Although phototransistors would appear to be optimal in most situations, they are self-biasing which makes automatic gain control extremely difficult. Given the added complexity of designing an AGC for a phototransistor, I decided against including one in this hardware revision. The final sensor chosen, the SFH3410, is small, designed for visible-light sensing, and easily available at low cost.

A simple, passive biasing scheme is used to bias the phototransistor. The emitter is tied to ground and the collector is connected to Vcc with a large biasing resistor.[2] Since there is no active biasing scheme, the signal from the phototransistor must be buffered by an op-amp before filtration. The DC-level of the signal may be as low as 0.1V (the AC is on the order of a mV), so a low-offset, rail-to-rail op-amp is used for the buffer.

2. Actually a 500K potentiometer.

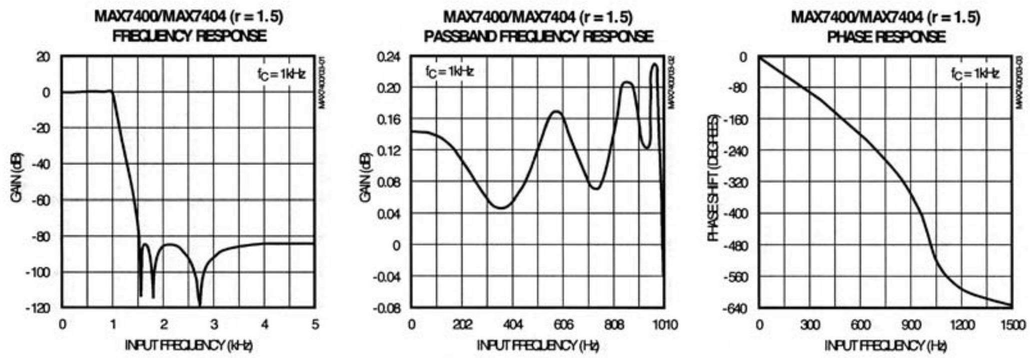
Filtration

The amount of detectable light from a television is dwarfed by the flood of environmental lighting. Even in a dim sports bar, unless one is standing right in front of the television, there is much more light coming from the surrounding halogen track-lighting. Fortunately, televisions flicker at around 60Hz, plug-in lighting such as from standard incandescents flicker at 120Hz, modern fluorescents flicker at 1KHz or higher,[3] and '12V' track lighting is DC driven and doesn't flicker at all. What this means is that once we filter out all light flicker above 60Hz, it is easy to determine if a television is in view using simple digital signal processing techniques.

To make the TV flicker detection circuitry work best, we must band-pass filter our photo-detector signal around 60Hz. The high-pass filter is necessary firstly because the active low-pass filter requires that there be no DC component to the incoming signal and secondly because we would like to reduce the effect of slower, ambient light level changes on the television detection hardware. As there are no common light sources that flicker at frequencies below 60Hz, the high-pass filtering is simple and can be performed using just a single-pole RC network for passive filtration. Since we have to AC-couple the signal into the active filter, the high-pass filter is placed after the buffer. The 3dB point for the filter is placed at approximately 30Hz, allowing for reasonably sized components and low-attentuation at the desired pass-frequency.

The low-pass filter is slightly more complex, requiring a high-order active filter. Ambient 120Hz signal can be up to 2 orders-of-magnitude larger than our desired 60Hz signal, which means that we must attenuate at least 4 orders of magnitude (80dB) to have a clean signal for processing. A passive 2-pole low-pass filter provides only 40dB/octave attenuation, clearly not enough, particularly since 120Hz is only 1/3 octave from 60Hz. In addition, at low frequencies, the inductors and capacitors for passive filters become

3. Older magnetic-ballast flourescents, known for causing headaches, run at 60Hz, which will confuse the glasses. These are becoming increasingly rare and are therefore not considered.



The MAX7404 has exceptional rolloff, providing more than 80dB attenuation at 1/3 octave. Since we are only filtering for one frequency, the passband ripple and phase response does not affect performance. (Source: MAX7404 datasheet)

exceptionally large. An active filter can provide much higher order filters at low power and with smaller real estate requirements.

There are four popular analog filter topologies: Butterworth, Bessel, Chebyshev and elliptical. Since we are only detecting one frequency, issues such as group-delay, phase-delay and pass-band ripple are irrelevant. The most important characteristic for choosing the filter is a steep enough rolloff to provide greater than 80dB attenuation at 120Hz with a 60Hz cutoff frequency. Therefore, filters such as the Chebyshev and elliptic are best suited, giving highest rolloff per order.

The first version of the low-pass filter was designed as a 6th-order Chebyshev filter, providing 60dB attenuation at 120Hz. The filter was implemented as a three op-amp active filter. Although providing fairly reasonable performance and low-power, the large number of resistors and capacitors required a large amount of board space, on the order of 1 cm^2. The second revision of the filter was implemented entirely using an integrated switched-capacitor filter. The integrated filters, sold by Maxim as the MAX740x series of switched-capacitor filters, is available in small form factors (such as 8-TSSOP and 8-SOIC) and high filter-orders (up to 5 and 8). Other benefits of using such filters are that they provide adjustable DC level shifting, run off a single supply and require no external components. One drawback is that the filter cutoff frequency is programmed by clocking the chip at 10*f_c, which means that either an external oscillator or microcontroller is required. Since I planned to use a microcontroller for the signal processing, and 6kHz is low enough to be generated using built-in interrupts, this requirement did not pose any problems. The MAX7404 (an 8-pole elliptical filter) was the final integrated filter chosen, giving a minimum of 80dB attenuation at 1/3 octave with 2mA quiescent current consumption at 3.3V and available in 8-SOIC packaging.

Digital Signal Processing

Once the signal from the photo sensor has been filtered, a microcontroller is used to detect whether there is 60Hz signal present. Usually, when performing such signal processing tasks, a dedicated DSP processor (or microprocessor with a DSP core) is used to perform FFTs so as to determine the frequency-makeup of the signal. These processors are often exceptionally powerful, and therefore too large and power-hungry for this application. Since we are only looking to detect a single frequency, a simple 8-bit microcontroller will suffice. By connecting the signal to a comparator and then counting cycles between pulses, the microcontroller can make 5% or better approximation of the main frequency component of the signal. Although this technique has only mediocre performance when more than one frequency component is present, with good band-pass filtering it is sufficient for a working prototype.

Since both program space and computation time are scarce, a simple technique is used for detecting 60Hz signals. The microcontroller counts the number of cycles between zero-crossings, and performs a two-level threshold/averaging calculation to determine the likelihood of a valid signal. The signal, biased at mid-supply, is input along with a low-noise DC reference, also at mid-supply, into a schmitt-trigger comparator.
The microcontroller is configured to execute an interrupt every time the comparator flips. Another interrupt, running at a fixed high frequency, increments a 16-bit counter. The counter is used, essentially, to count

cycles between comparator-changes. (This scheme is used because, although almost all microcontrollers have built-in counters, most are 8-bit, and would therefore overflow much too quickly.) At every comparator interrupt, the number of cycles since the last comparator interrupt is stored in a small array. Once the array is filled, the microcontroller compares the stored counter values to the target value for a 60Hz square wave. For example, if the microcontroller is running at 4MHz, the target number of instructions between interrupts is 66,666.[4] The number of values that fall within +-5% of the target is stored in a second, fixed-size, circular queue. The second queue stores the last 16 sets of values, so that the microcontroller can, in a sense, look at the last 256 comparator interrupt timing values in only 32 bytes of SRAM.

Every time a new value is inserted into the second-level queue, a second threshold calculation is performed on the entire data. The technique of using two threshold filters prevent spurious noise and transients caused by the wearer moving around to affect the steady state. First, the values in the queue are compared with a preprogrammed threshold value and assigned either a 1 (of they pass the threshold) or 0. For example, if, for a given set of 16 comparator-timing values, more than 5 of them are within +-5% of 0x208D, then that set of values passes. This is done for all 16 sets in the second level queue. Then, the values in the queue (1's and 0's) are summed, and compared to a second threshold. If the summation is higher than the threshold, the microcontroller decides that there is a consistent 60Hz signal coming from the phototransistor, and that there is a TV in view. Otherwise, the microcontroller assumes that there is not a TV in view.

Television blocking

Once the microcontroller has detected a television, it activates the blocking mechanism. The glasses use a simple technique for blocking out television: they just block out all vision. To perform this task, the glasses must use some sort of electronically-controllable sunglasses for lenses. In this case, a pair of electronic LCD shutter glasses was repurposed.

4. Since that number doesnt fit in a 16bit variable, the cycle-counting interrupt is actually set up to count only every 8th cycle to give a target value of 8,333, or 0x208D.

LCD shutter glasses are mostly used for stereoscopic (3D) games and CAD. The glasses contain two fairly large single-cell LCDs, which are controlled via two leads for applying the driving voltage. Since there is only one cell per lens, the entire lens can have only two states, on (when approximately -10V bias is applied) or off (when 0V bias is applied). LCD shutter glasses are fairly inexpensive, and come with lenses that are already shaped similarly to everyday eyeglasses lens and are therefore well-suited to this application. Auto-darkening weldor's helmets also use single-cell LCDs but these are much more expensive, and the lenses tend to come in large 'visor' sizes. Another option is to use small, multi-cell LCDs such as those used in mobile phones. A early attempt at using these sorts of LCDs as electronic sunglasses verified that these LCDs are not nearly dark enough to actually block out light and are much more difficult to interface with a microcontroller.

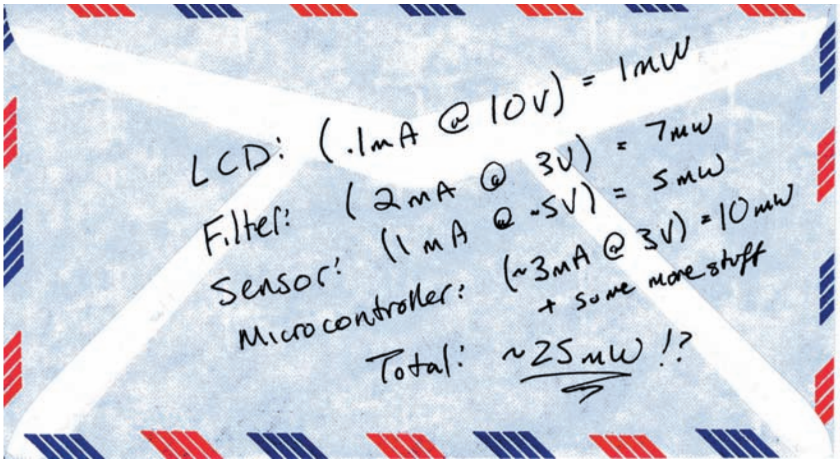
The current detection/blocking protocol is quite simple, the LCD lenses are darkened when a TV is in view. Since an LCD cell is basically a capacitor (of approximately 10nF) driving the LCD requires a push-pull stage that will dump charge to and from the capacitor via the DC bias voltage. The bias voltage is generated by either a switched-cap or boost regulator, and the push-pull stage is implemented with a rail-to-rail op-amp configured as a comparator. (A true comparator would be faster but slightly more expensive.) The LCD lenses may also be 'dimmed' by pulse-width modulating the input to the comparator, allowing for a slow fade-to-black instead of a quick blackout. Using a slow fade makes the 'blacking out' process easier on the eyes, and would perhaps function as a 'warning system'; the more television the user watches, the darker the glasses get until the viewer cannot see anything at all.

Microcontroller selection

The microcontroller performs various functions related to filtration, detection and blocking. First, it generates the $100 * f_c = 6$kHz clock signal required to set the cut-off frequency for the switched-cap filter. Second, it performs the calculations for detecting any 60Hz frequency components in the band-passed signal. Third, the microcontroller drives the push-pull stage that switches the LCD on and off.

For the first task, a dedicated PWM system is preferable. If that is not available, a timer that can trigger an interrupt at 12kHz will also suffice. For the second task, a pin-triggered interrupt system is necessary, and a built-in comparator is highly preferred. There must also be some counter for keeping track of cycles between interrupts, a small amount of RAM or register storage, for keeping track of timed-interrupt values, and enough program space for performing the calculations. For the third task, all that is needed is a CMOS output pin. Other preferable characteristics include: in-circuit programmability, small size and low power, low-voltage core (i.e. as low as 3V), and a built-in RC oscillator.

The microcontroller chosen in the end was the Atmel ATtiny13, a small 8-bit RISC microcontroller. Other options included Microchip PIC12F62x series and other ATtiny chips, all of which are 8-pin, 8-bit microcontrollers with internal oscillators. The ATtiny13 was eventually chosen over others because it contained 64B of SRAM, an analog comparator, 2 timers, and multiple internal oscillators, running as high as 8MHz. The chip is also much easier to program in assembly than the PIC series chips due to a very RISC-like instruction set. The microcontroller also has a built-in PWM circuit but since the output pin is the same as the comparator input pin, it was not used. Unfortunately, none of the available microcontrollers are particularly low-power, requiring 3mA at 3.3V. Texas Instruments' MSP430 series microcontrollers would be a good option for reducing the required power, requiring less than 1mA at 3V, but they are not available in 8-SOIC packages.



A back-of-the-envelope calculation of power requirements can aid in quick evaluation of various power supplies.

Power Supply

When designing portable electronics, the power supply often becomes a major portion of the design challenge. It must be lightweight, small, long-lasting, efficient, safe, and hopefully inexpensive. For the design of the *Media-Sensitive Glasses*, each of these design points were taken to the extreme. Not only must the power supply provide the required voltages, but it must also be small enough that it can be mounted inside the arm a eyeglass frame, light enough to not be unbalanced (thus making the glasses uncomfortable to wear), safe enough to wear next to the users face, and efficient enough to drive the circuitry for more than an hour on a tiny battery.

The design of the power supply can be divided into two subsections, the power source and the power conditioning. The power source in this case must be some sort of battery, and the conditioning is the methods by which the battery supplies the required power to the circuitry, usually implemented with integrated DC-DC converters, regulators, references, etc.

Power Source

Because of the weight and size constraints, only a few options were available for viable power sources. The two available options were either battery (either rechargeable or one-time-use) or solar power.[5] The benefits of using solar power over battery power are that the circuit would only be

5. Solar power is often used in auto-darkening welding helmets.

powered when there is light (such as that from televisions), and that the solar panel can also be used as the photo sensor. However, given that the required power could be as high as 25mW and that the glasses should work in dim locales such as bars and restaurants, simple experimentation verified that for the solar panel to provide enough power, the cells would have so large that the power supply would be heavy and aesthetically displeasing.

Most small portable electronics, particularly ones that are extremely small, use single-use coin cells as batteries. Lithium coin cells, in particular, are particularly well suited as they provide 3V, enough to run most electronics, and have reasonably high power density. Unfortunately, they also have extremely high internal resistance and wear quickly at high drains such as those necessary to run the microcontroller and active filter. Although it is possible to reduce the external resistance by connecting a few in parallel, in attempting to use these batteries in an early design, I found that the bulk of so many cells outweighed their functional simplicity.

Rechargeable batteries, such as Lithium ion, Nickel Cadmium and Nickel Metal Hydride, usually come in large form-factors and have lower power densities than single-use (Alkaline and Lithium) batteries. However, new research in low-power and low-weight RC hobbies has resulted in extremely light and small rechargeable Lithium Polymer cells. In particular, Kokam has recently produced ultra-light cylidrical batteries. I chose the KOK-20 brand battery, with dimensions of 50mm x 6mm x 4mm, providing 20mAh at 3.7V and weighing only one gram.

The form-factor and weight of this battery are well within the desired constraints, and the reasonably high voltage and power capacity are sufficient to run the circuitry for at least 2 hours, which is reasonable for a prototype design. Unfortunately, rechargeable lithium batteries are electrically delicate and can suddenly explode if discharged or charged beyond their capability. Since the battery is stored close to the users face, a protection circuit must be used in order to prevent an auto-incidiary disaster.[6] Many RC-supply stores carry protection circuitry, however, most are intended for large battery packs and are excessively large and overdesigned. Therefore, a simple battery protection was designed, on the order of the KOK-20 battery in terms of size and weight. The protection circuit consists of an "Efficient Single-Cell Rechargeable Lithium Protection IC" (DS2720 from Maxim) and a dual N-channel MOSFET IC for both charging/overvoltage and discharging/undervoltage protection.

Rechargeable lithium batteries also require specialized chargers, as trying to charge a battery faster than it is rated for can destroy it or cause a fire. Since this battery is new to market, no existing charger is capable of charging at such low rates. A custom battery charging circuit was designed for recharging the battery between uses. The charging circuit consists of a "Constant Current/Voltage Lithium-Ion Battery Charger controller" (LM3622-4.2 from National Semiconductor) and supporting circuitry. A resistor defines the 'constant' charging current, which must be less than 1C, which in this case is 20mA.

The complete battery solution is more expensive than using disposable coin cells, but works very well. As more micro-RC devices come to market, the availability of small and light batteries is expected to increase. Of course, custom battery configurations for large quantities are also available from multiple battery manufacturers in Shenzhen, China.

Voltage Regulators

Each sub-section of the glasses circuitry requires regulated power source. Again, the regulation system must have low quiescent power, require low PCB real-estate and have high conversion efficiency.

There are multiple constraints on required voltages. The strictest voltage

6. "Tito! Tito! My hair is on fire!" (M. Jackson, 1983)

requirements are for the active filter (either 3.3V or 5V) and LCDs (10V). The microcontroller and photosensor can run at voltages ranging from 2V to 6V, where the microcontroller preferably runs at a lower voltage (lower power) and the photosensor at a higher voltage (more dynamic range). Since the power source chosen provides 3.7V minimum, a 3.3V LDO regulator is smaller and more efficient than a 5V boost supply, I chose the 3.3V version of the active filter. Since the filter and microcontroller should have compatible I/O levels, I chose to run the microcontroller at 3.3V as well. For increased dynamic range, the photosensor was connected directly to the battery. Since the LCD must run at 10V, some sort of step-up regulator must be used. The two available options for small DC-DC step-up regulators were to either use two switched-capacitor voltage doublers (to boost 3.3V to 9.9V) or a boost regulator. Although both would be perfectly suitable, the single boost regulator has a lower part count and slightly smaller space requirements.
(Put table here summarizing regulators, efficiency, and components)

Conclusion

The Media-Sensitive Glasses were successfully designed and constructed during the fall term of 2004. Testing has shown that they are effective in detecting televisions and have virtually no false-positive detections. In certain lighting conditions (particularly well lit rooms) the detection circuit is ‘flaky’ and sometimes takes a few seconds to determine that there is a television in view. The power system also does not last as long as calculated, probably due to low battery efficiency, or false advertisement of the battery’s capacity.

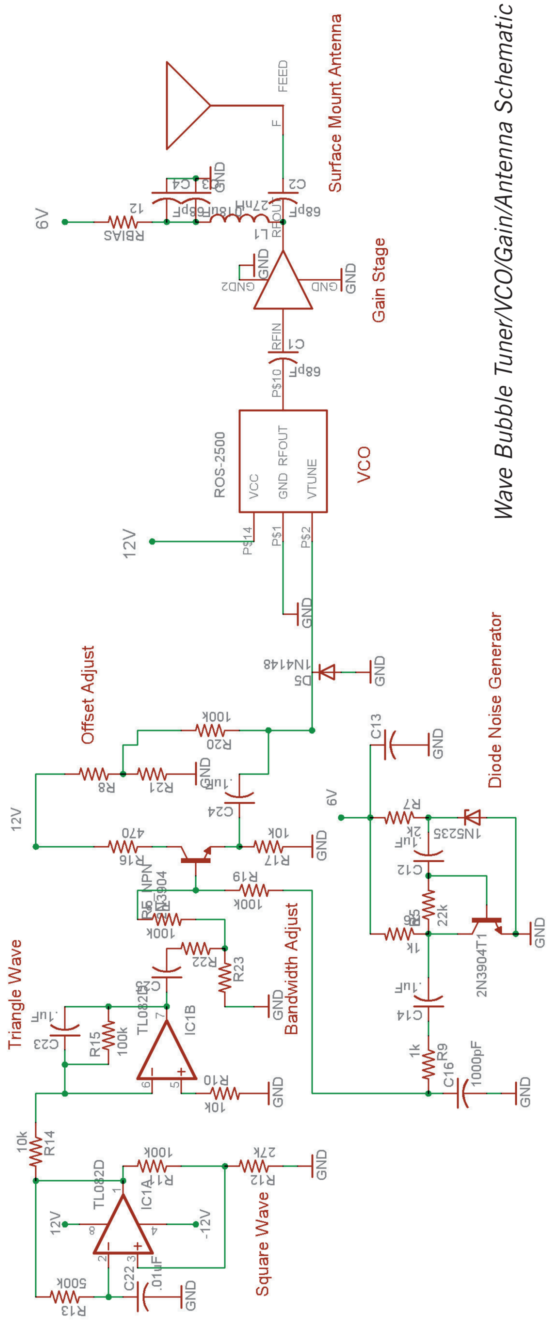
Improvements

There are many improvements that can be made to this system, in functionality and appearance. Most importantly, the system must be designed to last longer than the current hour or so. This could be accomplished by either lowering the electronics’ power consumption or increasing the battery power. It seems unlikely that the filter or sensor can be run at lower power, but as previously mentioned, there are ‘micropower’ microcontrollers that could be used instead of the ATtiny13. Using an MSP430 or equivalent could cut the required power by half. Also, instead of running all the time, the microcontroller could put itself and the active filter to ‘sleep’ and only wake up during interrupts (such as the comparator input interrupt) or during a timeout. This would cut power dramatically at a cost of slower reactivity and increased code complexity. Another option is to incorporate a better power source. Since the electronics is contained in only one arm of the glasses, the battery could be contained fully in the second arm. A battery that is the proper form factor could provide up to 500mW (150mAh) which could run the glasses for a full day on a charge.

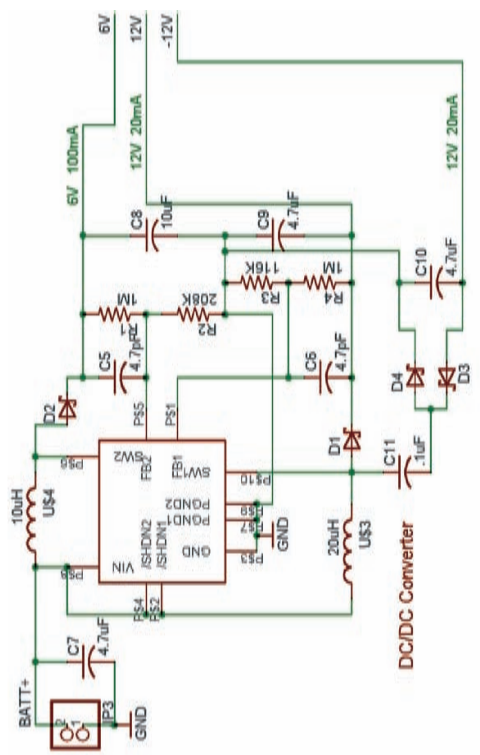
Another functional improvement would be to design a low-power AGC system for the photo-diode, this would allow the glasses to properly self-bias no matter what the ambient light level is. Currently, the biasing system is a simple potentiometer which must be adjusted if the ambient light level changes by more than an order of magnitude. This is not an issue if the glasses are consistently used in one location, but hinders their intended use as a constantly-worn visual prosthesis. Such systems have been designed for photodiodes but not for phototransistors. A fair amount of research would have to be done to design such a system and it may be easier to simply find a photodiode with similar characteristics.

One conceptual improvement that could be interesting to explore is operating the glasses more like shutter-glasses, whereby the glasses effectively block out the image of the television. This technique is used by 3D visualization software to create stereoscopic images: while wearing the shutter glasses that are sync’d to a television, the software alternately flashes left and right-perspective images. The synchronized glasses alternately black out the left or right lenses that correspond to the image displayed on the screen. Thus the visual cortex ‘sees’ a single-perspective stereoscopic image. Similarly, if the Media-Sensitive glasses were synchronized to a television in view, they could turn on during the redraw period and then turn off during the refresh period. Since television CRTs are more fluorescent than phosphorescent, this would, in theory, make the television appear to be off. That is to say, the user would see everything in the room as normal, except for the television screen which would be black, or at least extremely faint. While such functionality is ideal, and is close to the promise of pure mediation, there is a low probability that it would be effective. The rescan period of the television comprises only 45 'lines' out of a total of 525. The glasses would be transparent for less than 10% of the time, which would make the user feel like they were wearing very dark sunglasses. Regardless, implementation of such a design would not require any hardware changes and could be implemented completely in software.

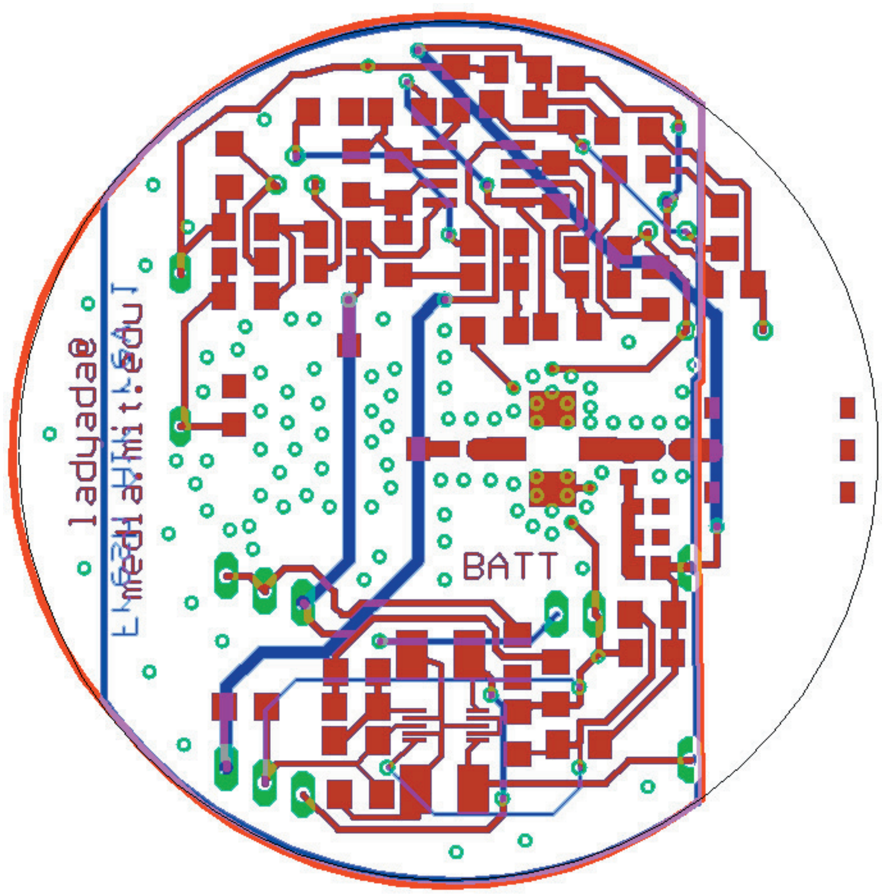
Appendix A:
Wave Bubble



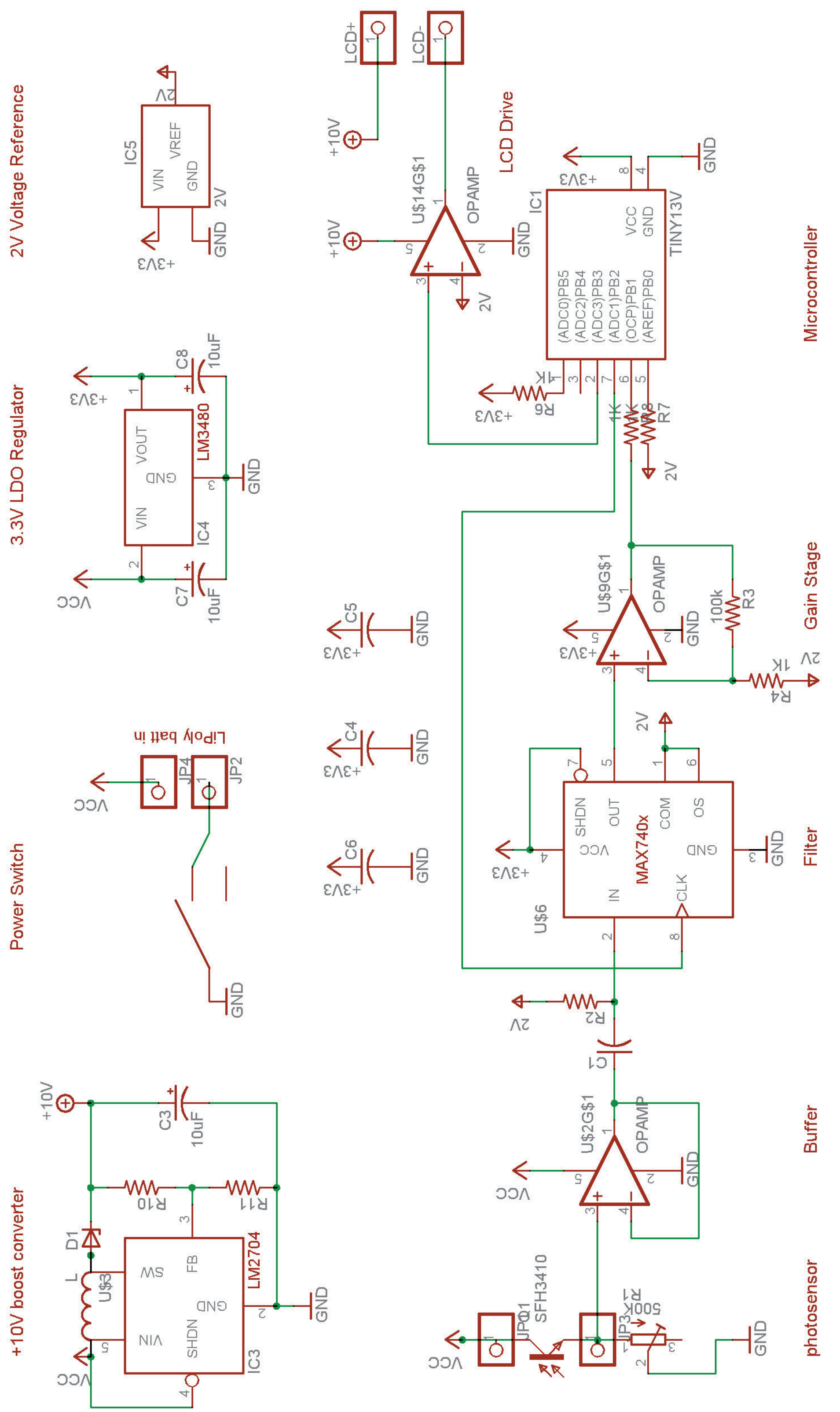
Wave Bubble Tuner/VCO/Gain/Antenna Schematic



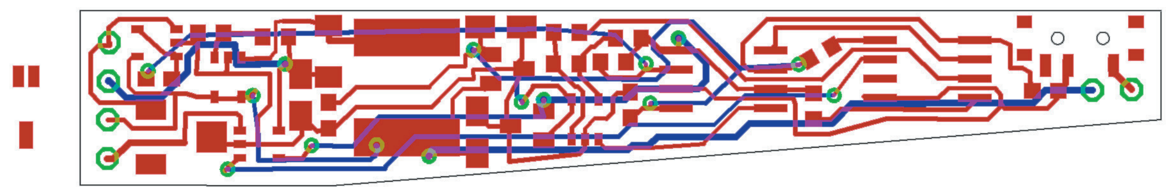
Wave Bubble Power Supply Schematic


BATT

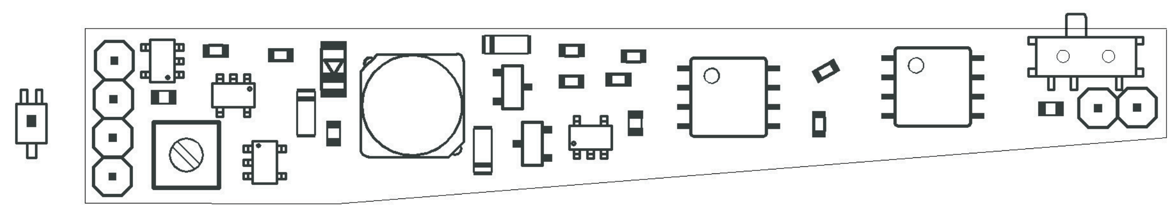
Appendix B
Media-Sensitive Glasses



Schematic for Media-Sensitive Glasses



Media-Sensitive Glasses- PCB layout



Media-Sensitive Glasses- Parts placement

```
.include "tn13def.inc"
.equ      FREQ                = 9600000

.equ      TX                            = 4     ; PB4
.equ      LCD                           = 3                 ; PB3
.equ      FILTERCLK           = 2                 ; PB2

.equ      STOPBITS  = 1                 ; # stop bits (for 8N1)_
.equ      LCD_ON              = 0

.EQU      CR                            = 0x0D    ; Carriage Return
.EQU      LF                            = 0x0A    ; Line Feed

;.EQU     MAX_COMP_VAL        =  0x10
.EQU      MAX_COMP_VAL        =  8
.EQU      comparator_values = 0x60       ; beginning of RAM

.equ      TCNT0_INIT                                        = 160

.equ      NOISE_THRESH                            = 0x05
.equ      VALID_MIN                                         = 0x4A00  ; -5%
.equ      VALID_MAX                                         = 0x5200  ;+5%
.equ      SCORE_THRESHHOLD              = 3

.equ      METASCORE_THRESHHOLD          = 3
;.equ     MAX_SCORE_VAL                           = 16
.equ      MAX_SCORE_VAL                           = 8

.equ      score_values        = comparator_values + 2*MAX_COMP_VAL
.def      score_val_index     = R9

.def      tv_status                     = R1
.def      last_t0_l                     = R2
.def      last_t0_h                     = R3
.def      last_timersum_l     = R4
.def      last_timersum_h     = R5
.def      metascore                     = R6
.def      status_bak                    = R7   ; status flag backup
.def      temp3                         = R10
.def      temp4                         = R11
.def      score                         = R12
.def      timersum_l                    = R13
.def      timersum_h                    = R14
.def      comp_val_index      = R16
.def      bitcnt                        = R18     ; used by uart
.def      lcd_config                    = R19
.def      temp                          = R20
.def      char                          = R21     ; used by uart
.def      temp2                         = R22
.def      comparator_timeout            = R23
.def      t0_temp                       = R24
.def      delay                         = R25     ; used by delay code
.def      tcnt0_l             = R26
.def      tcnt0_h             = R27
;.def     XL        = r26               ; X pointer low
;.def     XH        = r27               ; X pointer high
;.def     YL        = r28               ; Y pointer low
;.def     YH        = r29               ; Y pointer high
;.def     ZL        = r30               ; Z pointer low
;.def     ZH        = r31               ; Z pointer high

.org 0x0000
          rjmp      RESET
.org ANA_COMPaddr                                   ; Interrupt vector for analog comparator
          rjmp      AC_isr
.org TIM0_OVF0addr                                  ; Interrupt vector for timer overflow
          rjmp      T0_isr

;;;;;;;;;;;;;;;;;;;;;; INTERRUPT HANDLERS
.org ADCaddr+1
; timer 0, called 12.5KHz
T0_isr:
          in                  status_bak, SREG

          ldi                 t0_temp, TCNT0_INIT
          out                 TCNT0, t0_temp


          adiw      tcnt0_l, (255-TCNT0_INIT)/2
          adiw      tcnt0_l, (255-TCNT0_INIT)/2
          brvc      NO_TIMEOUT_INC
          inc                 comparator_timeout
NO_TIMEOUT_INC:
          ; Make 6KHz square wave for filter
          sbic      PORTB, FILTERCLK
          rjmp      T0_CLKLOW
          sbi                 PORTB, FILTERCLK
          rjmp      T0_FILTERCLK_DONE
T0_CLKLOW:
```

```
          cbi                 PORTB, FILTERCLK

T0_FILTERCLK_DONE:

          ; if (tv != on)
          mov                 t0_temp, tv_status
          cpi                 t0_temp, 0
          breq      T0_LCD_DONE

          ; Make 2KHz square wave for LCD
          inc                 lcd_config
          cpi                 lcd_config, 3
          brne      T0_LCD_DONE
          ldi                 lcd_config, 0

          sbic      PORTB, LCD
          rjmp      T0_LCDLOW
;         sbi                 PORTB, LCD
          rjmp      T0_LCD_DONE
T0_LCDLOW:
          cbi                 PORTB, LCD

T0_LCD_DONE:

T0_DONE:

          out                 SREG, status_bak
          reti
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; analog comparator
AC_isr:
          mov                 temp, tcnt0_h       ; if (timersum < NOISE_THRESH) goto AC_ISR_NOISE
          cpi                 temp, NOISE_THRESH
          brlo      AC_ISR_NOISE

          ldi                 comparator_timeout, 0
;         sbic      PORTB, LCD
;         rjmp      AC_TEST_LOW
;         sbi                 PORTB, LCD
;         rjmp      AC_TEST_DONE
;AC_TEST_LOW:
;         cbi                 PORTB, LCD
;AC_TEST_DONE:

          mov       timersum_l, tcnt0_l
          mov       timersum_h, tcnt0_h

          ; store values in RAM
          ldi       ZH, 0
          mov       ZL, comp_val_index
          lsl       ZL        ; multiply by two because we are storing 2byte values
          ldi       temp, comparator_values
          add       ZL, temp                      ; add the location of the index

;         ldi       temp, 0xFE
;         mov       timersum_h, temp
;         ldi       temp, 0xED
;         mov       temp, comp_val_index
;         mov       timersum_l, temp

          st        Z+, timersum_h
          st        Z, timersum_l

          cpi       comp_val_index, MAX_COMP_VAL
          brge      AC_ISR_DONE
          inc       comp_val_index

AC_ISR_DONE:
          ldi       tcnt0_h, 0          ; reset the counter
          ldi       tcnt0_l, 0

AC_ISR_NOISE:
          ; clear comparator interrupt just in case
          in        temp, ACSR          ; clear the analog comparator flag
          sbr       temp, 1<<ACI
          out       ACSR, temp

          reti

;;;;;;;;;;;;;;;;;;;;; main()
RESET:

; initialize the stack
          ldi       temp, low(RAMEND)
          out       SPL, temp

          ; intialize the internaloscillator calibration
          ldi       temp, 0x0           ; Load oscillator calibration byte
```

```
	out	EEAR, temp
	ldi	temp, (1<<EERE)
	out	EECR, temp
	in	temp, EEDR
	out	OSCCAL, temp

	ldi	temp, 0xFC	; set PB2-4 to outputs, PB0, PB1 to inputs (comparator)
	out	DDRB, temp
	cbi	PORTB, 0
	cbi	PORTB, 1
	cbi	PORTB, 2
	sbi	PORTB, LCD		; turn off the lcd

	ldi		char, 0xAA
	rcall	putchar

	ldi		ZL, low(HELLO_STR*2)		; Load Z with pointer to string
	ldi		ZH, high(HELLO_STR*2)

	rcall	puts

	ldi		temp, 0xDE
	rcall	printhex
	ldi		temp, 0xAD
	rcall	printhex
	ldi		temp, 0xBE
	rcall	printhex
	ldi		temp, 0xEF
	rcall	printhex

	ldi		comp_val_index, 0
	rcall	SETUP_T0
	rcall	SETUP_COMPARATOR

	ldi		temp, 0			; assume TV is off to start
	mov		tv_status, temp
	sei

LOOP:
	cpi		comparator_timeout, 3
	brlo	NOT_TIMEDOUT
	ldi		comparator_timeout, 0
	mov		temp, tv_status
	cpi		temp, 0
	breq	NOT_TIMEDOUT
	ldi		temp, 0
	mov		tv_status, temp		; it's off now
	sbi		PORTB, LCD		; turn off the lcd
	ldi		ZL, low(TV_OFF_STR*2)	; Load Z with pointer to string
	ldi		ZH, high(TV_OFF_STR*2)
	rcall	puts
NOT_TIMEDOUT:
	cpi		comp_val_index, MAX_COMP_VAL
	brne	LOOP

	rcall	TURN_OFF_COMPARATOR

;	mov		temp, comp_val_index
;	rcall	printhex
;	ldi		char, ':'
;	rcall	putchar

	ldi		ZH, 0
	ldi		ZL, comparator_values
	ldi		comp_val_index, 0	; i = 0;
	ldi		temp, 0
	mov		score, temp		; set score to 0 to start
	mov		timersum_h, temp	; initialize to 0
	mov		timersum_l, temp	; initialize to 0
	; for (i = 0; i<MAX_COMP_VAL; i++) {
PRINT_LOOP:
	cpi		comp_val_index, MAX_COMP_VAL
	brge	PRINT_LOOP_DONE

	mov		temp3, timersum_h	; temp3:4 = timersum
	mov		temp4, timersum_l

	ld		timersum_h, Z+		; timersum = comparator_values[i];
	ld		timersum_l, Z+

;	mov		temp, timersum_h	; printf("%d ", timersum);
;	rcall	printhex
;	mov		temp, timersum_l
;	rcall	printhex
;	ldi		char, 0x20
;	rcall	putchar

	add		temp4, timersum_l		; temp3:4 += timersum
	adc		temp3, timersum_h
```

```
;         ldi                 char, '('                     ; printf("(%d) ", temp3:4);
;         rcall     putchar;
;         mov                 temp, temp3
;         rcall     printhex
;         mov                 temp, temp4
;         rcall     printhex
;         ldi                 char, ')'
;         rcall     putchar
;         ldi                 char, 0x20
;         rcall     putchar

          mov                 temp, temp3         ; if (! (temp3:4 < VALID_MIN || temp3:4 > VALID_MAX))  {
          cpi                 temp, high(VALID_MIN)
          brlo      NOSCORE
          cpi                 temp, high(VALID_MAX)+1
          brsh      NOSCORE
          inc                 score               ;                   score++ }
NOSCORE:

          inc                 comp_val_index
          rjmp      PRINT_LOOP
PRINT_LOOP_DONE:

;         ldi                 char, '/'           ; printf("/%d/ ", score[i])
;         rcall     putchar
;         mov                 temp, score
;         rcall     printhex
;         ldi                 char, '/'
;         rcall     putchar
;         ldi                 char, 0x20
;         rcall     putchar

; compare it to the score theshhold
          ldi                 char, 'v'
          mov                 temp, score
          cpi                 temp, SCORE_THRESHHOLD
          brlt      SCORE_CHECK_DONE
          ldi                 char, '^'
          inc                 metascore
SCORE_CHECK_DONE:
          rcall     putchar
; ok we've compared it
;         ldi                 char, CR
;         rcall     putchar
;         ldi                 char, LF
;         rcall     putchar

          inc       score_val_index         ; increment the index into the score storage array
          mov                 temp, score_val_index
          cpi                 temp, MAX_SCORE_VAL     ; if we haven't filled it, loop again
          brlt      PRINT_DONE

          ldi                 temp, 0                 ; reset the index to 0
          mov                 score_val_index, temp

          ldi                 ZH, 0
          mov                 ZL, score_val_index
          ldi                 temp, score_values
          add                 ZL, temp

PRINT_SCORES_DONE:
          ldi                 temp, 0
          mov                 score_val_index, temp


;         ldi                 char, '['           ; printf("[%d]", metascore)
;         rcall     putchar
;         mov                 temp, metascore
;         rcall     printhex
;         ldi                 char, ']'
;         rcall     putchar
;         ldi                 char, CR
;         rcall     putchar
;         ldi                 char, LF
;         rcall     putchar

          mov                 temp, metascore
          cpi                 temp, METASCORE_THRESHHOLD
          brlt      TV_OFF

TV_ON:
          mov                 temp, tv_status
          cpi                 temp, 0             ; is it off?
          brne      METASCORE_DONE                          ; no it was on before
          ldi                 temp, 1                                 ; it's on now
          mov                 tv_status, temp

          ldi                 ZL, low(TV_ON_STR*2)          ; Load Z with pointer to string
          ldi                 ZH, high(TV_ON_STR*2)
          rcall     puts
```

```
        rjmp      METASCORE_DONE
TV_OFF:
        mov                 temp, tv_status
        cpi                 temp, 0            ; is it on?
        breq      METASCORE_DONE                         ; no it was off before
        ldi                 temp, 0
        mov                 tv_status, temp              ; it’s off now
        sbi                 PORTB, LCD                             ; turn off the lcd
        ldi                 ZL, low(TV_OFF_STR*2)        ; Load Z with pointer to string
        ldi                 ZH, high(TV_OFF_STR*2)
        rcall     puts

METASCORE_DONE:
        ldi                 temp, 0
        mov                 metascore, temp

PRINT_DONE:
        ldi                 comp_val_index, 0

;       sbi                 PORTB, LCD
;       ldi                 temp, 100
;       rcall     delay_ms
;       ldi                 temp, 100
;       rcall     delay_ms
;       ldi                 temp, 100
;       rcall     delay_ms
;       cbi                 PORTB, LCD

        rcall     SETUP_COMPARATOR

        rjmp                LOOP


;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; sets up the analog comparator to call an interrupt
SETUP_COMPARATOR:
;       ldi                 temp, 0x0A         ; turn on analog comparator interrupt on rise
        ldi                 temp, 0x08         ; turn on analog comparator interrupt on toggle
        out                 ACSR, temp
        ret

TURN_OFF_COMPARATOR:
        ldi                 temp, 0x0
        out                 ACSR, temp
        ret

SETUP_T0:
        ldi                 tcnt0_h, 0

;       ldi                 temp, 0x01                             ; use CLK as timer src
        ldi                 temp, 0x02                             ; use CLK/8 as timer src

        out                 TCCR0B, temp
        in                  temp, TIMSK0                 ;
        sbr                 temp, 1<<TOIE0
        out                 TIMSK0, temp
        ldi                 temp, 0xff
        out                 TIFR0, temp

        ldi                 temp, 0
        mov                 comparator_timeout, temp
        ret

;;; string is in Z, 0 terminated

PUTS:
        lpm                                    ; Load next byte from string into r0
        inc                 ZL
        brne      PUTS_L1
        inc                 ZH      ; if there was a carry, inc ZH too
PUTS_L1:
        mov                 char, r0
        cpi                 char, 0                      ; Is it the terminating 0-char?
        breq      PUTS_STR_DONE                ;  -yes, end transmission
        rcall     putchar             ; Send the character
        rjmp      PUTS                ; Repeat until whole string transmitted
PUTS_STR_DONE:
        ret

;;;;

; value is in temp
printhex:
        mov                 temp2, temp

        mov                 char, temp2
        andi      char, 0xF0
        swap      char
        cpi                 char, 0xA
```

```
        brlt     printhex_1dec
        ldi               temp, 'A'-10
        rjmp     printhex_1done
printhex_1dec:
        ldi               temp, '0'
printhex_1done:
        add               char, temp
        rcall    putchar

        mov               char, temp2
        andi     char, 0x0F
        cpi               char, 0xA
        brlt     printhex_2dec
        ldi               temp, 'A'-10
        rjmp     printhex_2done
printhex_2dec:
        ldi               temp, '0'
printhex_2done:
        add               char, temp
        rcall    putchar
        ret

;;;;;;;;;;;;;;;;;;;;;;;
; sends character in char out on pin TX, modifies temp, bitcnt and delay
putchar:
        in                status_bak, SREG
        cli

        mov               temp, char
        ldi               bitcnt,   9+STOPBITS                   ;1+8+sb (sb is # of stop bits)
        com               temp                                            ;Inverte everything
        sec                                                               ;Start bit


putchar0:
        brcc     putchar1  ;If carry set
        cbi               PORTB, TX          ;    send a '0'
        rjmp     putchar2  ;else

putchar1:
        sbi               PORTB, TX          ;    send a '1'
        nop

putchar2:                 ; cause the uc to pause for 8.6 us
UART_DELAY:
;       ldi               delay, 11                    ; 4.8mhz
        ldi               delay, 25                    ; 9.6mhz
U_DELAY_L:         ; loop is 3 instructions
        dec               delay
        brne     U_DELAY_L
        NOP

        lsr               temp               ;Get next bit
        dec               bitcnt             ;If not all bit sent
        brne     putchar0  ;   send next
                                                      ;else
        out               SREG, status_bak
        ret                                  ;   return

; Cause the uc to pause for TEMP number of milliseconds
DELAY_MS:
        rcall    DELAY_1MS
        dec      temp
        brne     DELAY_MS
        ret

DELAY_1MS:
        ldi               DELAY, 177
L_DELAY1:          ; this loop takes 8 cycles on avg
        dec               DELAY
        brne     L_DELAY1
        ret

HELLO_STR:
.db  CR, LF, " Media Glasses", CR, LF, 0

TV_ON_STR:
.db "TV on", CR, LF, 0

TV_OFF_STR:
.db "TV off", CR, LF, 0
```

Bibliography

AARL (2000). *The AAR UHF/Microwave Experiementer's Manual.* AARL.

Adams, D. (1979). *The Hitchhiker's Guide to the Galaxy.* Pan Books, London.

Center for Democracy & Technology (2004). Prepared Statement before The House Committee On Energy and Commerce.

Center for Interrogative Design (2003). No Contact Jacket. http://www.no-contact.com.

Dunne, A. (2000). *Hertzian Tales: Electronic Products, Aesthetic Experience and Critical Design.* Art Books Intl Ltd.

Dunne, A. and F. Raby (2001). *Design Noir: The Secret Life of Electronic Objects*. Birkhauser, Basel, Switzerland.

Fahey, V. (1992) TV by the Numbers. *Health* (Dec/Jan).

Green Bay Professional Packet Radio (2005). http://www.gbppr.org/

Hall, E. T. (1966). *The Hidden Dimension.* Anchor Press.

Kubey, R. and M. Csikszentmihalyi (1990). *Television and the Quality of Life.* Lawrence Erlbaum Associates.

Kubey, R. and M. Csikszentmihalyi (2002). Television Addiction. *Scientific American* (Feb)

Leach, N. (2002). *Designing for a Digital World (Architectural Design)*. Acadamy Press.

Lemelson-MIT Program (2004). Lemelson-MIT Invention Index.

Mann, S. (2003). Existential Technology: Wearable Computing Is Not the Real Issue! *Leonardo (*Vol. 26)

Negroponte, N. and M. Asher (1995). *Being Digital*. Random House, Inc.

Pavlov, I. (1927). *Conditioned Reflexes: An Investigation of the Physiological Activity of the Cereberal Cortex*. Oxford: Oxford University Press.

Plant, S. (2003). *on the mobile: the effects of mobile telephones on social and individual life.* Motorola.

Singer, D. G. and J.L. Singer (1980). Television viewing and aggressive behavior in preschool children: a field study. *Annals of the NY Acadamy of Science* (347)

Thorson, E., B. Reeves and J. Schleuder (1986). Attention to local and global complexity in television messages. *Communication Yearbook* (10).

Xora (2005). Xora GPS Time Track http://www.xora.com/timetrack/