



EYE SHOOTOUT: Contrasting Open Source and Big Retail Electronics

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<https://learn.adafruit.com/eye-shootout-contrasting-open-source-and-big-retail-electronics>

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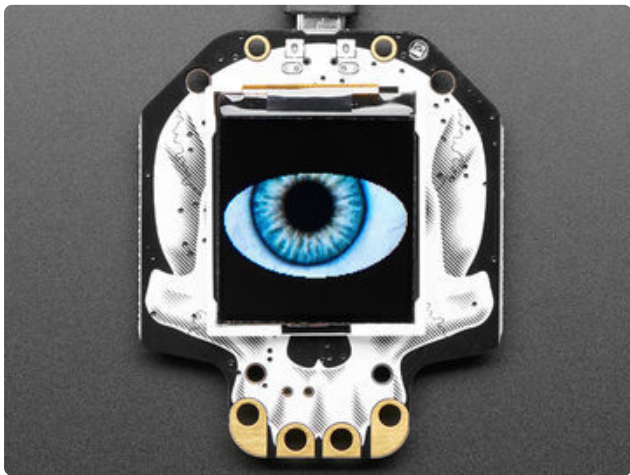
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Overview



It's a fact: **eyes are spooky**, a Halloween staple. If eyes are windows to the soul, then fake eyes are windows to the [Uncanny Valley](https://adafru.it/waA) (<https://adafru.it/waA>).



There's been a recurring theme of **graphical blinking eyes** in Adafruit projects. It's practically a [Halloween tradition](https://adafru.it/doO) (<https://adafru.it/doO>) each year, revisiting and evolving (<https://adafru.it/Ha4>) an earlier [eyes project](https://adafru.it/CwH) (<https://adafru.it/CwH>) into something more realistic (<https://adafru.it/zrC>) or more easily customized (<https://adafru.it/GfQ>). It became the whole focus of two subscription boxes: **Adabox 009: HALLOWING** (<http://adafru.it/3900>) and **Adabox 013: MONSTER M4SK** (<http://adafru.it/4343>).

We were tickled then to finally see this style of eyes appearing in **big-box-store Halloween items** in 2020. It makes perfect sense...electronic eyes are more reactive than the mechanical equivalent, and can benefit from automated assembly and ever-cheaper components.



First to bat are some large yard animatronics sold by Home Depot, where they've trademarked the feature as "LifeEyes™." It was obvious from the product photos and videos that someone involved in the design was at least aware of our work: the **skeleton's eyes borrow some graphics** — the pattern of veins is an exact match, and I know the original graphics didn't come from a third source...I took photos of a friend's eyes myself. I was curious to see if the similarities ended there, or whether they also adopted some our code, and how something like this gets streamlined for mass manufacturing. Ordered the **werewolf** to experiment on...it's both cheaper and fits in the house better than the skeleton...and I've been on a werewolf bender lately.



...Also learned that Costco has a similarly-priced offering in the shape of a **dragon!**

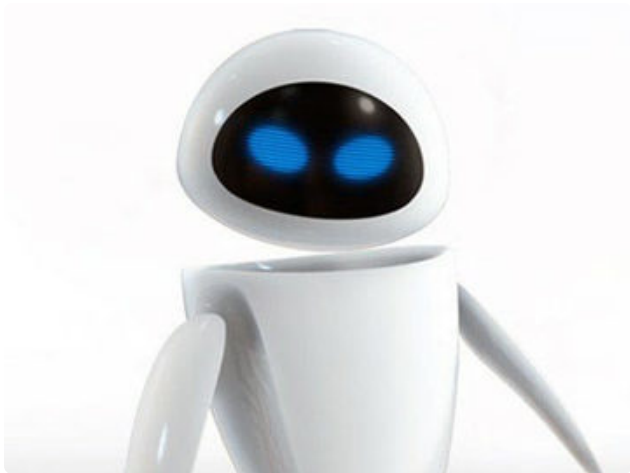
Photo credit: Costco.

But wait...can they do that? Aren't you angry / going to sue? They took your idea!

Yes they can do that, and no, not at all!



First, **it's not even an original idea...** intellectual property rules might even call it an "obvious invention," bound to come up when you have eye-sized displays. **AIBO** and **Furby** have used LCD eyes for some years now. Ours evolved from an earlier project with **LED matrices**, itself a well-trodden sci-fi trope.



Second, **Adafruit is an open source company.** Whenever possible, we use **very permissive open source licenses**, allowing code and related materials to be **used in others' designs**, even commercial ones, within some sensible rules. Quite a few projects have openly built on our work, it's generally allowed and we don't discourage it.



As an engineering education company, we make great kits and offer parts. We don't sell ready-made Halloween decorations, fun as they are, in the same way that, say, Apple doesn't make toaster ovens: it would only be a distraction from our core focus, it's not "lost profits." So we're cool that someone else does, and happy if our stuff helps. **A candle is not diminished by giving another candle light.**

So let's **get inside** and see **how it's made** and **how it works...**

Teardown



Photo credit: Home Depot

This is not a full review of the werewolf prop. You'll find plenty of customer reviews on these products' web pages. But overall, as store-bought (not DIY) yard haunt items go, it's an impressive amount of monster for the price. Though I did make a few small changes...

- Not a fan of the mangy-looking fur, I gave it all a good brushing out. I'm spoiled by luxurious Fabio-esque Van Helsing werewolves.
- Added a tail...actually something I had around from [a prior Adafruit project! \(https://adafru.it/tfQ\)](https://adafru.it/tfQ)
- He's awfully thin and I do plan to plump it up a little, with scraps of upholstery foam, or kitchen garbage bags stuffed with foam packing peanuts...anything lightweight, so the motors won't struggle...and can pack away after Halloween.

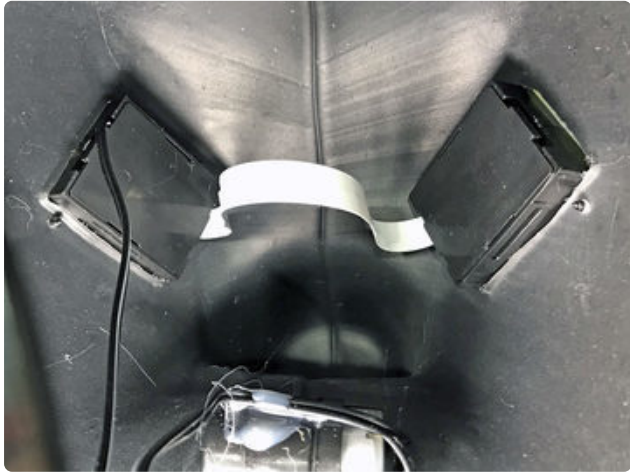


The included **power supply** was a bit **weak**, and the motion trigger electronics would **lock up** whenever the head-oscillating motor kicked in.

Rather than try to explain to tech support, I just ordered a beefier 6V 3A 5.5x2.1mm tip-positive power supply on Amazon for about \$7. Werewolf runs fine now.

If you plan to do your own experiments on these products' eye electronics, do not use the main power supply directly! Use a **multimeter** to check the voltage and polarity at the plug leading to the eyes. On the werewolf I probed, this was 5V, tip negative. Yours might be different.

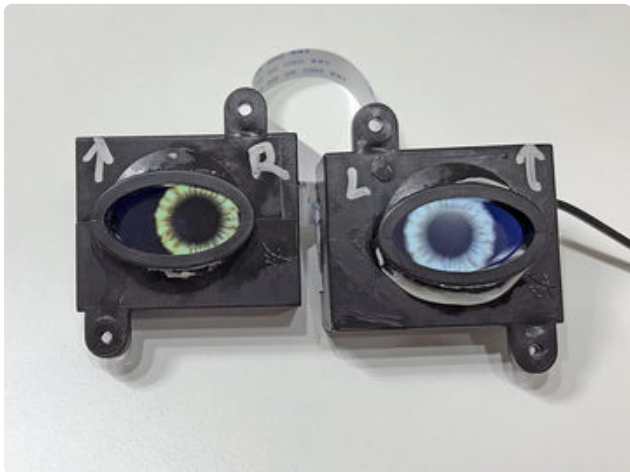
Getting Inside...



Looking up the werewolf's neck into its skull, we can see the eye electronics are self-contained in **two small boxes** joined by a flat flex cable. Mounting screws are inserted from the outside, so it seemed necessary to **peel back the fur and rubber skin** to remove these. Some glue was **cut** around the perimeter of the eyes, where the skin meets these boxes.

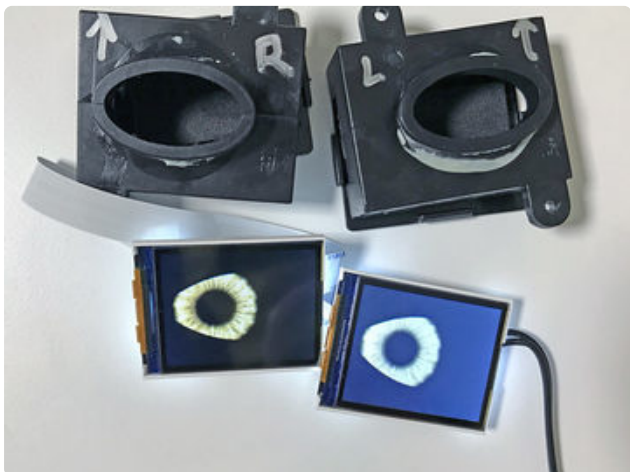


Peeling back the fur also reveals the maker's mark...[Seasonal Visions International \(https://adafru.it/MHF\)](https://adafru.it/MHF), who design pretty much all the big animatronic items at Spirit Halloween and other large retailers.



Eyes removed from the skull, then popped free of their housings.

As it turned out, the the enclosures are **snap-fit**, so it is possible to access the electronics **without all the above disassembly**...just remove them from the back, keeping the skull and skin intact.



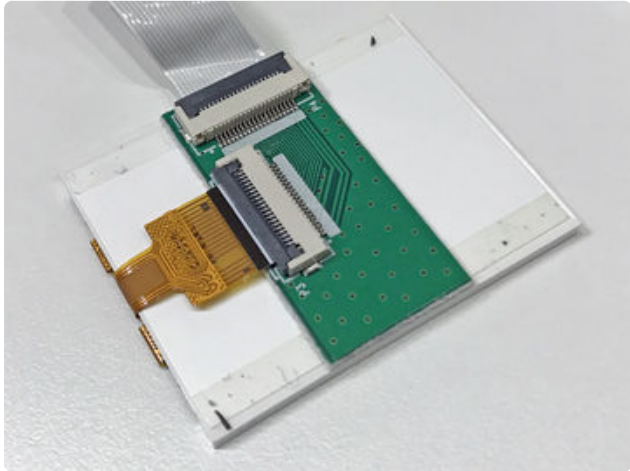
The eyes are both yellow in person...it's normal with low-cost TFT screens that the colors shift a bit when viewed off-angle, as is happening here.

The silver Sharpie marks are my own notes, so I can reassemble this later.

Identifying Components...

Let's see if we can figure out what's inside, and what it might cost. Most of these are very rough ballpark guesstimates. And remember that the bill of materials (BOM) cost is just a small fraction of the expense in bringing a retail item to market...engineering,

manufacturing, distribution and just keeping a business running all play a role. Focusing on the parts here though, as that can tell us something about how it functions...



First there's two 1.8" **160x128** pixel TFT color displays...a nice boost from the 128x128 pixels of our earlier eye projects. Possibly ST7735, or something similar...not too important, most small displays function very similarly.



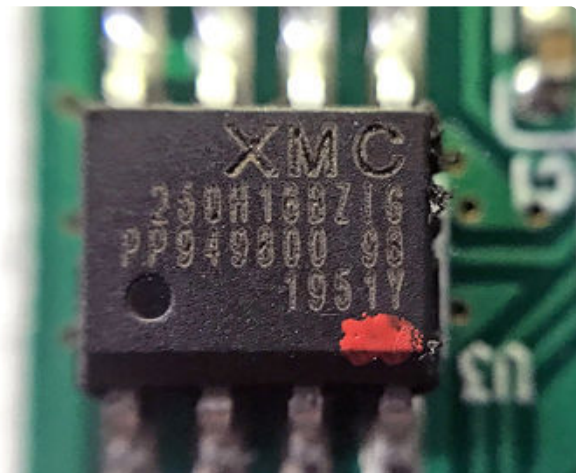
Around \$1-2 each in large wholesale quantities...probably the most expensive component of the eye electronics.

One display just has a passive adapter PCB with some connectors, while the other contains all the smarts...



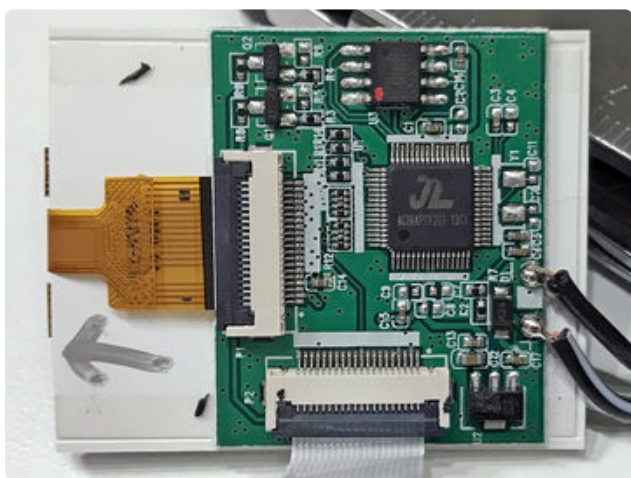
The microcontroller was the hardest part to characterize. An **AC19AP1Y201-13C1**, which I eventually traced to [ZhuHai JieLi](https://adafru.it/Mla) "Jerry" Technology (<https://adafru.it/Mla>).

Couldn't find more info as it's not shown in their current lineup...but considering their most recent offerings with Bluetooth or WiFi support are around \$1, and if the eyes work the way I think, this is probably a barebones 32-bit MCU at a fraction of that cost.



At least I could find a datasheet for the external flash, an XMC [XM25QH16BZ16](https://adafru.it/Mlb) (<https://adafru.it/Mlb>) — **16 megabits** (2 megabytes) with single/dual/quad SPI interface. Couldn't find a price, but a similar chip from Winbond is about 30 cents.

More interesting here is the **red dot**. This is a strong hint that all these “LifeEyes” creatures — the werewolf, skeleton and dragon — are using **identical hardware**, and each just has a different preprogrammed flash chip with that creature's graphics. Red dot = werewolf. Maybe it corresponds to the **red flannel shirt** that **all werewolves** are **required to wear**.



Remainder of the PCB is connectors and passives. Looks like power regulation at the bottom right, and TFT backlight driving at the top left. A few unpopulated pads that probably weren't needed in the final design.

I was hoping there might be a couple secret jumper pads to unlock other features (like on the Tiny Arcade retro games), but no such luck here. It has one job.

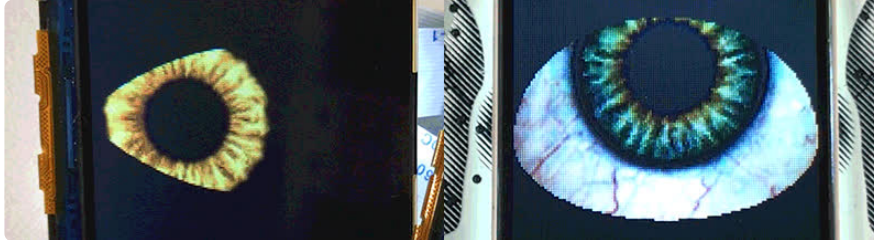
So we might estimate the total eye electronics BOM being roughly in the **\$5** ballpark, probably less, which seems sensible...it's just one small feature of the overall animatronic...competing with motors, a steel frame, growling sounds and molded parts.

At that cost, expect we'll see blinky eyes incorporated in more modest Halloween decor in the future. Start with the big \$200-300 animatronics, but it won't be surprising when it appears in sub-\$50 decorations and even masks...consider that the aforementioned Tiny Arcade units retail for around \$20.

Having **identified the major pieces** now, we'll take an **oscilloscope** to it, **make some observations** and try to **guess how it works...**

Analysis

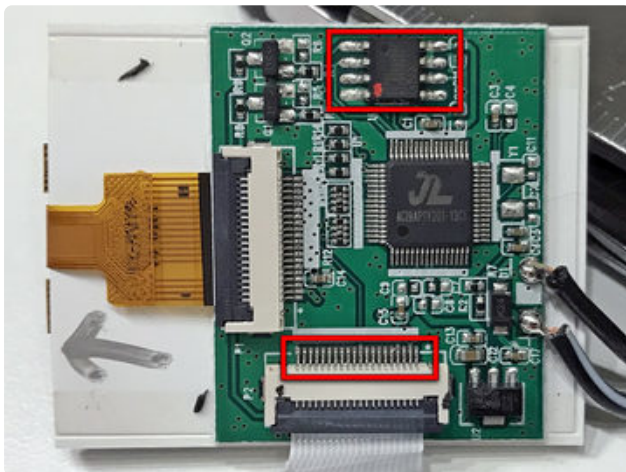
It only takes a few seconds' observation to recognize that **it's not our eye code...**



Spotting the difference is **nothing to do with shapes or colors...**that's all configurable in the HalloWing eye code. Rather, it's **the way the iris scales** (or doesn't) as the pupil dilates...on the left, it's a diffuse circle pasted over the iris...on the right, we'd put painstaking effort into getting the whole iris to morph.

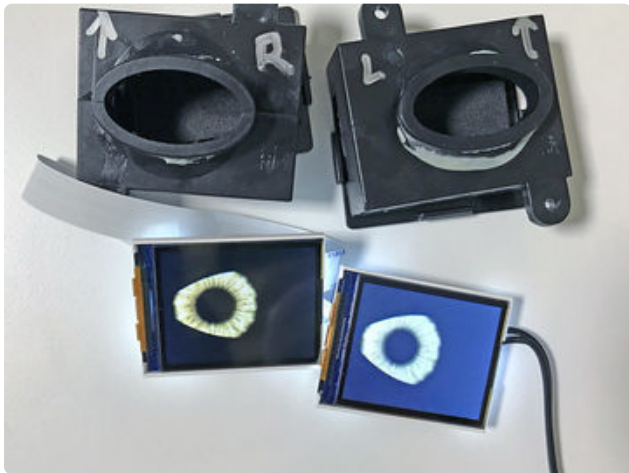
But that's okay! While it would be neat to see our code out in the wild, I'll explain in a moment why we're each making smart moves in the long run for our intended audiences.

Probing Questions



Using an **oscilloscope** to listen in on some signals was sufficient for a theory of how it works. This focused on one of the display connectors, and the flash chip.

Also, just looking at the screens as it worked...



For example, it's easy to spot that the **exact same image** is being shown on **both displays**. The signals are simply **split** and sent to **both** connectors.

In our two-eyed projects, each is controlled separately, there are distinct left/right eyes...they have a particular shape, and they “fixate” — slightly crossed, as eyes normally do in reality, to focus on nearby subjects.

Here they've cleverly approximated fixation by making the plastic housings distinct for left and right, creating a physical **stencil** of the larger eye image.

Didn't think to take screen shots from the 'scope, but descriptions should suffice...

The **TFT displays** are receiving data over an **8-bit parallel** connection. It's **unclear** whether this was for **cost** (some displays might be cheaper with parallel vs a high-speed SPI interface), or that a wider-but-slower connection might have better **immunity to interference** from nearby motors, or if the microcontroller couldn't drive SPI at sufficient **speed**.

The clock signal for this connection is running at **2.5 MHz**.

$2.5\text{M} \times 8 \text{ bits} = \mathbf{20 \text{ megabits}}$ aggregate throughput.

Two signals, most likely chip select and data latch, could be seen blipping around **60 Hz** — a likely screen refresh rate.

One screenful of data...160 x 128 pixels, most likely 16 bits/pixel...is **327,680 bits**.

$327,680 \times 60 \text{ Hz} = \mathbf{19,660,800 \text{ bits/second}}$... or about **20 megabits** again, the math checks out. They can pump **full frames** to the displays at this rate, no messing with “dirty rectangle” techniques.

Turning attention to the **flash chip**...

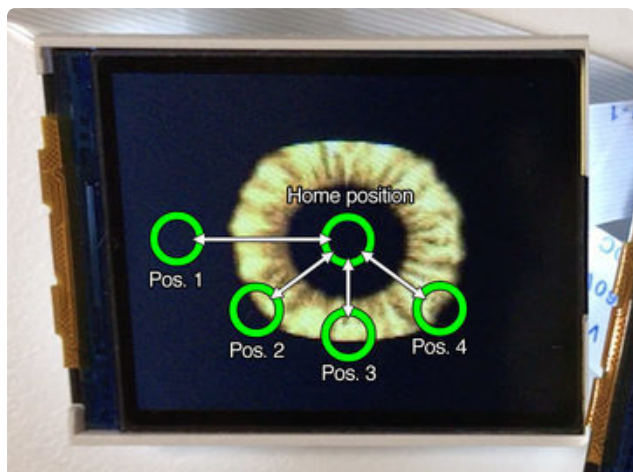
On our [MONSTER M4SK eyes](http://adafru.it/4343) (<http://adafru.it/4343>), the flash storage is **only accessed on startup** to load some graphics into RAM, then everything else happens internally on the microcontroller, using lots of math. It was odd to see **constant access** to the flash on the werewolf eyes...

The clock signal to flash was found to be running at **10 MHz**. Data could be seen on two channels — **dual SPI**.

10M x 2 bits = **20 megabits**. Same as the screen, exactly 1:1.

And that's all the info we need. Case closed.

There is no “eye code” here! It's a video player. Its whole job is to move frames from flash storage to screen.



It becomes even more apparent as you watch it run. You can't fit many frames in 2 megabytes, but they make good use of them. The eye only moves between five positions, always returning to the “home position” between moves. Never blinks or dilates when in motion, only at those locations. And the blinks and dilations are always symmetrical — the frames going into a motion match the frames coming out of a motion, just in reverse. The pattern repeats after about 15 seconds.

So, at this point, if we wanted to take it to the next level, we could desolder or blue-wire to the flash chip, extract its contents (datasheet and app note can be found through the link on the prior page), decipher how the data is laid out and **replace the graphics**. Reject their reality and substitute our own.



In practice though...while that would be a **neat hack**, and I'm sure someone will do it...very few readers will have the tools and methods to **follow along at home**, so I ended the exploration there.

It would be significantly easier (and also better looking) to simply swap out the eyes for a **MONSTER M4SK** (<http://adafru.it/4343>) board, which can then be customized with your own graphics over USB. We're **done** (<https://adafru.it/MJE>) this **exact thing** (<https://adafru.it/FNw>) in **several other guides** (<https://adafru.it/MJF>), so it's easy to follow along!



It's pretty clever though. My only disappointment is that the **eyes look so basic**. With pre-rendered frames and no realtime computational bottleneck, the eyes could have looked phenomenal, all smooth and antialiased and richly detailed, had someone just put in the work.

The manufacturer, Seasonal Visions International, has a U.S. office in Emeryville, California, a stone's throw from Pixar. I mean literally...step out front, throw a stone, hit Pixar. You'd think they could bribe someone with a case of craft beer or something.

Conclusion

Our eye projects are over-engineered because **that's our bag**. Our friends are cosplayers and coders and puppeteers, an audience that demands these details, that the eyes are asymmetrical and respond to inputs and light and never twice move or blink quite the same...they're "alive." Customizable, reprogrammable, or set them up for completely unrelated tasks, all through USB. We made something **perfect for our needs**.

A Halloween yard animatronic has **different goals**: scare the crap out of kids! This doesn't require finesse, and few if any will notice it's running in a loop.

More importantly though, had they programmed a chip to render the eyes procedurally — and the code was there for the taking — that's all it would do. Eyes. What they made instead — a super economical video looper — could be adapted to many other mass-produced products, most outside the Halloween realm...toys, plush, greeting cards...**never touching the microcontroller again**, just substituting a different preprogrammed flash chip (and leaving out the second screen in some applications). The engineering costs could be spread for years among a dozen product lines, instead of just one. It's stuck in a never-changing loop, but that works fine for the intended use. They made something **perfect for their needs**.



I see some parallels with last year's Speak & Spell reboot. While this could've used the original's exact voice — the [code's out there to emulate it \(https://adafru.it/MKa\)](https://adafru.it/MKa) — instead there's just a large flash chip of newly-recorded spoken audio samples.

It's disappointing from a technology purist's perspective...but on the flip side, they had to balance being a nostalgia product while simultaneously a modern educational product where people expect affordability and higher voice quality now. Engineering is expensive. Not much of a technical hack, but a good dollars-and-cents hack. **Both are valid.**

So if you'll excuse me, I need to hack this Speak & Spell into this werewolf now...

UPDATE: Digi-Eyes Mask

Well that was quick. On the werewolf [Teardown \(https://adafru.it/10Am\)](https://adafru.it/10Am) page, I predicted this tech would eventually find its way into inexpensive decor and masks. But just two years to trickle down to sub-\$20 items is a bit of surprise!

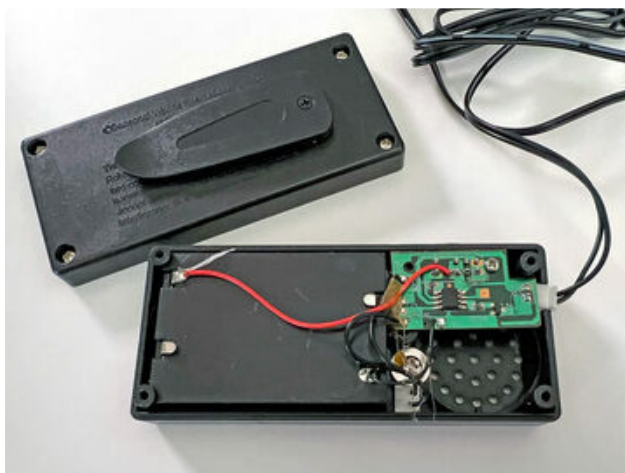


This **Digi-Eyes Mask** (Party City, Walmart, etc.) retails for \$16.97 + tax, and that's including a set of AAA batteries that are already flat and leaking.

Like the famous Home Depot Giant Skeleton, this plastic skull mask has my roommate's eyes staring back at me, so we already know there's some technological DNA in common with the prior products.

Also like the big LifeEyes™ props, the mask's eyes follow a repeating, fixed path and the pupil dilation is simplistic. One difference here is that the mask **never blinks** (pity... even if they didn't want to animate this, simply toggling the backlight can make for a passable blink). Though...one could easily argue it's just that skeletons have no eyelids.

I already have some theories what's going on, but let's peek inside...



A quick look inside the **battery box** first, because I was intrigued by the speaker grille. **Does this make noise? It does not.** Most likely, a generic box is being used across many products. The tooling for molds is astoundingly expensive, so it makes sense to use the **same box everywhere**, whether or not a particular item includes a speaker. Cheaper by the dozen million.



A small PCB holds the power switch, connectors and an unmarked 8-pin IC: almost certainly a 555 timer for the "Try me!" feature.



Three screws join the mask and “eye box,” which incorporates forehead support and the bridge of the nose.

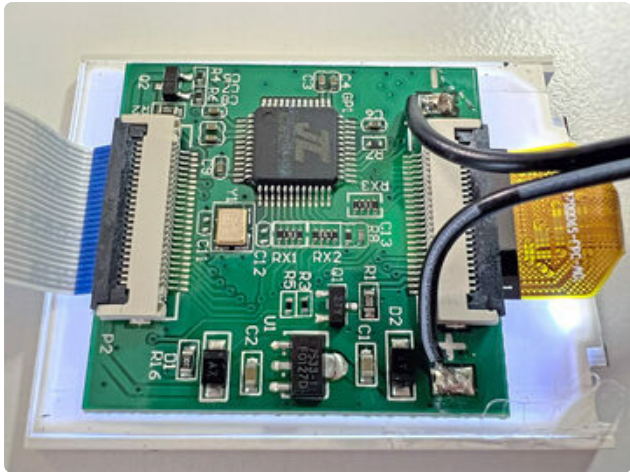


Easily moved to another mask or prop if desired, or pop into Jack o’ lantern...if that’s not already a product from the same company.



Familiar guts inside the eye box, at first glance appears identical the werewolf: driver board, ribbon cable and two budget low-contrast color LCDs. The screens are rectangular (160x128 pixels), but “stenciled” through round cutouts in the enclosure.





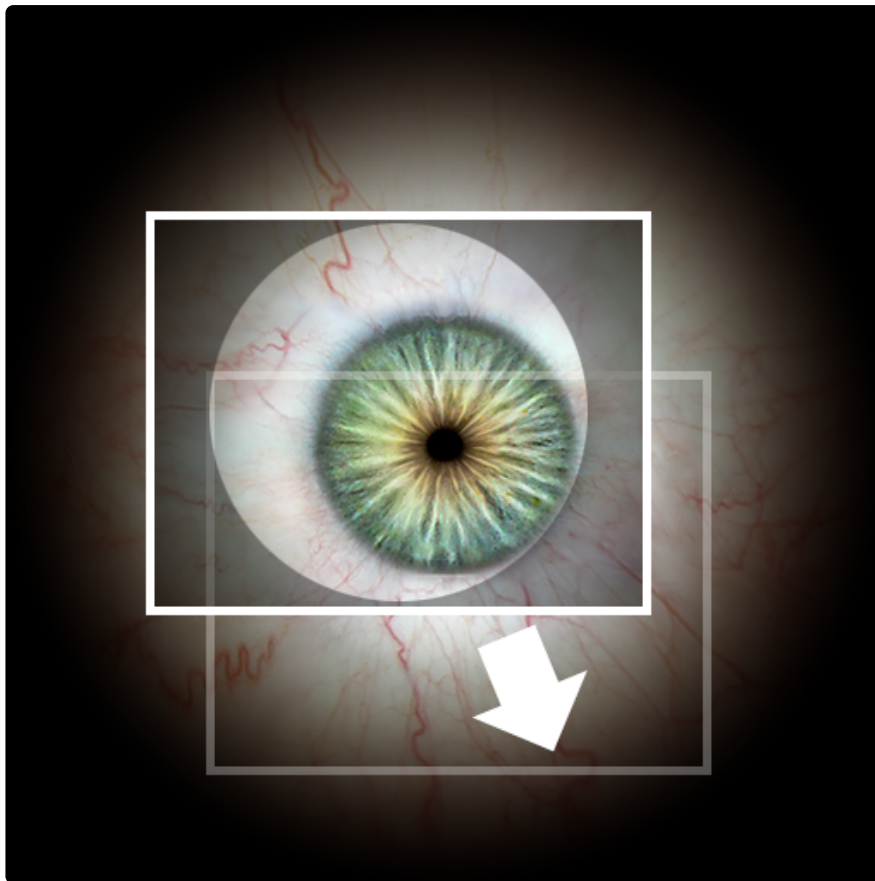
MCU信息

- RISC / 160MHz / 20K+8K
- flash / 2Mbit
- UART * 2 / IIC / SPI * 2
- 10bit ADC
- 16bit dac
- SD IO
- IR
- PWM * 4
- 16bit timer * 3

This board too uses a mysterious “Jerry (<https://adafru.it/10An>)” microcontroller. But it’s not identical. You’ll notice there’s **no flash chip** this time, knocking about 30 cents off the bill of materials. On the LifeEyes™ props, the whole eye animation cycle was pre-rendered in that flash chip. Without the chip, what’s up?

I couldn’t locate this exact JLT chip in the current lineup, but from other products there we might infer a reasonable amount of program flash space, perhaps 256K. Not enough for a whole animation as with the Winbond flash chip, but sufficient for a **single large image** alongside the code.

Thus...between the limited flash and the observed path of the eye animation, we can infer that this new “budget eyes” board is simply doing a **pan-and-scan** around a larger image, and relying on the round cutout to provide a stencil.



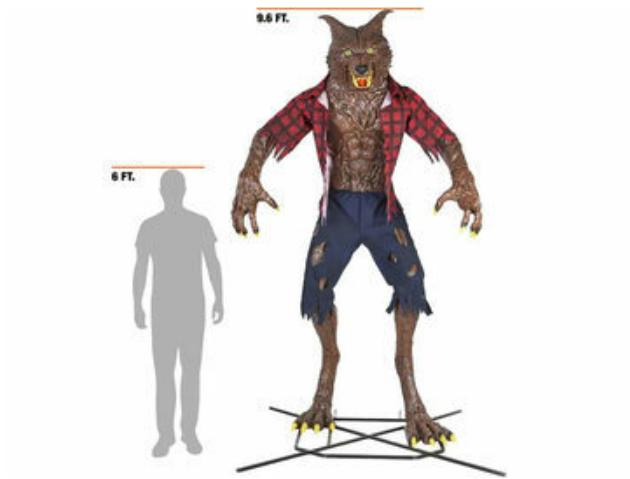
This is quite similar to what we're doing in the classic [HaloWing M0 Eye](https://adafruit.it/CEs) (<https://adafruit.it/CEs>) and [Spirit Board](https://adafruit.it/CBi) (<https://adafruit.it/CBi>) projects. The screen and microcontroller are a bit different, but it's the same pan-and-scan principle. Only significant change is that these projects perform the stencil effect in code rather than with plastic. That's also why HaloWing can blink, but the skull mask will win every staring contest.



The back of the PCB has “DP” and “DM” pads that might work for USB flashing or debugging...but without publicly-available chip documentation or toolchain, there's unfortunately **zero hacking potential** here other than repurposing the whole eye box inside something else. It's just one step away from an “epoxy blob” circuit. Not that they owe us those things, but it's always neat when it does happen.

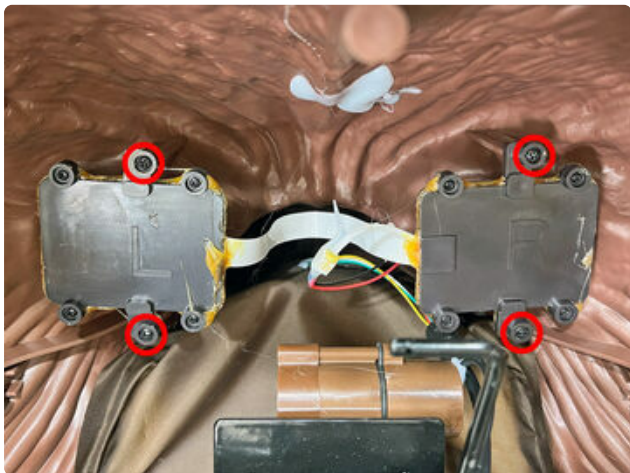
UPDATE: Giant Werewolf

One more time! This is likely the last, and won't go into any great detail, as **all the giant creatures are clearly using variations on the same approach**. But let's take a look inside...



Home Depot stepped up their werewolf game this year with a much larger **9.6 foot** model...sort of a cross between their prior 7 foot guy and the famous 12 foot giant skeleton. Of course it still has the red flannel as required.

Image credit: Home Depot



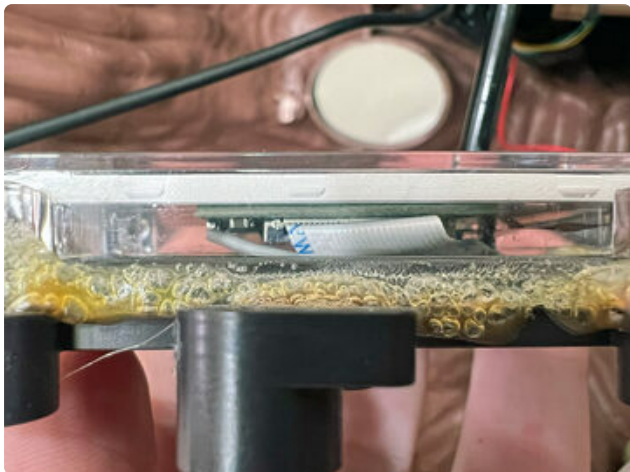
Eye modules (conveniently labeled left and right) come out easily with two screws each.

And with the eye cutouts in the werewolf's head, we can see the "stencil effect" is in full force. As we'll see later, when the eyes are open they don't even have to draw eyelids.

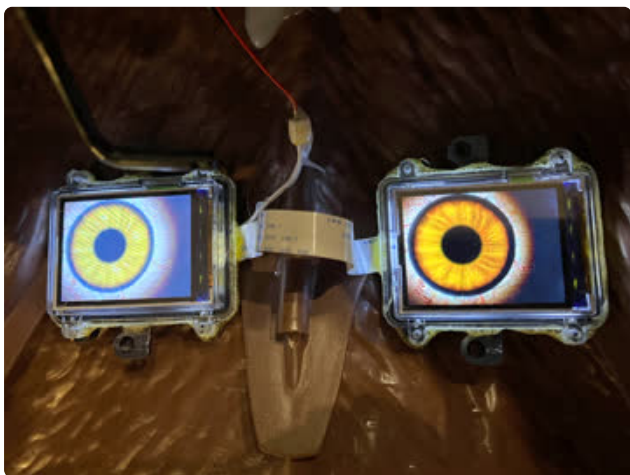




From the front, we can see the bitty 160x128 screens of the smaller props are upgraded here to common **320x240** displays...forgot to measure while they were out, but probably 2.4 or 2.8 inches.



Since these big props go out in the yard and not under a porch covering, the electronics are **fully enclosed and sealed** with what looks like polyurethane glue. Decided not to compromise the seal for further teardown...we can tell well enough from the animation and from this edge glimpse of the electronics that all the **same principles are in use**, just more pixels.



The animation leans on techniques from the earlier props...the motion is all “on rails,” with blinks and movements following a set path and returning to a home position.

When fully open, eyelids aren’t drawn, relying instead on the plastic outer shell to provide a stencil. So there’s probably not even run length encoding being used to save flash space, just full raw frames as with the earlier props.

The larger, higher resolution screens are a nice step up, it’s just unfortunate they still haven’t improved the graphics. Since it’s just whole frames being dumped, there’s no technical reason for a lack of nicely-rendered photorealistic eyes, it’s just a matter of putting in the time and effort.

The extensive waterproofing here would be difficult to replicate with a MONSTER M4SK or Pi eyes. Re-flashing with new graphics would be super technical. This one's probably **best left unhacked** with the original peepers!