ARDUINO MEETS WEARABLS

CODEMOTION
workshop 2013
KOBAKANT
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www.KOBAKANT.at

INTRODUCTION

This booklet is intended to be a very quick introduction to working with the LilyPad Arduino and making textile sensors. It introduces a selection of fabrics, threads and yarns that are either highly conductive or have interesting electrical properties such as electrical resistance which varies over distance or under pressure and strain. The conductive and resistive properties of such materials can be used to construct a range of textile sensors that can detect physical actions such as tilt, stroke, pressure, bend, stretch and squeeze.

The textile sensors described in this booklet include:

- Fabric Button
- Beaded Tilt Sensor
- Stitched Stroke Sensor
- Neoprene Bend Sensor
- Knit Stretch Sensor

Enjoy!

MATERIALS

Resistive Yarn Nm 10/3

Spun from a blend of stainless steel and polyester fibers, sold by Plug and Wear. Can be used to make a range of knit and crochet sensors.

Velostat

A black plastic film impregnated with carbon to make it conductive. It has a high resistance that increases over distance. When measureing resistance through the material, it decreses when pressured.

Conductive Thread

Silver Plated Nylon 234/34 4ply from Shieldex. Good thread for sewing with, and works nicely as bobbin thread in a sewing machine. Has some resistance to it.

Conductive Thread

30981 7x1 fach verseilt kupfer blank from Karl-Grimm. Highly conductive thread, great for soldering to SMD components such as LEDs.

Conductive Lycra

very stretchy and very conductive fabric. Great for making stretchy connections.

Metal Beads

For making tilt sensors or tilt switches. A heavy metal bead is best.

Glass or Plastic Beads

Good for isolting conductive thread as well as for decorative purposes.

Fabric

reagular fabric is a great base material for sewing circuits on. It can also be used to isolate conductive materials from one another. Natural fibers such as cotton or silk will not melt like synthetic fabrics if you plan to do any soldering on the fabric.

Fusible Interfacing

Also known as: Interweb, Bondaweb, Fusible, Interfacing, “iron-on“, Fusible web...
Fusible Interfacing is a heat activated fabric glue that can be used to fuse two pieces of fabrics together with the heat of an iron.

Foam

as a spacer material inside a fabric button.

Neoprene

A synthetic rubber that is produced by polymerization of chloroprene. Neoprene is used to make wetsuits and laptop cases and normally comes with a polyester-nylon farbric fused to either side.

Felt

A non-woven fabric that cuts nicely without having to finish the edges. Great as a non-conductive base for making sensors.

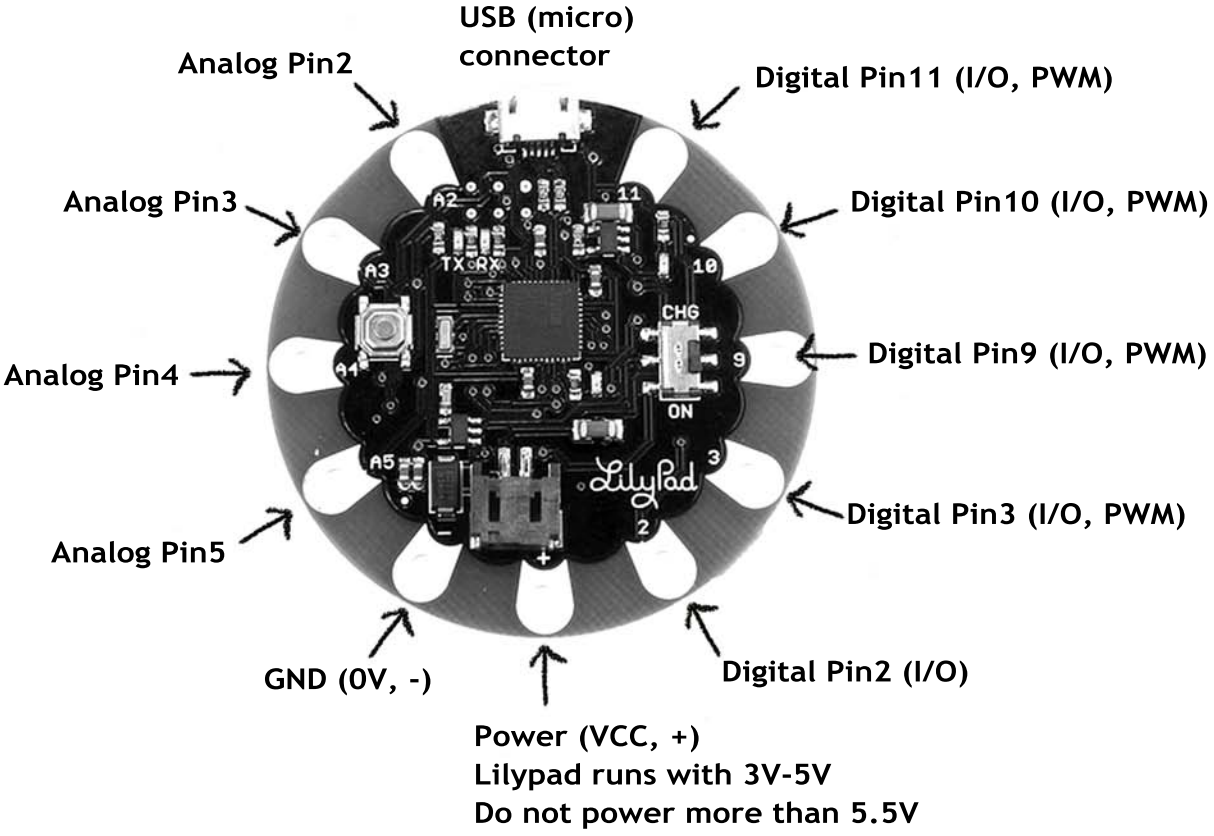
The materirals featured on this page can be purchased from the following websites:

www.lessemf.com (conductive fabrics, resistive thread)
www.plugandwear.com (conductive fabrics and threads, resistive yarn, Velostat)
www.karl-grimm.com (solderable conductive thread)
www.sedochemical.com (neoprene)
www.eeonyx.com (Eeontex)

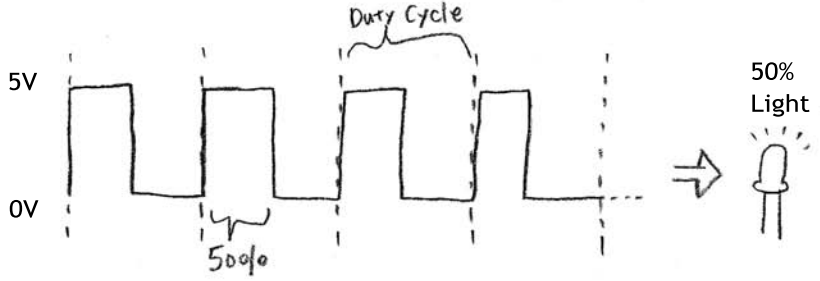
The parts featured bellow can be purchased from the following websites:

www.tinkersoup.de
de.rs-online.com
www.sparkfun.com
www.dx.com

LILYPAD


USB (micro)
connector
Analog Pin2
Digital Pin11 (I/O, PWM)
Analog Pin3
Digital Pin10 (I/O, PWM)
Analog Pin4
Digital Pin9 (I/O, PWM)
Analog Pin5
Digital Pin3 (I/O, PWM)
GND (0V, -)
Digital Pin2 (I/O)
Power (VCC, +)
Lilypad runs with 3V-5V
Do not power more than 5.5V
A2
11
A3
TX
RX
10
CHG
A4
9
ON
A5
3
LilyPad
2
+

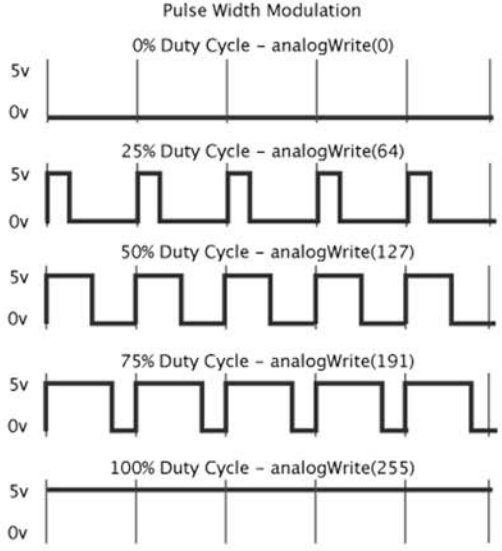
PULS WIDTH MODULATION



analogWrite (PinNumber, 128);

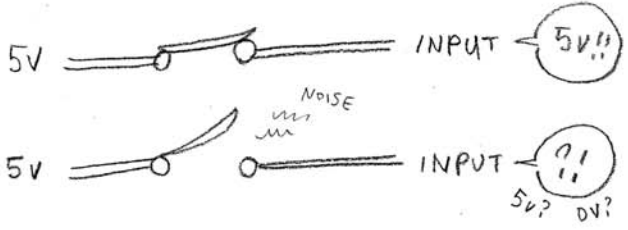
value: 0-255

Not all the digital output pins on Arduino can do PWM. Check the datasheet to see which of the pins on your Arduino is capable of doing PWM. On Lilypad, pins 3, 5, 6, 9, 10, and 11

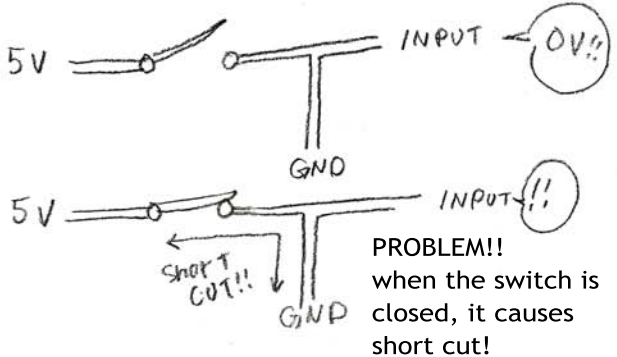


PULL UP/DOWN RESISTOR

Arduino Digital pins are reading if it is receiving 0V or 5V when it is set as INPUT pin.
so, if you just connect 5V to switch to an Arduino input pin...

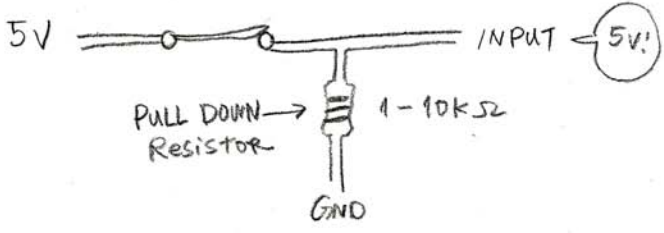


.. it does not work! The input pin floats when the switch stays open, so we need to pull down the pin to the ground

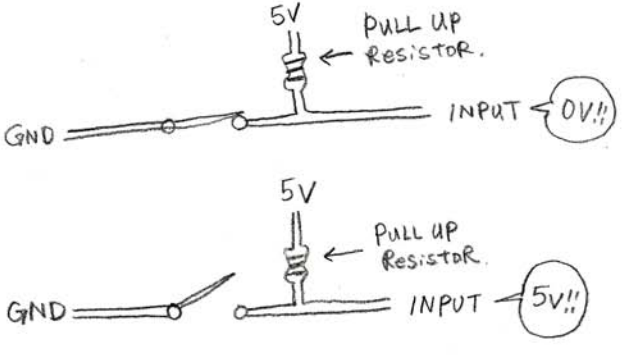


PROBLEM!!
when the switch is closed, it causes short cut!

Instead of directly connecting the pin to the ground, we add resistor to pull the pin to the ground. This is called pull down resistor

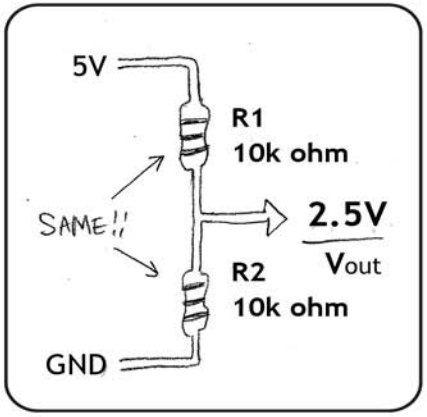


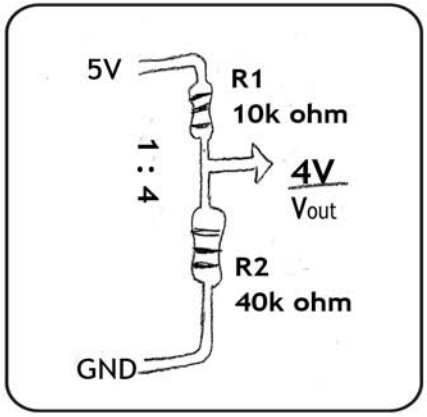
If you switch 5V and GND, you can pull up the input pin. When the switch is open, it receives 5V. This is called Pull up resistor.



VOLTAGE DIVIDER

Fixed Resistor





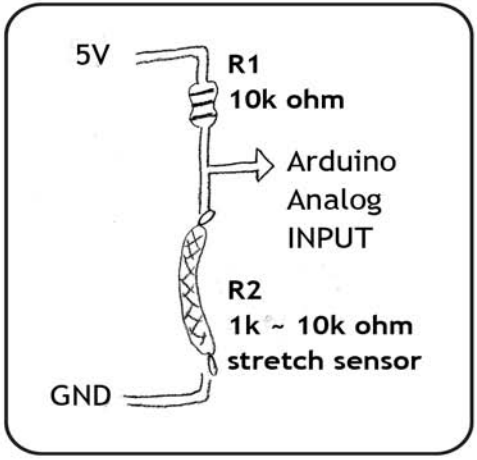
Analog input pin receives 0V to 5V
and converts them into 0-1023

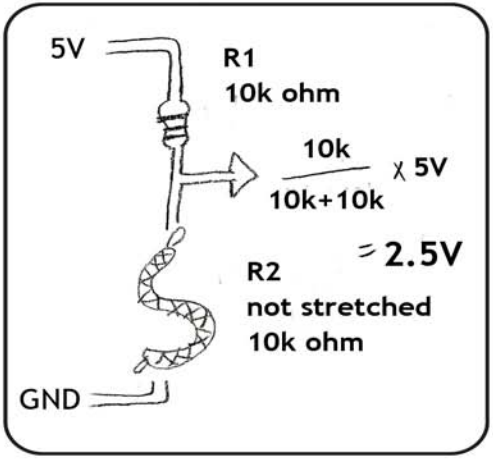
0V ⟷ 5V

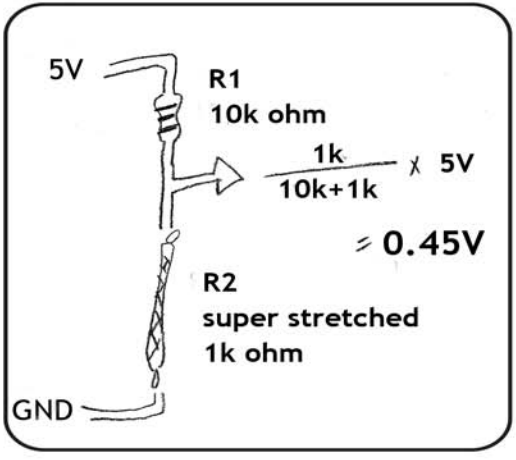
0 ⟷ 1023

$$Vout = \left(\frac{R2}{R1+R2} \right) \times Vin$$

Variable Resistor



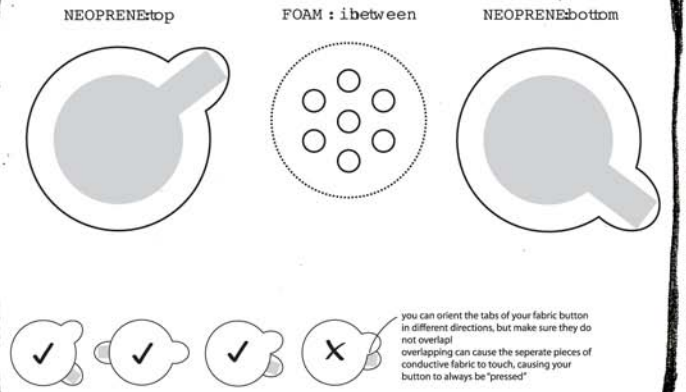




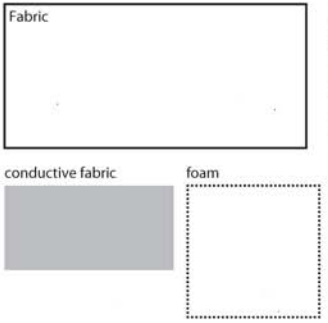
NEOPRENE PUSHBUTTON

Using conductive fabric as the contacts for soft push button and perforated foam as a spacer material, this fabric pushbutton is an extremely basic construction that can be used in many different ways.

DIAGRAMS

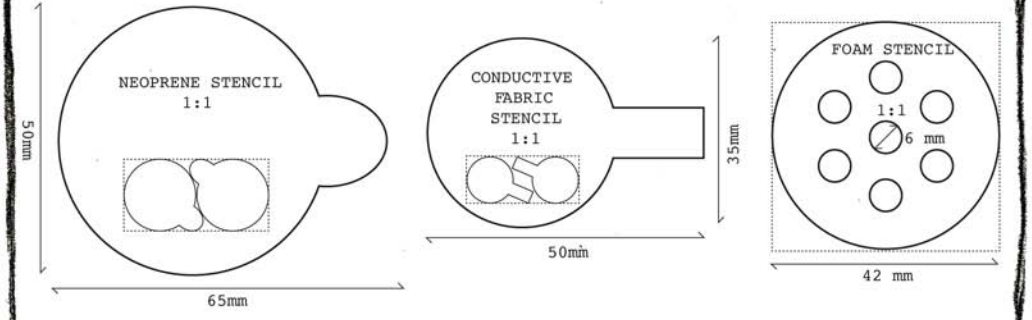


CONTENTS



Scissors, an Iron, a sewing needle and some regular thread

STENCILS



TRACE AND CUT OUT THE STENCILS 1

Cut or trace the stencils from the other side of this instruction sheet and transfer them to the apropriate materials.

PEEL OFF PAPER BACKING 2

Peel the backing off from the conductive fabric pieces.

FUSE CONDUCTIVE FABRIC 3

Place the conductive fabric pieces, with the glue side (shiny side) facing the neoprene. Set you iron to a medium heat (too hot will burn the fabric) and iron over the conductive fabric to melt the glue and fuse the fabrics together.

PERFORATE THE FOAM 4

If you don't have a hole maker then you can also make holes in the foam by simply folding it half twice and pinching or cutting of the tip of the triangle.

LAYER THE MATERIALS 5

Layer your materials so that the conductive fabric faces inwards with the perforated foam inbetween.You can arrange the tabs of your fabric button any which way you want so long as the don't overlap.

CLOSE THE PUSHBUTTON 6

Thread a needle with regular sewing thread. Tie a knot in one end and proceed to sew around the edge of your sensor. Be sure to stitch both sides of neoprene together, you do not need to include the foam in your stitch, as it will stay in place.

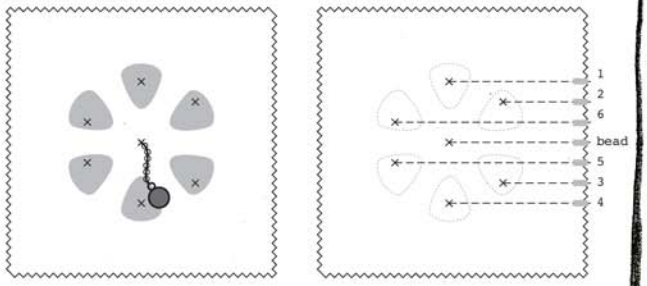
TEST FINISHED SENSOR 7

Connect the ends of your sensor to a multimeter set to measure continuity. When you press the pushbutton, your multimeter should read close to zero Ohm. When the button is not touched, the reading should indicate no connection.

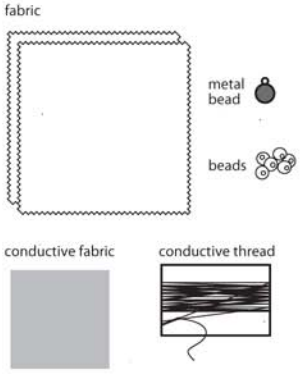
BEAD AND FABRIC
TILT SENSOR

Using a metal bead and conductive fabric petals to construct a six-way digital tilt-switch.

DIAGRAMS

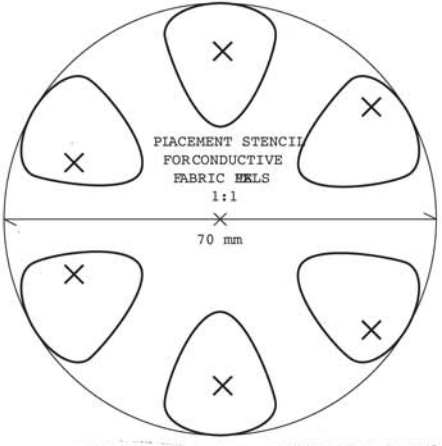


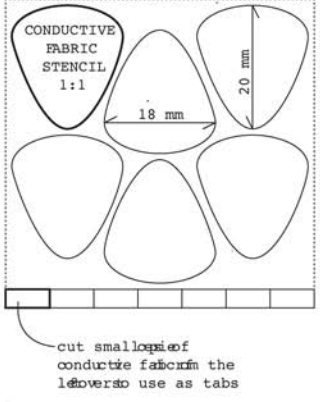
MATERIALS



Scissors, an Iron, a sewing needle and some regular thread

STENCILS



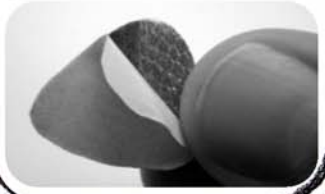


TRACE AND CUT OUT THE STENCILS 1

Cut or trace the stencils from the other side of this instruction sheet and transfer them to the apropriate materials.

FUSE CONDUCTIVE FABRIC 2

Peel off the paper backing from the pieces of conductive fabric. Place the conductive fabric petals, with the glue side (shiny side) facing the fabric. Set you iron to a medium heat (too hot will burn the fabric) and carefully iron over the conductive fabric petals to melt the glue and fuse the fabrics together.

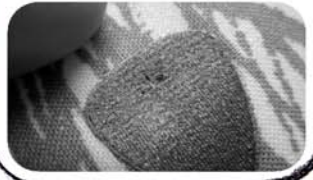


LAYER THE FABRIC 3

Layer the two fabric squares on top of each other, with the petals facing up and the tabs facing the back. Mark the X for each petal on the back of the petal layer. Thread a needle with some conductive thread and tie a knot on one end. From behind, sew into one of the conductive fabric petals where the X is marked.

CONNECT THREAD TO PETAL 4

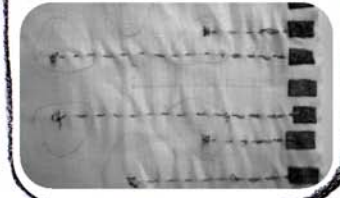
Stitch the conductive thread to the petal 3-4 times in the same spot to insure a good connection. Continue to sew, but only on the back piece of fabric. This way the conductive thread can pass underneeth the other conductive petals without touching them. End your sewing by stitching the conductive thread 5-10 times to the appropriate tab.



REPEAT SIX TIMES 5

Repeat the instructions in step 3 and 4 for all six petals. Make sure that none of the conductive threads touches another.

After connecting all conductive petals to their respective tabs, it is time to connect the metal bead, which explained in the next step.

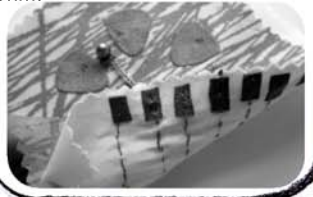


ADD METAL BEAD 6

This time start sewing from the conductive tab to the center of the square. In the center, sew through both pieces of fabric so that you are on the front side. String as many beads as necessairy, then add the metal bead last before sewing back through all the beads. Sew back through both layers of fabric and tie a knot in the thread.

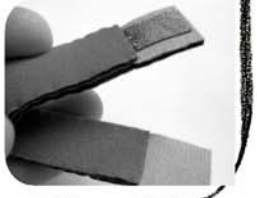
TEST FINISHED SENSOR 7

Connect one end of a multimeter set to measure continuity to the center bead connection of your sensor. In turn connect the other end of the multimeter to the other sensor contacts. When the metal bead touches the contact you are connected to, the multimeter should read close to zero Ohm.

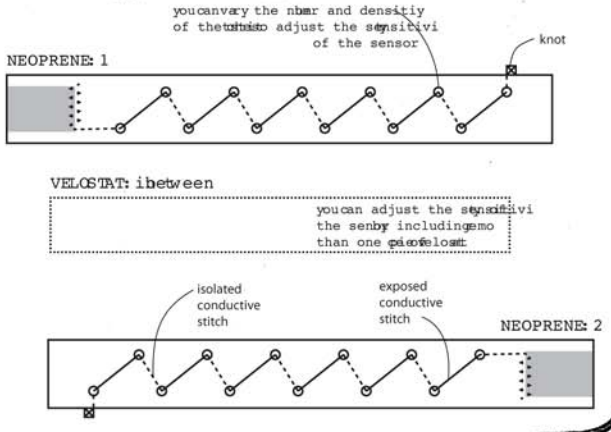


NEOPRENE
BEND SENSOR

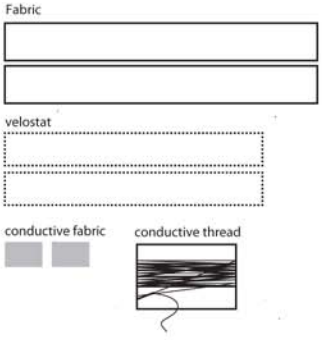
This sensor is constructed by layering conductive and piezoresistive materials. Velostat is a piezoresistive plastic film that reacts to stress with a decrease in resistance.



DIAGRAMS

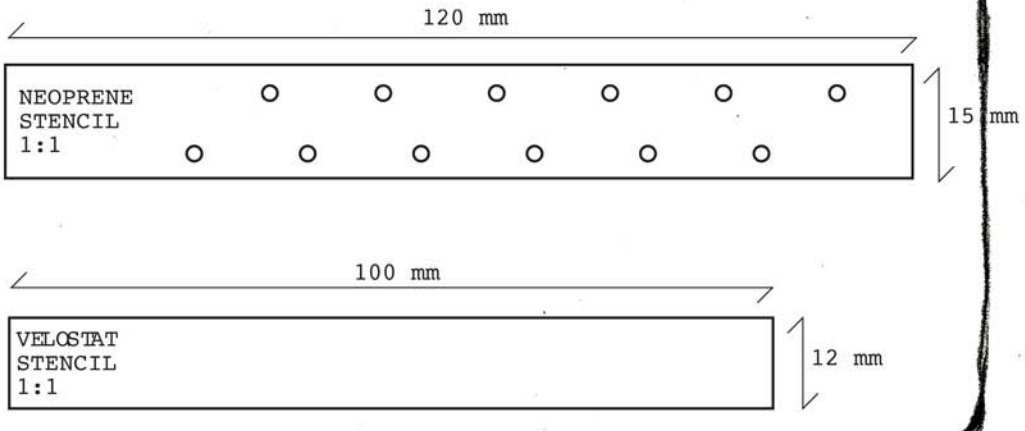


MATERIAL



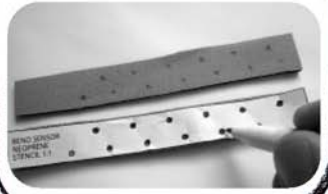
Scissors, an Iron, a sewing needle and some regular thread

STENCILS



TRACE AND CUT OUT THE STENCILS 1

Cut or trace the stencils from the other side of this instruction sheet and transfer them to the apropriate materials.
Mark the stitch-holes on both pieces of neoprene. Make sure the stencil always faces upwards, do not flip the sencil upsidedown.

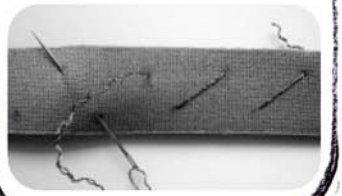


FUSE CONDUCTIVE FABRIC 2

Peel off the paper backing from the conductive fabric. Place the conductive fabric pieces, with the glue side (shiny side) facing the neoprene. Set you iron to a medium heat (too hot will burn the fabric) and iron over the conductive fabric to melt the glue and fuse the fabrics together.

SEW CONDUCTIVE THREAD 3

Thread the needle with conductive thread and tie a knot in one end. Stitch into the neoprene, exposing the thread in diagonal stitches as shown.



CONNECT THREAD TO FABRIC 4

Finish sewing the conductive thread with 5 to 10 tight stitches along the edge of the conductive fabric.
Cut the conductive thread close to the surface and repeat steps 3 and 4 with the second piece of neoprene.

LAYER THE MATERIALS 5

Layer one or two pieces of Velostat in between the two pieces of neoprene, with the conductive stitches facing each other. The conductive fabric tabs should be on opposite ends.
Make sure the conductive thread and the conductive fabric on either side never touch directly, only through the Velostat.

CLOSE THE SENSOR 6

Thread the needle with regular sewing thread. Holding the layered materials in place, stitch around the edges of the neoprene.
Do not sew through the Velostat, but surround it with stitches to keep it in place.

TEST FINISHED SENSOR 7

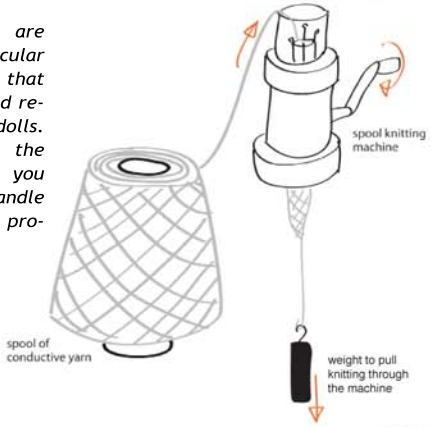
Connect the ends of your sensor to a multimeter set to measure resitance (Ohm).
As you bend or pressure the layers of the sensor together, the resistance should decrease. Depending on the construction of your sensor, the values should range from 2K - 200 Ohm.

KNIT
STRETCH SENSOR

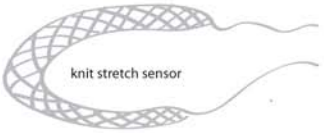
This stretch sensor is knit from a stainless steel and polyester yarn blend. The stainless steel strands in the yarn are short and compressing the fibers together increses the overall conductivity.

DIAGRAMS

Spool knitters are hand-crank circular knitting machines that have 4 needles and resemble knitting dolls. After threading the spool knitter you ***simply*** *turn the handle and the machine produces a knit tube.*



MATERIALS



Scissors, an Iron, a sewing needle and some regular thread

STENCILS

This sensor is knit from a stainless steel and polyester yarn blend. The stainless steel strands in the yarn are short and not continuous, so that stretching the yarn causes a decrease in electrical resistance as the individual conductive fibers make better contact among themselves.

Even without knitting the yarn into a structure you can use it as a stretch sensor by simply pulling it taught or relaxing it. Knitting the yarn into a narrow tube on a spool knitter makes the sensor stretchy and more robust. The knit structure also accumulates more yarn and thus more resistance in less length, giving you greater range.

THREAD THE MACHINE 1

Thread the resistive yarn into the knitting machine as shown in the photo.

ATTACH WEIGHT 2

Tie the end of the yarn to the hook on the weight. When you are knitting with the machine, always make sure the weight is pulling on the yarn at the other end. Otherwise the knit structure will not be pulled off the needles and will get caught up in the machine.

CATCH ON FIRST HOOK 3

Feed the yarn into the machine with one hand, and crank the handle with the other. Catch the yarn on one of the hooks.

SKIP HOOKS ON FIRST ROUND 4

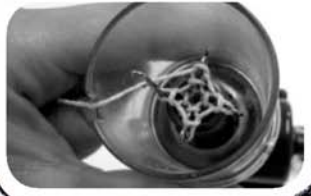
Skip the second hook and catch the yarn on the hook opposite the first hook that you caught it with. Again, skip the forth hook, and catch the yarn back on the first hook that you started on.

CATCH AGAIN ON FIRST NEEDLE 5

When catching the yarn on the first hook the second time around, make sure that the first yarn goes under the latch and the second yarn stays insidethe hook/latch. As the knitting machine turns it should be pulling the newer yarn through the loop from the previous round. Turn the machine slowly for the first few rounds to make sure.

KEEP KNITTING 6

Once you''ve completed the first few rounds, paying attention that the yarn is hooking correctly, you can crank the machine faster and pay less attention to the needles. Make sure the weight is pulling the knitt structure out the other end, and that the yarn feeds smoothly into the machine.



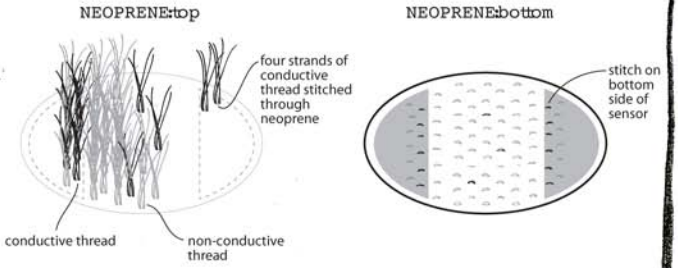
FINISHING OFF 7

When done, simply cut the yarn feeding into the machine and keep cranking. The knit structure will eventually fall out the back. Pick up the final four loops of the knitting with the loose end of yarn using a large sewing needle. As shown in photo.

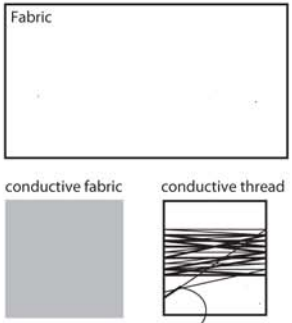
STITCHED
STROKE SENSOR

Using conductive thread and neoprene to stitch a fabric stroke switch. While tedious to make, the basic construction of this sensor has a wonderful effect.

DIAGRAMS

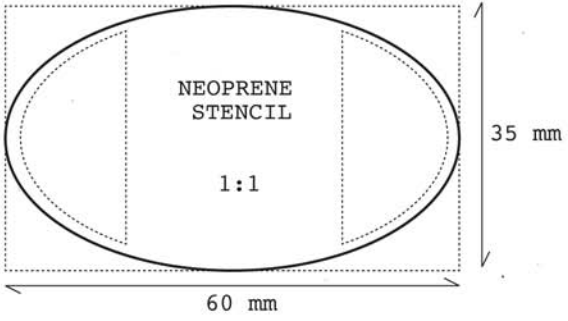


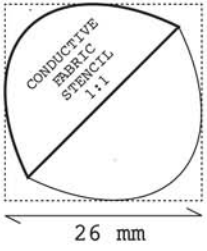
MATERIALS



Scissors, an Iron, a sewing needle and some regular thread

STENCILS





TRACE AND CUT OUT THE STENCILS 1

Cut or trace the stencils from the other side of this instruction sheet and transfer them to the apropriate materials.
Then cut out the shapes from the materials and peel away the paper backing from the conductive fabric.

FUSE CONDUCTIVE FABRIC 2

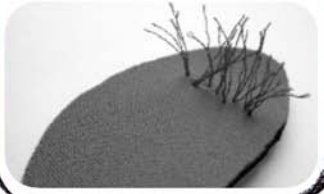
Place the conductive fabric pieces with the glue side (shiny side) facing the neoprene.
Set you iron to a medium heat (too hot will burn the fabric) and iron over the conductive fabric to melt the glue and fuse the fabrics together.

STITCH CONDUCTIVE THREAD 3

Thread the needle with conductive thread, feel free to take the thread double or quadruple.
Stitch into the neoprene from the top side (the side without conductive fabric), but don't pull the thread all the way through.

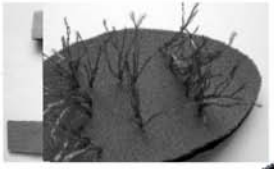
STITCH CONDUCTIVE FUR 4

After stitching cut the thread at desired fur length, roughly 2cm. Repeat 5 or 6 times. Each time the conductive thread should penetrate all the way through the neoprene and make contact with the conductive fabric fused to the reverse side.



STITCH MORE CONDUCTIVE FUR 5

Continue stitching conductive fur to both patches of conductive fabric and then add two or three stitches of fur to the center.
When you stroke over the fur, from one side to the other, the conductive threads from one side should touch the center ones, and these in turn should touch those on the other end.



ADD SOME NON-CONDUCTIVE FUR 6

Thread your needle as before, but this time with a non-conductive thread of similar weight. Any colour you like.
Proceed to stitch fur until the sensor is dense and the conductive fur contacts are isolated from one another, yet make contact when stroked.

TEST FINISHED SENSOR 7

Connect the ends of your sensor to a multimeter set to measure continuity.
As you stroke across the sensor the resistance should sink to near zero Ohm. Flickering is normal. When the sensor is not being stroked the multimeter should mesure no connection. Ruffling of fur may be necessairy at times.