random scratches, but I've proceeded to where there are recognizably denser and lighter regions. The key to improvement has been in reducing the workload on the Linux box to make it more responsive, and I'm creating a stripped-down system that doesn't run any unneeded software.

Although—or perhaps because—the laser mouse is so simple to build, it made me think about how inept modern desktops and laptops are when dealing with the outside world. I had to use an entire microcontroller just to get on and off signals to the laser driver, because there's no clean way for an ordinary mortal to tell a personal computer, "Please put 5 volts on this outside-accessible pin." And I had to carefully configure my Linux setup to allow my program access to the raw messages from the mouse. Normally programs are allowed to access the onscreen position of the mouse only within their own windows, which typically measure no more than 1800 by 1000 pixels. Because I track information from the mouse with my own code, the number of pixels in the image is limited only by the constraints of the available memory and the language, which in my case could mean an image as large as 25 000 by 20 000 pixels. (How big an actual engraving this translates to depends on a scale factor that determines how much the mouse can move and stay within the boundaries of a single pixel. In my system, this can be as small as 0.25 millimeters per pixel and as large as desired, within practical limits.)

On the positive side, one of the things I like about this project is that it is endlessly tweakable: In a single weekend you can have a basic version running with an Arduino and a prototyping board, or you can try being more ambitious by adding orientation sensing for higher accuracy, a custom mouse enclosure, hacks to draw all your laser power from your USB ports, and so forth (I've already swapped in a higher-power blue laser, for example). On the software side, you can go from simple positional lookup to complex interpolation, or even graphing code that controls the laser with no reference to a preexisting picture. (Of course, you could also burn or blind yourself, or burn down your house or apartment. If you're not sure what you're doing with a laser, don't do it.)

When I "finish" this project in a few years, I imagine that the ultimate laser mouse will look very different. The microcontroller will detect the mouse's position directly from the onboard electronics and read an attached SD card for the values of the image array. It will boast a couple of lithium batteries for power and accept additional special parameters via Bluetooth. Then all I'll have to do is build a mobile robot to wield it.

—Paul Wallich

tools & toys

Oldies But Goodies

When yesterday's gadgets are better than today's

SEVENTIES SOUND: This Pioneer SX-838 receiver, manufactured circa 1975, can output 50 watts per stereo channel. *PHOTO: TIM WHYTE*

Tech enthusiasts live in the grip of reverse nostalgia, forever pining for 18 months hence. After all, another way to state Moore's Law is "They don't make them like they're going to." But there are some electronic devices that were once made better or cooler. And there's a bustling retro-electronics subculture busy cataloging, chronicling, and collecting these old-school gems.

At the top of the stack is a world of 1970s-vintage high-end audio that Tim Whyte, based in Carmichael, Calif., caters to on his website, Classicaudio.com. To feel the difference from modern audio systems, he says, "all you've got to do is pick one of these things up. They're actually made out of wood, metal, glass. These things were a year's worth of mortgage payments back in the day."

During the golden age for audio equipment—the 1970s—emerging brands like Marantz, Nakamichi, Pioneer, and Sansui vied for the American leisure market with systems that were wildly overengineered. Whyte attributes this excess partly to tight standards imposed by the U.S. Federal Trade Commission on advertising claims about the watts-per-channel ratings for hi-fi amplifiers.

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CLASSIC LOOKS: A 1974 Marantz receiver [above left] is more robust than similarly priced modern receivers. For those who prefer film to digital, this Bell & Howell movie camera [above] will accept Super 8 film, while a real historical oddity [left] is the Fisher-Price PXL-2000, which recorded images captured by a CCD onto audio cassette tapes.

Amplifiers "had to do one-third of the rated power for 30 minutes and not blow up, which is considered a ridiculously hard test by today's standards," says Whyte, who has been working full-time since 2007 refurbishing and selling classic stereo components. "As a result, these things were built like tanks."

Today's home stereo components with four-figure price tags will likely outperform these veterans, but Whyte argues that in the range of US $400 to $600, refurbished 1970s amplifiers and preamplifiers sound as good as or better than any new equipment. And the classic components, built for a lifetime of use, can be expected to outlive their 21st-century equivalents. They're also often more easily repaired. Owners looking to replace a vacuum tube, for example, will find a flourishing market for tubes, often still in their original packaging, from companies like VacuumTubes.net and Vacuum Tubes Inc.

Outside of stereos, retro electronics is more catch-as-catch-can. There are no magic decades, for instance, of film cameras or televisions that put present-day video technology to shame. But there are individual product lines and quirky one-offs that can make the hunt back in time worthwhile. And there is no better chronicler of vintage tech on the Internet than the blog Retro Thing.

The site's two editors, Bohus Blahut and James Grahame, each has his own favorite categories and gadgets. Grahame notes that vintage Super 8 film cameras and Soviet-era still cameras are coming into their own for their value as purely mechanical, clockwork-wonder gizmos. Specialty websites like USSRPhoto.com and SovietCams.com detail the camera models to seek and the ones to avoid. Old Super 8 cameras are more widely available on sites like eBay. Although getting film developed is not as easy as it used to be, once again the Internet provides: Grahame recommends online film developing houses such as Dwane's Photo, in Kansas, and Spectra Film and Video, in California.

Blahut, a Chicago-based filmmaker and TV producer, enjoys early electronic video technology. He says he spent years hunting for the Fisher-Price PXL-2000 (PixelVision), a 1987 toy camcorder that recorded wildly wonky and distorted images to audio tapes. (Though he could have paid a premium and bought a PixelVision on eBay at any time, Blahut says he much prefers shopping for vintage tech in its native habitat—thrift stores and garage sales.) There are a surprising number of active PixelVision users, and there have even been PixelVision film festivals in recent years—

CLOCKWISE FROM TOP LEFT: TIM WHYTE; SSPL/GETTY IMAGES (2)

GAME ON: The *Gauntlet* arcade game's cabinet allowed four people to play simultaneously. *PHOTO: BRYAN KUNTZ/NYCDREAMIN ARCHIVES*

you can view some entries online at the blog PXL This.

"There are a lot of benefits to the retro lifestyle," Blahut says. "If you're into video games, you could go into any thrift store and buy [a PlayStation 2 console] for $10. And you can get as many games as you want for a buck. You just have to get over the cachet of having the latest and greatest thing."

For those who want to go even further back in time, plenty of early arcade games in their original cabinets are available on eBay and sites like the Vintage Arcade Superstore. Although it's possible, with emulators such as the Multiple Arcade Machine Emulator, or MAME, to run the actual code of classic titles like *Asteroids* and *Space Invaders* on modern personal computers, the original software was designed hand in hand with the cabinets and controllers. (The truly ambitious can travel down the path trod by *IEEE Spectrum* contributing editor Paul Wallich in his July 2011 article, "Building Your Own Arcade Game.") Games like *Missile Command*, *Battlezone*, and *Spy Hunter* had one-of-a-kind features like outsize trackballs, unusual screen arrangements, or gearshift levers that can't be replicated with generic modern hardware. Depending on the condition and title, prices range from the mid-hundreds to low-thousands of dollars.

—Mark Anderson

A version of this article appeared online in September.

start-up

LevelUp: Pay-by-Phone Innovator

Its mobile payment strategy emphasizes simplicity and security

In a few years, paying for goods and services with a smartphone could be as commonplace as swiping a credit or debit card today. According to the analyst firm Gartner, by 2016 the global value of mobile payment transactions will reach US $617 billion. But for now it's still early days, with a hodgepodge of technologies and business models vying for mindshare and market share, such as Google Wallet, Isis Mobile Wallet, and Orange's Quick Tap [see *IEEE Spectrum*'s special report "The Future of Money," June].

Boston-based LevelUp entered this arena last year with a free phone app that customers link to a debit or credit card. To pay at a store, the app generates an onscreen QR code (a type of high-capacity bar code). Holding the screen up to an in-store reader completes the transaction. No credit card information is transmitted. Instead, starting with the initial QR code scan, a series of tokens is passed from the customer, through the merchant and LevelUp's servers, and finally to one of LevelUp's payment processors: Braintree Vault and Bank of America. The tokens are then paired with credit card account information, and the charge is made.

The hook for customers is automated discounts: Typically, the first time users make a purchase from a merchant with LevelUp, they receive an instant credit from the merchant, usually in the range of $1 to $3 (merchants have the option of choosing to participate in this program). Subsequent purchases can then be tracked as part of a loyalty program determined by each merchant; for example, every $50 or $100 spent with a given merchant could trigger an immediate reward of, say, a $5 credit.

On the merchant's side, the appeal is the absence of per-transaction fees. With credit cards, these fees normally run to a few percent of each purchase. With LevelUp, merchants are billed only when a customer redeems a credit. Then, in addition to the cost of the credit itself, merchants are charged 35 cents on the dollar—for example, a $2 initial credit would cost a merchant a total of $2.70.

LevelUp claims that it can avoid charging per-transaction fees because of the system's low processing costs, which it attributes in part to the security of the token-based approach. LevelUp's stated fraud rate is 1 percent of that for conventional credit card use. The company is the