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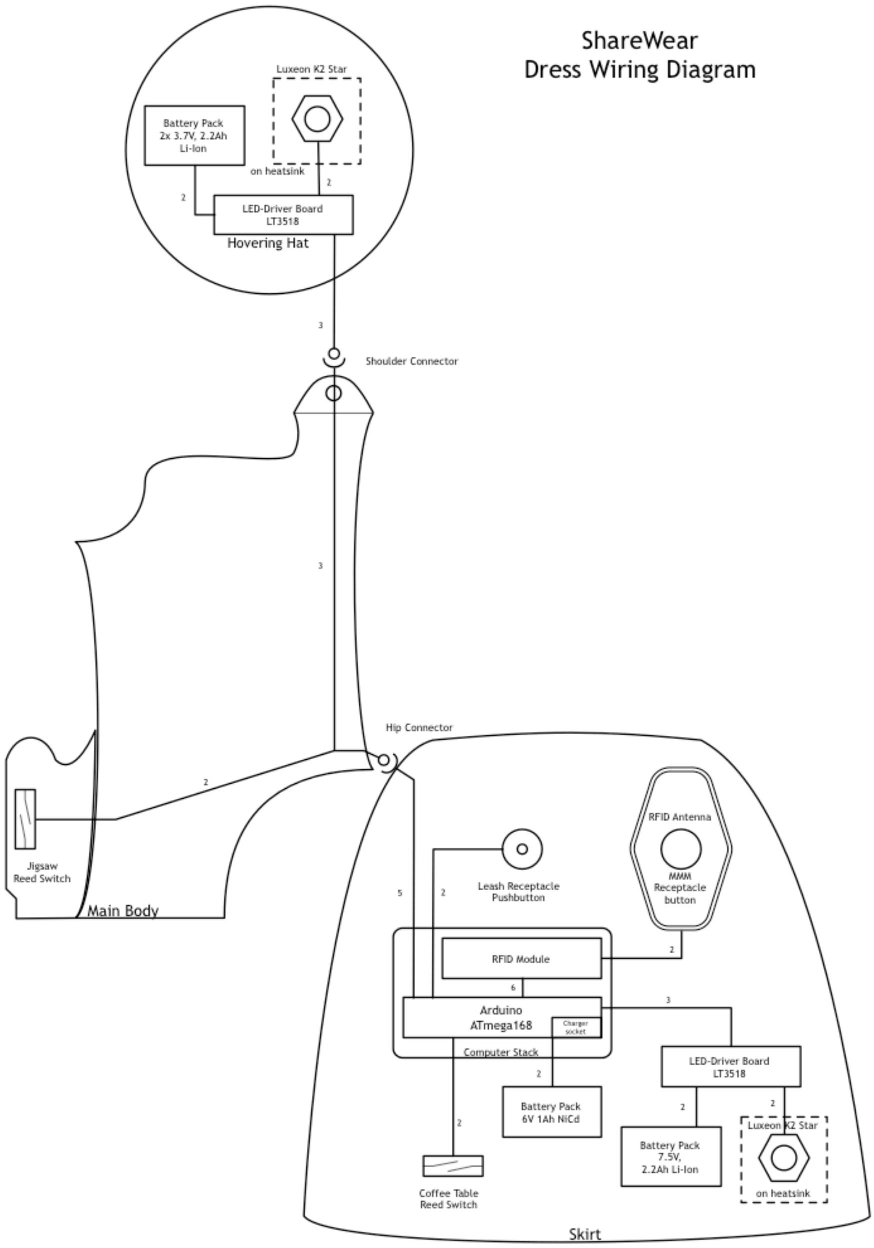
Hardware

This page describes the various bits of hardware, electronics, and mechanics, internal to the dresses. Both dresses have identical sets of electronic modules inside them, but they differ slightly in the mechanics and optics used inside the skirt-pods.

Electronics

The different modular sections of each dress contain electronic circuits, battery-packs and/or sensors. These are connected through connectors and wires running inside the dress-lining.



Most of the electronics are housed in the skirt-pod. The heart of the system is a simple single-board computer, the Arduino Diecimila board, based on the ATmega168 microcontroller from Atmel. The Arduino is essentially on standby (i.e. in a low power-consumption mode) until one of the sensors embedded in the dress is activated. These sensors detect when the two dresses join together in various possible ways. Depending on which sensors activate, the Arduino switches on either one or both the ultra-bright Luxeon K2 high-power LEDs, and modulates the light-intensity according to a pre-determined pattern.

If a 'Migrating Mood Module' (a.k.a. 'Magic Magnetic Mushroom') is present on the skirt-pod's 'Mood-Module receptacle button', the Mood-Module is detected by an RFID-reader built into the skirt-pod, and a different light-modulation pattern is used to modulate the LEDs' brightness.

New light-modulation patterns can be designed, associated with a specific Mood Module, and uploaded to the Arduino.

Arduino pin layout

This is the pin layout connecting the other modules to the Arduino board. The pin numbers are the digital pin numbers on the Diecimila *not* ATMega168 pin numbers.
From the RFID-module, serial data is only received, never transmitted, so only the RFID-module's TX-signal is needed, the RX-signal can be dropped.

name	arduino pin	function	port
RFIDTX	2	INT0	PD2
RFIDNACT	3	INT1	PD3
REED1	4	PCINT20	PD4
REED2	5	PCINT21	PD5
LED1ENABLE	6	DOUT6	PD6
LED2ENABLE	7	DOUT7	PD7
RFIDRESET	8	DOUT8	PB0
LED1PWM	9	OC1A	PB1
LED2PWM	10	OC1B	PB2
RFIDACT	11	PCINT3	PB3

Hip connector pin layout

Some of the Arduino signals (above) have to leave the skirt and connect to a sensor in the Jigsaw Armrest, which is part of the Main Dress Body, or up to the Hovering Hat (see below). The dress and skirt-pod plug together using a mini 5-pin connector. Each half of the connector is housed inside a magnetic ring, so that the connector-halves are forced together by the magnets. The magnetic Hip-connector is one of the 3 magnetic attachments-points by which the skirt-pod is slotted onto the main dress body.
This table lists the pinout of the Hip-connector, as wel as the colours of the wires attached to the Arduino-side.

name	pin	wire	goes where	Shoulder Hinge cable	Jigsaw Armrest cable
LED1ENABLE	1	red	Shoulder Hinge connector	white	
REED1	2	green	Jigsaw Armrest reed-switch		brown
GROUND	3	shield	Both	shield	white
REED2	4	blue	(not connected)		
LED1PWM	5	white	Shoulder Hinge connector	red	

Shoulder Hinge connector

The Hovering Hat (below) plugs into the shoulder-hinge, where the electrical connection is made by a mini-jack plug (in the Hinge-disc) and socket (in the Hovering Hat's support-rod). This connector carries the control-signals to the Hovering Hat's LED-Driver Circuit.

name	pin	wire (in dress)	wire (in Hovering Hat)
LED1ENABLE	tip	white	brown
LED1PWM	ring	red	white
GROUND	sleeve	shield	shield

Note how the wire-colours are switched in the Hip connector and switched again in the Shoulder Hinge connector:

- The LED1ENABLE signal is red, then white, then brown
- The LED1PWM signal is white, then red, then white

This is because the cable between the Hip connector and the Shoulder Hinge connector is a pre-fabricated cable for audio purposes, and there the mini-jack's tip is the left channel (white) and the ring is the right channel (red).

Skirt-Pod internal wiring

Since most of the electronics are housed inside the skirt-pod, a fair number of cables is used in there:

- The power-cable from the 7.5V battery-pack to the LED-Driver board has a simple 2-pin connector for the battery-pack. The Li-ion battery-charger has a similar connector. *Always* pay extra close attention to the *polarity* when connecting the battery-pack (either to the power-cable inside the skirt-pod, or to the charger!

name	wire
+	red or brown
- (GROUND)	black or blue

- The control cable from the Arduino to the LED-Driver board

name	wire
LED2ENABLE	brown
LED2PWM	white
GROUND	shield

- The cable from the Coffee-Table reed-switch

name	wire
REED1	brown
GROUND	white

- The cable from the Leash Receptacle switch

name	wire
REED2	brown

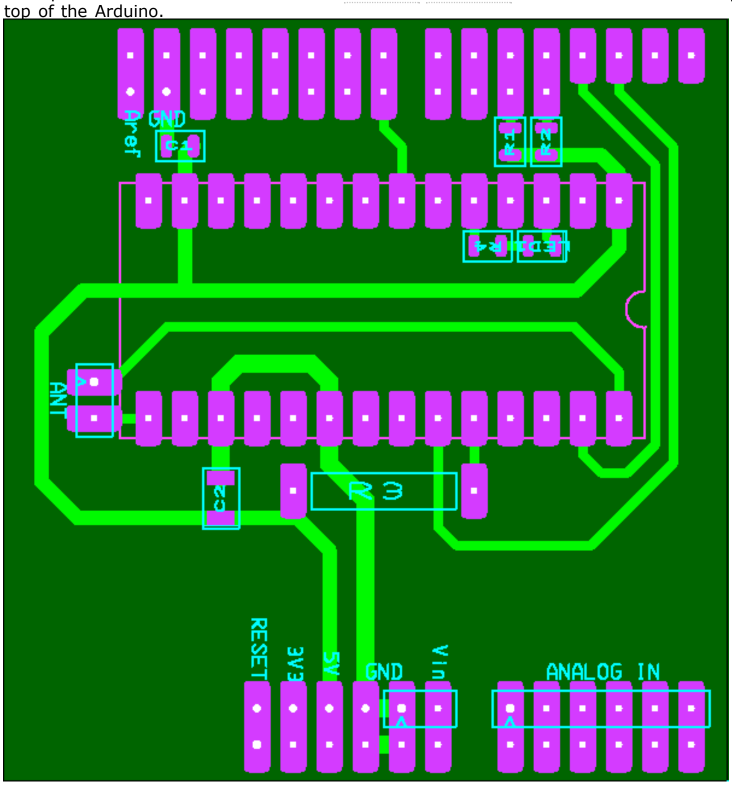
GROUND	white

- The cable from the RFID-antenna. This cable has a small green 2-pin connector that plugs onto the pins sticking off the side of the RFID board (below). For this cable, the polarity does not matter.

name	wire
antenna	brown
antenna	white

RFID Module

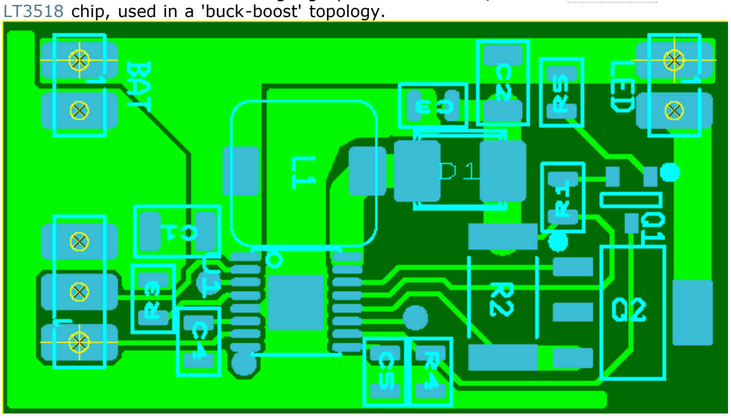
A simple circuit-board that contains the SonMicro CY8C0105 RFID-module and solder-pads for off-board connections. The whole board plugs into / on top of the Arduino.



The schematic drawing is available as PDF: RFID1.0.pdf

LED-Driver Module

This is a driver-curcuit for driving high-power white LEDs, like the Luxeon K2 we're using for this project. The circuit is based on Linear Technology's LT3518 chip, used in a 'buck-boost' topology.



The schematic drawing is available as PDF: LED-drv1.0.pdf

This circuit was originally designed to operate on a single-cell Li-ion battery-pack (3.7V), hence the 'buck-boost' topology. Unfortunately, because of time & budget constraints, i could not get the boards manufactured professionally, and i had to etch the boards myself, omitting the important 'thermal vias' that connect the metal bottom-plane of the chip to the copper plane on the underside of the board. Without these thermal vias, the chip does *not* get adequately cooled and will gradually overheat, resulting in an unstable circuit and a flickering LED.
To circumvent this problem, we are now powering the circuit with *two*-cell Li-ion battery-packs (7.5V), which means that the chip carries less current for a given amount of output-power, and it now takes substantially longer for the chip to overheat.
In addition, a heatsink is glued to the underside of the driver-board, but the benefit from this additional cooling is only marginal, because of the absence of the thermal vias.

In hindsight, given the 7.5V batteries we use now, Using the LT3518 in a slightly simpler 'buck' topology would have been sufficient, and maybe marginally more efficient, but the boards had been designed & built already by the time we discovered we needed the 7.5V batteries.

Batteries

Each dress contains 3 battery-packs:

- a 6V, 1Ah NiCd battery-pack (in white plastic) for powering the Arduino & RFID-reader
- a 7.5V, 2.2Ah Li-ion battery-pack (Enix brand, in black plastic) for the LED inside the skirt-pod

- a set of two 3.7V, 2.2Ah Li-ion batteries (Enix brand, in black plastic) inside the Hovering Hat, for powering the Hat LED.

Since the Arduino cannot be switched off, even with the Arduino in *standby*, the NiCd battery-pack will drain completely in about 2 days, and should always be recharged before each performance or demonstration of the dresses. Since this battery is permanently attached to the Arduino, it can be charged by connecting the NiCd-charger to the power-inlet on the Arduino board. In order for this to work, the reverse-voltage protection diode on the Arduino-board has been removed and by-passed, so care must be taken that no metal objects can find their way into this connector and short-out the battery. Also mind the polarity of the NiCd-charger; the central pin (i.e. inside) of the connector is the +, the outside is the -.
Note that a simple 6V wall-adapter is *no* substitute for a NiCd-charger, and should not be used!
The first symptom of the Arduino-battery getting depleted will be that the RFID-reader stops working, and the dress no longer detects the presence of any Migrating Mood Module. With the Arduino continuously operating (i.e. not going into *standby* because either one or both LEDs are on), the Arduino battery-pack is expected to last 5 - 6 hours. In reality, the Arduino will go into *standby* at least part of the time, greatly extending the expected operating time.

The Li-ion batteries, on the other hand, only drain when the LEDs are actually on (in principle). With the LEDs off, there will still be some tiny leakage currents (in the LED-driver chip, and in the battery-pack itself) but those are so small that the expected discharge time of the Li-ion batteries (with the LED's *off*) will be weeks, if not months.
When the LEDs are *on*, operating at an average 50% of full power, the Li-ion batteries are expected to last about 4 hours. The first symptom of the Li-ion batteries getting depleted is loss of brightnes from the LEDs (this will probably be a sublte effect, hard to notice at first). The Li-ion battery-packs have a built-in protection-circuit, which will switch off the battery-pack before it becomes over-discharged.
The Arduino's NiCd batteries can't be over-dischaged like Li-ion batteries. In fact, completely discharging NiCd batteries before recharging them is considered good practice, and will maintain the maximum battery-capacity over the battery's lifetime.

Mechanical

This section highlights some of the mechanical components (and related issues) of the dresses.

Heatsinks

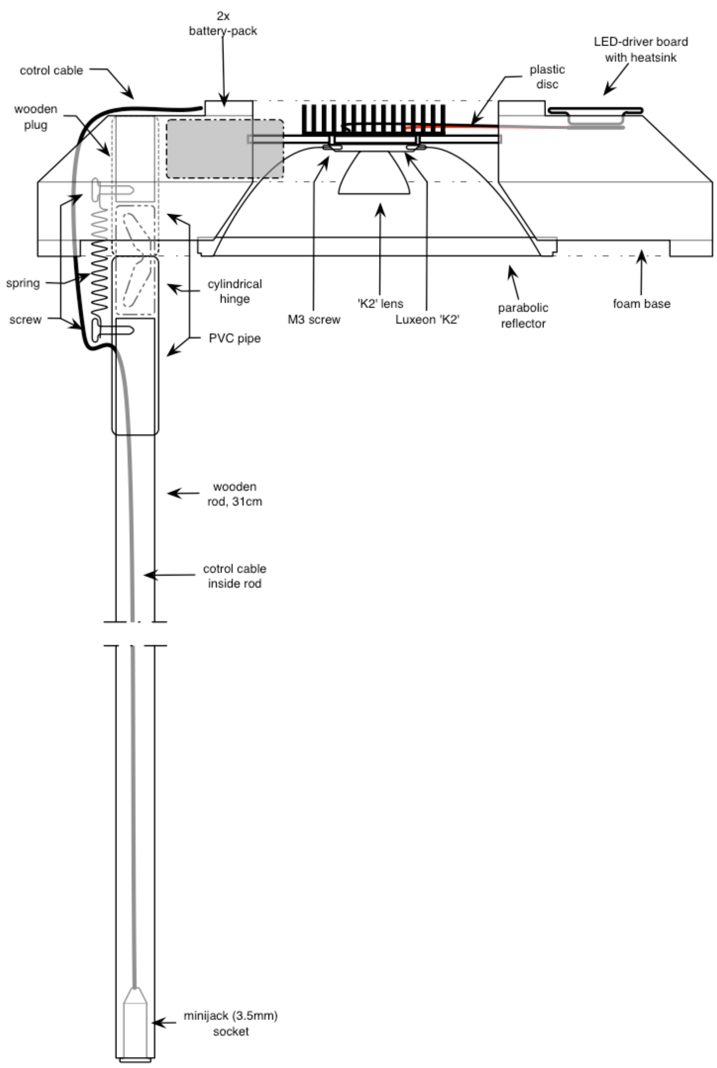
The Luxeon K2 LEDs used are very high-power lightsources. The LED-driver circuit described above can drive these LEDs at a peak current of 1.25A. At a forward voltage of 3.6V, each LED receives upto 4.5W of power. LEDs are much more efficient than incandecents, but even then most of the provided 4.5W are dissipated by teh LED in the form of heat. These LEDs really need to be mounted on a heatsink (see also: on Luxeon LED thermal design), and the larger the heatsink, the better the cooling. However, because the dresses should still be wearable, we shouldn't include any overly large blocks of aluminium. For a compromise, a heatsink has to be found with a reasonable size that can still provide adequate cooling. Ideally, the temperature of any part of the system should stay below 60°C at all times.

Given the available space & design constraints, we found a 4 x 4 cm heatsink to have a practical size for our application. However, tests with such a heatsink (40 x 40 mm, 18 mm deep, 12.2°C/W thermal resistance) have shown that the heatsink temperature exceeds 60°C after approximately 20 min at full power (4.5W), and even reaches 70°C (after about 45 min).
Fortunately, the LEDs will never operate at full power continuously. The light-intensity is modulated by pre-determined patterns from the Arduino's memory, and what matters here is not the peak power, but the *average* power. If we assume that the average power is 50% of the full power (i.e. 2.25W) then the heatsink temperature will never exceed 60°C but level out at a maximum of about 54°C. This is a reasonably safe assumption, because the LEDs will actually be switched off altogether for significant portions of time. Within a 45 min window (which is the time it takes for the heatsink to reach the max temperature at full power) it is quite likely that the LEDs will be more off than on, and hence the average dissipated power is likely to lie below 50% of full power.

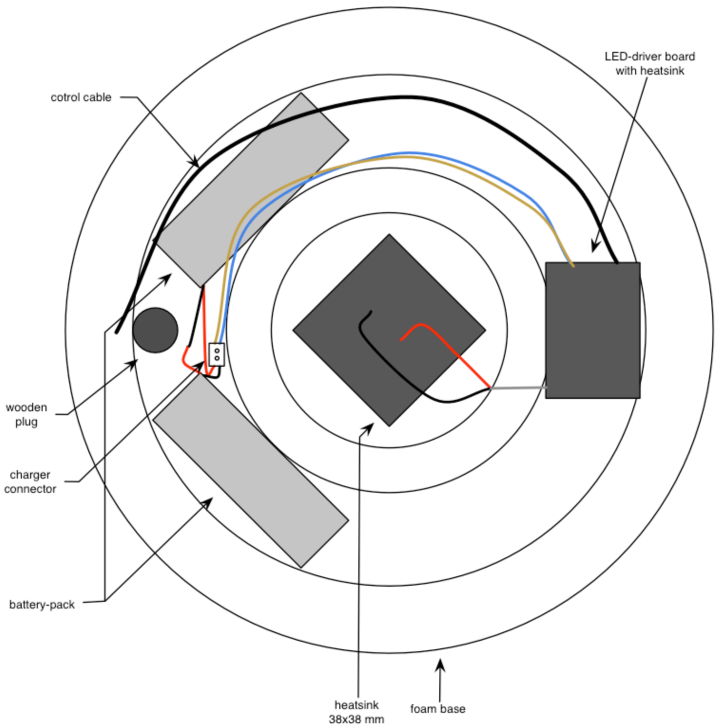
The Hovering Hat (below) had to be as flat as possible, so we decided to use a different, less deep heatsink for the LEDs inside the hat. This heatsink has less surface-area, and therefore a higher thermal resistance. Tests have shown that the heatsink temperature still stays under 60°C when the LED is operating at 50% of full power.

Hovering Hat

The Hovering Hat is a modular part of the dress. The hat is supported by a wooden rod plugged into the Shoulder Hinge and it actually hovers above the head of the wearer. The wooden rod has a second hinge built into it right below the hat, which allows for 'tipping one's hat'.



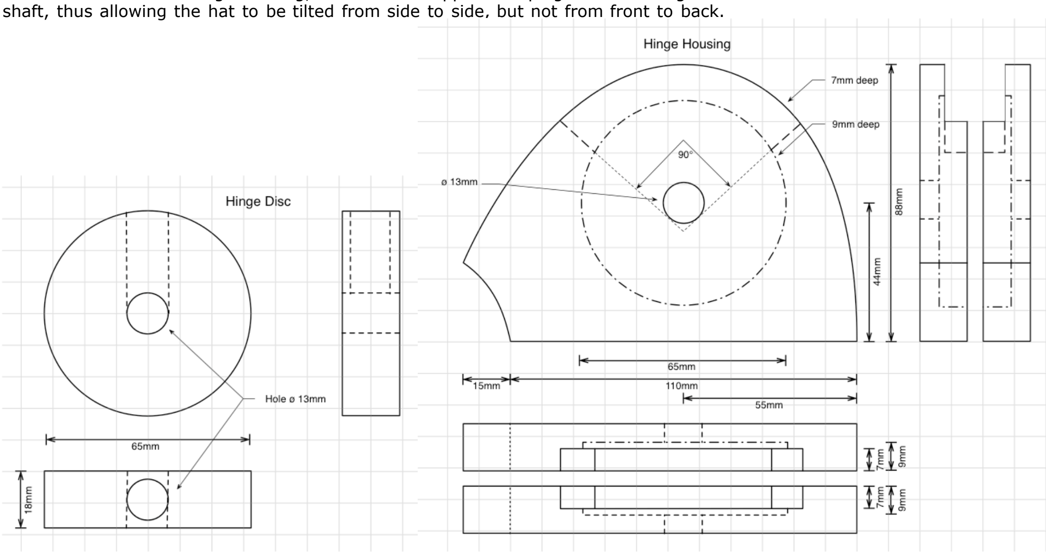
The Hovering Hat contains a Luxeon K2 (on a heatsink) with a clear plastic lens that bundles the light from the LED into a narrow (6°) beam. The LED + lens assembly is mounted in the focal point of a parabolic reflector which bundles any of the remaining light which shines out of the lens sideways. In addition, the hat contains an LED-driver board and 2 single-cell Li-ion battery-packs. The control signals for the LED-driver come up via a cable hidden inside the wooden support-rod.



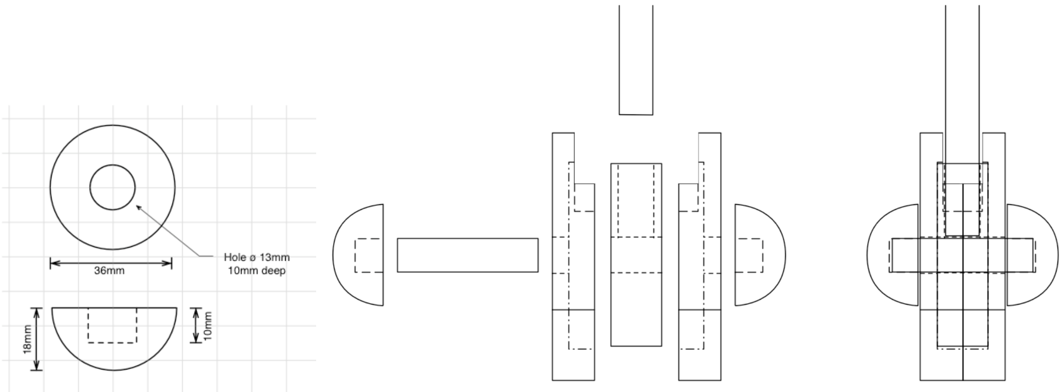
The Hovering Hat also has a simple 2-pin socket for connecting the Li-Ion battery-charger. Again, pay close attention to the *polarity* of the battery-connector and the charger-connector. Make sure the red wire on the charger lines up with the red wire inside the hat.

Shoulder Hinge

The Hovering Hat's support-rod plugs into the wooden Shoulder Hinge on the dress's main body. The hinge is constructed as a disc clamped between the two halves of the hinge housing, and the hat support-rod plugs into the hinge's central disc from above. The disc can rotate around the central shaft, thus allowing the hat to be tilted from side to side, but not from front to back.



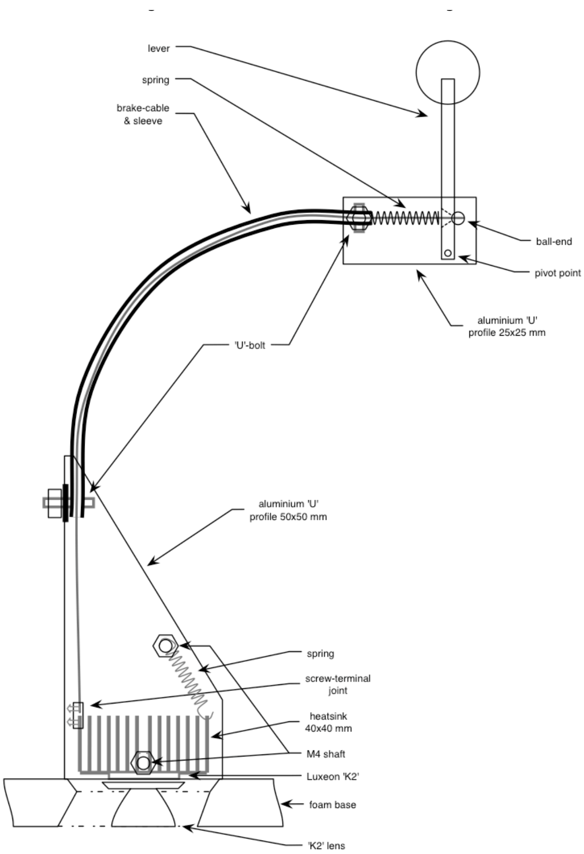
The front and back halves of the hinge housing are permanently attached to the dress's front and back straps, respectively, and the two halves of the hinge housing snap together magnetically. The hemispherical wooden end-caps attach to the central hinge-shaft where it comes through the fabric of the dress in the front and in the back.

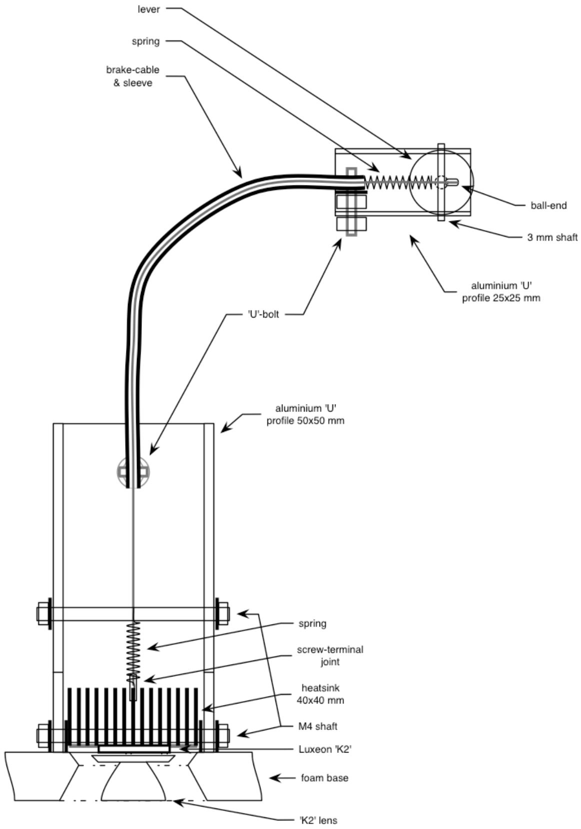


Embedded inside the hinge's central shaft is a 3.5mm right-angled minijack plug, with the business-end pointing up into the hole where the hovering hat support-rod plugs in (not drawn). The support-rod has a matching minijack-socket embedded in the end of the rod, and this connector-pair allows for the control-signals to the Hovering Hat LED-Driver to be carried to the Hat, and allows for the support-rod to pivot inside the shoulder hinge.
The cable from the minijack plug inside the hinge comes out the back end of the central shaft, and is re-routed (underneath the back endcap) into the dress-lining of the back strap, and from there on down to the hip-connector.
The front endcap has a magnet inside, and it snaps onto te front end of the central shaft, which has a steel screw inside it for the magnet to adhere to.

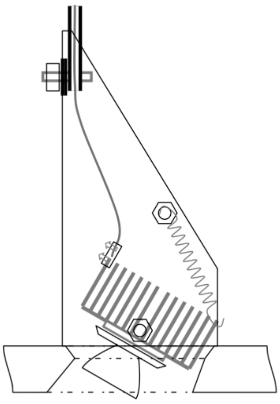
The Tilting Taillight (Dress 1)

Each dress has one light-source inside the skirt-pod, and the light (beam) from these sources can be manipulated by the wearer by means of a wooden lever sticking out of the skirt-pod. However, the placement of the light-source and the way in which it can be manipulated is different for each dress.
Dress 1 has a 'taillight' which shines a narrow bar of light down onto the floor behind the wearer's legs.



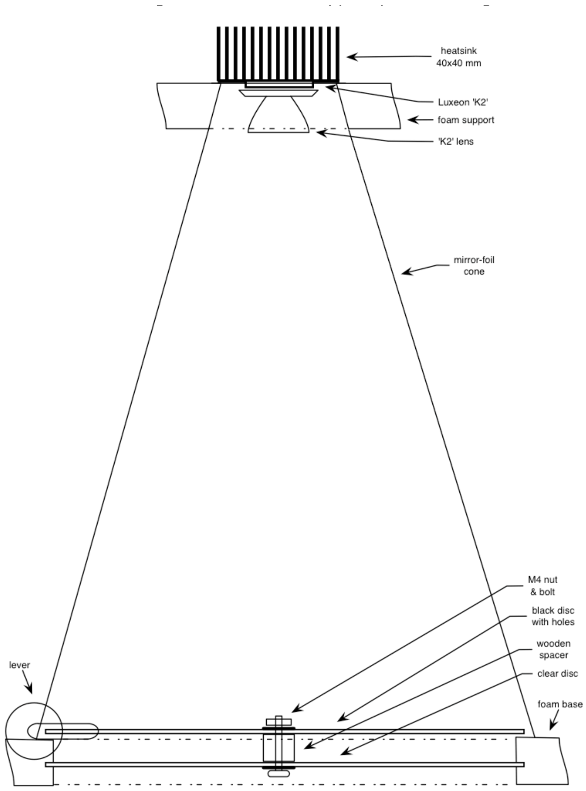


When moving the lever, the up/down motion of the lever is translated by means of a cable-and-sleeve system to the light-source assembly (i.e. Luxeon K2 on heatsink, with narrow-beam lens) which can tilt to throw light onto the floor further back from the wearer, or inversely, throw light onto the wearer's legs.



The Dappling Footlight (Dress 2)

Dress 2 has a 'footlight' which shines dappled patches of light onto the floor beside the wearer's legs.



In this case, the LED + lens assembly is mounted at the apex of a cone made from mirror-foil. At the bottom end of the cone there is a non-transparent disc with holes in it, mounted concentrically on top of a transparent disc. A wooden lever is attached to the top disc, allowing this disc to be rotated by applying a front to back motion to the lever. Rotating the disc will in turn rotate the pattern of dapples on the floor.

Attachments

- ab05.pdf (380.9 kB) -"on Luxeon LED thermal design", added by simon on 2008-02-19 14:18:14.
- RFID1.0.pdf (153.3 kB) -"Arduino RFID-module Schematic", added by stock on 2008-02-28 15:56:12.
- CY8C0104_5.pdf (342.1 kB) -"datasheet SonMicro CY8C0104 / CY8C0105 RFID module", added by stock on 2008-02-28 16:05:10.
- RFID1.0_board.png (14.9 kB) -"RFID-board for the Arduino", added by stock on 2008-02-28 16:24:02.
- led-drv1.0.png (11.8 kB) -"LED-Driver board", added by stock on 2008-04-28 17:54:21.
- LED-drv1.0.pdf (60.5 kB) -"LED-Driver board - Schematic", added by stock on 2008-04-28 17:55:16.
- Hovering_Hat_Sideview.png (73.3 kB) - added by stock on 2008-04-30 12:34:03.
- Hovering_Hat_Topview.png (112.9 kB) - added by stock on 2008-04-30 12:34:58.
- Shoulder_Hinge_disc.png (31.2 kB) - added by stock on 2008-04-30 12:35:40.
- Shoulder_Hinge_housing.png (64.8 kB) - added by stock on 2008-04-30 12:35:55.
- Shoulder_Hinge_endcap.png (20.2 kB) - added by stock on 2008-04-30 12:36:14.
- Shoulder_Hinge_assembly1.png (25.7 kB) - added by stock on 2008-04-30 12:36:48.
- Conelight.png (66.7 kB) -"The 'Dappling Light' source inside the Dress 2 skirt-pod", added by stock on 2008-04-30 12:38:05.
- Taillight_Sideview.png (94.0 kB) -"Side view of the 'Tilting Taillight' inside the Dress 1 skirt-pod", added by stock on 2008-04-30 12:39:58.
- Taillight_Topview.png (80.7 kB) -"Front view of the 'Tilting Taillight' inside the Dress 1 skirt-pod", added by stock on 2008-04-30 12:40:25.
- Taillight_Action.png (35.2 kB) -"Side view of the 'Tilting Taillight' tilting", added by stock on 2008-04-30 12:41:06.
- Dress_wiring2.png (86.8 kB) -"The Dresses' wiring-diagram", added by stock on 2008-04-30 13:01:18.