About the technology

The Acreo Display is an electrochromic display, based on research around conductive polymers. At RISE Acreo AB, we create Acreo Displays with an (almost) conventional screen-printing process, using a proprietary conductive ink. Based on PEDOT:PSS, the Acreo Display is more robust than its predecessors and better for the environment.

A truly <u>flexible</u>, <u>robust</u> and environmentally friendly display:

- One of the first true "printed electronics" components
- With very <u>low power consumption</u>
- Easy to drive with <u>conventional drivers</u>
- Possible to integrate in <u>high-speed</u> printing processes
- With an almost "free form factor", as you can print <u>any shape</u> you want
- And <u>overprintable</u> with graphic (screen, flexo) print to make the display interact with the application/packaging.

WARNINGS

The Acreo Display can be severely damaged if you power it incorrectly.
- Blue-to-white switching with a too long voltage pulse will cause device degradation.
- Accurate pulse cut-off is critical.
- Operating conditions, storage and handling will affect the performance.

If you need any assistance, do not hesitate to call us! (We're at CET, Stockholm/Paris/Rome time).

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Short operating instructions

Coloration from white to blue: connect 0 V to the silver pad that connects to the black line observed from the front side. Connect 3 V to the other electrode(s). Apply the voltage for about 1 sec, which should be sufficient to reach the fully blue-colored state.
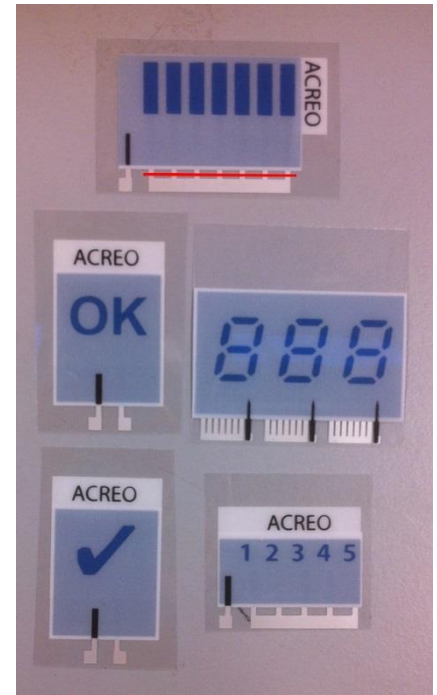
As you can see in the image, the segment electrodes are jointly connected in some of the displays. If you want to uniquely address a specific segment, you should simply cut the common part of the segment electrodes, which is also illustrated by the red line in one of the displays in the image.

To switch the display from blue to white simply reverse the voltage polarity. In this switching direction, it is important not to use too long pulse length; disconnect as soon as you don't see any more color change, e.g. after 1 sec or even less.

If operational lifetime is important during your evaluation, you could also try to add a resistor (in the range 10 kΩ - 50 kΩ) in series with the common electrode, which is the electrode showing a black line on the front side.

In general, the pulse length is dependent on switchable area, resistance along the conductors, etc., and it is therefore difficult to provide you with a specific drive protocol. Common sense usually works fine; when no more color change can be observed, you should simply stop charging.

Be careful with the blue-to-white switching; too long pulses will cause degradation.

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FAQs

Operating conditions, robustness and lifetime

Performance of the Acreo Display depends on <u>humidity</u> and <u>temperature</u>. We've performed durability and accelerated lifetime tests but not all scenarios have been verified as there are a multitude of parameters that are interdependently affecting how the display functions. <u>How you drive the display</u> is a key component when it comes to lifetime, even more important in difficult conditions. In short, extremely humid, or very cold and dry climates will affect the display performance.

Is the Acreo display dot matrix or segment?
Segmented. Matrix versions exist on lab scale. Please contact us for a discussion.

Can you use paper as a substrate?
Currently, Acreo focuses on flexible and organic electrochromic displays based on plastic substrates. Nonetheless, <u>we can still manufacture displays with paper as the substrate</u>. Please contact us for a discussion on your application.

What is the maximum size?
In theory there is no limit, but in practice it will depend on your machinery. The maximum pixel area is mostly a question of switching time, a large display segment will become a bit slower. In the Acreo production environment we can currently handle up to <u>A3 sheets</u>.

Samples, customized design and tooling

Standard samples
We send standard samples for free (EXW Sweden), but we need to have a small agreement in place before shipping.

Customized projects and samples
Please send us a drawing of the targeted design for a feasibility check! The cost for a prototype series of displays depends on a number of factors. We typically charge a symbolic 3500 Euro, including design, printing tools, production, materials consumption and testing.

Tools
The print tools involved are relatively inexpensive (screen printing mesh).

Delivery times
Standard samples: one week.
Custom samples: three weeks.
Production series: <5000 units typically 4 weeks.
Production series: >5000 units, please check with us.

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Substrate and thickness

Typically PET 100 µm (possible from 50um to 250 µm), but polycarbonate is also possible.

What is the final thickness of the display and substrate?

Around 120 µm.

Adhesives, lacquer, graphic print

Can we use adhesive on the display?
Yes, on the back side. This is where the contact pads are located, so you probably want to glue them on top of your substrate.

Overprinting with graphical print
This is one of the great things with the Acreo Display; you can alter it and combine it with your own graphical effects.
- Registration tolerance +/- 100 µm is desirable.
- Offset, Flexo and high precision screen printing
- It is possible to hide conductive tracks and other circuitry/components.

Drivers and voltages

Voltages
- 2.2 V are needed in order to reach full contrast.
- High voltage: requires caution with pulse lengths to avoid degradation.
- 3 V is a typical voltage at which many microcontrollers are operated.

Drivers and circuits
Example: Systems with only one display segment, e.g. the word "Hello":
1. You will not need a specific driver.
2. You will need a circuit that decides when to switch the display.
3. Sensor -> Microcontroller (reads sensor, decides if the display should be updated)-> Display.

Each use case will require different drivers, and Acreo is not supplying integrated circuits today. We can use, but are not limited to, for instance:
Microchip (http://www.microchip.com/pagehandler/en-us/products/picmicrocontrollers)
NXP (http://www.nxp.com/products/microcontrollers/)

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Power consumption

Switching the Acreo electrochromic display requires a maximum of 500 µC per cm^2 of switchable display area. Additionally, the display is semi-bistable, which means that the color will gradually disappear. To retain the colored stated, you typically need to supply a refresh pulse, e.g. every 15 minutes, but this updating charge is then less than the full switch, i.e. about a few hundred µC per cm^2 of switchable display area.

A display segment is charged like a capacitor, with an initially high current level (several mA), then dropping to µA. It makes more sense to integrate the current by using the term of charge, indicated by the unit Coulomb (C). With a battery of 10 mAh and a 1 cm^2 display area consuming 500 µC this corresponds to 140 nAh, and about 70000 switches with a 10 mAh battery, or 35000 coloring cycles and 35000 bleaching cycles.

Switching times

Switching time varies with display area, impedance in conductors and drive voltage. A smaller display needs less charge and will have a shorter switching time. The voltage required for the switching is unaffected by the display area.

Typically, a few hundred milliseconds are sufficient to switch the display in both directions, i.e. from white to blue as well as back. Please note that you need to be careful during the blue-to-white switching since a too long voltage pulse will cause device degradation.

Potential development paths / scenarios

Continuously on?
Continuous updating of the display might result in temporary exhaustion effects as the device is relying on electrochemistry. However, more than 200000 switch cycles have been obtained by optimizing the drive protocol.

Transparency/Shutter effect
There are various kinds of shutter effects available. One example is a "hidden message" in the background which reveals itself when the display is switched. The Acreo display is typically operating in reflection mode by using an opaque electrolyte, and it is difficult to hide a predefined message completely in such architecture. However, in a proprietary display design, in which the display segment appears to be pixelated, the predefined message can be completely hidden, and upon applying the voltage the message is revealed.

Transmissive (clear) displays
A display device operating in transmission mode could be accomplished with transparent electrolyte and electrodes. This is difficult to obtain with organic-based electrochromic materials, but may not be impossible. Please contact us for an in-detail discussion.

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