PRIMER

ELECTRO-LUMINESCENT (EL) WIRE

It's easy to work with flexible strands of light.

By Louis M. Brill and Steve Boverie

An electric field can excite phosphorescent materials to glow; that's the principle of electroluminescence. Since the mid-1970s, this cool form of illumination has back-lit flat panels for gauges and small displays, and in the 1990s a company called Elam found a way to create the same glow from bendable, shapeable wire.

Electroluminescent wire, aka EL wire or lightwire, soon became a favorite medium for creative electronics projects that light up at night. The wire's flexibility and length let you draw and animate on a grand scale. Its durability withstands harsh treatment and environments. It stays cool and draws far less power than neon or rope lights or even LEDs. And its otherworldly color can lend its creations an almost hallucinatory look.

This article describes how lightwire works and how you can bend it to your will. »

Photograph by Sam Murphy

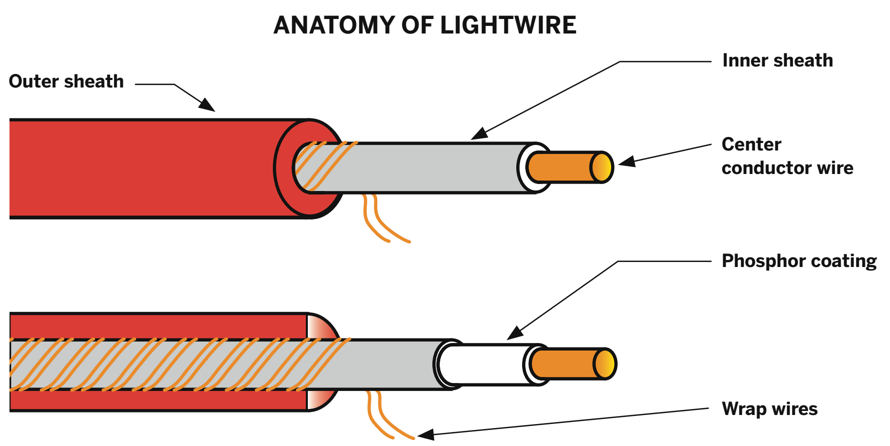
ANATOMY OF LIGHTWIRE

Lightwire consists of a **copper conductor** or **core wire** coated with a layer of electroluminescent **phosphor** material and wrapped with a coil or mesh of fine **outer** or **wrap wires** that's thin enough to let light through (Figure A). When you connect high-voltage, high-frequency AC power between the core and outer wires, the phosphor layer in between glows.

Covering this coaxial sandwich are one or two **vinyl sheaths** that protect the outer wires and filter the light to create different colors.

Lightwire comes in diameters ranging from superfine 0.9mm to 5mm, and also in non-round cross sections such as D-type for application to flat surfaces or T-type for stitching onto textiles.

Other flavors include outdoor wire with UV protection, marine wire with greater water resistance, twin-core wire, high-brightness wire, and Lumiflex, an industrial-strength lightwire cable for robust, professional applications.



A

COLORS, VOLTAGES, AND FREQUENCIES

Lightwire now comes in 11 colors, including green, blue, aqua, white, yellow, pink, red, lime green, orange, and purple. Originally, all colors used the same aqua-glowing phosphor material inside, but white wire now uses a pinkish phosphor and an aqua coating, which comes out as a brighter white.

You typically run lightwire at 100V–120V AC, with a frequency between 400Hz–2,000Hz. Increasing the frequency changes the aqua phospor's glow color from green to blue, with a brightness peak at around 2,000Hz (cyan). Running lightwire at 3,000Hz will even turn it purple, although the glow is dim. At peak frequency, increasing the voltage will make the wire glow brighter, but also shorten its lifespan; lightwire slowly fades with use.

Lightwire is shaped like other wires, but you don't connect each end and run current through it. Instead, the two connections are made to the center conductor wire and the outer wrap wire at the same end.

The far end of the lightwire is left unconnected. In component terms, a lightwire connects and behaves like a capacitor, with its capacitance proportional to its length.

Illustrations by Gerry Arrington

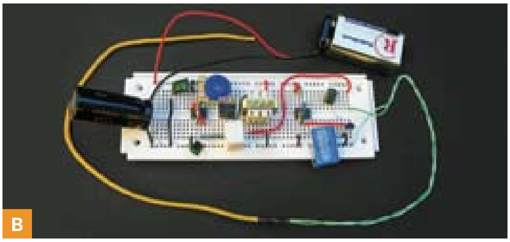
DRIVERS AND SEQUENCERS

Most lightwire projects run on battery power, which lets you take them out at night. To convert the battery's DC to high-voltage (but low-amperage) AC, you need a **driver**. A mini industry of inexpensive lightwire driver boxes has emerged, and these are what most people use; the boxes are small, cheap, and easy.

There's currently a range of drivers, each designed to illuminate specific lengths of lightwire, from just 1' on up to 330' of a single strand, or several separate strands that total 330'. If the length to be illuminated exceeds the limit of a driver, a more powerful driver must be used.

You can also build your own driver to fine-tune the AC, giving you more control over the lightwire's appearance. Figure B shows a simple lightwire driver and strobe circuit based on two 555 dual-timer chips (or one 556), a TIP120 Darlington transistor, and a small transformer. This circuit will power about 10' of wire. The left side of the circuit, the driver, has a potentiometer knob that sets the AC frequency, which changes the wire's brightness and color.

The right side is a simple strobe that switches the wire on and off. As with other 555 flashers, connecting a pot to Pin 7 of the chip or a trim cap to Pin 2 will let you adjust the blink rate. For a schematic and a components list, visit makezine.com/21/primer.


B

By lighting up multiple strands of lightwire in sequences or other patterns, you can create animations and other visual effects. You can also buy mini **sequencers** for lightwire that act like switchboards, taking the driver output and routing it to multiple channels in a series of patterns, like the way some Christmas tree light controllers operate.

Fancier boxes, such as the CAT-09 sequencer used in the Annie's Blinking Eye project on the next page, have a driver built in and do tricks like letting you program and switch between multiple patterns.

For ultimate control, you can program a **microcontroller** to switch lightwires on and off, using **triacs**. The triac, a component that's like a transistor or relay for AC, switches the AC between each microcontroller output pin and the lightwire strand it controls; the triac's gate pin connects to the microcontroller, and its other 2 pins connect the lightwire to voltage or ground.

LIGHTWIRE VS. LEDS

In lighting design for costumes, signage, theater sets, or other projects, one of the first questions to answer is whether to use lightwire or light-emitting diodes (LEDs). The decision is mainly a matter of aesthetics and what reads best design-wise. Here's a comparison.

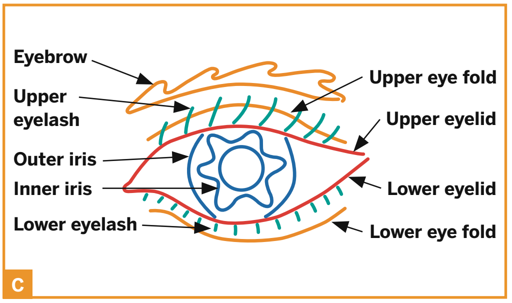
	Lightwire	LEDs
Pluses	Creates smooth, clear contours; off-the-shelf drivers and sequencers run many effects (strobes, blinks, sequences); flexible to apply, and easy to remove	Less complicated to achieve fading, blinking color, and color-mixing effects; less expensive, lower energy consumption, more illumination per area; can project light over a distance (with a lens)
Minuses	Does not color blend; fades over time; if you cut the wire too short, you have to start over	Tedious to attach multitudes (100s) of LEDs into a single circuit; control circuitry needs to be custom built

Photography by Paul Spinrad

LIGHTWIRE ANIMATION PROJECT

ANNIE'S BLINKING EYE

Here's a project that illustrates the steps and considerations for using lightwire to create a successful animated image: in this case, a large, blinking eye.



C

1. Make a full-sized drawing.

First, sketch out the object you want to animate. We've seen running horses, jumping kangaroos, flying saucers, and leaping dolphins. The best designs can be understood from just a few contours.

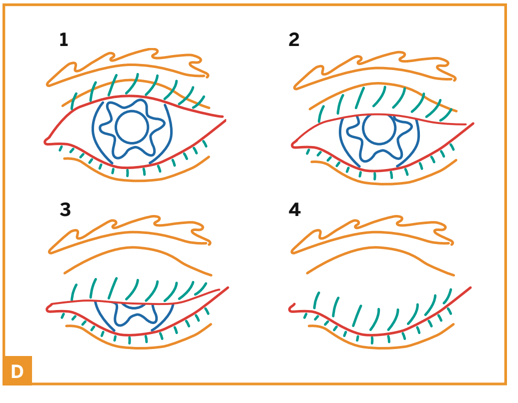
Once you've refined your idea, draw it at full size on one or more sheets of paper. You need to figure out which elements are always on — the common frame — and which will be animation frames.

In our case, the common frame included the eyebrow, the folds above and below the eye, and the eye's bottom edge and eyelashes. The animation consisted of 4 frames (Figure D) that showed the eyelid and lashes, iris, and pupil in various stages of open- and closed-ness. To distinguish the various parts and make the animation easier to view, we decided to use yellow for the eyebrow and folds, green for the lashes, pink for the eyelid, and blue for the iris and pupil.

We made a full-sized master drawing of the fully opened eye (the common frame plus frame 1) and then 3 more drawings for frames 2–4. To make the movement of the upper lashes appear smoother, we drew them on a separate piece of tracing paper and simply translated them downward for frames 2–4 without foreshortening the lashes' length. This allows successive lash segments to overlap from frame to frame, which helps the viewer follow them and see them as the same thing. The animated movement reads better this way, even though real lashes don't stay upright.

MATERIALS AND TOOLS

- **2.5mm lightwire, "High Brightness Standard" in yellow, pink, blue, and green, 6' lengths of each** $1.40/ft from Light 'N Wire (lightnwire.com)
- **Standard driver (cube driver) for lightwire** Light 'N Wire part #CB-SD01, $8
- **10-channel sequencer for lightwire** Light 'N Wire #SQ-XC01, $75
- **Heat-shrink tubing, various diameters**
- **Foamcore board, 2'×3'×¼" thick**
- **Copper tape** available at stained glass supply stores
- **Steel wire, 28 gauge, uninsulated**
- **Network cable, 8-conductor, 24-gauge twisted pair wire, 3' long**
- **Snap connector leads, lightwire side (5)** Light 'N Wire #SNR-LSC02, $1 each (1 included with each lightwire order)
- **Small zip ties**
- **Duct tape**
- **12V DC battery holder, 8×AA "brick"** Light 'N Wire #PS-BB01, $2
- **AA batteries (8)**
- **9V battery snap**
- **Colored pencils and paper**
- **Scissors**
- **Wire cutter/stripper**
- **Heat gun**
- **X-Acto knife**
- **Needlenose pliers**
- **"Helping hand" mini workstand**
- **Alligator clips (2)**
- **Paper or masking tape** for labeling wires
- **Palm drill and small bits**
- **Lightwire stripper (optional)** Light 'N Wire part #AC-WS01, $5
- **Soldering iron and solder**



D

2. Transfer the drawing to the mounting medium.

You can attach lightwire to almost anything. We mounted our eye to a sheet of foamcore board. To transfer the drawings, we taped them onto the board, then followed along each line with a stylus, making an indentation by pushing down into the board. Then we filled in the indented lines with different colored pencils for each frame.

3. Measure and cut the lightwire.

For each eye image segment, hold the corresponding color of lightwire along its line to measure out the proper length, then cut it to size, adding about 6" of extra length. Label each segment with tape to identify it, for example, "eyelash/frame 1." Group the cut segments together by frame: common or 1–4.

For elements like the eyelashes, which are laced in and out of the board, follow the wire's path back and forth with a piece of string, holding it along the way with bits of masking tape. Then measure the lightwire against the string and cut it to length plus 6".

NOTE: Lightwire can't be folded or bent too tightly. For corners, use separate segments or thread a single segment out the back, loop it, and bring it back to the front at a new angle through an adjacent hole. To black out short sections, cover the wire with tape or heat-shrink.

4. Attach the leads.

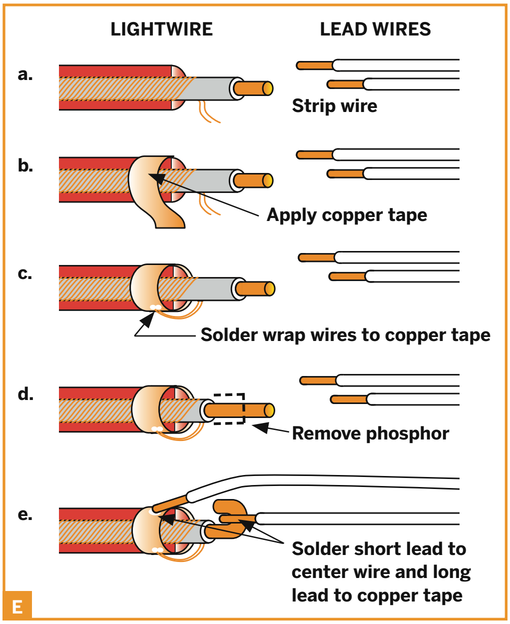
Before mounting, each segment needs to be connected to its 2 lead wires (Figure E). Our leads came from cutting open a network cable, which contains matched pairs of wires in 4 colors. This is helpful for color-coding our 4 animation frames. (Five colors would be even better, to include the common frame.) Here's how to connect each segment to its leads:

» Strip off about ¾" of the lightwire's outer vinyl sheath(s) at one end.

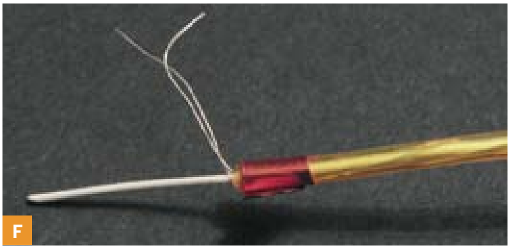
» Tease away the tiny wrap wires, then stick a cuff of copper tape around the sheath, right behind where you began stripping (Figure F).

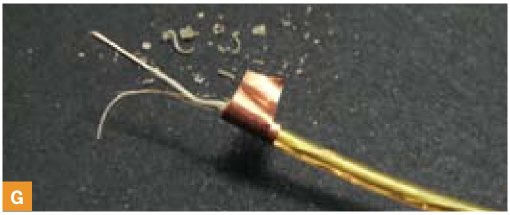
» Bend the wrap wires back over the copper tape and solder them to the copper tape.

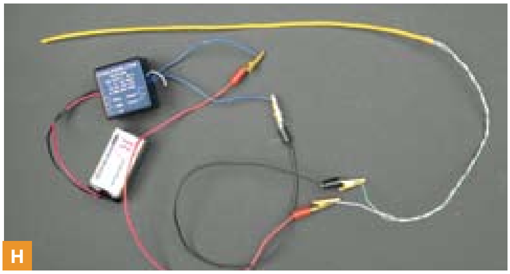
» Scrape off the phosphor layer to completely expose about ⅜" of the tip of the core conductor wire (Figure G).



E

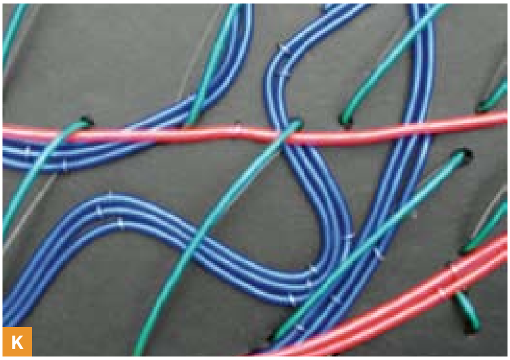

F

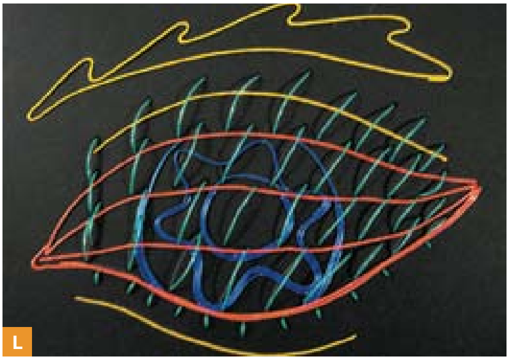

G


H


I


J


K


L

» Cut and strip 2 leads about 12" long. Solder one to the bare core conductor and the other to the copper tape. Use the proper color leads to designate the frame (but stripe vs. solid can go either way).
» Test the segment by connecting it to a working driver (Figure H, previous page). If it lights up, cover the joint with a piece of heat-shrink tubing.

5. Mount the segments, frame by frame.

Starting with the common frame, attach all the segments for each frame to the front of the board, following the drawing and running the leads out the back. To minimize the spaghetti in back, pick one side of the board to carry the leads, and drill pilot holes on that side where each segment starts.

To hold the segments down and guide them around curves, we made "staples" out of 28-gauge steel wire. Drill pilot holes where you want the staples to sit, run each end of the staple through the holes, then fit the staple snugly around the lightwire and fold its ends flat on the backside using needle-nose pliers (Figures I and J).

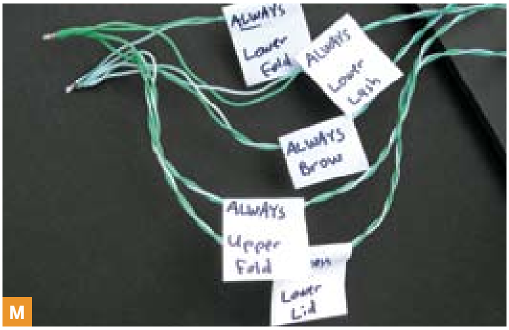
The blinking eyelid covers different amounts of the blue iris and pupil, so frames A–C all include iris and pupil segments, even though these elements don't move. Where the frames' segments represent the same lines in the original drawing, we mounted them side by side so they wouldn't block each other (Figure K).

After mounting all the segments for each frame (Figure L), bundle the leads together in back and label them for final connection later.

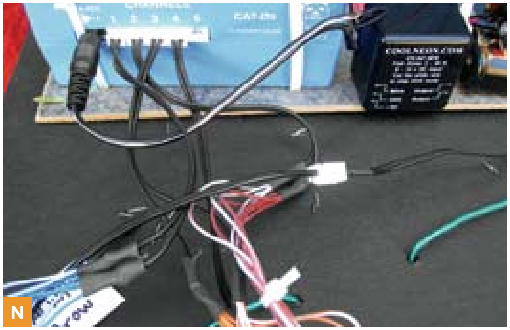
6. Connect the frames to the driver and sequencer.

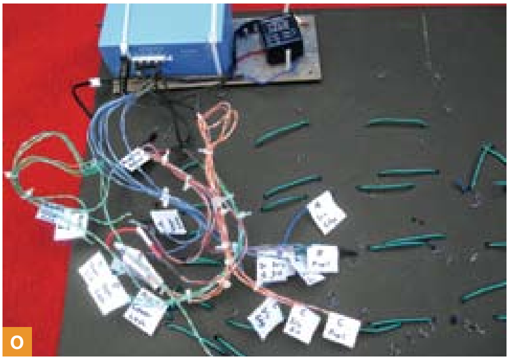
The 10-channel sequencer can switch from frame 1 to frame 4, but it doesn't include an always-on output, so we connect the common frame leads to a different box, a cube driver.

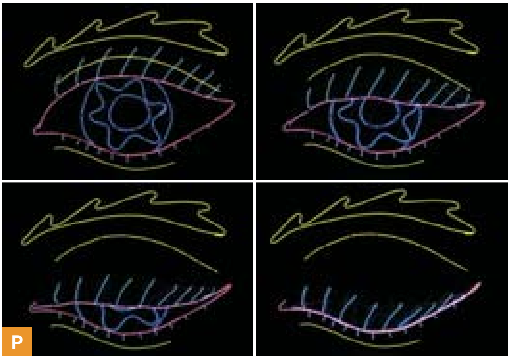
Test each lightwire strand again by alligator-clipping its leads to a driver. Although we tested them before, the soldered connections can break when the strands are mounted, and it's easier to identify and repair individual elements before they're connected together.



M


N


O


P

For the wires in each frame, bundle all of their leads together and separate the solid and striped wire pairs. Twist the solid leads and the striped leads together into 2 pigtail connections for each frame (Figure M), then solder the 2 masses to a snap connector. You should wind up with 5 snap connector plugs, each of which connects in parallel across all the segments in a single frame and plugs into the sequencer or cube driver (Figure N).

7. Final assembly.

The sequencer and driver both run off the same 12V battery brick. Each has a battery snap that plugs into the brick's 9V-style terminals, so you need to solder an additional 9V battery snap to connect it to both boxes. Then mount the brick, sequencer, and driver together on the back of the board near the lead bundles. We just stuck them on with cardboard, metal fasteners, and zip ties, and then neatened up the wires in back with more zip ties (Figure O).

Finally, plug the frame 1 connector into the sequencer's channel 1 port, frame 2 to channel 2, 3 to 3, and 4 to 4. Plug the common frame connector into the cube driver. Choose the sequencer pattern that makes sense for the project; in this case, "1-2-3-4-3-2-1" gives the illusion of the eye opening and closing (Figure P). You're done!

RESOURCES

- **Animated image of Annie's Blinking Eye:** makezine.com/go/blink
- » **Elam EL Industries** LyTec lightwire manufacturer's site, with product datasheets: elam.co.il
- » **Instructables** How to add EL wire to a coat or other garment: makezine.com/go/elwirecoat
- » **ePlaya** Burning Man Community Discussion Board: eplaya.burningman.com
- » **Light 'N Wire Productions** for lightwire, drivers, sequencers, and more: lightnwire.com

Louis M. Brill ("Louie Lights") and Steve Boverie ("Dr. Glowire") are co-founders of Light 'N Wire Productions, (lightnwire.com), an art-technology resource center dedicated to EL wire. They teach classes on EL wire at The Crucible in Oakland, Calif., and via touring "Tupperwire" seminars.