A Batteryless Remote Control For Volvo, results of a feasibility study

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Abstract

This paper describes the design of a human-powered, batteryless remote control for the Volvo S80, designed at Volvo Car Company and Delft University of Technology. The proposed remote control is powered by bending a piezo element using the muscle power of the user. The main objective of the project was to remove the battery from the remote control, leading to an improved reliability and a reduced environmental impact of the remote control. Removing the battery also greatly reduces the discomfort due to empty batteries or malfunctions in the power supply, as experienced by users. The project demonstrated that a piezo-based generator is a viable, reliable and environmentally sound alternative for batteries.

1. Introduction

Despite major advances in portable electronics, batteries have changed little. Even so, they continue to be the main power supply system for many portable (audio) products and, considering their advantages (high energy density, widely available, internationally standardised, etc.), they will remain in this position for now [1]. Apart from their positive features, the use of batteries can be cumbersome as well; they run out of energy when you need them most, then they're not available, and they have to be replaced in a troublesome way. What is more: batteries turn out to be quite an expensive power source in the long run, especially in energy consuming applications. As a consequence of the increasing number of battery-powered portable products, the environmental impact of battery use is steeply increasing. Substantial amount of research is being done to improve the environmental performance, parts of which focus on the use of alternative power sources as human power.

Within the Human Power Research Group, we focus on all relevant aspect of the use of the human body to power electronic consumer products. The goal of the research is to provide industrial design engineers with a knowledge base on these aspects. In cooperation with industry we have set up a number of projects for testing the feasibility of the concept of human-powered energy systems in consumer products.

The Human Power Research Group is part of the faculty of DEP/Industrial Design Engineering at Delft University of Technology (DUT). The School of Industrial Design Engineering offers education at a university-level, leading to a Masters degree in Industrial Design Engineering. Its curriculum provides with a complete group of activities focused on a methodical and creative way of improving and developing consumer goods. Our mission is: *'creating products for people'*.

The reasons for Volvo Car Company to join the project were both the environmental aspects involved as well as the alleged durability of an alternative powered remote control. Volvo encountered some user-discomfort as a consequence of not properly functioning remote controls (mainly due to battery related problems), so a batteryless remote control would fit well in Volvo's policy to improve the reliability and durability of their products. The functionality of the new remote control was supposed to be identical to the existing remote having four functions; (un)lock all doors and trunk, open trunk, turn on interior and exterior lights and panic/alarm.

2. Project set-up

After having analysed (EPAss method [7]) the current remote control solution on power consumption, marketing and aesthetic aspects, we compiled a problem definition comprising four important issues: reliability, comfort, environment and brand identity. As a results of the initial analysis, next to the design assignment, two research subjects were identified; (1) lowering the power consumption of the remote control and (2) finding ways of harvesting a sufficient amount of energy from the human body and convert this into electricity. The trade-off between user comfort and generating energy turned out to be one of the most challenging issues in the research project. In fact, the user should not be aware of the action of generating energy while using the product.

Results from the research into power generation, conversion, storage and consumption were translated into three design proposals. An assessment of the three design proposals, based on a specific set of pre-defined criteria, was used to select the most promising idea. Finally, the engineering and styling aspects of the chosen design proposal were specified.

3. Energy analysis; supply, storage and demand

In the analysis phase of the project, we used the next figure to model the energy input and output of the remote control. The next chapters discuss the various items in this model.

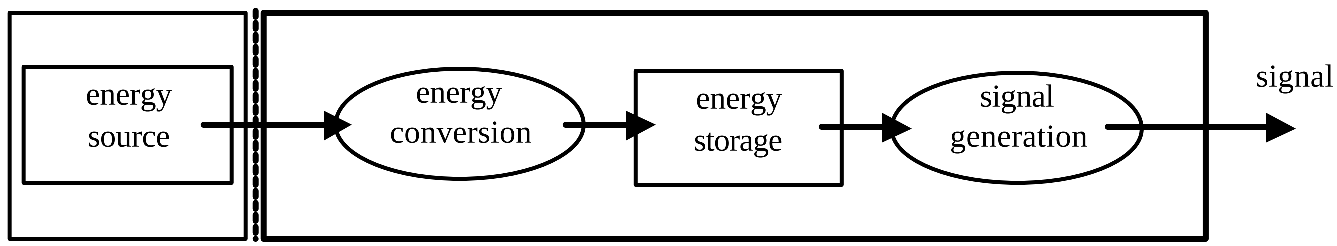

Figure 1 Energy input-output model of the remote control [3]

3.1 The supply side; an alternative energy source

In our effort to find an alternative power source for the remote, we took one step back in order to take a holistic approach to the problem. In theory, there are three possible energy sources for an alternatively powered remote control:

1. the environment surrounding the user and the car,
2. the car and
3. the user.

In the environment of the user and the car, the sun proves to be the only viable energy source. A solar cell area of 70 mm^2 would suffice in generating the required power, assuming the user drives his car in daylight at least twice a day for 15 minutes. The user has to put the remote on the dashboard.

Energy from the car itself could be harvested using either heat (from the engine), the cars movement (vibration, movement of the steering wheel, ….) or electricity from the cars battery. This last option proves to be the only feasible one.

The energy type from the user can either be kinetic (body motion), electric (skin potential) or thermal (body heat). The last two possibilities do not provide a sufficient amount of power and are therefore discarded. The first type (kinetic) should be divided into two categories: active power and passive power, this distinction is made on basis of the level of awareness of the user while delivering the power. An example of passive use of human power is the generator inside kinetic watches of various brands; it converts the movement of the wrist into electricity to power the watch. An example of active power is the use of the hand while gripping, squeezing or pinching (Figure 2).

In this specific product, using the active power from the movements of one or two hands proved to be the most feasible human-power option. Earlier research at DUT [2] found the following data for examples of typical power requirements of consumer products:

- Pushing a button with one thumb (as with a ballpoint): 0,3 Watt
- Squeezing hand-held generator called "Alladin power" (one-hand squeeze): 6 Watt

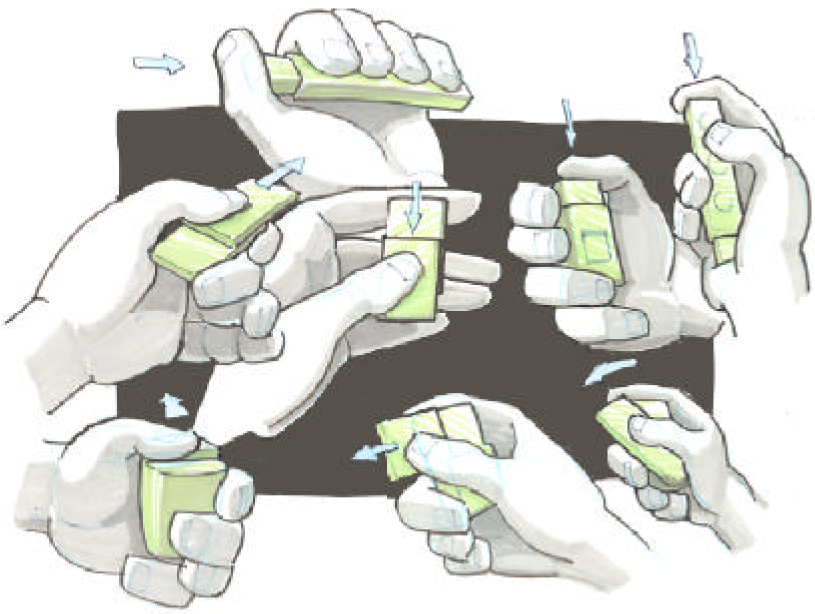

Figure 2 Using various movements of the hand [3]

At this point in the project, it was decided to drop both the solar cells (we can't expect the user to drive only during the day and the remote *has* to be put on the dashboard) and the ideas of harvesting energy from the car (heat and vibration are no feasible sources, using the car battery means placing the remote in a 'loading dock') and concentrate on using active human power as input for the remote control.

3.2 Energy conversion and storage

In order to find appropriate systems to convert the 'active human power' produced by gripping, squeezing or pinching, we examined the feasibility of three options;

- Micro-generator (rotating induction element) using a small dynamo (analogous to the system inside kinetic watches mentioned before). The complicating factor in the design of these micro-generators is the trade-off between the transmission ratio and the size of the components.
- Vibrating coil (oscillating induction element). The principle of using this solution has been demonstrated by the Swiss firm Ydea.
- Piezo element. Piezo ceramics produce electricity (high voltage, low current) when deformed, this can be achieved by bending or compressing a piezo element. A well-known application is the ignition in gas lighters. The challenge in using piezo elements in generating power consists mainly of converting the high voltage and low current.

Energy storage was divided in short term (seconds to minutes) and long term (months or years) storage. We looked at springs, various types of batteries, capacitors and even flywheels. Criteria for the evaluation of storage elements were (in no specific order):

- the maximum number of charging cycles,
- charging time,
- self-discharge,
- compatibility with other system components and
- volume and weight (energy content vs. the systems density) of the storage device.

3.3 Energy consumption; the demand side

The function of the remote control is to send a signal to a transmitter in the car, in general this signal consists of three parts:

1. header; indicating where the signal starts, so the receiver will start interpreting it,
2. key-identification signal and
3. function code; information for the receiver in order to respond with the required action.

In the search for less energy consuming protocols, the key-identification part of the signal required the most attention. In the existing remote control, the rolling code protocol is used to identify the key. Storing this rolling code in memory needs a small (10 µW) but nevertheless constant power source, in this way accounting for the largest part of the energy consumption over the life cycle of the remote. A non-volatile memory solution like EEPROM does not need a constant power supply and combines therefore well with alternative energy systems having limited energy storage.

4. Three design proposals

From the energy analysis described in chapter 3, it can be concluded that energy source, conversion, storage and energy consumption have to match well. In the first design stage, nine basic ideas were made out of matching combination of various working principles (as described in chapter 3). The majority of these basic ideas caused to alter the entire protocol for the communication between remote and car. Because this alteration did not fit within the scope of the project only three out of these nine basic ideas were engineered one step further. The three basic ideas used either the micro-generator (with or without additional energy storage) or the piezo element. A number of variations on these basic ideas were made, three most promising proposals will be presented here.

Figure 3 "Twister", handling and mechanism [3]

In the first proposal, Twister, the user has to rotate the top cover over an angle of 45º in order to open the remote and use the buttons. While rotating the cover, a micro-generator (similar to the generators inside kinetic watches) converts the motion in electricity. The energy is stored in a capacitor. An alternative idea is to open the cover by pushing a button (button releases a spring, cover 'flips' open and drives the micro-generator). In this case the energy needs to be generated by *closing* the cover and thus winding a spring.
Main advantages of this proposal: it can be made just as small or even smaller than the existing S80 remote and the push-button opening version has a high fun factor. Main disadvantages are: operating the remote is not simple (difficult manoeuvre with the hand), lots of gears necessary in order to convert a 45º rotation into sufficient speed for the generator.

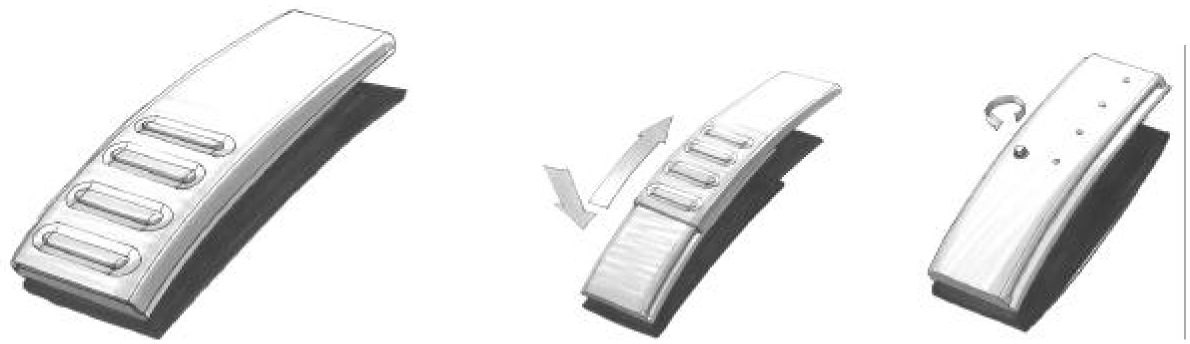

Figure 4 "Slide", handling and mechanism [3]

The second proposal, Slide, also uses a micro-generator. When the user slides the top cover upwards, a spring is charged. At the moment the slide reaches the top position, the (constant force) spring is released and drives the generator via a set of gears. Because the constant force spring drives the generator for a sufficient period, no energy is stored in e.g. capacitors. Main advantages of the proposal: flat design (fits easy in the pocket), unintended operation nearly impossible, large displacement of the cover decreases the need for large number of gears. Main disadvantage is the way the product needs to be handled; it is not easy to slide the cover up.

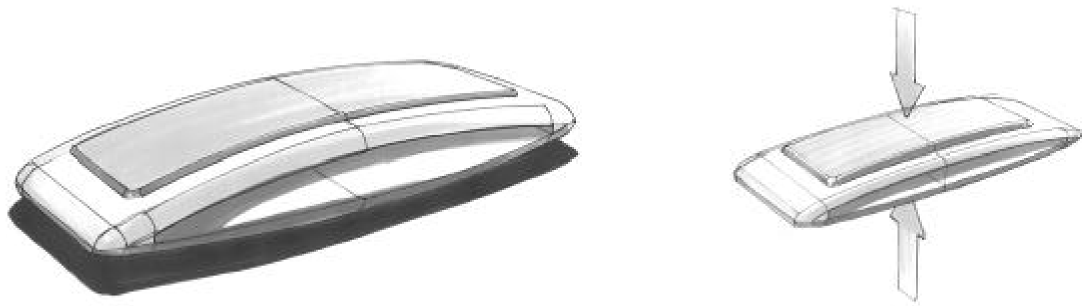

Figure 5 "Squeeze" and handling [3]

The third design proposal, called Squeeze, contains a piezo element. The piezo element is bent while deforming (squeezing) the housing. The energy is stored in a capacitor. Main advantages of the proposal: the remote is operated in a similar way as the existing remote (makes it easier to be understood by new users), little number of additional parts (low assembly and component costs, increasing reliability), remote can be small, remote can be sealed totally (no problem with moisture). Main disadvantages: development of the electronic circuit to convert the high voltage and low power into a more applicable current.

The evaluation of the three proposals was based on the following criteria (in no specific order):

- Handling of the remote (chance of unintended use, comfort for the user in force exertion, size and weight)
- Production of the remote (feasibility, costs, assembly)
- Styling of the remote in relation to the Volvo S80 interior and exterior
- Environmental impact during the life cycle of the remote control
- Reliability of the remote controlled system

In the assessment, the third proposal (Squeeze) outperformed the other proposals, this was mainly due to the ease of repeating commands, the expected low costs, the small size and the styling possibilities.

5. The final design proposal

In the final stage of the project, the engineering, ergonomic and styling aspects of the final design proposal were specified. Some of the features of the final design proposal will be discussed in the following paragraphs.

In combining the key and the remote, there are three feasible options (Figure 6): key-ring remote control (a), key folded inside the remote (b) and remote control in the handle of the key (c). The final proposal (Figure 7) features an integrated key, folded into the remote. When the black knob on the front side of the remote is pushed, the key flips out.

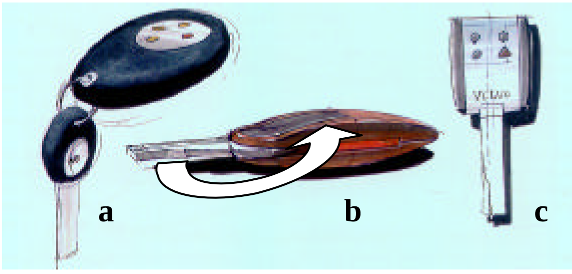

Figure 6 key-remote combinations [3]

The remote is a symbol, to the user it is an object that expresses his relationship to the car. The remote is the key through which the user has excess to all the services and benefits of the car, it is a symbol of ownership. The car most likely will be one of the user's most valuable possessions and for that reason the user may expect to see and feel this value. The remote control is part of this interaction with the car. In expressing its value, the design comes close to functional jewellery like watches and glasses. The study into colours and textures focussed on moving away from the traditional black remote control into the direction of using coloured plastic with a variety of textures. These should emphasise class and the association that the Volvo brand has with environmentalism and the outdoors. The study uses textures and colours of stones, sand, plants and wood to find a combination of materials that express class. The final choice has been to use a reddish sand colour and texture. It is a natural combination that fits the Volvo styling and that is modern at the same time due to the contrast with the aluminium of the middle part (Figure 7).

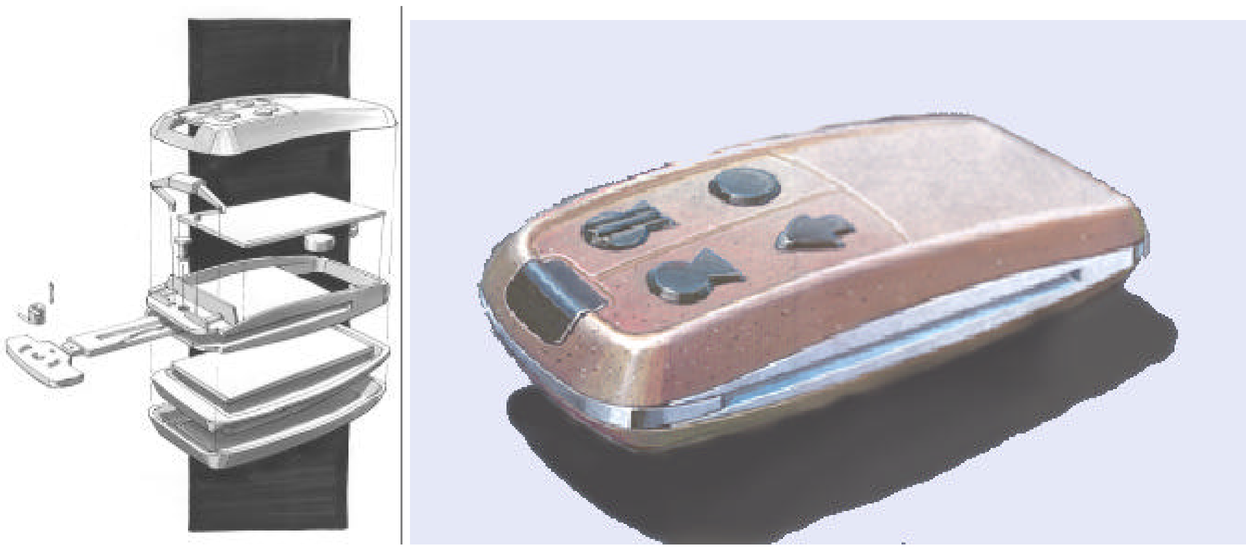

Figure 7 exploded view and rendering of the final proposal [3]

The remote control is build up from three layers. The first (bottom) layer contains the piezo element, the middle layer contains the key and the top-layer the circuitry. There also are three parts for the housing. The middle part separates the three layers and guides the bending of the piezo element. It got additional functionality in mounting the integrated key.

When the user operates the remote control he will press both the button and the bottom of the device. The bottom is flexible and will move inwards and at the same time bend the piezo element. The buttons on the top require a minimum force (10 N) to be activated. Before reaching this force the piezo element will have reached its maximum deflection and will have generated enough energy for the command that the user intends to send to the car. This energy is stored in a capacitor. At reaching 10N the button connects and the circuitry will use the stored energy.

Due to the lack of data on using a piezo element as a generator, the engineering of the generator got a somewhat empirical character. Starting from data on standard piezo elements (source: Philips Components), the required element (sizes 67 x25x1,45 mm) was determined. A parallel capacitor circuitry was used to transform the current.

The environmental impact of both the existing and the piezo remote was assessed by estimating the EcoIndicator'95 (EI-95) [4] value using EcoScan software [5] For the life of the remote, a ten year period was chosen. The EI-95 value for the existing remote is 2,75 mPt plus an additional 1,25 mPt for every battery used. The EI-95 value for the piezo remote is 2,50 mPt but this does not include the piezo element and capacitor (there were no EcoIndicator data available for these components at the time of the study).

6. Conclusions

The objective of the project was to design an alternative powered remote control for the Volvo S80, focussing on improving the reliability, comfort for the user, environmental impact and brand identity.

The design proposal improves the reliability due to its batteryless and sealed design. It also reduces the discomfort experienced by users due to empty batteries or malfunctions in the power supply.
The environmental improvements are hard to quantify due to lack of data, conservative assumptions however do show an improvement over the use of batteries. In our opinion, the proposed remote will contribute to the brand image of Volvo and suit its policy in producing reliable and durable products.

Using a piezo element as energy generator will have to be explored more intensively for it does offer a number of opportunities. (as demonstrated by Kymissis et. al. [6]).

The aim of this project was to develop an alternative-powered remote control, in the process of finding alternatives for a battery powered we also discussed a number of (more or less far-reaching) passive entry systems that did not fit in the scope of this project. One idea: instead of carrying an active element like the remote control, the user could carry a transponding element (the Volvo watch?) allowing the cars doors to be opened or even to start the engine without having to use a (physical) key. Although this proposal requires a lot of changes in the cars interior and user-interface, it does provide opportunities to enhance the user-friendliness and environmental impact of the car's security system.

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