The term “wearable” generally refers to clothing and accessories incorporating computer and advanced electronic technologies. The designs often incorporate practical functions and features as well as making a statement or establishing a technological look. In this article based on chapter 11 of Arduino in Action, the authors examine one of the two available platforms for creating wearable applications: the LilyPad.

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Introducing the LilyPad

The LilyPad Arduino was designed and developed by Leah Buechley in tandem with SparkFun Electronics. The LilyPad Arduino is a microcontroller board designed for wearables and e-textiles. It can be sewn into fabric and similarly mounted on power supplies, sensors, and actuators with conductive thread. There are two versions of the LilyPad you can choose from: one based on the ATmega168 and a higher-powered version based on the ATmega328. The differences between them are slight but substantial if you need higher power. The LilyPad Arduino is a circle, approximately 50 mm (2 in) in diameter. The LilyPad Arduino can be powered via the USB connection or with an external power supply. If an external power supply is used, it should provide between 2.7 and 5.5 volts. This can come either from an AC-to-DC adapter (wall-wart) or battery.
You can program the LilyPad by using SparkFun’s FTDI breakout board as shown above or you can use an encapsulated FTDI cable the green wire goes on the right and the black wire goes on the left. You can see a B and G in the wiring diagram below and it’s very important to keep the FTDI cable attached correctly or you run the risk of damaging the LilyPad.
As you can see, the LilyPad has 6 analog in pins, 14 digital in/out pins, and two pins to provide power and ground for the board. It also has a reset button and a 6-pin header to attach the programmer.

There are actually two versions of the LilyPad right now, the regular version outlined above and the simple, shown next. The LilyPad Simple has fewer input and output pins on it, but includes an on/off switch to make turning projects on and off easier. It’s also slightly less expensive than the regular versions.

**LilyPad accessories**

The LilyPad comes with lots of different kinds of accessories. Shown below are the Temperature Board and the VibeBoard, both of which are made by Sparkfun.
Powering your LilyPad project is a very important consideration. Since LilyPad projects are almost always worn or carried on the body, they don’t have an external power supply. Thinking about the power requirements of your application and how on you want to last, whether it can be turned on or off, how the power supply can be accessed to be changed are all important considerations that you should give careful thought to when planning.

Shown below are two easy ways of powering your LilyPad. On the left is the AAA Battery Holder that holds a single AAA battery and provides an easy interface to connect to the LilyPad. On the right is the LiPo Holder that allows you to connect a lithium Potassium battery that has a two pin adapter (most do these days, though you can also purchase them separately).

The length that either of these will power a LilyPad project depends on the application, what components you’re using, and how careful you are to avoid your circuits and connections leaking current. Conductive fabric and thread
can be a serious current drain if you’re not careful. What those are and how to use them correctly is explain in the
next part.

**Conductive thread and fabric**

Connecting your LilyPad to its circuits can be done using wires or a conductive thread. The advantage of a thread is
that it allows you to sew your components into the wearable itself, making a stronger bond with the fabric and the
surface of the garment. The disadvantage is that conductive thread had a much higher resistance than wire,
meaning that your signals will be weaker and precise communication like I2C or SPI can be affected. My general
approach is to use insulated wires when practical and in combination with conductive thread when practical.

![Conductive thread](image)

Figure 6 Conductive thread

<table>
<thead>
<tr>
<th>Name</th>
<th>Resistance</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ShieldEx sewing thread Size 33</td>
<td>40 ohms/meter</td>
<td>Has to be hand sewn</td>
</tr>
<tr>
<td>ShieldEx sewing thread Size 92</td>
<td>300 ohms/meter</td>
<td>Can be used in sewing machines</td>
</tr>
<tr>
<td>Conductive ribbon</td>
<td>0.3 ohm/meter</td>
<td>0.03 inches thick Can carry 3 signals</td>
</tr>
</tbody>
</table>

Conductive fabrics are a slightly different story than conductive threads, though the theory is the same: they
provide a medium for you to both attach to the fabric of your wearable and to connect components to. Extremely
flexible and nearly transparent circuits can be made using conductive fabrics. They can be painted or drawn on with
resist and then etched like a standard circuit board. Conductive glue or conductive thread is then used to attach
the components to the fabric circuit board. A few different types of fabric along with their resistivity, thickness and
a thoroughly unscientific assessment of their comfort level as a fabric is listed below:

<table>
<thead>
<tr>
<th>Name</th>
<th>Resistance</th>
<th>Thickness</th>
<th>Comfort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shieldex</td>
<td>0.3 ohms/sq</td>
<td>0.1 mm</td>
<td>Somewhat uncomfortable</td>
</tr>
<tr>
<td>MedTex 180</td>
<td>&lt; 1 ohm/sq</td>
<td>0.55 mm</td>
<td>Fairly comfortable to the skin</td>
</tr>
<tr>
<td>Nickel mesh</td>
<td>0.1 ohm/sq</td>
<td>0.08 mm</td>
<td>Uncomfortable</td>
</tr>
</tbody>
</table>

Depending on the fabric you can solder to fabric, though you need to be very careful when doing so. There are also
several types of conductive glues that are readily available if you don’t want to sew a component or a circuit or
component into place. These usually hover from around 300 ohms of resistance and can hold a few grams but
nothing extremely heavy or anything that will be stressed greatly. A quick search for wire glue or conductive
adhesive should help you locate something. This is good for actually attaching ends of components to conductive

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fabric or small mounting brackets, but it’s quite permanent so be sure about the placement and arrangement before breaking out the glue.

**Summary**

You’ve seen one of two different Arduino compatible boards that are small, lightweight, and easily powered by small batteries, all of which are important considerations when making a wearable. We covered the Arduino LilyPad, which is the larger board but built specifically for attaching conductive thread and has a large community of users who create wearables.
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  David Dossot and John D’Emic

Last updated: January 28, 2012