THE ELECTRIC TANK TOP
By Leah Buechley
USE SILVER-COATED THREAD AND A MICROPROCESSOR TO MAKE PROGRAMMABLE LED CLOTHING

I built this shirt to experiment with wearable computing and electronic technology, and realized along the way that the basic materials were actually quite easy to work with.

There’s lots of room for creativity at all levels, so I was inspired to write this do-it-yourself guide. Although challenging, everyone should play with this stuff! It’s great fun for both geeks and divas — build a sparkly fashion accessory and program it with hacker animations. Even better, make it a group project.

The code I wrote starts a “glider” (a figure in the Game of Life universe) that marches around your garment forever. Play with the code to get other life patterns. You’re guaranteed to turn heads whenever you’re out on the town.

Leah Buechley is a Ph.D. student in computer science and a member of the Craft Technology Group at the University of Colorado at Boulder, where she has found a place that she can unite all her interests. “I get to play with computers and sewing machines, electronics, fabrics, and beads. Heaven!”
[A] Silver-coated thread
members.shaw.ca/ubik/thread/crder.html

[B] Surface mount LEDs
100, or as many as you’d like. I
used a super-intensity red LED
(Digi-Key part #57-1653-1-ND).

[C] AVR ATmega16 micro-
controller Digi-Key part
#ATMEGA16L-8PC-ND

[D] IC socket for your
microcontroller Digi-Key
part #A9440-ND

[E] AVR programmer
Digi-Key part #ATSTK500-ND

[F] 9-15VDC power supply
For your STK500 programmer. Available at RadioShack.

[G] USB serial adapter and
included software This will
attach your programmer to
your computer.

[H] Battery and holder
I used a standard 6V camera
battery. For the holder, use
Digi-Key part #108KK-ND.

[I] On/off switch Digi-Key
part #401-1000-1-ND

[J] 30-watt or higher sol-
dering iron and lead-free
solder Remember: Keep it
lead-free!

[K] Multimeter

[L] T square or ruler

[M] Assortment of silver
and brass crimping beads
At least twice as many as you
have LEDs.

[N] Garment or a piece of
fabric and a pattern

[O] Sewing needle, fabric
marker, bottle of fabric glue

[P] Scissors

[Q] Sewing machine

[R] Insulating machine

For additional info
about materials
and equipment, visit
craftzine.com/01/led.
CREATE A BLINKING TANK TOP

Time: One Week  Complexity: Extreme

1. DESIGN YOUR PATTERN

1a. Decide on the number of LEDs you want and their general placement. I decided to sew a simple tank top, and I chose to place the LEDs evenly across my top every 2". Since my tank top is approximately 28" around and 12" tall, I needed 84 LEDs.

2. MAKE SEQUINS WITH YOUR LEDS AND BEADS

If you’re not up for soldering, you can substitute traditional through-hole LEDs for the surface mount LEDs, twisting their leads into spirals to make them stitchable. Read about this technique at craftzine.com/01/led.

2a. Get crimping beads and surface mount your LEDs. Using a soldering iron with a very clean tip, place the tip of the iron into a bead. Melt some solder onto the outside of the bead. With the soldering iron, drag the bead up to the LED as shown (middle right). When the melted solder touches the LED’s contact, the bead will adhere to the LED. Lift the soldering iron out of the bead.

Now take some measures to distinguish the cathode lead (-) from the anode lead (+) of each LED. The cathode end is often marked with a green line on the front or back of the surface mount package. To distinguish the two, solder a brass crimping bead to the cathode lead and a silver bead to the anode lead for each LED.

2b. Solder beads to the leads for your battery and switch, so that they can also be sewn on. This is the switch sequin.

TIP: If your soldering iron tip is dirty, it will stick to the bead and make the job very difficult. If this is happening, you should clean or replace your tip.
3. SEW YOUR LED PATTERN

3a. With a marking pen, mark the lines for your LED pattern on the garment. Also, mark where you want your microcontroller (IC socket) and power supply to be. You want a grid of conductive traces where the vertical traces do not touch the horizontal ones. A simple way to do this is to put one trace on one side of the fabric and the other trace on the flip side of the fabric, utilizing the fabric as a natural insulator. The lines for the vertical traces should be on one side of your garment, and the lines for the horizontal traces should be on the other.

I marked both sets of lines on both sides of my tank top to make sure my lines were well placed. Use a T square to get good right angles and straight lines.

3b. Make a bobbin of silver-coated thread for your sewing machine, and put it in the machine. Use a spool of ordinary thread for the top thread.

Using silver-coated thread in the bobbin of a sewing machine will allow you to sew conductive horizontal traces on one side of your garment and conductive vertical traces on the other side. As you sew, the bobbin thread will remain on the underside of the fabric you are sewing.

Q: So, if I want conducting vertical traces on the back, where should I draw my lines?
A: You should draw them on the opposite side, the front. The lines you draw will be facing up as you sew so that you can follow them. The conductive trace, from the bobbin thread, will be on the opposite side of the fabric.
3c. Sew 1 trial row-column crossing, and use the multimeter to make sure your threads are being sufficiently insulated by the fabric. If your fabric is too thin, the bobbin thread may be pulled through the fabric, and your crossing traces may short out (see related sidebar on page 62).

If there is contact at your intersections, you will need to take action to correct this. As you are sewing out the traces, you should stop the sewing machine just before each intersection, and, without breaking the threads, move your fabric past the intersection and resume sewing. This will insure that the silver-coated thread stays on the proper side of the fabric at each crossing.

3d. Sew out your vertical traces. Flip your garment over and sew out your horizontal traces.

You should stop your pattern stitches a few inches from the IC socket to leave room for the knots you will make when sewing the socket on by hand.

NOTE: Here are the top and bottom views of my partially assembled tank top after I sewed on my traces.
4. PREPARE AND SEW ON THE IC SOCKET

4a. Before you start sewing threads onto the IC socket, you should familiarize yourself with the pins of the microcontroller. Follow along on the pin layout diagram for the ATmega16 chip, shown below.

All the pins labeled PA0-PA7, PB0-PB7, PC0-PC7, and PD0-PD7 are general-purpose input/output pins that can be used to power LEDs and the like. See my sample code and header files at craftzine.com/01/led to see how to reference and control individual pins with your code. You can download AVR microcontroller datasheets from craftzine.com/go/avr8.

4b. Use the following diagram as a guide to tell you which thread goes to which socket. (If you've chosen a different number of rows or columns, you'll assign them to the PA-PD pins somewhat differently.)
“I added an infrared receiver to it and my friend wrote a program for his PalmPilot that lets people beam patterns to it.”
4c. Trim the pins off the bottom of the socket and pull off any tape or other material blocking the holes. If necessary, drill out the holes so that a needle can pass through them. Position the socket where you want it on your garment and stitch it in place with silver-coated thread, sewing traces from each microcontroller socket to the pattern traces you sewed.

You want to make sure that the silver-coated thread makes contact with each socket hole, but also be careful that no two threads cross. This is a delicate job that requires some patience, but if you're used to doing soldering or any other meticulous work, it should be no problem.

4d. Make sure that you tie your knots where there is ample room for them (away from the socket) and where they're less likely to cause shorts with neighboring traces. Coat each knot with fabric glue. This will keep knots from fraying and coming untied.

Q: What is a short?
A: A short or "short circuit" occurs when the positive terminal of a power supply is connected directly to the negative terminal of a power supply. On your shirt, if 2 neighboring traces are touching while one of them is high (positive) and the other is low (negative), a short circuit is created. This kind of short circuit will prevent your LEDs from lighting up and is likely to cause your microcontroller to overheat and eventually die. Short circuits in more high-powered applications can cause fires and explosions.
5. SEW ON YOUR LEDS

5a. Attach the cathode end of each LED to a row, and the anode end of each LED to a column (or vice versa). If you did not take steps during the soldering phase to differentiate the cathode from anode leads, you will have to make the distinction now.

The cathode end of the LED is often marked with a green line on the front or back of the surface mount package. If you are able to find this marking despite your soldering, you can use it. Otherwise, learn to distinguish the direction from the appearance of the face of the LED. Test one by running a current through it for reference. Be careful to use a voltage and current appropriate for your LED.

5b. While sewing, take care to make good connections between your thread and each bead, looping the thread through each bead several times, as shown here.

The fastest way to sew is to stitch each row and column continuously, not stopping to tie off the thread for each LED. In other words, sew in the cathode end of one LED, and sew down your row to the next LED cathode without cutting your thread. However, this makes replacing badly sewn or broken LEDs harder, since you’ll have to cut the continuous thread and tie the ends off in the event of a problem.

Alternatively, you can sew each LED on individually. This will make repairs easier, but your sewing will take much longer. I chose the first option for faster sewing, but I did have to replace a few LEDs.

Q: Can I do anything to make sure my LEDs won’t break off?
A: Before you sew any of the LEDs, abuse them a little to test your solder joints: twist and tug on the beads. The weaker joints will break and you’ll be left with the sturdy LEDs. I tried this method on the second shirt I made and not one of my LEDs has broken since I sewed it, and they’ve even withstood a few washings.
6. TEST YOUR CIRCUIT

6a. Using a multimeter, make sure none of your traces are shorting out with one another, and all of them are leading to the appropriate LED rows and columns. Silver-coated thread tends to fray and give off small "hairs."

Make sure there are no miniscule conducting hairs interfering with any of your traces.

6b. You may also want to make sure your LED pattern is working properly by attaching the leads of your power supply to the rows and columns of your pattern in turn.

Look at the specifications that came with your LEDs if you’re not sure what power supply to use or you may try all of your LEDs!

My multimeter (in beep mode) doubles as a low-current power supply, illuminating an LED when its leads are attached to the right threads.

6c. Once you’ve done some thorough testing, glue an insulating backing onto the traces you sewed for your IC socket, so that your power supply will be easy to attach and these traces will remain in place without fraying with wear.
7. ATTACH POWER SUPPLY AND SWITCH

7a. Sew the switch and power supply to the garment.

7b. Glue an insulating backing over your power supply and switch traces so that you will not accidentally turn on your display.

Here is the inside view of my tank top after I sewed on the power supply. Notice the insulating backing that was applied prior to sewing.

You're done! Now program your microcontroller (see craftzine.com/01/led for coding examples) and you'll be the light of the party.

FINISH X

MORE RESOURCES

This shirt is a big attention-getter. People want to touch it and scrunch it up and examine it up close. Everyone wants to know how to wash it (carefully and by hand!) and whether it will work in the rain (alas, no). I've gotten all sorts of business advice, from the cynical, "They'll be making those in China for $5 a piece," to the exuberant, "You're going to make millions!"

It's been especially fun to wear since I added an infrared receiver to it and my friend wrote a program for his PalmPilot that lets people beam patterns to it. People have a blast with this, though I imagine it can be potentially risky to relinquish control over what you're wearing!

For tips on troubleshooting and customizing your garment, options for a simpler project, and how to make an electronic sewing kit, visit craftzine.com/01/led.

Now go out and wear it!