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Miniature counter device

Abdulaziz Alsumait
Northeastern University

Adam Rocha
Northeastern University

Dan Kennedy
Northeastern University

Kirsten Baxter
Northeastern University

Sangwon You
Northeastern University

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MINIATURE COUNTER DEVICE

MIME 701-702

Technical Design Report

Miniature Counter Device

Project #3

Second-Quarter Report

Design Advisor: Prof. Levendis

Design Team

**Abdulaziz Alsumait, Adam Rocha
Dan Kennedy, Kirsten Baxter,
Sangwon You**

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**Department of Mechanical, Industrial and Manufacturing Engineering
College of Engineering, Northeastern University
Boston, MA 02115**

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Copyright

“We the team members,

Abdulaziz Alsumait

Adam Rocha

Dan Kennedy

Kirsten Baxter

Sangwon You

Prof. Levendis

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MINIATURE COUNTER DEVICE

INTRODUCTION

To function properly, cars need to have their oil changed at regular mileage intervals. Currently, stickers are adhered to the inside of a car's windshield with a mileage or date written on them to notify a car owner when the car's next oil change should be. When the car reaches the specified mileage or date written on the sticker, it is time for the oil to be changed. Because people often fail to check their sticker, the sticker is hard to read, or they simply remove it from the windshield for aesthetic purposes, this system is inefficient. A more practical system is warranted so that people remember to change their oil at the proper time. An improved oil change reminding method will benefit the owner of the vehicle because their engine will perform better and last longer. It will also benefit auto-mechanics as they will experience a regular flow of work in the form of oil changes.

PROBLEM STATEMENT

There are several problems with the current sticker system used to remind people when their car needs an oil change. The writing on the stickers may smear or become faded. The extreme temperatures experienced within a car may cause the sticker to peel and fall off. People may also remove the stickers themselves for aesthetic reasons.

A better method of reminding the owner when their car needs its oil changed is desired to replace the current sticker system and the problems associated with it. A sticker substitute must have the following design qualities: small size, readable display, low cost, ability to adhere to solid surfaces, reusability, manufacturability, and an attractive appearance. A small size is important so that the device is discreet and unobtrusive to encourage usage. The device must also provide a clear and easily readable mileage display. Low production costs are important so that mechanics can provide the mechanism to customers at no additional charge. It must be able to be attached to a surface in the car, ideally on the dashboard, and be able to be removed without damaging the car's surface. It should be attractive and blend in so people will be willing to place it in plain sight.

LITERATURE SEARCH

The literature search was concentrated on discovering all forms of counting devices currently patented. Although nothing was found to be patented for the specific purpose of this project, there were various types of counting mechanisms discovered. The procedure of injection molding was also researched in order to identify any necessary design methods for this particular process. Further research was conducted into piezoelectric technology for a potential vibration sensing solution.

Current Counting Devices

Research was focused on counting devices such as pedometers and odometers because these devices closely resemble the desired finished product of this project and have very similar applications. Patents as well as product websites were investigated for similarities in design solutions. Research here is focused on mechanical devices because attempts to find patents for similar digital devices were unsuccessful.

Mechanical counters typically use a series of counting wheels as pictured in Figure 1[1].



Figure 1: Counting Wheel

Several wheels are aligned next to each other along a single shaft. The wheels are connected through a succession of gears which have ratios such that as one wheel makes a complete revolution the wheel for the next largest digit makes a tenth of a revolution. The smallest counting wheel that can be measured in diameter and still have numbers that are easily readable is about 0.6 inches. The researched counting devices were designed to be housed in dashboards of cars, boot heels, or other small casings typically measuring at least an inch in height, width, and depth.

Patent number 542,107, Pedometer [2], describes a pedometer which uses a series of counting discs pictured in Figure 2.

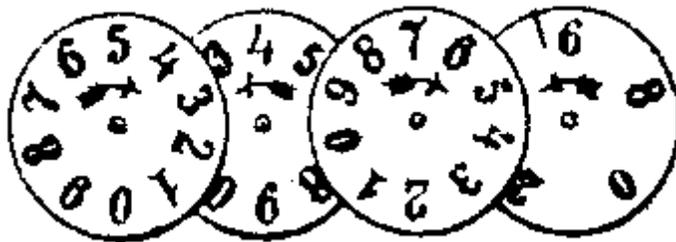


Figure 2: Counting Discs

Discs are each mounted on individual shafts and are connected through a series of gears such that as the wheel on the far right makes one revolution, the wheel next to it makes a tenth of a revolution. The discs can be made smaller than the counting wheels, both in thickness and diameter.

Mechanical combination locks are relevant to this application because they have numerous independently spinning dials with numbers printed on them. The numbers lock into place so that the mechanism is aware when the desired combination has been entered. Patent number D477,525, Combination Lock [3], outlines this concept.

Counting devices that use mechanical methods often utilize rotating wheels and spring controls to prevent backward motion. Specifically, patents titled Mechanical Counter, number 4,255,650 [4] and Mechanical Golf Counter, number 6,543,681[5], respectively outline counters for cycle-generating office machinery and golf scores. The counter designed to keep track of cycles that are run in office machinery, such as a copy machine, counts down from a preset number of cycles to cause the machinery to shut-down when it has completed the task (see Figure 3). The golf counter utilizes star wheels connected by levers to keep track of scoring. The process is enabled by physically clicking a pushbutton.

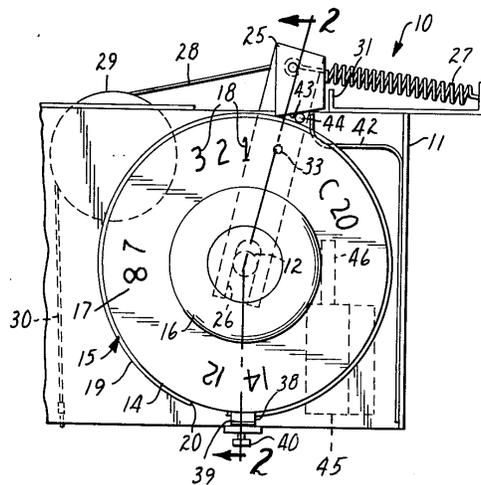


Figure 3: Mechanical Counter for use in office machinery

PRIMARY DESIGN SOLUTIONS

Three different solutions to this problem have been designed. Each utilizes a small plastic casing, which would be injection molded. The plastic used for injection molding would be low-density polyethylene because this material relatively inexpensive and can withstand a wide range of temperature variances. This is important because car interiors can experience wide temperature fluctuations. The three specific designs utilize magnetic, mechanical and electrical solutions.

Mechanical Device

The mechanical counter (Figure 4) is composed of eight parts: a front case, a back case, and six flat disks. The counter's overall size measures 3.5" x 0.8" x 0.25". The front case has six viewing windows used to display the desired number on each numbered disk. The front and back cases are designed to press fit into one another. On each casing part, the disk shaft mates into a corresponding shaft holder on the opposite case. The shafts and shaft holders alternate on each casing part acting to stagger the position of the disks so that they overlap. A detailed schematic can be found in Appendix 1.

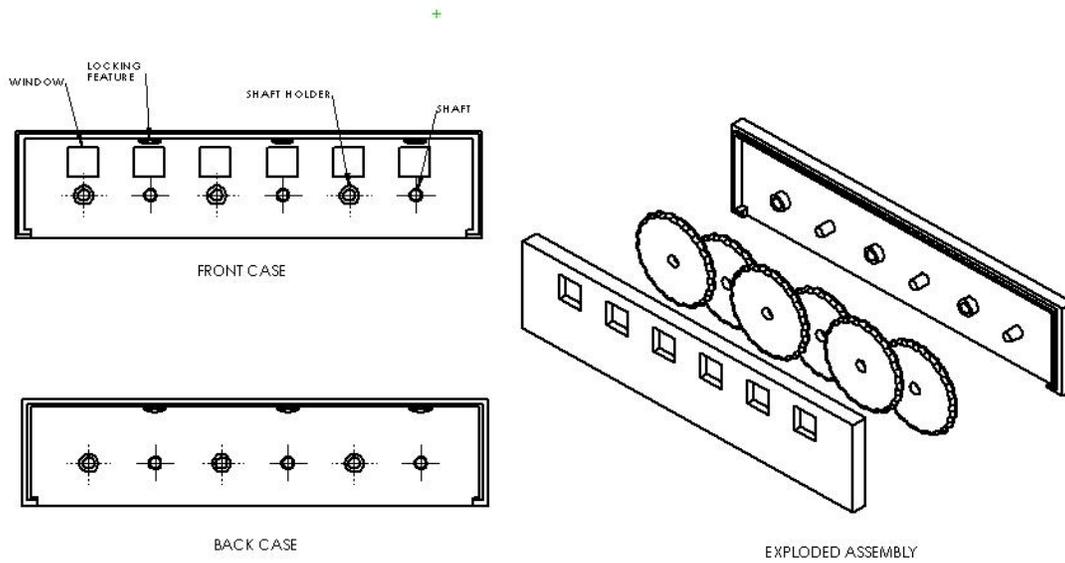


Figure 4: Mechanical Counter

The disks will be capable of displaying ten numbers, zero through nine (Figure 5). A small portion of each disk will protrude from an opening in the bottom of the casing allowing each disk to be manually rotated individually about their shaft. Small rounded teeth are built into the top of each casing to prevent the disks from rotating freely.

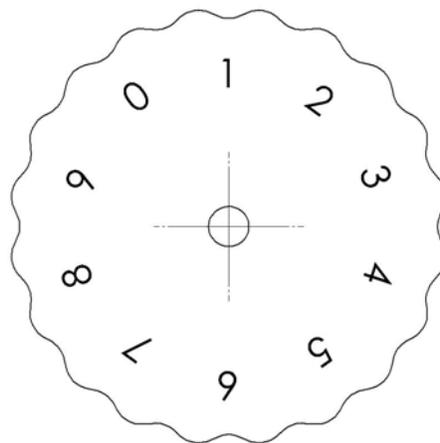


Figure 5: Numbered Disk

The design of the mechanical counter has its benefits and disadvantages. The benefits are its ease of use and the fact that it is self contained. The disadvantage of this device is that it has to be long in order to accommodate all the disks.

Magnetic Device

The concept behind a magnetic device would be having the digits 0-9 printed onto thin magnets, which can be taken out and replaced to form different number combinations. To help visualize what this means, think of the displays at most gas stations to show the price of gas. When the price needs to change, the numbers are taken down and new ones put in their place. Each device would be sold with 60 number magnets (6 of each digit). The mechanics would also be able to purchase replacement packages of numbers. The advantages of a magnetic device would be the ability to make the device very small and thin overall, while allowing the numbers displayed to be larger. The major disadvantage would be the need for extra pieces peripheral to the device.

This design has gone through a series of changes. Initially there was two equal sized pieces, front and back, which connected using a complex track system. Prototypes were created with a 3-D printer, which showed some problems with the design. For one, there was too little clearance left for the two pieces to fit together as planned. The style of the design also caused the tracks to break easily. Finally, in order for those designs to work, a mechanism to lock the two halves together was needed, but no solution was reached.

Considering these factors, the final design for the magnetic device is as follows. It has an outer case which is 2.2" wide, 1.5" tall, and 0.25" thick, with a 0.05" round on each edge. The top-half of the front face has a recessed section 2.1" wide, 0.55" tall, and flush to the right side of the device, leaving an open end. The recess is 0.15" deep, with 0.05"x0.05" grooves running down each sidewall 0.05" from the top surface which act as tracks. This is shown by the top and side views of the device in Figure 6. The bottom of this recessed section has a 0.015" thick magnet glued to it, which the numbered magnets are mounted on.

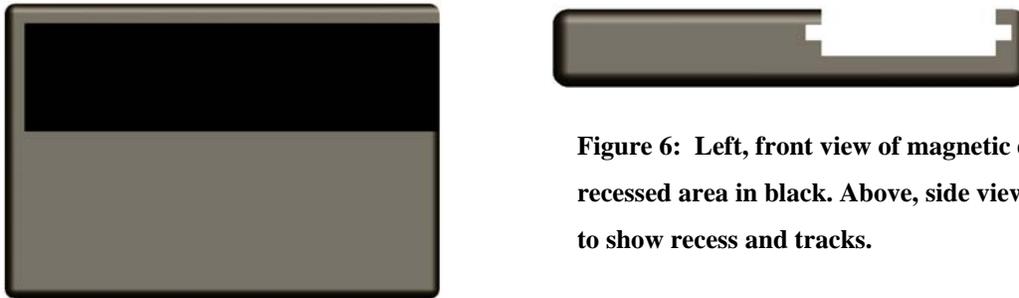


Figure 6: Left, front view of magnetic device, with recessed area in black. Above, side view of device to show recess and tracks.

A cover slides into the tracks, designed with a 0.01" clearance on all sides. This cover has six viewing windows, each 0.45" tall by 0.25" wide. These windows show the number on each 0.5"x0.33" numbered magnet, while the divisions hide the seams between the magnets to give it a cleaner look. Figure 7 shows the cover design. Appendix 2 shows a detailed schematic of each part of the magnetic counter



**Figure 7: Front and side views of
magnet cover**

SECONDARY DESIGN SOLUTION

In addition to designing a method of displaying the mileage of a car's next oil change, the development of a smart device was investigated. The goal of a smart device would be to develop a sensor capable of detecting when it is necessary for a car's oil to be changed. It was decided to use a car's vibration as a means of detecting its use.

The group interviewed Professor George Adams, who teaches Mechanics and Vibrations at Northeastern University. The purpose of the conversation was to determine what types of vibrations a sensor would need to detect and how sensitive it would need to be in order to monitor the vibrations of a running car. The possibility of translating the amount of vibration into a mileage based on the vibration's frequency was also discussed.

One design concept was to have a device that would track the mileage based on the amount of vibrations in the car. It would work by correlating a higher frequency with the engine running faster, and translating that into counting the mileage at a faster rate. The goal would be a self-contained device that provides a reliable estimate of the amount of mileage a car has driven.

This concept will not be taken forward because there are far too many variables to achieve a reliable result. Other sources of vibration such as different road surfaces, wind and rain noise, car radio speakers, tire conditions, and noise from the driver would all cause great inconsistencies in the data.

According to a study conducted by ESPEC Corporation, "Combined Environmental Testing for Equipment Used on Automobiles", most vibrations felt by a car in motion are below 100 Hz. There are circumstances that can increase this value (although most of the time the total vibrations are well below this value) close to 2000 Hz. Therefore a sensor utilized for this purpose would need a sensitivity range of 0-2000 Hz. Figure 8 is a chart summarizing the various vibration sources and their average corresponding frequency values that a car might undergo while running [9].

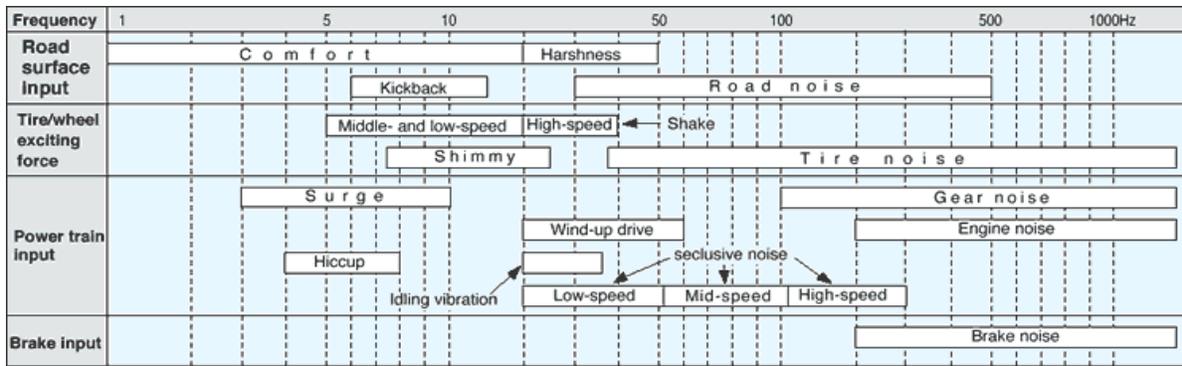


Figure 8: Vibration Sources

The final design proposal incorporates a sensor that will track the hours of operation of the vehicle. When the sensor detects the vibration of the car running, greater than 1000Hz, it will begin to count hours of operation. Inversely, when the car's vibration is absent, the device no longer counts. Figure 9 shows a graph relating the number of hours a car has operated to the corresponding miles traveled. The graph draws this relation for several different speeds of a car. Based on the graph, it was decided a car may operate for 100 hours before and oil change is necessary. Two different sensor devices were proposed that incorporate vibration sensing: a mechanical and an electrical.

Miles vs. Hours

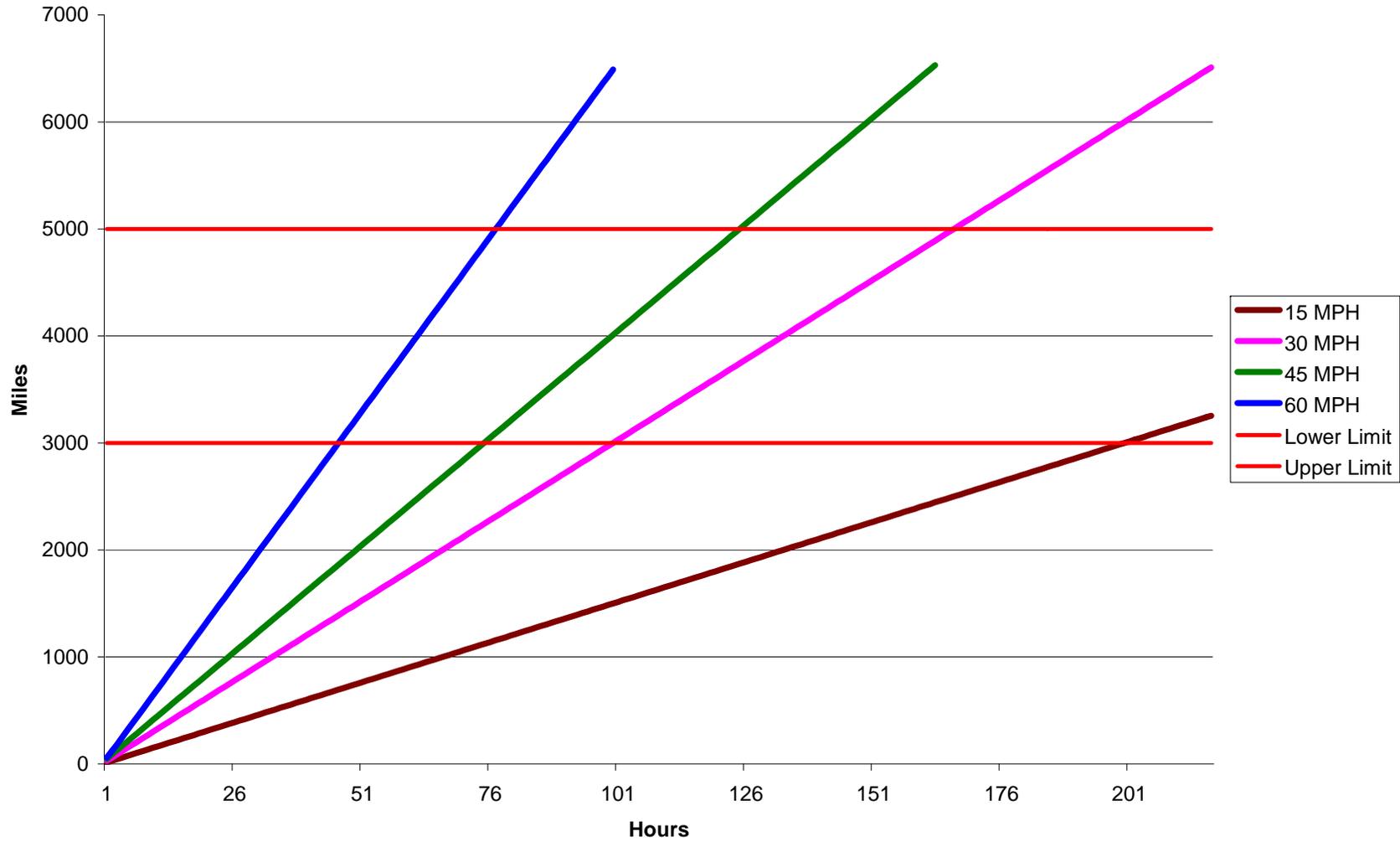


Figure 9: Miles vs. Hours

Mechanical Sensor

The mechanical sensor design would be based on the technology such as what is found in modern self-winding watches. There would be a disk with an off-center weight which would act as a pendulum. This disk would be mounted on an axis and allowed to rotate freely.

When the housing on which the disk is mounted moves back and forth, the weight will tend to stay facing down, causing the disk to turn on its axis. This pendulum disk would be attached to another gear with a ratcheting system, causing it to turn slightly every time the device is moved back and forth. The ratcheted gear would then translate this rotation through a gear system to eventually turn a final gear one revolution over a desired length of time.

In order to determine if this design is feasible, it is necessary to compare the natural frequency of the pendulum disk to the frequency of a car in operation. The vibration of the car will only cause the pendulum disk to vibrate if it is close to the disk's natural frequency. According to the Environmental Testing Information for Technical Personnel on ESPEC's website, the combined sources of vibration for a car in operation result in a frequency of over 1000 Hz, ranging up to multiple kilohertz.

The natural frequency of the disk can be found using the following equations. Due to design requirements, a disk radius of 0.5" (0.0127m) is assumed, and a weight of 0.5kg to start.

m = mass

r = radius

I = mass moment of inertia

d = distance from pivot point and center of mass

ω = natural frequency

$$I = \frac{1}{2}mR^2, \quad I = \frac{1}{2}(0.5kg)(0.0127m)^2 = 4.0 \times 10^{-6} \text{ kgm}^2$$

$$\omega^2 = \frac{mgd}{I}, \quad \omega^2 = \frac{(0.5kg)(9.8m/s^2)(0.0127m)}{4.03 \times 10^{-6} \text{ kgm}^2}, \quad \omega^2 = 1541.31 \text{ rad}^2/s^2$$

$$\omega = 39.3 \text{ rad/s} * \frac{1}{2\pi \text{ rad}}, \quad \omega = 6.25 \text{ Hz}$$

With a ω of 6.25 Hz, the disk would not be activated by the vibrations in a car, and therefore this design concept would not work. Appendix 3 shows a chart of this calculation repeated varying the radius and mass. It shows that the mass has no effect on the natural frequency, and that in order to get a ω close to 1 kHz, the radius of the disc would need to be less than one millimeter. Due to these calculations, the mechanical vibration sensor is not a feasible design concept. Because a mechanical device would not work, an electrical device was pursued.

Electrical Sensors

An electrical sensor would make use of a piezoelectric crystal. Piezoelectric crystals are used to convert energy from mechanical to electrical form, and vice versa. The concept utilizes a polarized crystal where pressure is applied. The mechanical deformation of the crystal creates an impermanent electrical charge as the molecular structure shifts. This concept can be applied to a multitude of sensor devices, including accelerometers. In an accelerometer, the force of the acceleration on the crystal causes the deformation.

The basic concept developed for employs a small accelerometer that uses a piezoelectric vibration sensor. The output of the sensor is connected to a circuit. This circuit will be set up so that when a vibration is detected, the sensor begins to count. Inversely, when there is no vibration, the sensor no longer counts. In this manner, vibrations can be monitored and that information can be translated into a digital read-out that will display the hours of operation picked up by the sensor.

Existing Device

One device that currently is used to monitor the use of machinery by sensing vibration is the SenDEC vibration activated Hour Meter 806- 601- 3037. The SenDEC device measures 2.125” x 1.490” x 0.550”, which is close to an acceptable size. The counter is started when a wire on the back of the device is cut. After cutting the wire the device cannot be stopped or reset. It is activated when vibration occurs, at which point a small icon in the LCD display begins blinking to notify the user that it is counting. When vibration stops, the icon stops blinking as well, indicating that the hour meter is no longer counting. This device was purchased and tested for functionality in a car.

The test consisted of the SenDEC Hour Meter being mounted on a dashboard of a car in front of the passenger seat. After the sensor was mounted in the car and before the engine was started, the icon did not blink; as soon as the car was started (without the car being in motion) the icon began blinking. The car was left running but stationary for six minutes, at which point the display showed “0.1” hours. When the engine was turned off, the icon stopped blinking. The car was then turned back on and driven for 30 minutes, after which the display showed “0.6” hours (0.1 + 0.5 hours). This shows that regardless of the frequency level of the vibration, the meter is simply activated or deactivated. This test supports the idea that a cars vibration may be accurately tracked for determining hours of operation.

Even though the SenDEC device worked well, improvements can still be made to its technology in order to customize the device for use within a car. Flaws associated with the SenDEC Hour Meter include that it cannot be reset and it does not display an obvious signal when maintenance is to be performed. Due to these flaws, it was decided to develop a specialized hour meter for car oil changes.

Proposed Device

The proposed electrical sensor still needs to meet the original design requirements of cost, reliability, appearance, etc, that the mechanical and magnetic devices are designed to. In addition, it is desirable to incorporate improvements over the SenDEC device discussed in the previous section. Improvements include a reset button and an LED that would illuminate when the sensor reaches the desired time interval.

For the design of the vibration sensor an accelerometer was found that meets all of the requirements, acknowledging that it is more expensive to utilize a vibration sensor rather than simply display a number. The ACH-04-08-05 Multi-Axis Accelerometer is designed by Measurement Specialties Inc. Its dimensions are 11mm x 12mm x 1.8mm with a total weight of 0.35 grams (See Figure 10).



Figure 10: Accelerometer

This accelerometer senses frequencies from about 0.5Hz to above 5000Hz, much higher than what is needed for this purpose. It is also relatively inexpensive, costing \$25.

MANUFACTURING AND COST

The devices designed for this project must be capable of being produced in high volume at a low cost. An ideal manufacturing method for production would be injection molding.

Injection Molding

To prepare for high volume production, the processes of injection molding and mold design were researched. Injection molding allows for easily repeatable, identical units at a low cost. A variety of polymers can be used in the injection molding process.

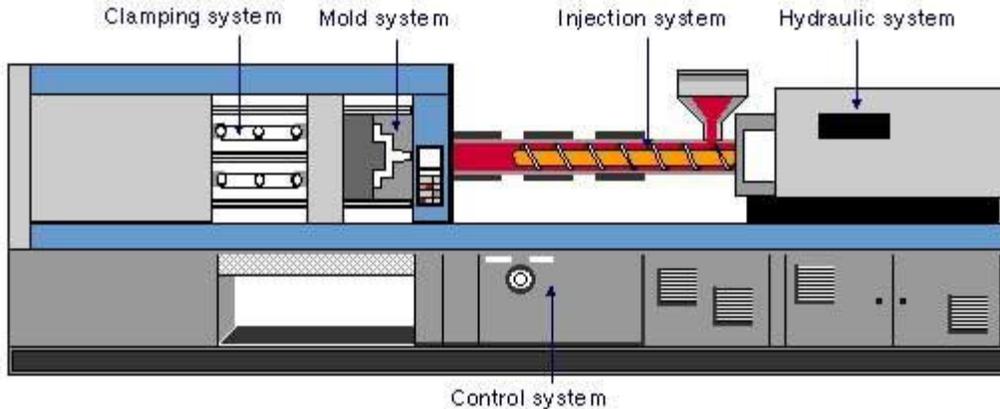


Figure 11: Injection Molding Machine

Injection molding is the process of inserting a melted polymer into a hollow mold. In the injection molding process, a polymer is injected into a hollow mold cavity by a large force after the melting of a pellet or powder resin [6]. Through this method, a high volume of identical parts can be produced. This process can be used to form a wide variety of products with high levels of complexity. Molds to accommodate part sizes ranging from very small to large can be made. The approximate cycle time in a typical injection molding process is around 10 to 100 seconds. These times are dependent on either the controlling time of the thermoplastic or the curing time of the thermosetting plastic [7]. Figure 11 demonstrates a typical injection molding machine.

There are several guidelines that must be followed when designing a mold. A uniform wall thickness throughout the part will help to eliminate warping and will improve cycle time. Using the smallest wall thickness possible will lessen cooling time and decrease overall cost. It is also ideal to design parts so that they can easily be withdrawn from the mold. This is often done by using a tapered design [8].

Material Selection

The material selected for the production of the mechanical and magnetic devices is low-density polyethylene. This material was chosen because it is a cheap plastic that can easily be injection molded. In addition, this polymer has a wide temperature range. Low-density polyethylene maintains its properties from -40°F to 110 °F.

In addition to a plastic to make the casing, an adhesion method must be selected that allows the devices to be attached to a user's dashboard or windshield. The adhesive must also allow the device to be removed and reused without leaving behind any sticky residue. A double sided polyester tape provided by Arlon meets the requirements. The 1404 Differential Permanent/Removable Tape is permanent on one side, to be attached to the device, and temporary on the other side, to be attached to the car. This particular tape was chosen because its permanent side bonds well to polyethylene and it is resistive to ultra violet light and moisture. The non-permanent side is designed for clean removal.

The magnets chosen to use for the magnetic counter are from All Magnetics, Inc. Part number ZG1524GW, at 0.015” thick, has a glossy white face ideal for a sleek look.

For the prototyping of the mechanical and magnetic devices, a stereolithography machine was used. Stereolithography machines use a fast, 3-D layering process to make prototypes out of polymers.

Cost

The market cost of each device depends on the costs of injection molding, screen printing of numbers and adhesive per device, with the additional cost of the magnets for the magnetic device. An estimate for the market cost of each unit was made using price quotes received from companies for each of the above mentioned factors. See Appendix 4 for a breakdown on the calculations made to reach these estimates on cost.

- Mechanical Counter Retail Price ~ \$0.65 per counter
- Magnetic Counter Retail Price ~ \$0.41 per counter

RECOMMENDATIONS

If the development of this product continues, some recommendations for further work include the full development of the vibration sensing device, market research, and preparation for high-volume production.

Due to time constraints, the development of a circuit to interpret output from the vibration sensor was not completed. If completed, this circuit should translate vibrations sensed by the accelerometer as a logical high or logical low, with high being above a certain set frequency. When it received a high reading it would add one second onto a counter. The counter would send a message to an LCD screen which would change the display every 1/10th of an hour. A switch would also be programmed so that when a button is pressed, the counter is reset back to zero. There may also be 3 different alarm-points set, so that the user can choose between city (100 hrs), normal (70 hrs), and highway (50 hr) driving. When the counter reaches the selected amount of hours, an LED would light up to draw attention to the device. The LED would be turned off when the counter is reset.

Before developing this device further, market research should be done. The desire for a miniature counter to replace the sticker was proposed from one mechanic, but we do not know how strong the consensus is among mechanics. The prototypes should be taken out to different mechanic shops and both mechanics and customers should be asked if they would use the device. It would most likely be necessary to get patents for the designs before showing them to a large number of people. It's important to know the demand for the product before deciding how to move forward with its production.

In order to provide any of the devices free to consumers, they would have to be produced at a very high volume to keep the cost minimal. Now that there are working prototypes, the injection molds of the magnetic and mechanical

devices can be made, as well as the bulk magnets and adhesives. Once all these materials are procured, along with the method for screen-printing and a site to manufacture them, the devices will be ready for mass-production.

References

1. Nice, K., How Odometers Work, <http://www.howstuffworks.com/odometer>, August 8, 2005.
2. Reinisch, A., and Kratochwil, L., 1895, "Pedometer," Patent 542,786, U.S. Patent Office.
3. Ling, R., 2003, "Combination Lock," Patent US D477,525, U.S. Patent Office.
4. Giorgini, N., 1981, "Mechanical Counter," Patent 4,255,650, U.S. Patent Office.
5. Wiederrecht, J., 2003, "Mechanical Golf Counter," Patent US 6,543,681, U.S. Patent Office.
6. EMachineShop, Plastic Molding, <http://www.emachineshop.com/machines-molding/injection-molding.htm>, 2003-2005
7. Online chemical engineering information, Basics of Injection Molding, <http://www.cheresources.com/injectionzz.shtml>, 2004.
8. University of Connecticut, Injection Molding, <http://www.engr.uconn.edu/cheg/polymer/injmold.htm>, May 1997.
9. ESPEC Corporation, Combined Environmental Testing for Equipment Used on Automobiles, http://www.espec.co.jp/english/tech-info/seminar/tp72-2/detail_tp72-2.html, 2005.
10. Measurement Specialties Inc., ACH-04-08-05 Multi-Axis Accelerometer, <http://www.meas-spec.com>, 2005.
11. Cypress Industries, Products and Services: Plastic Injection Molding and Tooling, http://www.cypressindustries.com/plastics_tooling.html, 2005.
12. All Magnetics, Inc., Flexible Magnetic Sheeting, <http://www.allmagnetics.com/flexible/sheeting.htm>.