



Student Paper

Force-feedback human interactive device

Author(s):

Huber, Remo; Kretz, Adjan; Fjeld, Morten

Publication Date:

2004

Permanent Link:

<https://doi.org/10.3929/ethz-a-004840336> →

Rights / License:

[In Copyright - Non-Commercial Use Permitted](#) →

This page was generated automatically upon download from the [ETH Zurich Research Collection](#). For more information please consult the [Terms of use](#).

Force-feedback Human Interactiv Device*

Remo Huber
huberr@ee.ethz.ch

Adjan Kretz
kretza@ee.ethz.ch

Morten Fjeld
morten@fjeld.ch

January 2004

1 Abstract

In the work presented, we study the mechanical and electrical requirements of a force-feedback human interactive device. The system which came out of our work, offers a hierarchical interface to a high-level Application Programming Interface (API). It consists of a motorized fader, power electronics to drive the motor, a P-regulator, an AD/DA-interface to a computer, and a high-level API library.

We built a prototype of this system to gain real experience with touch control and to make certain measurements.

2 Introduction

In our daily life, we control a variety of machines with knobs, buttons, sliders, and dials. Most of them are mechanical interfaces, e.g. a car's steering wheel and a gear-lever. In both these cases, users have to apply light forces to control the system, thereby giving its users a force feedback.

At the same time, many interactive devices consist only of sensors. Feedback in such systems is mostly visual and/or acoustic. This is also the case for most electronically-controlled machines; including computers. This causes perceptual and usability problems due to of the following reasons:

- we are used to have a feedback of what we touch
- we are confronted with too much of visual information
- we learn things better if we have a touch control

*Semester thesis of Remo Huber ITET, ETH Zürich and Adjan Kretz ITET, ETH Zürich supervised by Morten Fjeld IHA, ETH Zürich, October 2003 - January 2004

As more and more systems are controlled by computers, it is of high importance to have good computer interfaces. Drive-by-wire is just on example.

3 Force-feedback sliders

In order to meet challenges raised through the perceptual and usability problems mentioned above, we view force feedback sliders as one alternative way to system control.

3.1 Applications

In the past, sliders are used to control values, where it was important to have a simple visual and haptic¹ feedback. They are in use for mixers, in panels to adjust the temperature of the heating etc.

Today digital mixers are in wide use. They are equipped with motorized faders just for adjusting presets. But if we have a sensor and actor combined in one interaction device, there are a lot more 'things' we can do, than only move to a defined position. Applications in education and industry are seen of particular interest.

3.1.1 Education

It is very hard to learn and teach the behavior of complex systems. There are a lot of parameters, which depend on each other in a highly non linear way. One example is economics. We could use several force feedback-sliders in parallel, one for each parameter. In connection with a simulation software we can show the dependencies of each of them. e.g. if the user raises duties, economics are growing less. Furthermore, if a parameter has negative influence we could make it stronger to move the knob. If a parameter can have only discreet values, we should adjust in steps.

3.1.2 Industry

The work in the industry is a hard job, it takes our full attention, because the several machines and computers need a 24hours supervision. A good example is the work in nuclear reactors. At night it has to be controlled by a person as well. This is done in a room separate from the reactor. The state of the reactor is often presented visually and an emergency is indicated by acoustic means.

¹you can feel the position of the knob

With a force-feedback interaction device, we can present the state directly at the handle. As an example we think of controlling the pressure. Then the force is increased by raising the pressure. Especially at night this could be a benefit in security.

3.2 Concept

As we neither know the exact requirements of such a force feedback device (force and velocity of the motorized fader), nor the user expectations, we have decided to proceed step-by-step. In a first, prototypical approach, we set out to realize a hardware-based test environment. Motorized faders are no standard parts and there are only a few suppliers in the world. We choose to use ALPS N-Series. Additionally the minimal requirements are power electronics and simple regulators.

As a next step, we can connect the slider to a computer with an analog interface card. All other functions can be implemented with software and can thus be implemented very quickly and comfortable by a high-level language such as MATLAB or LabView.

Figure 1 shows the necessary hardware and a operating panel with two potentiometers, one to adjust the position the other to limit the motor force. This configuration is just for testing.

Figure 2 is the block diagram of the simplest way to have a force-feedback device connected to a computer. The device is controlled by software. Now we can study the requirements in details. Experiments with a small user group can give some preliminary information of the acceptance and expectations of such a device. Especially the shape and color of the handle could have a great influence.

If all parameters and some other important information are known, we can define what to implement in hardware and what in software. With that information, it's a lot easier to build hardware. Every parameter which can be avoided, will facilitate things. This results often in a economical benefit, as development time can be saved and simple hardware is cheaper. As a final step the software API can be implemented in a common programming language, such as java or C[++]. Figure 3 shows the final configuration where the Computer is connected with a standard digital interface such as RS-232 or USB.

We think this is a very flexible approach. In every step it is possible to consider the latest findings from the previous one. It's also the most economical way, because the risk to invest large amounts of money in hardware, which is useless afterward due to the lack of certain features.

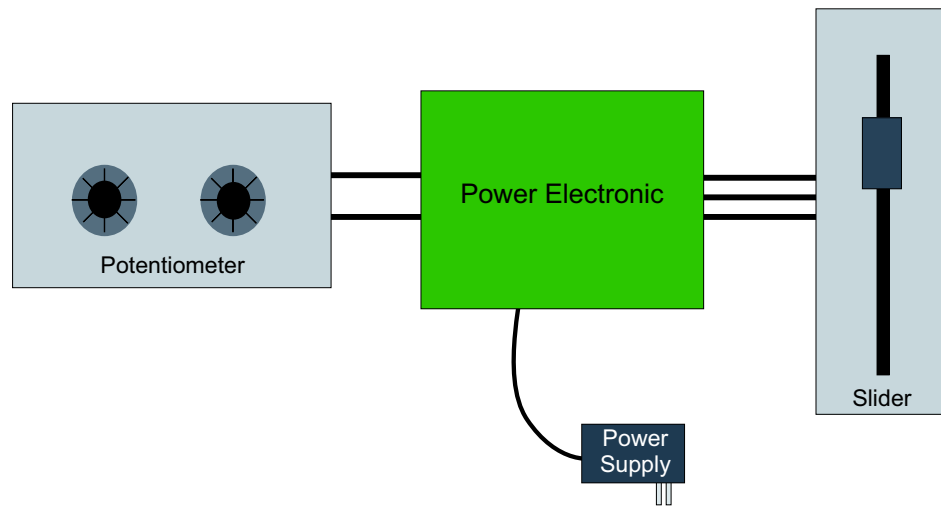


Figure 1: First Step: Force and Position are controlled by two potentiometers

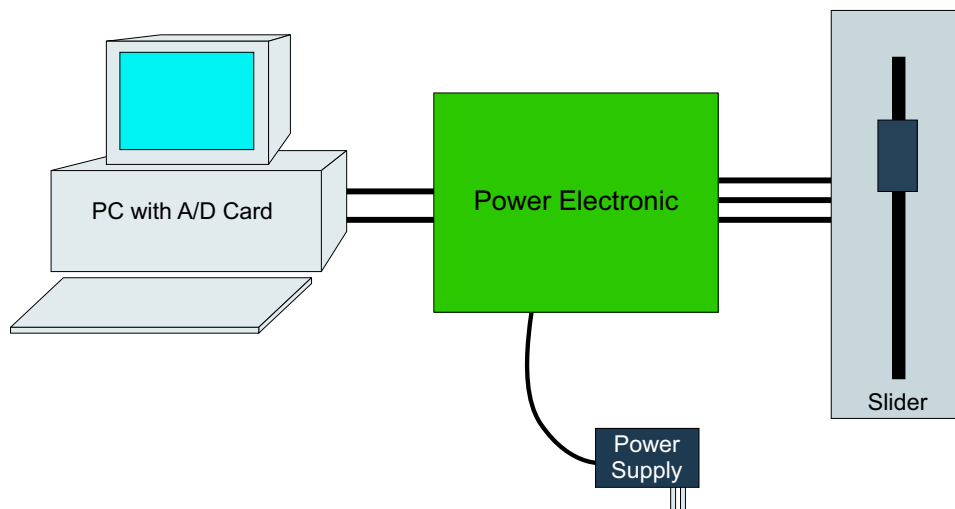


Figure 2: Second Step: A single slider is connected to the computer

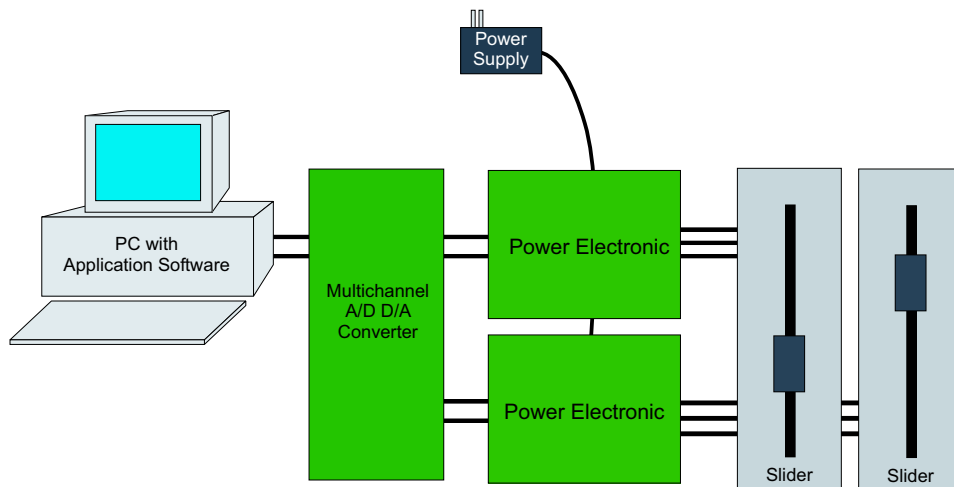


Figure 3: Third step: Multiple sliders connected to the computer using a standard digital Connector. This is the final configuration.

3.3 Interface

In a top-down, hierarchical approach, we first define the operating modes, then explain the software API, followed by the analog interface.

3.3.1 Operating modes

Position The fader is used only as input device, the motor is switched off. The user can move the fader as he likes.

Elasticity A default position and maximal force is set. The user has to surmount a force. If he releases the handle, it goes back to the default position.

Friction A default position and maximal force is set. The user has to surmount a force. But if he releases the handler it stays in that position.

Gradual A number of discreet steps is set and the handle catches them.

Texture A high frequency - low intensity vibration is superimposed to the handle. This should give users an impression of a surface.

Oscilation Emulation of damped sine movment.

3.3.2 Software API

The application on the computer choose one of the operating modes, described above, and sets the desired parameters. If the user interacts with



Figure 4: The prototype

the handle the application software is informed by an event passing method. This is an efficient method that allows to react quickly to users interaction. All parameters can be read and changed anytime.

All other processing is done transparently by lower layers. The separation between hardware and software depends on specific implementation details and can not defined finally.

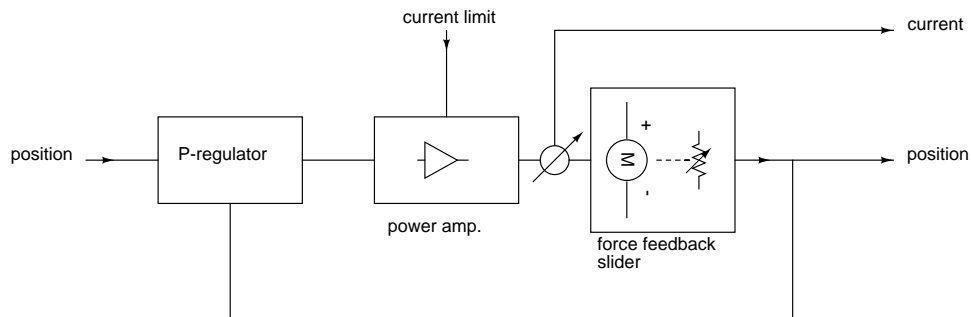
3.3.3 Analog interface

At the lowest layer we have an analog interface to the slider. The handle is moved by a DC-motor. The force at the handle is proportional to the motor current. Thus we can set the force by limiting the current. To set the position, we need a regulator. We used a P-regulator. It has shown that this is working very well, although the handle has clearance. Because the user interacts with the handle, we need also the actual position. To determine the users force we have to know the motor force by measuring the current.

This four signals (desired position, actual position, operating force and applied force) are of minimal complexity but provides complete functionality. This interface is described in section 4.3.

4 Prototype

Based on the ideas we presented in the previous chapter, we have designed and built the power electronic and regulator for a motorized slider. (see Figure 4) The circuit drawings you can see further below. (see Figure 5 and Appendix) With the two rotating potentiometers on the control panel you



Remo Huber, Adjan Kretz

Figure 5: Block diagram of the analog part

can set the position (with the right one) and the torque (force). That will allow us to do a lot of various measurements with the slider. This panel is wired with the power electronic. The wire interface is defined below. The device needs a $\pm 12V$ voltage source.

4.1 Mechanical Characteristics

Below we characterize the physical data of our prototype, needed to connect the prototype and characterize its capabilities.

mechanical data:

| | | |
|---------|-----|----|
| length: | 120 | mm |
| width: | 65 | mm |
| height: | 40 | mm |

feedback force:

| | | |
|-----------------|-----|------|
| friction force: | 200 | mN |
| minimal force: | 1 | N |
| maximal force: | 2.5 | N |

4.2 Electrical Characteristics

power supply:

| | | |
|-------------------|------|----|
| V_s- | -12 | V |
| V_s+ | +12 | V |
| $V_{reference}$: | +5 | V |
| I_s- | -500 | mA |
| I_s+ | +500 | mA |

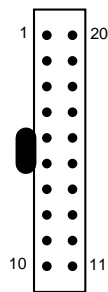
inputs:

| | | |
|---------------------|-----|------------|
| signal level (min): | 0 | V |
| signal level (max): | 5 | V |
| input impedance: | 100 | k Ω |

outputs:

| | | |
|---------------------|---|------------|
| signal level (min): | 0 | V |
| signal level (max): | 5 | V |
| output impedance: | 1 | k Ω |

4.3 Pin connections

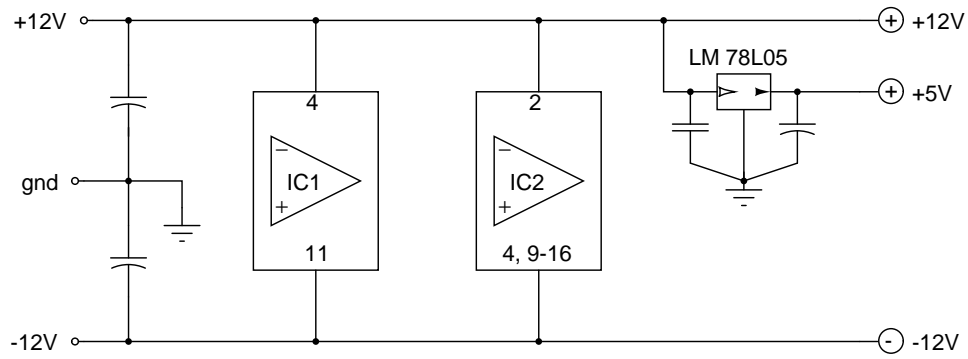


| PIN | Description | PIN | Description |
|-----|-------------------|-----|-----------------|
| 1 | $V_{reference}$ | 20 | $V_{reference}$ |
| 2 | V_s+ | 19 | V_s+ |
| 3 | V_s+ | 18 | V_s+ |
| 4 | position (output) | 17 | gnd |
| 5 | position (input) | 16 | gnd |
| 6 | force (input) | 15 | gnd |
| 7 | force (output) | 14 | gnd |
| 8 | N.C. | 13 | N.C. |
| 9 | V_s- | 12 | V_s- |
| 10 | V_s- | 11 | V_s- |

5 Visions

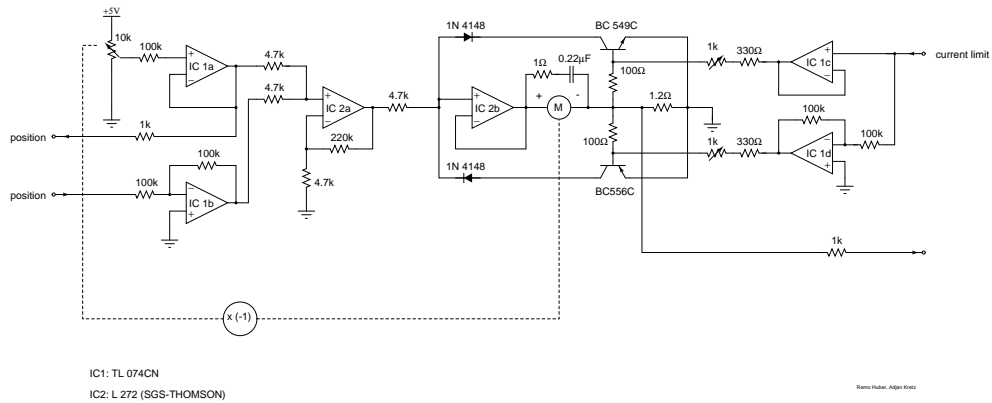
The Vision is to have a device, that allows a new form of interaction with a computer or even with a whole system. Also it will help us learn faster and/or avoid making fatal mistakes. There will be a lot of areas where this device can be of use.

A Circuit Drawings



Remo Huber, Adjan Kretz

Figure 6: Circuit drawing of the power supply



Remo Huber, Adjan Kretz

Figure 7: Circuit drawing of the regulator and power amplifier

B PCB layout

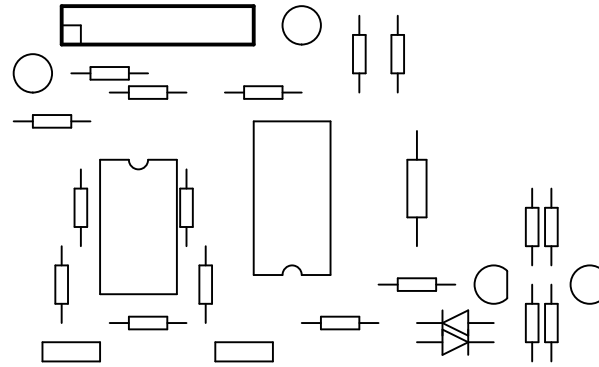


Figure 8: Component silk

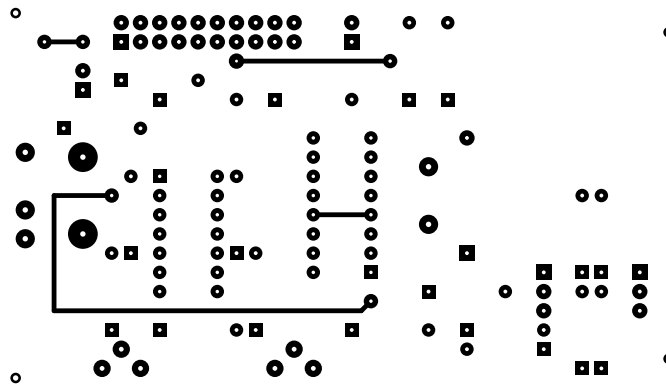


Figure 9: Component side

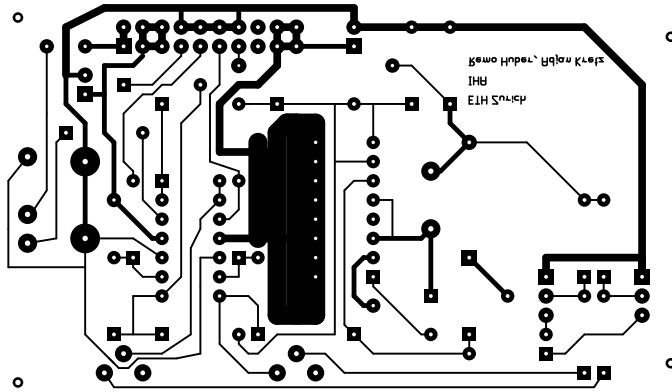


Figure 10: Solder side