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October 2014
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  3 UARTs · I²C · SPI

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  I²C · SPI · CAN · eTPU (for I/O handling, serial communications, motor/timing/engine control applications)

- MODS4415
  250 MHz processor with 32MB flash & 64MB RAM · 42 GPIO · 8 UARTs
  5 I²C · 3 SPI · 2 CAN · SSI · 8 ADC · 2 DAC · 8 PWM · 1-Wire® interface

- NANO54415
  250 MHz processor with 8MB flash & 64MB RAM · 30 GPIO · 8 UARTs
  4 I²C · 3 SPI · 2 CAN · SSI · 6 ADC · 2 DAC · 8 PWM · 1-Wire® interface

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508+ Pound Thrust (0.3" per second)

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<td>Max. sampling rate</td>
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<td>Function generator + Arbitrary waveform generator</td>
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<td>Digital inputs</td>
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<td>100 MHz max. frequency, 500 MS/s max. sampling rate</td>
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www.picotech.com/pco528
Don’t Get Stung by a Wall Wart

Wall warts are used in place of internal AC-to-DC power supplies in most small devices — and for good reason. The powered unit can be more compact because of the obviously smaller parts count. There’s also no need to make allowances for convection cooling of components in the powered unit. The downside, of course, is the need to control a never-ending, space-hungry herd of wall warts.

Until recently, a typical wall wart in my collection required at least two outlet spaces in my power strips: one for the prongs of the wall wart and at least one adjacent outlet partially obscured by the body of the wart. Given that new compact switching wall warts are so inexpensive, I recently upgraded my collection of conventional transformer and diode bridge warts to the switching variety. I’ve been happy with the upgrade — there’s more space in the outlets and less clutter around my workbench.

Unfortunately, I learned the hard way that the latest generation of “regulated output” switching wall warts can have at least one major shortcoming: the regulated output can be up to 100% over the stated output voltage with no load. For example, a 9 VDC wart can output up to 18 VDC with no load. This isn’t universal, but depends on the design of the switching supply.

I discovered this when I shipped out a dozen Arduino-based animatronic systems for a research project. The systems left my shop — fully burned in — without a problem. However, the systems (which used 9 VDC switching wall warts for power) were DOA. I first thought of ESD, and modified the front end circuits of the animatronic systems to bleed off any electrostatic charges.

Luckily, before I sent the second batch of units off to the field, I ran across a thread in a forum about the no-load voltage levels in the same switching power supply warts I was using. It turned out that the users of my systems were plugging in the warts first, and then connecting the animatronic systems. This was guaranteed to generate a chip-killing spike if the no-load voltage was significantly greater than the load voltage. I solved the problem by ordering a dozen of the old-fashioned bulky wall warts with conventional non-switching circuitry. Problem solved — after quite a bit of expense repairing and reshipping the animatronic units.

Of course, not all switching wall warts suffer from this no-load voltage problem. The wall warts weren’t something I found on eBay. They were standard items from my favorite parts supplier. Bottom line: Verify that the wall wart’s output is what you expect before plugging it into that new system you’re designing. NV

Count(er) Me In

Robert Reed’s frequency counter project in the August issue is the best article I’ve seen yet in N&V. The counter could be adapted for use in many applications, and construction is well within the abilities of most hobbyists. His previous signal generator articles were great, but the counter is a home run.

Richard Duncan

Open Door for Apps

I really enjoyed Frank Muratore’s article on “The Versatile Wireless Doorbell” (August 2014). He has some interesting applications. I’d like to add one more. My mother-in-law lives with us and requires 24/7 care. I attached the pushbutton to a lanyard around her neck so she can summon help whenever she needs us. We use a battery powered receiver that is usually in the hallway, but we can take it outside if we’re working in the yard.

Don Hicke

Diggin’ the DIY Digits

Bryan Bergeron’s editorial ("The DIY Differential") in the August 2014 issue was of interest to me because I’ve long had a thing for digital clocks. I built my first one in the mid-1970s from an article in the old amateur radio magazine, 73 using an analog 5314 clock chip and 4” Nixie-type displays from an old stock market display system. In the following years, I built and either gave away or sold more than 50 digital clocks using the Nixie tubes with series-connected LEDs in a seven-segment setup and — when the prices came down — regular seven-segment LED displays.

In his editorial, Bergeron had been interested in a "large digit" LED clock. I’m curious as to what was meant by “large digit.” Of all the LED display clocks I made, the ones that people liked the most had 4” digits for the hours and minutes, and 2” displays for the seconds. Many people said that when they’d glance at the clock to see the time, their eyes were naturally drawn to the larger digits, quickly giving them the current time. The smaller seconds digits were easy to see but couldn’t be confused with the others.

What I’d like to see is an article about a six-digit clock which would drive many different display sizes. This would give the builder a wide choice of designs. Of course, 5” common-
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Different Type of Refrigerator Magnets

The concept of magnetic refrigeration has been around for over a century, being based on the magnetocaloric effect first observed in 1881. It was then discovered that ferromagnetic materials heat up when exposed to a magnetic field and cool off when the field is removed. An early magnetocaloric refrigeration system built in 1933 produced a temperature of 0.25 K (-272.9°C), and similar units have been used for years — largely for cryogenic applications in laboratories. Such systems basically operate by mechanically moving the ferromagnetic materials into and out of strong magnetic fields and using a fluid-based heat exchanger.

The main obstacles to producing commercially viable units have been the need to produce sufficiently powerful room-temperature permanent magnets and to come up with ferromagnetic compositions that produce a wide enough temperature change within a useful range. It appears the old compressor systems will begin to disappear within a few years, however, several companies have reported notable successes with magnetic system designs. These include General Electric (www.ge.com) which has a prototype that can reduce temperatures by 80°F while using 20 percent less electricity. The feat is accomplished by using a multi-stage process that involves 50 cooling stages to incrementally cool a water-based fluid.

Although the unit is presently about the size of a pushcart, GE believes that it will soon have systems that are small enough to fit inside a standard refrigerator or window air conditioner while producing 100°F of cooling with a 30 percent reduction in power consumption. There are, naturally, videos on YouTube. Just search "GE magnetic refrigeration" and you’ll be offered videos ranging from two minutes to about half an hour.

Live Long and Shop Lowe's

Like many advanced technologies, the first concept to emerge from Lowe's Innovation Labs (www.lowesinnovationlabs.com) was inspired by science fiction. Unlike many such concepts, however, you won’t have to wait years to see it in action — at least if you live in or near Ontario. The Lowe’s Holoroom — derived from and named after the Holodeck appearing in various incarnations of Star Trek — is already operational and ready to be installed in some Toronto stores later this year. According to Kyle Nel, executive director, "We know that for many homeowners, the struggle to visualize a completed home improvement project or to share that vision with others can stop a project in its tracks. The Holoroom is our solution, enabling consumers to visualize their project and share that vision with family and friends."

Before you get too excited, though, bear in mind that similarities between the Holoroom and the Holodeck are more metaphorical than literal. In the Lowe’s version, you are not surrounded by realistic holographic images and authentic sounds. Rather, you use a tablet to choose furniture, appliances, plumbing, flooring, and other items, and arrange them inside a simulation of a room in your house. The augmented reality part of it kicks in when you walk around and aim the tablet at the chosen items which you can view from different distances and angles. You can make any changes you want and eventually come up with a completed design.

Finally, Lowe’s will give you a printout to take home, and you can even share the model using a free app for iOS or Droid devices. It was further noted, "Additional product categories and rooms will be added to the Holoroom to help plan projects throughout the home over the next 12 to 18 months. Lowe’s Innovation Labs will share updates on the Lowe’s Holoroom as well as future initiatives on Twitter at twitter.com/loweslabs."
Two-in-One Means Business

It appears that — having read reports of Microsoft losing $1.2 billion on its Surface laptop-to-tablet convertible computers — Hewlett Packard (www.hp.com) management said, "Hey, we could do that, too." The result is the HP Pro x2 612 — it’s similar, but geared primarily for enterprise applications. Like the Surface Pro 3, the HP 612 can be attached to a full-size keyboard (with its own embedded battery) or be used as a stand-alone tablet.

Unlike the Surface, it includes such business-oriented security features as HP BIOS, HP Client Security, HP Sure Start, HP Trusted Platform Module, a smart card reader, and an optional fingerprint reader. Powered by Intel Core i3/i5 processors, it also sports a 12.5 inch HD display, two USB 3.0 ports, and LTE broadband mobility via a Qualcomm 4G LTE modem.

Other features include dual high-def webcams and an optional battery-free Wacom pen, allowing users to write and draw graphic content with 1,024 levels of pressure sensitivity and palm rejection technology. HP claims 8+ hours of battery life when the 612 is used as a tablet only, and 14+ hours with the tablet and keyboard combined. As of this writing, HP is still mum about the retail price.

Better Satellite Images

Back in June, the US Department of Commerce decided to relax its restrictions on the distribution of high-res satellite imaging which previously required vendors to pixilate any views that exceeded 0.5 m resolution (i.e., in which features smaller than 50 cm are visible). Under the new rules, vendors will now be permitted to sell imagery at up to 0.25 m panchromatic (gray scale) and 1.0 m multispectral (color). Shortly thereafter, DigitalGlobe, Inc. (www.digitalglobe.com) — one of several satellite imaging companies — announced the upcoming launch of WorldView-3: the latest in the company’s fleet of five Earth imaging satellites. According to DigitalGlobe, WorldView-3 "will set a new technological bar for commercial satellite imagery, offering customers the highest available resolution, revisit rate, capacity, and spectral diversity." The system is capable of providing 31 cm resolution which is a grade better than WorldView-2’s 46 cm.

In practical terms, this means that you will be able to view and download black-and-white images in which things like mailboxes and manholes are easily discerned. Color imaging will be available down to 1.24 m resolution which allows a viewer to distinguish houses, individual cars, and so forth. How this will affect what you retrieve from an Internet search is hard to pin down at this point.

At present, DigitalGlobe’s customers include US federal agencies including NASA and the DoD, and it provides services to Google Earth and Google Maps. Google recently shelled out half a billion dollars for Skybox Imaging — a start-up competitor that plans to have its own fleet of 24 satellites in orbit by 2018.

In any event, it’s going to be much easier to spy on each other.
Free Your PDFs

Somewhere along the line, Adobe decided to allow PDF file creators to impose a range of security restrictions that prevent others from opening, printing, copying, or otherwise modifying the file. Unfortunately, this means that a fair number of documents that you might download may be of little or no practical use to you. Never fear, however, because it appears to be no big deal to remove the restrictions. One of the easiest ways is to log on at www.pdfunlock.com and upload your file. An unlocked version will be returned to you shortly. The service is free, but you are encouraged to make a small donation either directly or by clicking on a link to the National Multiple Sclerosis Society.

Wi-Fi Your Arduino

If you are among the many people using Arduino microcontrollers to create gadgets (and there are an estimated quarter of a million of you), you know that the basic unit can be extended by plugging in various "shields" (i.e., boards that provide a variety of specialized functions). There are shields for MP3 playback, weather detection, motor drive, voice recognition, and pretty much anything else you could imagine. If your project needs to have Wi-Fi capabilities, you will, of course, need a Wi-Fi shield.

One of the latest is the xPico® device from Lantronix (www.lantronix.com) — a company that specializes in "smart Internet of Things solutions." The xPico supports simultaneous LAN client connectivity (802.11 b/g/n) and access point functionality, making it easier to connect to the Arduino via web-based tools and smartphone and tablet interactive apps. The company notes that the device "allows engineers, designers, students, and hobbyists to quickly add smart Wi-Fi solutions to Arduino designs while offloading the burden of TCP/IP stack and networking applications to the included xPico Wi-Fi module." It is said to be easily configurable with little or no software development, and takes up only 24 mm x 16.5 mm of board space. The xPico retails for $59, but a little online shopping can turn one up for as low as $29.99.

4K/25p Wearable Camera

If you are certain that your life is so interesting that it deserves to be recorded and broadcast to the hum drum outside world, Panasonic has just the thing for you. With the company's new HX-A500 point-of-view wearable camcorder attached to your head, you can record your every activity, even if you are slogging through a dust storm (it is dustproof), taking a shower to get rid of the dust (it is waterproof to 3 m for up to 30 min), or operating in a less challenging environment. The quality of the video will be second to none, as the A500 shoots in 4K ultra-HD picture quality at 25 frames per second. The main body includes a 1.5 inch LCD monitor, and it is equipped with near-field communication capability so it is "just a swipe away from a Wi-Fi connection via your smartphone or tablet. Through the Panasonic Image App, you can then record and edit your video remotely, share your creations via social media, as well as broadcast them live using UStream."

The main operating unit weighs only 119 g (4.2 oz), and the camera just 31 g (1.1 oz). The unit features automatic leveling correction and image stabilization, and a slow motion function ups the speed to as much as 200 frames per second (with a corresponding reduction in picture resolution). The A500 will run you $399.99 retail.
All-electric cars have not exactly taken the market by storm, as they are plagued by many problems including weight, cost, long charge times, fire hazards, and a limited number of charge/discharge cycles. The problem is that batteries — in spite of many improvements — still store energy in a chemical reaction, the same as when Alessandro Volta invented them in 1800. This has led many prognosticators — including Tesla Motors’ CEO Elon Musk — to speculate that ultracapacitors may someday supersede batteries in the automotive industry. The advantage is that ultracapacitors store energy in an electric field rather than an electrolyte, so they can be charged much more quickly and can handle hundreds of thousands more cycles than batteries. Conventional wisdom is that ultracap technology hasn't quite reached that level yet, so it is somewhat surprising to discover that earlier this year an ultracap-powered bus was put into service in Sofia, Bulgaria. (Bulgaria has Europe's highest atmospheric concentration of sulfur dioxide and carbon monoxide, so it was a logical place to start.)

The bus is the result of a partnership among Israeli-Bulgarian bus builder Chariot Motors (www.chariot-electricbus.com), China's Higer Bus Company, and ultracapacitor producer Shanghai Aowei Technology (www.aowei.com). “This is the first electric bus on European streets that does not require traditional battery charging and can cover its whole route on a single charge requiring just a few minutes. However, I'm confident that it won't be the last," said Zwiki Zimmerman, Chariot Motors chairman. Reportedly, Aowei's ultracapacitors have been pushing buses around the streets of Shanghai for more than seven years to the tune of more than 8,000,000 km. You have to wonder: Do they know something we don’t?”
In 1819, Danish scientist Oersted discovered that current flowing through a conductor (wire) produces a magnetic field that encircles the conductor. In 1820, French scientists Biot and Savart developed the Biot-Savart law which predicts the magnitude and direction of this magnetic field. The magnitude of the magnetic field is a function of the magnitude of the electrical current in the wire, and the direction of the magnetic field is determined by the direction of current as shown in Figure 1 for one conductor.

An electrical power cord is made up of two or more current-carrying conductors in close proximity. Figure 2 shows the current and magnetic field directions for a two-conductor cable.

For the two-conductor power cable, the current in each wire is equal and flows in opposite directions, so the magnetic fields are equal in strength and opposite in direction. Therefore, the effect of these equal and opposite magnetic fields is to cancel each other. When an ammeter is clamped around both wires, there’s no magnetic induction, thus a zero current reading on the ammeter. This is a common occurrence.

The way to measure the current using a clamp-on ammeter is to clamp only one wire at a time. This can be done in the motor’s junction box. CAUTION: Turn off power when working with your body parts inside any electrical device. (1) Turn the power off the motor at the breaker and then remove the junction box cover. (2) Pull one power wire out (not a neutral on three-phase or...
ground on single phase) and clamp the ammeter around this wire. (3) Once your hands are clear of the wiring, turn on the breaker, power up the motor, and take your current readings. Typical readings for AC motors are: 115 volt single phase (most residences use single phase), 14 amps per horsepower (HP); and 230 volt single phase, seven amps per HP. If your friend happens to have three-phase motors (shown on the nameplate), the expected currents are: 230 - 2.5 amps/HP; and 460 - 1.25 amps/HP.

Good luck and work safely. Let me know your results.

Outdoor Reception of TV Audio

I have a next door neighbor who asked me to help him with a sound problem. His wife is an avid gardener and she likes to listen to the audio portion of TV shows while she works in their rather large back yard and shed. I suggested he get an FM transmitter and connect it to his TV so she would be able to listen by using an inexpensive FM radio headset while she works. He ordered the FM10C FM transmitter kit from Ramsey Electronics and I helped him put it together. This seemed to work very well and sounded great when we tested it in the house. However, when his wife tried it out, she said the audio would fade out and become just static when she was at the back edge of the yard or in their back shed. To fix this, I was thinking we might be able to boost the output from the FM transmitter, but a friend (ham radio operator) said this isn’t legal to do — is this true? If so, can you think of some way I might be able to fix this issue and get clear signal all the way to the back of their yard?

— Carlos Simmons, San Marcos, TX
power (ERP) of one watt or less. These regulations are designed to keep different radio transmissions from interfering with other radio transmissions (like an “overpowered” CB radio being received on your TV or PA system). The FCC levies pretty stiff fines ($10,000 to $75,000) for violating these regulations which keeps most people honest.

Ramsey Electronics’ website says the FM10C transmitter has enough power to cover “a city” block and refers the user to the manual for antenna and range info. The first thing I would try is to check the transmitter frequency as outlined in their manual on page 14. Modern digital radios stay pretty well on the tuned frequency, whereas the analog tuning of the FM10C tends to drift due to component aging and temperature variations. If the transmitter and receiver are not tuned close to the same frequency, there will be an effective loss of the signal by the filtering action of the receiver.

Next, check the power supply voltage you are using. The Ramsey specs say the FM10C can operate with a range of voltages between 5 VDC to 10 VDC. A little secret: The higher the voltage you operate the transmitter, the higher the output power which means the longer the range of reception. If these remedies are not enough, look at antenna placement relative to the backyard (I assume that is where most of the time is spent based on your letter).

If the transmitter is hooked to the TV at the front of the house, there may be enough signal loss due to the house’s building materials to cause your problems. The ideal placement of the transmitter using the whip antenna that comes standard with the FM10C is on a deck in the middle of the back of the house (I realize audio cable runs may be a nightmare unless the TV is near a back window).

You could look at using an external FM band antenna installed in the backyard with as “short as possible” coaxial transmission line (coax in CB and ham lingo) between the transmitter and antenna (check with Ramsey to find the impedance of the antenna so you can match the coax characteristic impedance to the antenna’s impedance or there will be a LARGE signal loss). You should be able to hook the coax shield to the FM10C antenna ground and the center conductor of the coax to the FM10C’s signal (the other antenna connection). Make sure the antenna ground and signal connections are not shorted together or you will lose all signal power and possibly damage the FM10C’s power circuits.

The American Radio Relay League (ARRL) website at www.arrl.org is a good place to start looking for alternative antennas (which is too lengthy to cover here). A metal sheet placed about one antenna length behind the whip antenna would tend to increase the effective radiated power into the backyard (experiment with reflector spacing and antenna length/height/tilt for the best signal coverage).

In the “days of yore” with analog TV a solution, you would have been able to buy a receiver for the TV FM audio signal. With the advent of digital TV, I do not know of any portable audio receivers on the market for TV audio only.

My commendations go out to everyone today who builds electronics kits or devices. Kit or scratch building is a great way to learn electronics. In this day of “cheap manufactured” electronic entertainment and instant gratification, most people have forgotten the technology that gives them these fantastic devices (philosophy lesson for the month).

Good luck and let me know how things turn out. NV
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Propeller Reanimator

If you’re a Halloween enthusiast like I am, this time of year gets pretty busy. Every year is an attempt to out-do the successes of previous years, and it rarely gets easier. Long gone are the days when a simple paper mache decoration was enough to impress the neighbors. Special effects in films and television have made us all very sophisticated and wanting more when it comes to entertainment — even the homegrown variety. Thankfully, those of us who are also microcontroller enthusiasts have a bit of an edge. No, our skills don’t help with the sculpting, molding, casting, and painting of props — but after that part is done, we get to work magic with circuits and code.

As you know, I’m one of those lucky guys that gets to work in and around the entertainment industry. Not only do I get to work with some of the best artists and special effects engineers in the world, I get to learn from them — which really helps me this time of year! Oftentimes, Hollywood schedules are compressed on-the-fly — and they typically starts at ridiculous. This is why artists in the industry are constantly honing their skills and work very hard to develop a useful “bag of tricks.” This is why I chose the Propeller.

One of my friends and clients in the business is Steve Wang. He’s a heavy-hitter in the make-up and effects world (he writes and directs, too), and is one of the kindest, most generous people I know. Steve loves artists, and shares what he knows with those who are sincere about improving their skills. Steve can turn a blob of clay into anything. Give him some material and some paint, and he can make it look like anything. That’s his gift (that he’s ardently developed over the past 30+ years). What Steve doesn’t know or do is electronics or embedded programming — so he calls on me to help him with special projects.

Like most genius artists, Steve is very fluid in his thinking. We have worked on projects for his clients where he’s giving me suggestions nearly as quickly as I can type code. Thankfully, I have a large collection of objects and routines built up that I can call on. The power of the Propeller, my code base, and a lot of practice allow me to be responsive to Steve’s requests.

In the end, he is being responsive to his clients, and that’s what really matters. In January, I was in his shop when a client came in to see a finished project. Tears were welling in her eyes because she was so moved by its splendor. This is why I like working with Steve and his team. Their hard work and devotion to the craft affects people at incredibly deep levels. To me, that’s what entertainment is about.

We don’t always have the time to do custom programming, but we still want a fantastic display for Halloween, right? What do we do? For projects that involve simple motion and lighting control, I developed a set of programs that work in conjunction with animation software. The first part (streamer) accepts servo and lighting data as a serial stream, and will convert that data to the appropriate outputs. The second program (player) can play the show data from an SD card after it has been exported by the animation program. The player also allows us to connect to an external audio device for synchronized sound. It’s pretty easy, and it works — so well, in fact, that it’s in use at two major theme parks in southern California, and one of them has adopted a variation of these programs for servo animatronic displays that are sent all around the world.

Using the streamer and player programs allows us to focus more on the art of the display, because doing that part well will always be challenging. For most of my streamer/player projects, I use the EFX-TEK HC-8+ controller combined with the AP-16+ audio player (this is what the amusement parks use, as well).

I’m part of EFX-TEK, so I have them at my disposal. I understand that you may not, so I’m going to present these projects as platform-agnostic as possible. As long as you have some sort of Propeller board, you’ll be able to use the code and circuit options presented here with the streamer and player programs.

Stream Me Up, Scotty

The purpose of the streamer program is to control our prop hardware by interpreting data from an off-the-shelf animation program. My choice is Vixen. It’s free, it’s easy, and the creator (K.C. Oaks) is another one of those nice guys that really cares about the people who use his stuff. Every time I have asked him for a custom plug-in or add-on for Vixen, he has happily created it for me. We’ll be using a couple of those here.

You may be asking, "Isn’t Vixen a lighting controller?" Yes, it is. That said, the output from Vixen is a serial stream of numbers that we can interpret in any way we choose. The ease and flexibility of Vixen — along with its responsive
development team—has made it a very popular choice for all kinds of interesting control projects.

(I use Vixen 2.1. There is a Vixen 3.x available, but the modules required for the streamer and player programs do not work with that version. I am waiting for Vixen 3.x to stabilize before transitioning to it.)

Okay, then, how does Vixen tell the streamer what to do? This happens through the use of an output plug-in which controls how Vixen formats the serial output. The protocol we’re going to use was created by a long-time friend of Nuts & Volts readers, Scott Edwards. Way back in the day, Scott created a device called the MiniSSC (serial servo controller) that allowed one to control a bunch of servos using a simple serial message over a single wire. The MiniSSC takes care of the grunt work of refreshing the servos every 20 ms—something that was really tough for the BASIC Stamp 1, which was about the only game in town when the MiniSSC was created.

The MiniSSC protocol is simple. For each channel update, there is a three-byte packet:

<SYNC> <CHANNEL> <VALUE>

The sync byte is $FF; this defines the start of a new channel packet. The next byte is the channel which can be from 0 to a theoretical maximum of 254. The final byte is the position value, 0 to 254. Of course, the MiniSSC would convert the position byte to an appropriate servo control pulse, and we will too. Every Propeller project has a serial programming connection; that’s what we’ll use to send data from Vixen to the streamer program.

The streamer will use FullDuplexSerial (the default serial object used in most Propeller programs) to handle the data coming from Vixen. For outputs, we can use servos, dimmers/digital outputs, or a combination of the two. Constants in the program take care of instantiating the servo and dimmer objects:

```cpp
pub setup_objects
    serial.start(RX1, TX1, %0000, BAUD)
    if (SERVOS > 0)
        svos.startx2(SERVOS, SVO_BASE, { }
            SVO_MIN, SVO_MAX, { }
                @ServoStart, $FF)
    if (DIMMERS > 0)
        outs.start(DIMMERS, DIM_BASE)
```

Note that I’m referring to the second object as a dimmer. This can also be used for pure digital outputs like pneumatic valves and relays—we just have to ensure that control of such channels uses only 0 and 100% values on the Vixen timeline. I think the cleanest approach to parsing the MiniSSC data stream is to use a finite state machine. Here’s the whole Magilla:

```cpp
repeat
    case state
        0 :
            sync := serial.rxtime(3)
            if (sync == $FF)
                state := 1
                high(G_LED)
            else
                low(G_LED)
        1 :
            ch := serial.rxtime(1)
            if ((ch => FIRST) and (ch <= LAST))
                state := 2
            elseif (ch == $FF)
                state := 1
            else
                state := 0
                low(G_LED)
        2:
            level := serial.rxtime(1)
            if ((level => 0) and (level <= 254))
                update_channel(ch, level)
                state := 1
            elseif (level == $FF)
                state := 1
            else
                state := 0
                low(G_LED)
```

While in state 0, we will wait for a serial input of $FF (sync byte). If this is received, we advance to state 1, and then turn on an LED (this is optional, of course, but helpful to see that data is being received). If there is a bad sync byte or timeout due to the space between frames, the LED will be extinguished. In state 1, we are waiting for a valid channel byte, defined by constants FIRST and LAST. If we get a good channel value, the state is advanced. Otherwise, we check for a new sync byte. If the channel number is out of range and not a new sync byte, the state machine is reset and the LED extinguished. Finally, in state 2, we wait for a valid channel level (0 to 254). If valid, we update the channel, otherwise we look for a new sync byte as in state 1. Easy, right? (You should be nodding and say, “Yes, Jon, it is!”) With a valid packet in hand, we can update the channel. The constants for the program allow us to configure the streamer for servos and dimmer/digital objects. They also come into play when updating the outputs—we do that with update_channel():

```cpp
pub update_channel(ch, level)
    if (ch <= SVO_LAST)
        level := map(level, 0, 254, SVO_MIN, SVO_MAX)
        svos.set(ch, level, 0)
    else
        level := map(level, 0, 254, 0, 255)
        outs.set(ch-SERVOS, level)
```

In the program, there is a constant called SERVOS that sets up servo type outputs. The value of SVO_LAST is derived from SERVOS. If we’re using four servos in our project, SVO_LAST will be 3. If we’re only controlling...
dimmer/digital outputs, SVO_LAST will be -1.

In update_channel(), we check to see if the value passed in ch is in the servo range. If that is the case, the map() method will scale the 0 to 254 range to something more appropriate for servos, typically 600 to 2400 (microseconds). Channels that are not servos are considered dimmers or digital outputs. That's really all there is to the streamer: Accept serial input using the MiniSSC protocol, and then update outputs as required. It's important to note that the streamer program expects servo channels to be defined ahead of the dimmer channels. With a fixed number of outputs (as with the HC-8+), the number of servos limits the number of dimmer/digital outputs.

**Circuit Circus**

If you're going to run servos from the Propeller, I think it's best to boost its 3.3V output to 5V; this is what the servo expects, and the buffer will help suppress noise from the servo signal pin. If you have just a few servos, the TC4427 is an excellent choice. In fact, it's one of my favorite "accessories." This chip is actually a MOSFET driver that allows us to select the output voltage (Vdd pin). The stiff output is great over long wires. My friend, Lou, built a Propeller-powered zoom controller for cameras that uses servos to turn the lens elements; he found that adding the TC4427 allowed for longer wires and better control. Figure 1 shows the connections for the TC4427. For more servo outputs, we can use a buffer like the 74HC541 — you'll find this on the Parallax QuickStart, and on later revisions of the HC-8+. Figure 2 shows the connections for the 74HC541.

For LEDs, lamps, and pneumatic valves, the ULN2803A is a popular choice. The ULN2803A has built-in pull-downs, so we don't need to add them. Just remember that the ULN is an open-collector device which means it switches the ground side of the circuit. The other side — usually 12V — is the common side. Refer to Figure 3. Finally, if you're going to run files from the stand-alone player program, you'll need SD card access. The circuit in Figure 4 is what I use in my custom designs. EFX-TEK has a microSD adapter for the HC-8+, and Parallax carries a microSD adapter that is breadboard-friendly. They also have boards like the Propeller Activity board and Propeller ASC+ that include a built-in microSD socket. The ASC+ (Arduino Shield Compatible) and an appropriate output shield is an easy what to build a prop controller for Halloween. A word of caution for servo controlled props: Servos can demand far more current than we care to think about, especially with a heavy prop (like a talking skull) that is under load. For safety, budget at least 500 milliamps per servo from your 5V supply. For my skull project, I use a 5V/10A supply that I bought from Adafruit.
Getting Started with Vixen

Vixen doesn't have a traditional installer program. It's just a ZIP file that you can unzip to any location you choose in your system. To make things easy for you, I've created a ZIP file of my setup — this ensures you have all the latest drivers. The file is pretty big, so I've put it in the Vixen section of the EFX-TEK forums. You can always get the latest release of drivers there. After unzipping the Vixen 2.1.x.x folder, find and double-click on vixen.exe.

After a short splash screen, you'll be presented with a blank window. Vixen uses an MDI interface, so you can have multiple projects open at once, though I don't recommend it. Let's say we want to create a project with four servos and four dimmer outputs.

Click on Sequence\New Event Sequence\Vixen Standard Sequence. This will create an empty sequence with no channels (Figure 5). Set the number of channels to 8, and then click the maximize button to make things easier to work with (Figure 6). For servo animatronic projects, I use 20 ms event (frame) timing. To set up the sequence for the streamer, click on Sequence\Settings. In the dialog (Figure 7), we want to set the event period to 20 which corresponds to the update timing for standard servo drivers; this allows smooth updates from Vixen. Leave the channel level settings at 0 (minimum) and 255 (maximum).

When creating a new Vixen sequence, the channels get generic names; we can change that by right-clicking on a channel label. In the Channel Properties dialog (Figure 8), we can give the channel an appropriate name and even change the display color. The Enabled checkbox allows us to disable a channel without erasing the channel data. I find this useful for isolating a channel (e.g., the jaw movement of a talking prop).

If you're using servos in a prop, you may want to preset the value of those channels to the default position (usually centered, but could be something else). Right-click on the channel label again and select All Events To... in the context fly-out. To center servos, use 127 as the default value. Remember that we're using the MiniSSC protocol, so we have to convert the position value to something that fits into the 0 to 254 range. We can calculate the MiniSSC-compatible value with this formula:

\[
\text{value} = \frac{(\text{position} - \text{servo_min})}{\text{servo_span}} \times 254
\]

If we're using a 180 degree servo with a range of
600 to 2400 microseconds, the span would be 1800. If the desired position is 1500 (center), we get

\[(1500 - 600) / 1800 * 254 = 127\]

The final bit of setup before we can start streaming data is to connect an output driver — in our case, the MiniSSC. Click on Attached Plugins (in the sequence window) to bring up the Sequence Plugin Mapping dialog. Scroll through the list on the left and select MiniSSC. Click the Use button to add it to the plug-ins list for the project (Figure 9). Select MiniSSC from the right-side list and then click on Plugin Setup. In the dialog, we need to set the COM port to match our Propeller board (yours will probably be different from mine). The baud rate is set to 57600. Set the Minimum value to 0 and the Maximum value to 254 (critical!). Finally, make sure that the Scaling checkbox is, in fact, checked as in Figure 10. Note that we're allowing the sequence to express values in the full range of 0 to 255, and then using the output plug-in to scale to the MiniSSC range. Quite some time ago when I first started exploring Vixen as a sequencer for servos, I used 100 and 200 as the output values to conform to a 90 degree servo range of 1,000 to 2,000 microseconds. My SX-based controller would multiply the Vixen value by 10 to produce the servo pulse. Using 0 to 255 on the timeline gives us the best resolution using byte values. With a blank sequence setup, use Sequence\Save As to save the template for your hardware. To create a project, open this template and use Save As again with the project name.

Now it's time to play — and I seriously mean that! After the streamer program has been downloaded to the Propeller, switch over to Vixen and give it a try. Please, I beg you, give yourself an hour or two (or 10!) of play time with Vixen before you start on a real project. It's quite simple, but has lots of options and you'll want to explore them. I tend to use the ramping options most. Simply drag-select events on a channel, then click on a ramping button. There are even options for partial ramps which work well with servo movement. For projects that include audio, you can add it to the Vixen project using Sequence\Audio. Vixen accommodates a number of audio formats, though I think sticking with WAV or MP3 is the best way to go.

After connecting a piece of audio to the sequence, display it by clicking on the Audio Visualizer toolbar button (see the upper-right corner of Figure 11) — this button looks like a little audio waveform. Use the Column Zoom setting to make synchronizing events to the audio file easier.

**Play It Again, Sam**

In the Vixen Add-ins menu, you'll find a selection called Raw Data Export (Figure 12). This dialog writes the show data to a binary file (only the show data; audio is handled separately). When I worked with K.C. on this, we borrowed a page from the WAV file format: The binary export has a header, followed by the track data for all the frames exported. We'll cover the details later.

The player program is set up to wait for a trigger input. If you're programming a Halloween prop, a PIR sensor could be used. One of the amusement parks I work with uses big kid-friendly buttons on their displays. Once a start input is detected, we'll open the file and play it. For file access, I use FSRW; it has been around the longest and seems to have the best performance. In fact, at EFX-TEK, we use FSRW in the AP-16+ audio player to read WAV files from the SD card. FSRW works in my book; you can trust it.

**FSRW** provides medium-level access, so I have several shell methods in my apps that use files:

```
pub mount_sd | check
check := \sd.mount_explicit(SD_DO, SD_CLK, SD_DI, SD_CS)
if (check => 0)
    mounted := true
else
    mounted := false
return mounted
```

![Figure 9. Vixen Plugin Mapping dialog.](image1)

![Figure 10. Vixen Mini-SSC setup.](image2)
The first method — `mount_sd` — gets us connected to the SD/uSD hardware. Note the use of the abort trap (\) in the code — this is important and FSRW makes nested calls. If an SD/uSD card is present, this method will set the global variable `mounted` to `true`:

```c
pub open_file(p_zstr, mode) | check
    if (mounted)
        check := \sd.popen (p_zstr, mode)
        if (check => 0)
            if ((mode == "r") or (mode == "R"))
                \sd.seek(0)
                return true
            else
                return false
        else
            return false
```

This method opens a file in the desired mode (Read, Write, Append, or Delete). If successful, the method returns `true`. I found through experiments that initial file access seemed faster if I included a call to FSRW's `seek()` method for files opened in Read mode:

```c
pub read_buf(p_buf, n) | check
    check := \sd.pread(p_buf, n)
    if (check == n)
        return true
    else
        return false
```

This is the method we'll used the most; it transfers a block of `n` bytes from the open file to the buffer pointed to `p_buf`. With that, let's get back to the file header.

The header consists of three 16-byte elements: channel count, event/frame timing (ms), and the total frame count. You may be wondering why we have a 16-bit value for channels when it's not possible to support that many. Let me explain. In the player program, we have these variables:

```c
var
    word filechannels
    word eventms
    word frames
```

Recall that variables of the same type will be laid into memory in the order they are declared. That said, it is critical to the operation of the player program that we do not change the order of these variables. When we want to play a file, we'll open using the `open_file()` method — something like this:

```c
open_file(string("VIXEN01.BIN", "R"))
```

This example is just to cover the syntax; again, we pass a pointer to a z-string and the mode as a letter. With the file open, we can transfer the header into our variables like this:

```c
ifnot (read_buf(@filechannels, 6))
    close_file
    return
```

The first parameter of `read_buf()` is the location the bytes from the file will be transferred to; in this case, we are providing the address (@) of `filechannels`. The second parameter is the number of bytes to read. We must use six to cover three 16-bit variables. If there is a problem with the read (e.g., end-of-file indicator), we close the file and return to the caller.

This works because Vixen and the Propeller store values using Little Endian format (low byte, then high byte). By copying the first six bytes of the file to these variables, they are automatically set to the correct values. We use words for all three so that we can do this with a single call to `read_buf()` — better to give up one byte for a variable than several for multiple calls to import all header values. This would be required if we decided to make `channels` a byte — it would no longer lay into memory in the order we declared it.
At this point, playback of the file is very straightforward:
- Read a frame of channels into a buffer.
- Iterate through buffer and update outputs.
- Wait for the end of frame timing.

That's it. We'll run this loop the number of frames specified in the header. Let's have a look at the core playback code:

```c
pub play_show(show) | frametix, t, ch, tix
byte[@ShowFile][5] := "0" + (show / 10)
byte[@ShowFile][6] := "0" + (show // 10)
ifnot (open_file(@ShowFile, "R"))
close_file
return
ifnot (read_buf(@filechannels, 6))
close_file
return
if (filechannels > CHANNELS)
close_file
return
frametix := MS_001 * eventms
t := cnt
repeat frames
if (read_buf(@framebuf, filechannels))
repeat ch from 0 to filechannels-1
update_channel(ch, framebuf[ch])
waitcnt(t += frametix)
toggle(G_LED)
else
quit
close_file
low(G_LED)

The `play_show()` method expects a show number — 0 to 99 — though most projects will only use three or four. The first thing we do is update an embedded file name string:

```c
ShowFile byte "vixen00.bin", 0
```
with the desired number. A series of check steps verifies that we can open the file, read the header, and that the file data is compatible with our hardware (channel count). Assuming all these pass, we convert event/frame timing (milliseconds) to system ticks, and then drop into the player loop. At the top of the loop, `read_buf()` is used to transfer a frame (of bytes) to an internal buffer. We iterate through the buffer using `update_channel()` to take care of the physical outputs. After the frame delay (using `waitcnt`), we toggle an LED before calling the next frame. This loop will continue until all frames are played. When done, we close the file and kill the LED before returning.

You're probably wondering, "What about audio?"
That's easy, too. In my projects, I use the Propeller-powered AP-16+ audio player. It has a half-duplex serial control port that allows easy integration into our projects. To keep things simple, I use the AP-16+'s standard naming convention for WAV files: SFXnn.WAV, where nn is a two-digit number.

The AP-16+ includes a serial command to play an SFXnn.WAV file by number. I encapsulate that command with this method in the player program:

```c
pub ap16_sfx(addr, sfx, rpts)
audio.str(string("!AP16"))
audio.tx(addr)
audio.str(string("PS"))
audio.tx(sfx)
audio.tx(rpts)
```

We can selectively enable audio in our project with the `USE_AUDIO` constant. Adding audio to the `play_show()` method is done like this:

```c
if (USE_AUDIO == YES)
ap16_sfx(%00, show, 1)
```

This is inserted immediately before the play loop. If you're using another audio player with your project, you'll need to modify the method that sends the appropriate serial command. Okay, I know what you're thinking now: "What about random playback of multiple files?" Excellent question, and the answer will help you create more interesting props and displays.

First things first. We will need to create a set of animation files for our prop — with audio, if that's a part of the project. Remember to keep the file names in sync with each other: VIXEN00.BIN corresponds to SFX00.WAV, etc.

A simple loop is used to inventory the show data files on the player's SD card. Note that this inventory method is limited to the number of bits in the `hasfiles` variable; I'm using a word, so I can inventory and manage up to 16 files (more than enough, I assure you):

```c
hasfiles := $0000
repeat fn from 0 to 15
byte[@ShowFile][5] := "0" + (fn / 10)
byte[@ShowFile][6] := "0" + (fn // 10)
if (open_file(@ShowFile, "r"))
hasfiles |= (1 << fn)
close_file
playlist := !hasfiles
lastfile := -1
```

The global variable `hasfiles` is used as the file inventory — each bit in the value (up to 16 bits for my projects) represents a file that is available on the SD/SD card. We start by clearing that, then running a loop (0 to 15) that updates the embedded file name string, and then attempts to open the file. If the file is present and can be opened, a 1 is added to `hasfiles` in the appropriate position. Let's say, for example, that we have files VIXEN00.BIN through
VIXEN03.BIN (four files). This would result in a value of $0000 (0000) in hasfiles.

Two more variables are used for random playback: playlist and lastfile. The former is used to keep track of the files played in the current cycle. This is initialized to the inverted value of hasfiles. A 1 in playlist means the file corresponding to that bit position is not available or has already played. In a 16-file project, a value of $FFFF in playlist means that all available files have played and we can re-initialize for the next cycle.

There's one more detail that matters: the last file played. In my projects, I don't like to have the same file play back-to-back when I'm using random access. By checking the value of lastfile, we can ensure that we don't play the same file twice in a row:

```plaintext
pub random_start | btn, show
    repeat
        prng.random
        btn := ttl_pin
        if (btn == 0)
            repeat
                show := prng.random & %1111
                ifnot ((1 << show) & playlist)
                    quit
                play_show(show)
                lastfile := show
                playlist |= (1 << show)
            if (playlist == $FFFF)
                playlist := !hasfiles
            quit
        else
            pause(50)
```

If the player is set to random mode, the `random_start` method takes care of generating a random show number using the rules we've just covered. Using the HC-8+, a method called `ttl_pin` returns a value of 0 to 7 based on which TTL input pin is active. If none are active, that method returns -1. For random play, we only need to monitor one input (IN0).

When IN0 goes active, a random value is generated and then masked with %1111 to force it into the range of 0 to 15. If the new show number was not the last played, then a mask is created and tested against playlist. If the new show number was not the last played and hasn't been played in this cycle (i.e., not in playlist yet), we can break out of the inner loop and play the show.

After the show is finished, the values in lastfile and playlist are updated. When the playlist is full ($FFFF), it gets re-initialized using hasfiles.

Okay, there you have it. If you're using the HC-8+ and AP-16+ combination like I do, the streamer and player programs will run without modification. If you're rolling your own, you'll probably have to modify the pin constants and make changes to the input methods, as well as the control methods for your audio player. That should really be very easy work, however. Hit me up in the Parallax Propeller forum if you need an assist. The key now is to focus on the art of the project. In Figure 13, you can see the beast that I'm trying to tame (those of you that attended HauntX in Reno last May will have seen this dude on the EFX-TEK table running from an HC-8+ using the streamer program). It's a servo controlled talking skull built by my friend, Jack Mangano. Jack's skull is something to consider if you want a very special greeter or talking Halloween attraction and you don't mind spending less that half of what a well-known commercial product goes for. Don't wait too long to get your order in with Jack, he's going to be very busy. And, yes, Jack uses the the streamer and player programs with the HC-8+ and AP-16+ for his own and client projects. You can see a little demo video at www.youtube.com/watch?feature=player_detailpage&v=CUnMmFDUUMk.

I'll close with a few tips from my friend, Peter, who is an expert at talking animatronics (see his website www.socalhalloween.com for proof). If you're going to create a talking prop, make sure that the audio is clean (just the voice), and that you're only running the jaw movement until that is perfected. Once the jaw movement is ready, you can enhance the audio (I use Audacity for this) and add other movement tracks to the project.

To create the initial jaw movement, find the frame that is at the start of a syllable, and then open the mouth. Create a ramp on the other side that closes the mouth in about one second. Of course, most syllables are much shorter than this, so the jaw won't fully close before it is opened again. Remember that the lack of facial muscles and skin on many Halloween props removes information — we need to exaggerate the jaw movement a bit to make it seem natural to our eye.

Okay, then, have a safe, fun, and happy Halloween, and until next time, keep spinning and winning with the Propeller. NV
BEVEL GEARS

The new 32 pitch/24 tooth Actobotics bevel gears from ServoCity allow users to build right angle drives inside or outside of channel. These bevels work well for building differentials or any application where you need to transfer rotational motion 90 degrees.

Now offering both metric (4 mm - 6 mm) and SAE (1/4") bore diameters, these gears are appropriate for all kinds of applications. Simply slide the gear on the shaft and tighten the set screw. They are manufactured from hardened brass gear stock for extreme durability and strength. Prices start at $5.99/each.

REDESIGNED LINEAR SERVOS

A redesigned heavy duty linear servo is also now available from ServoCity. While a linear servo may appear similar to a linear actuator, it runs on a completely different signal. The linear servo can plug into just about any servo controller — wired or wireless. The advanced internal circuit board reads the PWM signal received from the servo controller and will precisely control the position of the linear servo. A PID algorithm is used in order to minimize settling time and overshoot.

The 24 kHz PWM output frequency creates very smooth movements without any PWM noise. The internal board is nearly bullet-proof as it’s protected against reverse polarity, over-current, and over-temperature. There is a built-in circuit (BEC) that supplies power (5V, 500 mA) to your servo controller so that everything can be powered off a single power source. The aluminum construction ensures tremendous durability and reliability.

These linear servos are offered in stroke lengths from two inches up to 12 inches; the extension shaft is .785" in diameter. Mounting points are 5/16" diameter and are directly compatible with various ServoCity mounting brackets. Prices start at $299.99/each.

For more information, contact:
ServoCity
Web: www.servocity.com

If you have a new product that you would like us to run in our New Products section, please email a short description (300-500 words) and a photo of your product to:
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R/C AND SENSOR TRANSCEIVER MODULE SERIES

Linx Technologies announces the release of the first of many new RF modules in its next generation Hummingbird platform: the...
HOTROD YOUR ELECTRIC GUITAR WITH ACTIVE TONE CONTROLS

By Thomas Henry

In this day and age of highfalutin audio electronics, it is somewhat surprising that most electric guitars sport tone controls that weren't cutting edge even half a century ago. A new guitar still has a non-zero probability of sounding pretty "blah" no matter how good the pickups are. It may have a weak low end response, or perhaps the treble setting is dull. Maybe it doesn't offer much variation in tonal quality overall. This article describes a retrofit you can make that will give your guitar the controls it deserves. Even the most plain Jane instrument leaps alive with a full range of bass, mid, and high end color. Best of all, it does it quietly; noise, hum and hiss are simply not an issue thanks to several tricks explained here.

The Problem with Passive

To better understand the value of what's coming up, let's see how things are handled in a stock unit. The controls on a typical two-pickup electric guitar are often passive in nature (Figure 1). The capacitors shunt higher frequencies to ground, while their series potentiometers vary the amount of this action. Clearly, the most you could hope for with such a simple affair is the ability to gently roll off the treble response at about –6 dB/octave. The effect is so feeble that many guitarists simply leave the tone controls at full resistance and alter the sound on their amplifiers. Completing the circuit, two additional potentiometers directly parallel the pickups, providing control over the volume. In general, passive tone controls like this have a low input impedance which can load down the pickups appreciably. This typically results in an attenuation of the higher frequencies, yielding a sound lacking sparkle or brilliance. To lessen this effect, 500K potentiometers (a fairly high value indeed) are used throughout. This then raises the output impedance of the circuit, giving less than optimal results when
driving the audio cable and amplifier. Actually, it all gets quite complex with other matters such as signal-to-noise figures, RF interference, and even the capacitance of the connecting audio cable complicating the issue. In any event, the result is usually a poorer tonal response than we’d hope for even with the controls open full tilt. So, we have several problems to overcome. Passive circuitry like this: tends to load the pickups down; has a high output impedance less than ideal for driving the amp; and offers no more than a –6 dB/octave cut, which isn’t very inspiring.

**Enter the Active Controls**

Pretty clearly, the solution lies in internal active electronics. Commercial affairs didn’t appeal to me because of the price, and a search of previous DIY projects failed to turn up circuits with the features I desired. So, I decided to go it alone by starting from scratch.

What resulted is a tiny bit of circuitry fitting completely inside the electric guitar. It offers a whopping 15 dB of both cut or boost in three separate bands. Many people think of emphasizing a frequency range to be the touchstone, but actually the deep reductions possible with this unit are just as important. It is often the case that pickups on their own emphasize the midrange which (to my ears) yields a muddy result. With this circuit, it is possible to flatten out the response giving a fuller sound at the two extremes. Of course, with multiple bands, it’s possible to create all sorts of tonal mixtures right from your fingertips.

The benefits don’t stop there, however. Even if you ran this device flat (the bass, midrange, and treble controls set to their midpoints), your guitar would still sound more alive. The reason for this is that the pickups are now fully buffered. Loading and attenuation of the highs are nothing more than memories. Moreover, the output has a very low impedance, allowing you to drive any amplifier or effects device without losing crispness. Of course, this is also a preamplifier, which can boost the signal and may prove useful for overdrive applications, among other things. If this all sounds appealing, then let’s get into the circuit details.

**A Look at the Circuit**

Figure 2 shows the schematic for the active tone controls. We’ll move the pickup switch to the input of the rig now, which allows us to buffer any combination selected; compare the location of the switch in Figures 1 and 2 to see this. The wiring of your guitar may change, but you shouldn’t have to drill any new holes or leave old ones unused. (Many electric guitars have four potentiometer

![FIGURE 2.A three-band internal equalizer.](image)
holes with an additional hole for the pickup selector switch).

The pickups are buffered by IC1a. Recall that the non-inverting input of an op-amp sports an extremely high input impedance. So, now instead of a 500K pot bridging the pickups as in Figure 1, we have something on the order of many megohms doing so. In effect, we have completely unloaded the pickups, permitting every natural frequency component to pass with ease. The buffered pickups are then capacitively coupled by C6 to the remainder of the circuit which implements a three-band EQ. The basic topology for this comes from a manufacturer’s datasheet, Audio Handbook (Santa Clara: National Semiconductor Corporation, 1977), pp. 2-44 through 2-49, edited by Dennis Bohn. The frequency-determining components cluster around potentiometers R9, R10, and R11 which are the bass, midrange, and treble controls, respectively.

You’ll note that the entire three potentiometer structure is in the feedback loop of IC1b. As we’ll see in just a moment, it isn’t necessary to understand the mathematics of this circuit in order to customize it. If you’re interested, the datasheet mentioned gives the details of the derivation. By the way, the only purpose of capacitor C1 is to suppress spurious supersonic oscillations or RF interference. Finally, the output is AC coupled by C7 to volume control R5. By using capacitive coupling here, any small DC offsets are blocked from hitching a ride to the volume pot, which typically results in scratchy noise as the control is rotated. I suppose it would be possible to run this affair on a single battery with some additional components, but I decided to go with two for several reasons: There’s more headroom, even with all the boost available; clipping is never an issue; most op-amps perform better on a dual supply; a single supply requires additional components; and in any event, the two batteries last darn near forever since this is a low current affair.

**Personalizing the Frequency Response**

Let’s get serious about investigating what you can expect from the tone controls. When I first set about this project, I spent many hours pondering exactly how I wanted my axe to perform. I decided that my goal was to attain a full-bodied sound with decent control over the bass, midrange, and treble, but not really get into wild special effects. I next ran repeated SPICE simulations to see how the controls would interact. Don’t kid yourself. A three-band circuit like this is going to lead to some incredibly messy and difficult equations on paper. The only reasonable approach nowadays is to model the behavior on the computer before committing. The values shown in the schematic of Figure 2 are those from the original datasheet mentioned earlier, and they worked very nicely on my Gibson Les Paul Standard. On the other hand, I ended up tweaking various values when I built another version for my less expensive Epiphone guitar. When the three controls are centered, the response is essentially flat, as the computer simulation software will confirm (more on that in a moment). Figure 3 shows what happens when you cut or boost the bass,
midrange, and treble. The vertical axes are measured in decibels, while the horizontal axes are laid out in octaves (each tick mark represents a doubling of frequency). As you can tell from the curves, this circuit offers more than you’d ever find in the passive controls of the typical electric guitar.

I also ran checks on how the three bands work together. I essentially tried every combination of boost or cut for each of the bands in pairs, and then in trios. Don’t feel obligated to stick with my choices. Altering the response is as simple as changing the capacitor or resistor values around any of R9, R10, and R11. In any event, the basic topology (and hence the printed circuit board; PCB) remains unchanged, so you can go with any option you want. Now’s your chance to personalize things! Do what I did — run the simulation software to arrive at values you like best. “A Touch of Spice,” by Peter J. Stonard, Nuts & Volts, Dec 2008, pp. 50-56 will get you started, and even tells you where you can locate the software for free.

Getting Ready to Build

So, we now understand the basics of the circuit and presumably you’ve arrived at some component values to give you the response you’re after. Electronically, this is an easy project to construct but putting it inside your guitar takes patience, care, and attention to detail. I’ll explain the steps I took (which worked out remarkably well, I must say), but you’re on your own here. You’ll have to decide if you have what it takes to work neatly on an instrument you love. That said, here’s what I did. The first step was to gut the guitar of the existing passive circuitry. As mentioned earlier, I’ve actually done this on two guitars now. To make the discussion specific here, I’ll show you how it went on my road-worn but trusty Gibson guitar. Similar steps should apply to other instruments.

I began by opening up the three cavities housing the existing controls, the pickup selector switch, and the output jack. I carefully desoldered the pots, switch, and jack. The first step was to rewire the switch as indicated in back as in Figure 2. I made it a point to label the various wires running throughout the channels in the body of the guitar as I went along. The pots were set aside altogether since I opted to start over again with four new and better quality ones. (I did save them in case I ever wanted to revert to stock again.) The main thing here is to clean out the cavities completely, which will probably entail vacuuming the sawdust left by the manufacturer (I’m not kidding). Incidentally, now’s the time to work out the replacement potentiometer business. Both Jameco and Mouser had the knurled shaft pots I needed for my two guitars, but you might have to scout around depending on your make. The main thing here is that I only took advantage of existing holes; once complete, there was no change to the external appearance of either instrument.

Now comes an aspect that’s just as much a part of the success of this project as anything. Most guitars are simply wood and little more. Thus, the cavities housing the controls, switch, and jack are not shielded and open to attacks from 60 cycle hum. To save money, guitar makers get around this by running a wire from the metal bridge of the guitar to ground. The general idea is that when your body is in contact with ground through the strings and bridge, it acts as a shield in some strange sort of way. (Don’t ask me how it works, but it does). I don’t know about you, but I don’t really like being a conductor. If hot and neutral to the AC supply of the guitar amplifier and the PA system, say, are flipped, then you’re really opening yourself up to a shock hazard. (You can probably tell I’ve spent some 20 years of my life playing dilapidated ballrooms with substandard wiring.)

My solution was to completely remove the connection from the bridge to ground, and simply shield all inner surfaces with copper foil tape. So, locate the single wire coming from the bridge to the main control cavity, desolder it from ground, wrap it up, cover it with electrician’s tape, and poke it in an out-of-the-way spot. Don’t just clip it off in case you later discover you really do need it to avoid hum problems. Next, using copper foil tape, completely cover the inner surfaces of the three cavities.
The tape is conductive on both the front and back sides, so you can overlap things bit by bit with smaller pieces to blanket even the most curvy area. Figure 4 shows this in progress for the control cavity. When you’re done, screw a solder lug into the wood so that it contacts the foil, and connect a single ground wire (from the output jack, say) to ensure each cavity is grounded.

Don’t forget to apply foil to the back side of the covers; you can also see this in Figure 4. Once the seals are in place, all of the pots, the switch, and jack are completely enclosed just as if you had built them within a metal box. I’m amazed at how well this all worked. I have no hum whatsoever, and best of all, will never have to worry about sparks from the lips again. You can seal up the switch cavity now, but leave the control cavity open since we still have to implant the electronics.

Bring On the Circuitry

Now comes the easy part. Building the active tone control is quite straightforward. Since this has to fit inside the control area along with four pots and two batteries, space is at a premium. For that reason, a PCB is the only way to go. Artwork is available at the article link, while Figure 5 here shows the parts placement guide. Be sure to check all electrolytic capacitor polarities carefully, as well as the orientation of IC1. The potentiometer wiring scheme is depicted there, as well. Notice too that the pot lugs are numbered on the schematic which helps keep you from wiring them backwards. Speaking of which, it makes sense to prewire the potentiometers as much as possible since the control cavity is fairly tight to be sticking a soldering iron there.

One final detail. The active tone controls give a flat response when in their central positions. This means that you’ve got to be able to find that setting easily. A neat solution is to use some nickel-plated knob indicators which are secured in place over the pot bushings by the pot nuts. The pointers remain static while the numbering on the knobs register against them as the controls are turned. In my setup, when the bass, midrange, and treble controls are aiming at 5, then I know I’m at my flat reference point. Moreover, when the volume control is at 5 as well, I’m at the correct “normal” level for my system. The Parts List describes where you can locate the knob indicators and other items out of the ordinary. So, if Dullsville is the name of your guitar, consider resuscitating it with active tone controls. It takes care and planning to perform surgery on a valued instrument, but it really paid big dividends in my case. I hope it does for you too!

---

**ITEM** | **DESCRIPTION**
---|---
Fixed resistors are 1/4 watt, 5% values. |  
R1, R2 | 1.8K  
R3, R4 | 3.6K  
R5 | 10K linear potentiometer  
R6 - R8 | 11K  
R9, R10 | 100K linear potentiometer  
R11 | 500K linear potentiometer  
All capacitors are 16V or better. |  
C1 | 10 pF disc  
C2, C3 | 0.0047 μF mylar  
C4 | 0.022 μF mylar  
C5 | 0.047 μF mylar  
C6 | 1 μF electrolytic  
C7 - C9 | 10 μF electrolytic  
Semiconductor |  
IC1 | TL072 dual op-amp  
Other components |  
J1 | 1/4" phone jack, with DPDT switch  
B1, B2 | 9V battery  

**Parts List**

Printed circuit board, IC socket, battery snaps, copper foil tape, knobs, knob indicators, wire, etc.  
Most of these parts are available from any number of electronics suppliers. The more unusual copper foil tape, switching jack, and knob indicators are available from: Stewart-MacDonald  
21 N. Shafer Street  
Athens, OH 45701  
www.stewmac.com

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The job is done and ready to be sealed up.
Readers of this magazine have probably come to realize that I am enamored with microcontroller projects that blink and flash. Examples that have been published in this magazine include:

1. The Infinity Portal  
   August 2011  
2. The Desktop Contemplator  
   Dec 2012  
3. Smart Necklace, July 2013  
4. A Unique LED Clock  
   March 2014

The availability of faster and faster microcontrollers and individually addressable RGB LEDs is a dream come true for someone like me. So, it probably comes as no surprise that when I saw a panel of 32x32 RGB LEDs (1,024 LEDs total) at a reasonable price, I jumped at the chance to build something with it. This is the same type of panel described in the article, "Giving Life to the Adafruit 32x32 RGB Matrix Panel" by Theron Wierenga in the July 2014 issue of Nuts & Volts.

I have dubbed this project “The Light Appliance” because it can be made to do so many fun, interesting, and creative things. In a nutshell, the Light Appliance is an Infrared (IR) remote controllable 32x32 RGB LED display that with the hardware and software I will describe:

1. Can run approximately 30 highly colorful graphics routines including plasmas and fractals.  
2. Can function as an Open/Closed sign for a business.  
3. Can function as an analog or digital clock with battery backup.  
4. Can function as a decorative mood light.  
5. Does real time decoding and display of animated GIF images in 32x32 format.  
6. Has general, Christmas, Valentine’s, Halloween, and 4th of July animation modes for your holiday parties.  
7. Has time, date, and temperature display modes.  
8. Can function as a canvas for painting with the remote control.  
9. Can play numerous classic computer games such as Snake, Pac-Man, Ending, and Breakout.
If you have a fascination with projects like this, you can build a Light Appliance of your own. If you have modest electronic skills, can solder, and read a schematic you should be good to go. A somewhat dated video of the Light Appliance in operation is available at www.youtube.com/watch?v=VrOEJqX1-mE. Many new functions have been added to the unit since this video was made, but it will give you an idea of how things work.

**Hardware**

The brains of the Light Appliance is a Teensy 3.1 microcontroller. This controller is much more powerful than your typical Arduino at only about a quarter of the size. Table 1 details the relevant specifications; a Teensy 3.1 controller is shown in Photo 1.

Paul Stoffregen of pjrc.com designed and manufactures the Teensy 3.1. Through hard work, he has made the Teensy usable in the Arduino Integrated Development Environment (IDE) and has ported many of the most popular Arduino libraries to the Teensy, as well. This means you can develop code in the Arduino IDE and download it via USB to the Teensy just as you would if you were using an Arduino. He calls his adaptation of the Teensy into the Arduino environment, Teensyduino. (More on the Teensyduino software shortly.) Cheers to Paul for a job well done. After using the Teensy 3.1 in a couple of projects, I’m really impressed with its quality and performance. I don’t think I’ll use a stock Arduino again.

Note, the Teensy 3.1 must be modified when used in this project. On the bottom of the printed circuit board (PCB), there is a trace between two pads that must be cut which prohibits powering the Light Appliance display from the USB port. These pads can be seen about halfway down at www.pjrc.com/teensy/teensy31.html in the Pinouts section. Check out the upper right portion of the rear view of the Teensy 3.1 labeled VUSB. An X-ACTO™ knife works great for making this cut.

The 32x32 RGB LED matrix we will be using is shown in Photos 2 and 3. I won’t go into the specifics of the electrical interface required for driving the matrix since all of that is taken care of for you if you use the circuitry

<table>
<thead>
<tr>
<th>Feature</th>
<th>Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU – ARM Cortex-M4</td>
<td>Clocked at up to 96 MHz</td>
</tr>
<tr>
<td>Flash (program) memory</td>
<td>256 KBytes</td>
</tr>
<tr>
<td>RAM</td>
<td>64 KBytes</td>
</tr>
<tr>
<td>EEPROM</td>
<td>2 KBytes</td>
</tr>
<tr>
<td>DMA channels</td>
<td>16</td>
</tr>
<tr>
<td>Digital I/O</td>
<td>34 3.3V and 5V tolerant pins</td>
</tr>
<tr>
<td>ADC (analog-to-digital converters)</td>
<td>2 with 16-bit resolution</td>
</tr>
<tr>
<td>DAC (digital-to-analog converters)</td>
<td>1 with 12-bit resolution</td>
</tr>
<tr>
<td>Timer/counters</td>
<td>12 total</td>
</tr>
<tr>
<td>USB ports</td>
<td>1</td>
</tr>
<tr>
<td>Serial ports</td>
<td>3</td>
</tr>
<tr>
<td>SPI ports</td>
<td>1</td>
</tr>
<tr>
<td>I2C ports</td>
<td>2</td>
</tr>
<tr>
<td>CAN bus</td>
<td>1</td>
</tr>
<tr>
<td>I2S audio port</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1. Teensy 3.1 Specs
shown on the schematic in Figure 1. A Parts List is shown in Figure 2. The Light Appliance was designed with flexibility in mind. It is possible to build a base system without a Real Time Clock (RTC), without an SD memory card, and without the temperature sensor if you so desire. Doing so, however, severely limits the functionality of the Light Appliance. If you want to include the RTC, you must solder a 32.768 kHz crystal onto the bottom of the Teensy.

Power Input

+5VDC 2A min

Teensy 3.1

Optional Battery for RTC

BATTERY

32.768 KHz

Optional Crystal for RTC

Optional Temperature Sensor

IR Receiver/Detector

Teensy must have VUSB separated from VIN (via trace cut) and must have 32.768 KHz crystal soldered on back of PCB for RTC

Circuit can be built on breadboard or a pixelmatix.com shield can be used. If shield is used the battery, SD card, temp sensor and IR receiver can be wired to expansion connector.
3.1 controller (see www.pjrc.com/teensy/td_libs_Time.html#teensy3). If you want to have a battery backup for your RTC, you need to incorporate the optional 3V battery with the connections shown on the schematic. If you want to include the temperature sensor, you must add a DS18B20 sensor and 4.7K resistor, and connect as shown. NOTE: This sketch will need modification if one or more of the optional hardware items are left off. We will show how this is done in a bit.

I have built two Light Appliance units. The first, I wired up point-to-point on a breadboard using the circuitry shown on the schematic. Unfortunately, it was kind of a mess, and eventually something shorted out and caused my Teensy to emit the magic smoke that we all try to avoid. Luckily, there is an alternative which saves some of the breadboarding effort. Louis Beaudoin of pixelmatix.com has made a SmartMatrix Shield Kit for Teensy 3 which makes for a much neater and robust build. I used his shield for my second Light Appliance. Photo 4 shows the assembled shield with the Teensy installed. An expansion connector on the side of the shield makes most of the Teensy 3.1 pins available that are not used in driving the matrix.

All of the optional hardware components that I have designed into the Light Appliance still need to be built on a breadboard of some type and attached to the expansion connector on the shield. NOTE: The connection for the RTC backup battery is not made available on the expansion connector, so it has to be soldered directly to the Teensy PCB. Don’t get me wrong. Building your unit on a breadboard without the shield is definitely doable if you take your time and double-check your work.

My Light Appliance is powered by a five volt/two amp DC power supply that is external to the device itself (it’s a wall wart type of power supply). You, of course, could choose to build the power supply into your device. Two amps is the absolute minimum rating for the power supply. If all LEDs are run at full brightness — which would be blinding (think Time Square brightness) — a larger power supply would be required. My Light Appliance sketch intentionally reduces the brightness of the LED panel to reduce power consumption and to keep the brightness at a level appropriate for my living room.

**SD Memory Card Prep**

The Light Appliance uses an SD memory card (2 GB or less) for storage of animated GIF files. The SD card is prepared as follows:

1. The card must be formatted in the FAT16 format. You do this using a formatting program such as www.sdcard.org/downloads/formatter_4/ or by using the file manager/explorer on your computer. Don’t do a quick format; do a full format of the card.
2. Create the following directories off of the root directory of the SD card:
   A. *gengifs* - which will contain the general animated GIF files
   B. *xmasgifs* - which will contain the Christmas themed animated GIF files
   C. *halogifs* - which will contain the Halloween themed animated GIF files
   D. *valgifs* - which will contain the Valentine’s Day themed animated GIF files
   E. *4thgifs* - which will contain the 4th of July themed animated GIF files
3. Download the file *Lindley_Animated_GIFs_Collection.zip* at the article link and unzip it.
4. Copy the animated GIF file from the unzipped file to the corresponding directories on the SD card.

NOTE: You can add your own animated GIF files to these directories as long as they are 32x32 resolution.

**Software**

The software for the Light Appliance consists of two major parts: the low level driver for the LED matrix panel and the Light Appliance sketch itself (*LightAppliance.ino* along with its associated files). The panel driver that I use was also written by Louis Beaudoin. This is an amazing piece of software that allows the panel to run in 24-bit full color mode with a 120 Hz refresh rate which results in a totally flicker free display. To make things even better, the panel is driven in the background using the Teensy 3.1 Direct Memory Access (DMA) hardware which makes almost all of the microcontroller’s considerable processing power available to our application. Louis’ driver also supports drawing pixels, lines, rectangles, circles, etc., to the display, in addition to the low level driver functionality. Props to Louis for making the driver available to everyone on an open source basis. There are other less capable drivers for this panel available but this is the best one I have found for this application.
All of the Light Appliance and supporting software is available free, but you must still configure your development computer to be able to use it. I develop on a Mac but you can do everything on a PC, as well. Links to all of the required and optional software are listed in **RESOURCES**. Use the following as a check list to make sure you have all the required parts:

1. If you haven’t already done so, download and install version 1.0.5 or newer of the Arduino IDE.
2. Download and install the Teensyduino add-on.
3. Connect your Teensy 3.1 to your computer via a USB cable. You should see the LED on the Teensy blink once a second; the Blink sketch is loaded into the microcontroller during the manufacturing process.
4. Set the board in the IDE Tools menu to Teensy 3.1 and set the CPU speed to 96 MHz (overclock). Pick a serial port for use with the IDE’s serial monitor that is appropriate for your development computer.
5. Load the Blink example sketch into the Arduino IDE. Click the verify button to compile the sketch to verify your setup.
6. Click the Upload button to program your Teensy 3.1 with the Blink sketch, then verify the LED still blinks and that no errors occurred.

7. Close the Arduino IDE.
8. Insert your newly prepared SD card into its socket.
10. Download the file Lindley_LightApplianceLibraries.zip and unzip it. Copy the contents of the zip file into your Arduino libraries directory.
11. Restart the IDE, load the Light Appliance sketch, power up your Light Appliance, and click the Upload button to program your Teensy 3.1.

If all is well, you should see your display light up and be able to control your Light Appliance with the remote. The Light Appliance sketch assumes — by default — a full hardware build. As mentioned, the unit can be built leaving out some hardware components, but modifications to the sketch will be required to support this. Find the following code at the top of the sketch **LightAppliance.ino**:

```cpp
// Define the optional hardware. If missing hardware set value to 0
#define HAS_RTC 1
#define HAS_TEMP_SENSOR 1
#define HAS_SD_CARD 1
```

If you don’t want to use the RTC, set **HAS_RTC** to 0. If you don’t have the temperature sensor connected, set the **HAS_TEMP_SENSOR** to 0. If you aren’t going to use the SD memory card, set **HAS_SD_CARD** to 0. By doing this, you remove the functionality the hardware device would provide. Removing the SD memory card functionality means the Light Appliance cannot display animations which, in my opinion, is the best feature.

If you would like to try out the Painter sketch, load it into the Arduino IDE and reprogram your Light Appliance with it. There is a read me file in the sketch directory which details how to use the program.

### Controlling It

The Light Appliance is controlled via the nine button SparkFun IR remote control shown in **Photo 5**. The basic functions of the buttons are detailed in **Table 2**.

Controlling the Light Appliance with the remote will become second nature after a little practice.

### Packaging

Being a woodworker, I decided to build a custom case for my Light Appliance (see intro photo). I had a broken display case laying around which had nicely carved wooden sides, so I made my enclosure from that. An off-the-shelf packaging alternative is an 8” x 8” black shadow box from Michaels (item# 10223090) which is almost a perfect fit. If you use the shadow box, you might want to

<table>
<thead>
<tr>
<th>Button/Key</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Symbol</td>
<td>If the Light Appliance is off, it turns it on. In a submode like Patterns, brings you back up to the main mode selection mode.</td>
</tr>
<tr>
<td>A</td>
<td>Used in Mood Light mode to turn on all LEDs.</td>
</tr>
<tr>
<td>B</td>
<td>Used in Mood Light mode to turn off second LED.</td>
</tr>
<tr>
<td>C</td>
<td>Used in Mood Light mode to turn off every third LED.</td>
</tr>
<tr>
<td>Up Arrow</td>
<td>Used to increase a value as in incrementing the minutes count of the RTC. Also used for navigation in the games.</td>
</tr>
<tr>
<td>Left Arrow</td>
<td>Used to select a previous function or used for navigation in the games.</td>
</tr>
<tr>
<td>Select or 0</td>
<td>Selects the current function.</td>
</tr>
<tr>
<td>Right Arrow</td>
<td>Used to select the next function or used for navigation in the games.</td>
</tr>
<tr>
<td>Down Arrow</td>
<td>Used to decrease a value as in decrementing the minutes count of the RTC. Also used for navigation in the games.</td>
</tr>
</tbody>
</table>

**Table 2. Remote Control Button Functions.**
RESOURCES
The following sources provide more information about this project and its background.

- For information about and/or to purchase the Teensy 3.1 microcontroller board, go to www.pjrc.com. There is a forum for information about the Teensy line of microcontrollers at [http://forum.pjrc.com/forum.php](http://forum.pjrc.com/forum.php). Questions regarding the Teensy should be directed there.
- The Teensyduino (version 1.18 or newer) software development add-on to the Arduino IDE is available at [www.pjrc.com/teensy/teensyduino.html](http://www.pjrc.com/teensy/teensyduino.html) as are instructions for installing it.
- Information about the SmartMatrix kit and/or the SmartMatrix driver can be found at [www.pixeMatrix.com](http://www.pixeMatrix.com). The most current version of the driver is available at [https://github.com/pixeMatrix/SmartMatrix](https://github.com/pixeMatrix/SmartMatrix).
- The collection of animated GIF files for the Light Appliance is contained in a file called Lindley_Animated_GIFs_Collection.zip. The Light Appliance and Painter sketches are contained in a file called Lindley_LightAppliance-PainterSketches.zip. The libraries required for the Light Appliance are contained in a file called Lindley_LightApplianceLibraries.zip. All of these files are available for download at the article link.
- Jason Coon ported the computer games to the Light Appliance.
- Other microcontroller based projects of mine can be found at [www.craiganheather.net/celepage.html](http://www.craiganheather.net/celepage.html).
- For background information about GIF files, computer graphics, and image processing, see my book *Practical Image Processing in C*, published by John Wiley & Sons. This book is out of print but used copies are available from many sources.

experiment putting various materials between the LED panel and the glass front to diffuse the light from the LEDs. Even a single sheet of paper has a visible effect. Drafting film could be used for even more diffusion. A sheet of thin white translucent acrylic would really blur out the display and produce some rather spacey effects. However you decide to package your Light Appliance, make sure to position the IR receiver/detector so that it’s visible from where you plan on controlling your device.

Now, go light things up! NV
I’m lucky to get to see and work on a lot of vintage radios and stereos at my small shop in Seattle, where I repair all kinds of gear from early tube radios going up to the modern era. This 1963 Zenith hi-fi stereo console is one of my favorites. The classic styling would look great with modern accents, too — it would look just as good with a flat-screen TV on top instead of a typewriter, and could even play its audio (Figure 1).

This was a top-of-the-line piece in its day, built by hand in the USA with precision electronics, carefully selected speakers, and a heavy wooden console cabinet made to be a prominent piece of furniture in the home. With a total of 19 tubes, it could really heat up a room.

This particular model came with a pair of efficient, fantastic sounding three-way speakers with powerful magnets driving a 12” woofer, twin smaller cone midranges, and a horn tweeter. When running properly, it sounds lively and musical — so when it started to sound worse and worse and take a longer and longer time to warm up, its owner knew something was going wrong. I made a house call to remove the guts; there were two big metal chassis: one for the amplifier and power supply; and a second for the tuner and pre-amp (Figure 2).

The front control panel is a masterpiece of space age design. It looks like the control panel of an old rocketship.
Preserving a piece of stereo history ... a tube console stereo repair story.

Don't just plug in a piece of vintage gear you find to see if it works! This can be dangerous and might cause a fire or shock, depending on its condition. Solid-state gear after about the mid-'60s can be powered on safely to see if it hums or makes any sound, but most tube gear from the early '60s and before probably needs service before it will work safely and reliably. Early electronics used parts which break down with age just sitting on a shelf, and it only takes a few seconds for something to go seriously wrong and burn up an important component.

I think that’s one of my favorite things about this stereo. It has quite a few functions: there’s the function selector on the left; the tuner, loudness, and balance on concentric controls in the middle; the stereo function switch; the power switch along the bottom; and along the side, separate treble, bass, and presence controls. It’s fully customizable (Figure 3).

Digging into the Repair

The amplifier chassis — hidden inside the cabinet — is a lot more minimal. There’s the output tubes: a pair of 6BQ5s for each left and right. You might know them as EL84s, and in this amp they produce a nice clean sound with plenty of power for the efficient speakers they’re driving (Figure 4).

It’s pretty chaotic underneath. By this time, they’d invented printed circuit boards but they hadn’t taken over yet, and many consumer electronics just used good old fashioned point-to-point wiring. It works, but it can look like a hot mess! With the components spaced so far apart, though, it’s easy to give it a quick look-over for obviously bad parts — and there’s a problem that shows up right away (Figure 5).

This capacitor is attached to the power amplifier circuit — and it’s blown a piece of its plastic casing clean off! Modern capacitors are made of durable and reliable materials — often plastic and metal films and ceramics. Back then, though, these materials had just started to become available, and most electrical components were still ultimately made of paper and foil with special packaging. This one used a plastic and epoxy package but over 50 years, the paper and foil degrade and start to leak electricity. This creates a heat build-up that can release gasses which expands in the sealed body, and ... pop! Off goes a piece of plastic.

Even with this failure, the amp continued to try and play — vintage gear can really take a beating. Once the parts get to this stage, though, there’s no sense in just replacing a few. They’re all the same age and they’re all...
going bad, even if a few have somehow survived this long. It’s time for a complete overhaul to make sure it stays a great performer for a long time to come (Figure 6). It’s handy to have some special equipment for working on tube gear, but you don’t really need much more than a soldering iron and multimeter to take care of most of the basics. In this case, though, I started off testing the tubes; a few in the radio needed to be replaced but most were good. This radio was handed down from the current owner’s parents, and they’d looked after it over the years, replacing some of the power tubes as they’d worn out, but most of the others were the original Zenith parts (Figure 7).

I went slowly, replacing the components as close to their locations as possible. Old capacitors were usually made of paper and foil; old carbon composition resistors tended to absorb moisture from the atmosphere over the years and change in value. Resistors which dissipate more power and put out more heat tend to have it worse. I tested a sampling of the resistors to check their tolerance, paying special attention to the bias resistors. Only a few had drifted past their marked tolerance bands and needed to be replaced. Zenith picked good quality parts when they built this originally. Most of the resistors were stable, even over more than 50 years (Figure 8).

The amplifier and power supply were great to work on, with a ton of room and a clean easy-to-follow layout. The tuner and pre-amp chassis was a different story. It’s a densely packed multi-layer maze of different construction resistors and capacitors, mixed in with a few coils and sockets for good measure.

Zenith mixed and matched a few styles of capacitors

As with all electronics projects, take proper safety precautions while servicing a vintage radio or stereo. General precautions always apply, but tube electronics run on much higher voltages than solid-state gear, plus tubes get extremely hot while operating. Be careful of unsafe vintage wiring schemes that put mains voltage on exposed bare metal parts of the chassis like control shafts. Go slow and be careful!

Figure 6. The Precision 10-20 tube tester.

Figure 7. Underside of the 7K31 amplifier after replacing the bad capacitors.

Figure 8. The chaotic underside of the 12K25 tuner chassis.

Tubes were designed to last a long time, and they don’t generally go bad on a shelf. So, unless it was just rode hard and put away wet its entire life (or hit by a power surge), most of the tubes you find are likely to be good. Some tubes which develop a white coating inside have lost their vacuum over the years, but most will probably be in good shape. Even if not, you can track down new old stock replacements for most tubes without too much trouble.
while building this, which makes it a bit tough to tell if something is a replacement or original. There’s the “black beauties” — the black cylinders with color bands similar to a resistor. There’s more of the epoxied plastic paper capacitors in white; a handful of classic cardboard capacitors; and a handful of assorted early film or paper/mylar caps — not to mention two styles of disc capacitor, and several mica “domino” rectangular capacitors.

I had to work with needle-nose pliers in each hand for most of the tuner section repairs to thread the parts exactly where they were originally. These high performance circuits were sensitive to positioning, so even changing where the wires run or the components hang can cause problems with reception and feedback (Figure 9). The tuner section had a mix of older style and newer style capacitors. The Sprague is probably a coated paper model; I always make sure to replace ones like that when I see them so they don’t cause problems later on (Figure 10).

Most tube amplifiers used output transformers to connect to the speakers. Zenith ran the leads for both speakers to a terminal strip on top of one transformer with convenient color-coded labeling. One thing that’s pretty unusual about this Zenith is the output transformers had separate windings for different drivers. The 12” woofers are on their own secondary from the horn and midrange drivers.

I’ve run into a few Zeniths which used a similar scheme, but I’ve never seen another manufacturer do this. (Feedback windings and matching taps are pretty common — but multiple driven secondary windings seem to be pretty rare!)

**Finishing Up**

I hooked up a whole mess of clip leads to four bench speakers for testing since I’d left the original drivers mounted to the cabinet. With resistors and capacitors replaced, it’s safe to run the stereo for the rest of the process: alignment, bias adjustment, and burn-in testing. I started with the bias adjustment since that will ensure safe amplifier operation and good sound quality through the rest of the process (Figure 11).

In this photo, I’m adjusting the bias potentiometers. I hooked my multimeter up to the underside while making these adjustments since (at the time) I didn’t notice the convenient top side test points they provided. Oh well! Both channels were really pretty close already, but I tweaked them to perfection for good measure. With the amplifier section sorted, it was time to move on to the tuner alignment.

For a receiver, alignment is the process of adjusting the tracking and reception of the tuned circuits for the best performance. If you’ve ever owned an older piece of...
gear like an FM radio, you know that sometimes the dial indicator can get out of sync with the stations, making them come in at the wrong locations on the dial. Sometimes, components drift and settings change, and this can cause distortion in the audio or weak reception. With an accurate signal source, you can adjust the tuned circuits in the receiver to bring everything back to where it should be.

Alignments can be a bit tricky. There are several adjustments to make in an alignment for a receiver like this one, since there are separate adjustments for every stage for both AM and FM independently. In all, the radio needs the antenna, front end RF amplifier, dial tracking on both the high and low sides, and the intermediate frequency stages all to be re-tuned. Plus, on the FM side, there’s a series of additional adjustments for the stereo functionality. All told, there’s eight RF transformers in this radio, plus four coils used in the FM stereo de-multiplexer (Photo 12). It’s fairly easy to do an AM alignment “by ear” using nothing but an adjustment wrench and whatever broadcast stations you happen to be able to receive with a short antenna. AM radio is a very simple technology that’s been around over 100 years, so there’s really not much to it in most cases.

An FM alignment is a lot more challenging, though. It’s possible to do an FM alignment with a multimeter and an AM signal generator (and a fair amount of patience), but for best performance you generally need a sweep signal generator or an FM signal generator and an oscilloscope in addition to the multimeter. Trying an FM alignment by ear usually doesn’t turn out well (Photo 13).

Since there’s so many adjustments, I didn’t take a photo of each individually, but I did a full AM and FM alignment. The AM side only needed minimal adjustment as it was coming in pretty close. The FM side was still in great shape, needing just minor adjustments to bring it back to full performance. Miraculously, the FM stereo tuning was in perfect shape and didn’t need any adjustment at all. Zenith’s quality really showed here; the adjustments stayed solid for 50 years (Figure 14).

All told, this vintage hi-fi stereo console took quite a bit of work to clean up, but it turned out fantastic. I replaced a few burned out light bulbs on the dial to make it really shine. It was a real shame when I had to take it back to its owner after letting it play on my bench for its

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**Guglielmo Marconi** developed the first commercial radio system in 1894, but it wasn’t until 1906 when Reginald Fessenden and Lee de Forest developed Amplitude Modulation (AM) that radio started to explode, and it didn’t make it into most households for another two decades. The technology is mostly unchanged since then. A radio made back in 1924 will happily tune in one of today’s AM stations.

**Figure 12.** The tuner chassis showing all eight of the RF transformers to adjust.

**Figure 13.** Adjusting one of the RF transformers with a non-inductive alignment tool.

**Figure 14.** All lit up like the cockpit of a space ship.
burn-in period. It sounded so nice!

I removed quite a few bad parts from the amplifier and tuner while it was on the bench: resistors, capacitors, bulbs, and a couple of tubes which tested bad. It looks like a handful all laid out (Figure 15).

It took me about 24 hours of working time, plus a few more for research and testing to bring this unit fully back to life. With the new parts and tubes and a full alignment, it’s back to playing as good as it did when new, and it will continue to be a great décor piece and functional stereo for many years to come (Figure 16). NV
The Prop Dropper 2 allows you to drop scary Halloween props such as bats and spiders onto unsuspecting trick-or-treaters and play scary sounds at the same time! Built around the Parallax Propeller microcontroller, this project is highly customizable and expandable.

History

In the October 2009 issue of Nuts & Volts, Vern Graner published his Prop Dropper project using the EFX-TEK Prop-1 controller, which is based on the Parallax BASIC Stamp 1. The project used a Parallax PIR sensor to detect motion, which then triggered a pair of servos to drop the ‘critter’ onto the ‘victim.’ If you haven’t seen this article, I highly recommend checking it out. Inspired by the simplicity of this project, I discussed with Vern the possibility of making an upgraded version, and the Prop Dropper 2 was born!

How It Works

The Prop Dropper 2 is very similar to the original in that it waits until a person is detected and then drops a prop nearby to scare them. As mentioned, in addition to dropping the prop, a sound (.WAV) file is played to add to the effect. But wait! There’s more! The Prop Dropper 2 also waits until the person moves again and then drops a second prop and plays a second sound file giving them an almost immediate second scare! You’re actually not limited to just two props and sound files. The Propeller chip provides sufficient I/O and resources to realize many droppers and the flexibility to configure things the way you want. More about that later.

When powered up using the...
code supplied at the article link, the Prop Dropper 2 will drop both props, wait three seconds, and then wind them up again while playing an evil laughing sound. This serves two purposes. First, it makes sure the props are both properly initialized in case the power was shut off in the middle of a wind up cycle. Second, it makes sure your sounds are playing properly.

Once the props are back in position, a Parallax PING ultrasonic range finder is used to detect when a person enters the target area. Once they do, the first prop is dropped and an accompanying sound file is played. When the person starts to move forward again, a second prop is dropped and that sound file is played. After the person leaves, the props reset and the system is ready to scare the next victim.

While a PIR sensor can be shrouded to focus the detection area to be more limited, I opted to use the PING sensor. This gives me the ability to see not only when someone is in range to drop the prop on, but I can detect their distance from the sensor. This means I can control which prop drops and when.

Like Vern’s original Prop Dropper, this unit uses two servos for each prop we’re going to drop. Each pair of servos consists of a tilt (standard) servo and a wind-up (continuous rotation) servo joined together. The tilt servo is responsible for tipping the wind-up servo, which inherently tilts the spool that holds the string the prop dangles from. By tipping the spool vertically, the string unravels all at once resulting in the prop dropping suddenly until it reaches the end of the string and stops. Figure 1 shows a completed dropper assembly installed on a board.

When we want to reset the prop, we simply move the tilt servo to set the wind-up servo (and therefore the spool) back to a horizontal position and then rotate the wind-up servo to raise the prop back up, ready to drop again.

Getting Started

You will need to copy sound (.WAV) files to the microSD card from your computer. A card reader or adapter may be required to connect the microSD card to your computer. I have tested the WAV player object with 11 kHz and 22 kHz mono WAV files in both an eight-bit and 16-bit format. I am unclear if other formats are supported by the object used. You can use a free audio utility such as Audacity to record, edit, and modify sound files.

In the Parts List, you will find the main Parallax components I used in this project, as well as other items used in the build. The first thing I did was set everything up on my desk as a prototype so I could make sure I had all the required objects for the hardware, and so I could center/calibrate the continuous rotation servos. In Figure 2, you can see my setup.

Prototyping is essential for hashing out designs like this because you have software and hardware components mixed together. In this case, I needed to synchronize the motions of several servos (both standard and continuous). I also tested each section independently before connecting everything together to make it easier to debug later. Servos are inherently slightly different from each other, so you have to test to find the right pulse values to make each servo do what you want.

Notes:
All connections are in relation to the Propeller Activity board.
Servo voltage jumper set to 5V.
All connections use servo headers.
Components shown are not to scale.
Building the Hardware

If I used this system in an actual haunted house capacity, things will likely need to be set up much differently. Each dropper assembly will need to be where it can be positioned effectively. A suitable audio system would need to be installed, etc. In this article, I will describe how I built the basic demo unit and offer some ideas for customizing and expanding it. Additional resources for some of these options are at the article link.

The first thing to do is put together the prop dropping assemblies which consist of one standard servo and one continuous rotation servo. In Vern’s original article, he hot-glued most of the parts together. I looked through my parts bins and found many miscellaneous brackets, so I decided to connect the servos in this manner for a couple reasons. One, if a servo was damaged, replacement would be easier. Also, I could handle heavier props without worrying about the servos coming apart. Figure 3 shows some of the servos with the various brackets needed to connect everything.

The standard servos horns were connected to the bracket that ties into the continuous rotation servo. The standard servos then mounted to my wood platform via some right-angle brackets. I chose to use wood spools available at any craft store and screwed the horn from the continuous rotation servo into the spool (Figure 4). It’s important to make sure the horn is centered before drilling into the spool, otherwise it will wobble when winding up the prop. This might cause the prop to bounce and not reset properly.

The hole in the spool allows you to screw the servo horn into the continuous rotation servo. With the brackets attached, that completes the wind-up stage of the servos.
Figure 5 shows a completed wind-up stage and the other continuous rotation servo ready to have the spool attached to it. Next, we'll attach the continuous rotation servo to the standard servo horn, completing the entire drop assembly (Figures 6A and 6B). This is duplicated so there are two droppers in the system. Each pair of servos was coupled using the same pieces of hardware. I cut the longer brackets down so they connected to the right-angle brackets mounted to the servos.

Now, it's time to connect these completed dropper assemblies to the Propeller Activity board. Take note of the I/O pin assignments in the code when connecting everything to it. My servo cables weren't long enough, so I got a three-wire extension cable pack and used several three-pin single row headers to extend the servo cables to the board as well as to the PING)))) sensor. I used a speaker and mounting bracket for programming and testing (Figure 7). Refer to the Parts List for specifics. All the servo connections and the PING)))) sensor connect to the servo headers on the Activity board. The microSD card is in the socket and the speaker is plugged into the audio jack.

Completed Hardware

In order to realize a working demo in a reasonable space, I attached all my parts to a 3' length of plywood to use as a platform. Figure 8 shows the demo completely assembled and ready for the props to be attached.

The power supply for the demo is a lithium-ion battery pack. I find these very useful for providing portable rechargeable power for my projects.

Writing the Software

As is typical for many programs based on the Propeller chip, the top object was written completely by me while several other objects from various sources were referenced to make use of some of the hardware. I implemented the Ping and Servo32 objects from the Propeller library, as well as the KISS WAV Player V2 written by Kye from the Parallax forums.

The program initializes the servo and WAV objects, then starts a loop where the droppers go through a reset phase, then wait for a person to scare. While the wind-up servos were idle, I adjusted the potentiometer on them so they didn't spin at all. This is the typical center calibration required for continuous rotation servos. It took several tries to get the exact pulse values to use for the tilt servos to get them to drop vertically and reset horizontally. These values were different for each tilt servo.

The same testing was required to get the wind-up directions and speeds. All these values get plugged into

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**Parts List**

Parallax Parts:
(1) - Propeller Activity Board (#32910)
(1) - 2 GB microSD Card (#32319)
(1) - PING)))) Ultrasonic Sensor (#28015)
(2) - Parallax Standard Servo (#900-00005)
(2) - Parallax Continuous Rotation Servo (#900-00008)
Assorted Three-wire Extension Cable Pack (#751-00010)
Three-pin Single Row Headers (#451-00303)
Veho Speaker (#900-00018)
Mounting Bracket (#725-32905)
Lithium-ion Power Pack Full Kit (#28989)

Miscellaneous:
Plywood
Wood spools
Hardware for your specific application/setup
the correct constants at the beginning of the code. I can guarantee the default values won’t work. Depending on the file names of your sound files on the microSD card, you will most likely need to edit the names in the code where the sounds are played. These are commented to make them easier to find.

**Ready for Testing**

The demo unit was placed on top of a ladder since that was the tallest platform I had available. I attached a bat and a spider that my wife picked up from a craft store. I loaded the microSD card with both a bat screech and scream WAV file, and adjusted the code accordingly.

When the bat drops, it makes a screech sound; when the spider drops, it makes a female scream/shriek sound. Of course, you can use any sounds you want or even record your own.

**Modifications and Expansion**

Typically, when I create a new project, I actually come up with different ideas for how things could be done while I’m building or testing the code. This time was no exception. As mentioned, the ZIP file at the article link will contain not only the schematic and code used for what is covered in the article, but also two variants I experimented with. V1.0 provides a single sensor for detecting people and a simple timed rewind cycle similar to what was used in Vern’s original Prop Dropper. V1.1 adds an infrared encoder to the wind-up servo, so that it will wind based on turns instead of time. V1.2 adds an extra PING))) sensor and allows each prop dropper to work independently rather than being synchronized with one sensor.

You can add additional dropper assemblies and even more sensors. One Propeller Activity board can control many sensors and servos, allowing for a good amount of expansion.

An XBee module could be added to integrate this system to another dropper or related project, synchronizing them. For more discussion about this or for questions or comments on the information given, please visit the project page listed in Resources.

**Final Thoughts**

The options here are nearly endless. Just put your imagination to work and you’ll soon come up with some very interesting and unique projects.

Have a Happy Halloween. I hope this project provides a welcome addition to your haunted house!
One of my favorite new trends when it comes to decorating for Halloween is using what is called "digital decorations." These are essentially digital animations that have been created to use for props during the Halloween season. These digital decorations range from family friendly frights to downright macabre and ultra-violent scares that can give even the most hardcore of Halloween fans a good startle.
ompanies such as AtmosFearFX offer a wide variety of digital decorations from friendly shadows to use in your upstairs windows, to home-invading zombies punching through your wall (Figure 1). With a little hunting online, you can find free animations that other Halloween fanatics have created and uploaded to places such as YouTube and various Halloween forums. You can use your imagination and creativity in numerous ways when it comes to setting up these digital decorations, but perhaps the easiest way is through the use of projectors.

Projectors have come a long way over the past few years. Evolving from large bulky items (Figure 2 and 2A), projectors are now small sleek devices that you can hold in a one hand (Figure 3). Some projectors can even be found in pocket-sized offerings now, which can lead to some really neat uses when it comes to decorating for Halloween.

The price for purchasing a projector has drastically changed, as well. While some projectors can still run in the thousands of dollars, there are plenty that can be purchased for way less. I was able to come across two small 3M mobile LED projectors last year online for $99 each.

There are other smaller projectors available for as little as $50 through various online resources; just do a Google search to see what you can find. With a little effort, you can get a projector to fit your budget.

Once you have a price range in mind, there are a few other things to consider when purchasing a projector. A unit’s brightness is measured in lumens, and most projectors will list the lumens/output right on the device. The higher the number, the brighter the projector will be.

Don’t feel like you have to purchase a projector based solely on its output. Surrounding light pollution can greatly affect a unit’s ability (Figure 4).

If the digital animation will be set in a dark area, a lower lumen projector will work just fine. If you are battling a lot of nearby light pollution — such as street lights or other sources — then be sure to look for units with a decent amount of output.

If you are looking to haunt a large scene (like your upstairs window with a passing ghost), I recommend a projector with at least 2,000 lumens. If you want to do something a bit smaller in scope and size (such as a haunted portrait or singing pumpkin), a unit with less lumens will do the trick.

Resolution is also something to consider when
purchasing a projector. Much like purchasing a TV or computer monitor, the higher the resolution, the more detail you will achieve with your image. While it’s important to have a nice resolution for watching movies or playing games, with a projector it’s not as important when using it for a digital decoration. In most cases, your display will be ghosts, shadows, and other such haunting things. A little fuzziness will only add to the creepy factor.

In addition to a projector, don’t forget music/sounds to play, as well! Most projectors will connect directly to a laptop or PC with either a DVI cable or VGA cable (Figure 5), and will allow you to play right from your hard drive. If having a computer near your projector is an issue, most units will also have other input options allowing you to use a DVD player or even a digital media player. Be sure to set your DVD player or media player to repeat/loop to keep the scare going.

Once you have a projector and a playback device picked out, it’s time to set everything up. Perhaps the easiest digital decoration to create is a haunted window (Figure 6). With numerous digital decorations available, windows make the perfect place to display them. Because you can’t simply project the image onto the window itself, it’s necessary to set up what’s known as a scrim.

This is a piece of material that appears to be opaque until lit from behind. The easiest solution to this is a cheap white plastic shower curtain. Simply raise your blinds and hang the shower curtain in the window.

Once the curtain is in place, make sure all the lights in the room are off and position your projector behind it. You will need to adjust the distance between the window and your projector until you feel the image size is adequate and provides a life-like representation of the particular display you are using (Figure 7).

Be aware the image will appear reversed to people viewing it from outside, so keep this in mind if you are using any displays that might include text or other such things. If everything is set up correctly, you should now have a haunted window complete with ghosts and other spooks that will appear out of the darkness. I took video of how the effect looks in my upstairs window (see Resources).

One upside to using small projectors is that they are easily hidden and can be mounted in places where people won’t notice them. These small projectors can be put inside a pumpkin or behind a tombstone. When coupled with a great digital decoration and a little imagination, you can create some really neat Halloween props that people will be sure to talk about.

Last year, I came across a few videos of people using

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**FIGURE 5. DVI - VGA.**

**FIGURE 6. Projected displays from AtmosFearFX.**

**FIGURE 7. Adjusting the distance for the projector.**

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**RESOURCES**

Video of my upstairs Halloween window projections from 2013  
http://youtu.be/5GPlboED520

Really awesome projector for home and yard haunts  
www.youtube.com/watch?v=RDJJMhgyRg

Eerie Acres Cemetery YouTube Channel  
www.youtube.com/channel/UCzJHc0LIEmdp1NUjbx3r4q

Eerie Acres website  
www.eerieacrescemetry.com/
There are numerous applications that these small projectors are perfect for. Create a wall full of scurrying insects at your next Halloween party, put a ghost at the end of a dark hallway, or even recreate the famous head of Madame Leota from Disney’s Haunted Mansion using a fishbowl with a blank white Styrofoam head in it.

Thanks to the recent affordability of projectors, media players, and new digital decorations being created each year, there is no limit to the fun that can be had! Happy Haunting!  

Don’t forget you can apply this technique to other holidays, birthdays, weddings ... any kind of special event.
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Open to the public
Dealer Room
Makeup Demos
Costume Ball
Prop Building Workshops
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Belle of Baton Rouge Hotel & Conference Center
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- USB or ethernet device
- with a rich set of features
- including PLC functionality and up to 8-axis stepper motor controller
- all accessible via free .NET, ActiveX or C++ library
- cross-platform
- configurable with free software

PoKeys

Or this...

- all in one: Oscilloscope, Data Recorder, Logic analyzer, Analog and digital signal generator
- smallest USB 2.0 portable 1MS/s oscilloscope
- data acquisition of analog and digital signals
- data recording
- export to CSV, XLS, PDF and HTML
- simple usage of advanced features
- examples for C++, VB, Delphi and LabView
- free software and updates

PoScope Mega1+

www.PoScope.com
Wiring and Testing the BalloonSat Extreme Flight Computer

Last time, we built the BalloonSat Extreme—an advanced BalloonSat flight computer based on a BASIC Stamp 2pe (BS2pe). Because of the BS2pe's memory banks, the BalloonSat Extreme lends itself extremely (get it?) well to modeling the integration of experiments into a single payload. I believe this process of experiment integration is a good activity for students as it simulates the work of scientists integrating their experiments into a single JPL spacecraft.

Wiring

There are a total of seven cables (for a total of 14 wires) in the flight computer. With the PCB (printed circuit board) turned so that the wires exit the top of the board, the wire pairs from left to right are: servo power indicator; servo power switch; servo battery; commit; main battery; main power switch; and main power indicator.

You may wonder why the BalloonSat Extreme uses separate batteries for the servo and main power. It’s because servos can draw a lot of current when stalled or under load, and we don’t want a distressed servo drawing so much current that it causes the BASIC Stamp to “brown out” (an unintentional drop in voltage that causes the Stamp to reset and begin executing its code from the beginning). A much more graceful failure mode is to have the servos fail to function properly without harming the operation of the flight program.

The wires are protected from breaking off by passing them through strain relief holes in the PCB. I’m a big proponent of strain relief; I’ve seen too many wires break in my student’s soldering projects. It’s important to protect wires because if they break during a mission, the experiments are likely to fail. All that money spent and no data returned.

Figure 1 shows an image of a wire incorporating strain relief. Notice that the wire passes through a larger diameter hole located at the edge of the PCB before it’s soldered to the board.

I recommend cutting the wires for the power switches, power indicators, and commit one foot long. For the main power, you can use a six volt four “AA” cell holder or a 7.2V rechargeable lithium polymer (LiPo) battery. Since servos work on 4.5 volts, you can use a three “AA” cell holder for servo power.

If you decide to use cell holders rather than LiPo batteries, then solder the battery holder’s wires to the PCB. If you opt to use LiPo batteries instead, then solder one foot long wires for main and servo power, and terminate them with the appropriate connector for the battery pack. I have found that rechargeable R/C car LiPo batteries work well for near space missions.

After soldering all 14 wires to the PCB, strip the opposite ends of the power switch, power indicator, and commit wires. Solder sub-mini toggle switches to the power switch wires and LEDs to the power indicator wires. Be sure to slide heat shrink tubing over the wires prior to soldering the switches and LEDs.

The last wiring step is the termination of the commit pin wires. A method I recommend is to solder the commit wires to the tabs of a female sub-mini (3/32”) mono jack panel mount. The commit pin is a male sub-mini mono jack with its tabs shorted together with a short length of wire. Refer to Figure 2. When the commit pin is plugged into the panel mount, commit is shorted out and the Stamp detects a logic low. When the commit pin is removed, the short in the commit is removed and the
Stamp detects a logic high.

Mount the power switches, power LEDs, and commit panel mount to a stiff sheet of plastic. The arrangement should be logical, so place the switch and LED for main power next to each other, and the switch and LEDs for servos next to each other. Place the commit panel mount in the middle or off to one side. The plastic panel is mounted into the airframe of the near spacecraft during its construction. This gives the launch crew easy access to the power and launch functions of the craft. There’s no need to open it up just to power-up and launch.

Testing

Now that construction is complete, it’s time to test the assembly. Therefore, don’t install the Stamp or connect the battery at this time. The first two tests must be done without a battery since it’s harmful to a digital multimeter (DMM) to measure either resistance or continuity while the circuit is live (powered up). The first two tests are designed to verify there’s no short in the flight computer and that it’s safe to insert the Stamp. While it’s very likely your flight computer has been constructed properly, it’s a good idea to wait until you have proof before inserting the microcontroller.

First, inspect the bottom of the PCB and make sure there are no shorted connections. This happens if solder overflows its pad or if a PCB trace was poorly made. After the visual inspection, it’s time to start the electrical tests.

The second half of the first test is to measure the resistance between the positive and negative terminals of the battery connections. Set the DMM to “continuity check" and verify there is no short between power and ground. Do the same for the servo power. Make one more continuity check by measuring the resistance between pins 4 and 21 of the Stamp IC socket. Again, there should be no shorts. Only after passing these two tests is it safe to connect batteries to the flight computer.

The second test is the voltage test. So, set the DMM to measure voltage (if the DMM is not auto-ranging, set it to the 20 volt scale). Now, throw the main power switch and verify that the LED illuminates. With the DMM, measure the voltage between pins 4 and 21 on the Stamp socket (where pin 4 is ground and pin 21 is +5 volts). The DMM reading should be between 4.75V and 5.25V.

If not, look for a bad solder connection or an incorrectly soldered voltage regulator. If the LM2940 voltage regulator feels hot or if the output voltage is wrong, then shut off the power switch immediately and look for a short, broken connection, or incorrectly installed voltage regulator. Figure 3 is a diagram of the voltages expected on each lead of the voltage regulator (assuming a 6V battery pack).

There’s one last set of tests to make on your BalloonSat Extreme for the servo power. Repeat the same tests as you did for the main power. Make sure there’s no short between the positive and negative leads of the servo power battery pack with a continuity test. Then, insert the batteries and flip on the servo power switch. The servo power LED should illuminate. Now, measure the voltage.
Near Spacecraft Mission Proposals

I’ve been giving some thought to how students should propose an experiment for a BalloonSat Extreme mission. First, the students need to know that a near space mission is being planned and they can propose meaningful experiments for it. The limitations of the near spacecraft have to be clearly spelled out, so students can intelligently plan an experiment for the flight and write a proposal advocating its acceptance.

Each student proposal must clearly define the purpose of the experiment and its requirements. That reduces the chances of redundant experiments, an overweight near spacecraft, or an over-taxed flight computer. In addition, each proposal should explain how the student experiment will be designed, built, and tested to meet the timeline of the launch. That way, the flight is not held up by a slow experiment.

After evaluating all the proposals, the best are selected and the students are given the deadline to deliver whatever is going up on the balloon. So, here’s what I believe the process should look like, based on a simplified version of what I understand is used in science and industry.

Request for Proposal (RFP)

The RFP describes the proposed near spacecraft mission and the near spacecraft’s limitations. After reading the RFP, students should understand enough about the near spacecraft to design a suitable experiment. So, here’s an example:

The proposed mission is expected to reach an altitude of 90,000 feet during a 90 minute ascent which is then to be followed by a parachute descent lasting 45 minutes. The balloon burst and initial descent is traumatic and experiments can expect to experience forces across a range of gs in multiple directions and over very short time scales. The near spacecraft’s flight computer is limited to eight analog ports, five digital ports, three servo ports, and one GPS port. All signals are limited to five volts. Up to 0.5 amps of five volts is available to power all the experiments. Each experiment can expect up to three I/O connections to the flight computer through the use of three-pin headers with 0.025 inch wide square leads and 0.1 inch lead spacing. The header is configured such that the pins are designated as ground, +5V, and I/O. Experiments can store 2,048 records in either one byte or one word data records. The near spacecraft is limited to six pounds of total weight, including its flight batteries and airframe. The volume is not restricted. A portion of each experiment can reside outside the near space vehicle and will be attached to the airframe (made from 1/2 inch thick Styrofoam) using #6-32 bolts, nuts, and fender washers. Experiments can be extended away from the airframe using lightweight booms of Styrofoam and/or Syntra (foamed PVC).

The Experiment Proposal

Here’s what I propose each student team provide to the mission design. This should be enough information for the near spacecraft designer to lay out the near space vehicle, calculate total weights, and assign I/O and memory to experiments. Students should be given a blank document to fill in with this information so they don’t leave anything out:

- Name of the experiment
- Purpose of the experiment
- Theory behind the experiment (why does it work)
- Weight of the experiment
- Volume of the experiment (interior and exterior portions of the experiment)
- Structure of the data (words or bytes)
- Number of servos
- Number of analog channels
- Number of digital channels
- Whether GPS data is required (and which fields)
- A budget that includes money to purchase parts, and time to assemble and test
- Sketch of the experiment showing its dimensions
- Past experience showing the team can complete this experiment on time
- Procedures used to verify the experiment will operate for the duration of the mission
- Outline of program used to verify that the experiment is working properly
- Outline of the flight code

Acceptance and Deliverables

After having their experiment accepted, I would encourage students to produce more than one copy of their experiment. One copy would be the flight article, and I recommend that it be the last one they assemble. The prior experiments are test articles and they give students the opportunity to refine their design, assembly, and testing. Student teams must document their construction and testing. They must also document how well the experiment meets its requirements. Upon delivery, the experiment must be complete — no last minute fixes are allowed. The delivery of the flight article must also include the tested subroutine used to operate the experiment and collect its data.

So, what do you think? I invite N&V readers to contact me with their ideas for this proposal process.

Across the servo port, as illustrated in Figure 4, the outer pins of the servo port are ground and the middle pins are 4.5 volts (assuming your flight computer is using a 4.5 volt supply for the servos).

So far so good? Next time, I’ll explain all the code you need to operate a BalloonSat Extreme mission. Remember, the goal of this flight computer is to create a platform for advanced students where they practice integrating their experiments into a single near space vehicle — just like scientists do for the JPL space vehicles. So, the code for the BalloonSat Extreme uses lots of subroutines designed for each particular experiment.

Onwards and Upwards,
Your near space guide NV

---

**Figure 4.** The standard arrangement of pins in a servo connection looks like this.
Cathode displays are now available, but cost quite a bit more. The smaller displays are very affordable. It would be ideal to make available a PCB for the project, a programmed chip, and a crystal for the time base. Most DIYers would have the other parts needed. The PCB could be made small so that builders could use a variety of case sizes depending on the size of the displays used. It wouldn’t hold the displays themselves; the builder would mount them as needed. For my old clocks, I mounted the 4” and 2” displays on a thin sheet of plywood painted black in a case made from pieces of acrylic I got at Tap Plastics.

Jack Rubeck

Thanks for the feedback. We have the same definition of “big” — I’ve used Futurlec displays and other large digits in my clocks. I’m familiar with 73 and Nixie displays, as well. I’m sure we share quite a few experiences. Again, thanks and – I assume – 73s.

Bryan Bergeron

Can’t Get Swing of Math

Regarding the parameter amplifier article in the June 2014 issue, I haven’t gotten the frequency of a simple pendulum to equal 1.5 Hz using Richard Panosh’s equation with the numbers in the article. I put the numbers into Excel and it is 10 times under the 1.5 Hz. I checked my numbers with XLC and it will draw the correct equation.

James Thompson II

Sorry to hear you’re having trouble with the expression for the frequency of this simple pendulum.

Take the free length of the string as four inches long. Add the radius of the ball to this to obtain the total length to the center of mass:

4 inches + 1/2 (3/4 inch ball diameter = 4.375 inches)

4.375 inches x 1 ft/12 inches = 0.36 ft

Hope this clears up the issue. Thanks for your interest and good luck in your studies.

Richard Panosh

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The gauntlet has been thrown!

If you’re interested in taking a crack at this project, email VernGraner@nutsvolts.com.

Feedback Motion Control

The Old Way
1) Build robot
2) Guess PID coefficients
3) Test
3a) Express disappointment
3b) Search Internet, modify PID values
3c) Read book, modify PID coefficients again
3d) Decide performance is good enough
3e) Realize it isn’t
3f) See if anyone just sells a giant servo
3g) Express disappointment
3h) Regress PID coefficients
3i) Switch processor
3j) Dust off old Differential Equations book
3k) Remember why the book was so dusty
3l) Calculate new, wildly different PID coefficients
3m) Invent new, wildly different swear words
3n) Research fuzzy logic
3o) Note that it is certainly not working in uncertain ways
3p) Pull hair
3q) Switch controller
3r) Regress PID coefficients
3s) Switch programming language
3t) Start a new project that doesn’t use feedback control
3u) See parts are love, feel guilty. Go back to old project
3v) Start testing every possible combination of PID coefficients
3w) Apologize now or no red, blurry eyes are produced
3x) Well, it’s working!
3y) Decide not to do any more projects that require control systems
3z) Wonder why someone doesn’t just make a thing that tunes itself

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October 2014 NUTS&VOLTS 59
ZigBee was originally designed as a lightweight network. The idea was to be able to send small packets of data over limited distances. Thus, ZigBee was aimed at low data rate sensor networks and industrial control applications. It seems that everything these days that finds its way to the Internet and ZigBee is no exception. Today, remote ZigBee networks can be easily monitored and administered via an Internet connection. In this installment of Design Cycle, we will explore the use of the Internet to propagate ZigBee monitor and control data. Instead of focusing on relatively complex industrial sensor applications, we will go "home" and perform some home automation-based data exchanges over the Internet.

What are We Trying to Do??

Our goal is to assemble a two-node PAN (Personal Area Network) that is, in reality, a HAN (Home Automation Network). Our PAN will consist of a single FFD (Full Function Device) node that will be under the control of a PAN Coordinator. Once we get the PAN online, the next step will be to contact the Coordinator via an Internet-routed Telnet connection. This particular “home-based” PAN will be logically considered “remote” as we will only access the PAN via an Internet connection. If all works as designed, we will be able to query and control the devices attached to the remote FFD node. We will also be able to interact in a remote manner with the PAN Coordinator.

The HAN FFD

The FFD HA device you see in Photo 1 is hosted by a Telegesis ETRX357 ZigBee radio module that is loaded with a ZigBee PRO stack and custom HA firmware. This custom firmware was seeded from the ZigBee Home Automation Public Profile. Access to the HA profile is provided by Hayes-like AT commands which result in easier HA application development. The AT command set is universally recognized and easy to use. In this case, the AT commands provide a simple user and application interface to the complexities of the ZigBee stack. Telegesis Five-In-One firmware is loaded on the FFD data radio. The FFD endpoint firmware has the capability of servicing a maximum of five monitor and control functions using a single ETRX357 radio. As you can see in

<table>
<thead>
<tr>
<th>ENDPOINT</th>
<th>DEVICE NAME</th>
<th>DEVICE ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x01</td>
<td>ON/OFF OUTPUT</td>
<td>0x0002</td>
</tr>
<tr>
<td>0x02</td>
<td>LEVEL CONTROLLABLE OUTPUT</td>
<td>0x0003</td>
</tr>
<tr>
<td>0x03</td>
<td>LIGHT SENSOR</td>
<td>0x0106</td>
</tr>
<tr>
<td>0x04</td>
<td>TEMPERATURE SENSOR</td>
<td>0x0302</td>
</tr>
<tr>
<td>0x05</td>
<td>ON/OFF SWITCH</td>
<td>0x0000</td>
</tr>
</tbody>
</table>

FIVE-IN-ONE DEVICE ENDPOINTS

Figure 1. The devices native to the Five-In-One HA device you see in Photo 1 can be accessed using these Endpoint and Device ID combinations.
Figure 1, one pair of the five endpoints performs light on/off and light dimmer functions. Onboard FFD sensors provide temperature and luminance data (lower left corner of Photo 1).

There is also a fifth on/off switch function. The five endpoints are accessed with AT commands that originate at the Combined Interface (CI) device which is also a specially prepared Telegesis ETRX357 radio module. The CI firmware runs on an ETRX357 module that needs to be active at all times. Thus, the CI is powered from a permanent power source. The FFD nodes can sleep while the CI stands watch. This allows the FFD devices to be permanently powered or battery powered, depending on the needs of the application.

The HAN CI

That little black box under the lights in Photo 2 is actually a Telegesis ZigBee Communications Gateway. Yes, I was tempted to show it to you with its clothes off. However, we really don’t need to know what’s going on inside. We simply need to know how to use what’s inside.

The ZigBee Communications Gateway has printed circuit board (PCB) space for two Combined Interface Control and Indicating Equipment (CICIE) friendly ETRX357 radios. The Communications Gateway we have in our possession contains a single Telegesis ETRX357 CICIE capable radio module which is configured to operate in CI mode.

The ZigBee Gateway is truly a “black box.” The outside world only sees a single RJ-45 Ethernet jack, a USB portal, and two exposed switches. Configuration of the Gateway is performed using a web browser to interact with the web pages that are served by it. Power for the Communications Gateway is obtained from the USB portal. The trio of switches performs reset functions and user-selected message transmission via pushbuttons and a paper clip. ZigBee connection and Ethernet link status are conveyed via a quintet of LEDs. The status LED patterns can be seen in Figure 2. It’s rather obvious that green and amber are good operational colors.

Configuring the Telegesis ZigBee Communications Gateway

The ZigBee Gateway implements the UPnP discovery service. This means that with Windows 7 and 8, we can see the Gateway by simply viewing the network infrastructure. All we have to do to get to the Gateway web pages is right-click on the entry as shown in Screenshot 1. You can also gain access to the Gateway’s web pages using a standard web browser once you know the Gateway’s IP address.

I used the MAC address printed on the bottom of the Gateway and my router’s device list to get the current IP address of the Gateway. The MAC or hardware address is 00:21:ED:20:04:8F, which I matched up to the router entry in Screenshot 2. Thanks to DHCP being enabled by default in the Gateway configuration, I can be sure to get an IP address if it has joined the LAN. Now that I have an IP address, I can use Firefox to gain local access to the ZigBee Gateway web page.
Once the bits and status LEDs align (green-amber-green in Figure 2), Screenshot 3 appears. Since we will be accessing the Communications Gateway using an Internet connection, we will need to configure a static IP address and assign our desired Dialin TCP socket port. These adjusted configuration values must match the configuration values that exist in the router that is serving the Gateway.

I’ve decided to assign the ZigBee Gateway a static IP address of 192.168.0.97 with a port number of 8800. Scanning Screenshot 4 reveals the disabling of DHCP and defining the LAN default Gateway IP address in addition to assigning the TCP socket values (192.168.0.97:8800). For this magic to work, we must also configure the LAN router has been configured to allow traffic to pass to and from the 192.168.0.97:8800 socket interface.

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router to allow traffic to pass over our newly configured socket to the Gateway. You can see how this is done in Screenshot 5.

We’re not done with the LAN router. Normally, the ISP (Internet Service Provider) will frequently change the IP address it assigns to the router. So, we can’t hard configure the router’s IP address as it is subject to change. We could lease a static IP address from the ISP, but that is expensive. The alternative is to use what I consider one of the best Internet tools available: the DynDNS service. I’ve set up a DynDNS host on the router in Screenshot 6 called telegesis.dyn dns-remote.com. The link isn’t complete until I create and activate an identical host on the DynDNS website. Screenshot 7 tells that tale.

At this point, everything should be in place. The Gateway is configured to be contacted from a LAN or Internet connection. If all works as designed, we should be able to Telnet into the ZigBee Communications Gateway and gain access to the PAN on the other side of the Gateway.

**Heating Up the HA PAN (HAN)**

There are multiple ways to bring up our HA PAN (HAN). We can choose to bring it to life locally or we can configure the HA Five-In-One device to join a particular HA PAN when it becomes available. Let’s keep this simple and initiate the birth of our HAN locally. However, instead of doing it this way, we will breathe life into it over the Internet.

As it stands right now, the Communications Gateway is physically and logically connected to a LAN. It is listening behind the socket 192.168.0.97:8800. There are no active HANs. The objective is to contact the Gateway by way of a Telnet session which we will initiate with Tera Term Pro. Screenshot 8 is our ticket in and eventually to its HAN.

Kicking off the Tera Term Pro session bore fruit in Screenshot 9. The initial AT was answered by the Gateway with an OK. Things are looking real good at this point, so I decided to query the Communications Gateway. It replied with the internally mounted data radio type, the data radio firmware version, and the data radio’s 64-bit EU1.
Okay, it’s time to throw the meat into the HAN. I sent the ZigBee Gateway a command to form a new PAN which to our HA nodes will become our new HAN. The official PAN construction orders can be seen in Screenshot 10. I took the easy way out and left the PAN creation details up to the data radio firm ware. After confirmation that the PAN had been created, I flipped the “you can join my PAN” bit. In the meantime, I attached the FFD node to a Telegesis Terminal session. Knowing that a PAN was already in existence, I simply instructed the FFD node to join the first available one. These orders are displayed in Screenshot 11.

Once becoming a member of the ZigBee Communications Gateway’s PAN, the Five-In-One FFD is assigned a Node ID (51DB in Screenshot 10). The Gateway is also now privy to the new member’s EUI, (Extended Unique Identifier).

which can also be seen in the FFD’s response in Screenshot 10. We are finally at “home” and we’re cooking with gas!

**While We’re Here**

Let’s see what we can find out about Node 51DB. From the Telegesis HA documentation and the obvious name, we know our Five-In-One FFD has five endpoints. So, let’s send the AT command sequence you see in Screenshot 12 to query the first endpoint of Node 51DB. The IDENTIFY command is aimed at Node 51DB/endpoint 01 for 60 seconds. If the command is issued correctly and is valid at the receiver, a default response (DFTREP) is returned. In this case, the responding node is 51DB and the response emanates from endpoint 01. The associated cluster is 0003. The trailing zeros indicate a valid response.

Hmmmm. I issued the same command for all five endpoints and received identical default responses with only the responding endpoint field changed. So, if I didn’t already know, I would say that Node 51DB contains five endpoints that associate to cluster 0003. Einstein would try to prove his theory. So will I.

With that, I issued the command sequence you see in Screenshot 13. The DISCOVER command will query every node in the HAN that has a cluster 0003. In our case, there is only one node in our HAN (51DB). Its default response to our DISCOVER query lists five endpoints.
Now I’m dangerous. Consulting the HA documentation, I found that the red and green LEDs on the Five-In-One HA node can be reached via cluster ID 0x0006. According to the documentation, there are two endpoints associated with this cluster. Endpoint 0x01 provides access to the red LED, while endpoint 0x02 is a pathway to the green LED. Naturally, I used DISCOVER to verify the endpoints. Then, I used the nifty AT+RONOFF command to toggle the LEDs. You can see the command entries in Screenshot 14.

The red and green LEDs were extinguished when I issued the commands. As expected, they both illuminated upon the receipt of the default responses. The AT+RONOFF command can also be used to direct an ON or OFF state by adding an additional Boolean ON/OFF parameter at the end of the command string.

It’s Hot in Here

No way I could have this discussion and not take the room’s temperature. Behold Screenshot 15. To get the Five-In-One temperature sensor to speak, we issue the AT+READATR command. The targeted temperature sensor resides on Node 51DB at endpoint 4. The target cluster ID is 0x402. The returned temperature value is 0x0105. To convert the raw temperature value to Celsius, we simply divide the raw temperature data by 10, which gives us 26.1° Celsius.

While I was in the neighborhood, I decided to take a light reading. Without fishing out the technical details, all I can tell you is that it’s not pitch dark (0x0020 instead of 0x0000) in the lab.

It’s Good to Be Home (Automated)

In this discussion, we’ve looked at the basics of deploying a home automation solution using a Telegesis ZigBee Communications Gateway. The beauty of the Telegesis way lies in the home automation AT command set. Since the AT commands are composed of ASCII characters, the AT commands can be easily incorporated into all of the popular programming languages.

We only fiddled with LEDs in our examples. However, think about this. If you can control an LED, you can control a relay, a motor, shutters, door locks, alarm systems ... get the idea? Now add Internet access to the equation.

Including the Telegesis ZigBee Communications Gateway in your home automation designs makes for an endless home automation Design Cycle.
The Arduino Classroom

Arduino 101 — Chapter 9: Keeping Time

We have looked at keeping time with computers prior to this Arduino 101 series. Those Workshops were not as novice-friendly as this current series, but they contain a lot of information about computer time that the more curious reader might want to read to get more low-level detail than will be discussed here. The first article was published in the July 2012 issue and it had some general C programming theory plus discussion on a design for a printed circuit board (PCB) with the DS1307 RTC (Real Time Clock), and how to use it with an Arduino. Next, there was a series of articles that greatly expanded on the RTC by building an alarm clock with a C# based PC side application that works in concert with an Arduino proto shield alarm clock. Those articles were published in the January, February, March, and April 2013 magazines. (There are project kits available for these articles from the Nuts & Volts webstore.) In this article, we will take a much higher level look at computer time keeping, and learn to use some very novice-friendly applications available for the Arduino.

Keeping Time With the Arduino

Before we begin, let it be known that a raw Arduino isn’t all that good at keeping clock time. It may gain or lose several seconds in a day, which is fine for some of the applications we will do later in this series where we record data for no more than a day. If you really need long-term accuracy, then refer back to the aforementioned articles.

Computer Time

In case you didn’t know, time began on January 1, 1970. Or, at least Unix time began then, and since that auspicious moment many computers have counted the seconds. As of September 1, 2014 the count is 1,409,529,600, or about one and a half billion seconds. [This factoid is courtesy of www.epochconverter.com/epoch/timestamp-list.php] That, folks, is one whopping big number! However, it can be stored in a 32-bit integer which is a measly four bytes of data.

The World Will End in 2038

Using Unix time, everything will be just fine — until 2038 when the seconds exceed the capacity of a 32-bit integer and lights out! Sort of like it did in 2012 when the Mayan calendar ended and so did the world. Except, of course, it didn’t. The Mayans merely started their calendar over again, or would have if it hadn’t been for that conquistador thing.

We can expect the 2038 problem to be much like the Y2K (Year 2000) timekeeping issue that was going to bring the world as we knew it to a screeching halt according to media and other hysterics — only it didn’t. It did, however, employ a bunch of programmers for a few years, and the Y2.038K problem will probably do the same.

In the Meantime ...

Unix provided C functions and data types that let folks express those Unix time seconds as more meaningful (to us) units, such as calendar dates and clock times. This can get fairly arcane, and fortunately — like many other complex computing problems — some generous folks have given us an Arduino library — appropriately named Time — that makes things much easier for us. We will install this library in the Arduino directory in Lab X todo.

The Time library provides timekeeping functionality
using the Arduino by itself or with external timekeeping devices such as the DS1307 RTC. You can write code to get the time and date as second, minute, hour, day, month, and year, plus it lets us keep time in the earlier mentioned Unix time seconds which is more convenient to handle and store than traditional date and time notations. Also, it lets us set up alarms.

Rather than repeating all the functions here, please refer to http://playground.arduino.cc/Code/Time. Don’t worry if this seems a bit much. We will only be using a subset of what is available, and we will keep it as simple as possible to fulfill our meager requirements. We will, however, use a brand new program (to us, anyway) that will let us set the time on the Arduino very accurately. This program is called Processing, and as we will see in a moment, it looks kind of familiar.

**Processing**

The Processing IDE (integrated development environment) is shown in Figure 1. Look familiar? It should because the Arduino IDE is built from a version of Processing. You will want to visit processing.org and take a look at all the marvelous things Processing is used for. It was developed initially to provide a simple set of tools so that artists could use some of the visual effects that were becoming available in Java. Fortunately, since Processing is artist-simple to use and the Arduino IDE is based on it, we won’t have to learn much new stuff. In Lab todo, we will use a Processing module provided by the folks that wrote the Time library that lets us use the PC to set the time on the Arduino.

**Lab 1: Using the ArduinoTime Library**

The Time library is not part of the standard Arduino package, so you’ll have to download it and set it up yourself. After downloading the library, we will write code to let us set the date and time.

**Parts required:**

1 Arduino
1 Computer with Internet connection

**Estimated time for this lab:** 20 minutes

**Check off when complete:**

- You can get the Time.zip file at http://playground.arduino.cc/Code/Time. Download this file and unzip it. This will provide a Time directory.
- Next, find your Arduino directory (usually on drive C: — for instance, I have Arduino 1.0.5 located at C:/Arduino105).
- Copy the Time directory to the Arduino libraries directory. Figure 2 shows my Windows Explorer with the file copied to the correct directory. It must be in the libraries directory for the Arduino IDE to find it.
- Next, you want to verify that the Arduino IDE can find the Time library. Open the Arduino IDE and then click on the Sketch/Import Library menu item. You should see the Time library as shown in Figure 3. This verifies that you have successfully added the library to the Arduino directory.
- Click on ‘Time’ and it will add #include <Time.h> to your source code as shown in Figure 4. You are now ready to write code that will use the Time library.
- Open the File/Examples/Time/Examples/TimeSerial as shown in Figure 5.
- In the Setup() function, change the baud rate from 9600 to 57600.
In the `requestSync()` function, remove the ‘BYTE’ parameter from the `Serial.print()` function.

Run the program and open the Serial Monitor. You will see the message “7Waiting for sync message” displayed as shown in Figure 6.

In a computer browser, open `www.unixtimestamp.com` as shown in Figure 7.

QUICKLY copy the Unix time value, which was 1405096354 when I did this exercise as shown in Figure 7.

ALSO QUICKLY, paste this value into the serial monitor output box preceded by a ‘T’ as in Figure 8. I say quickly because the seconds that it takes to copy, paste, and send the Unix time will create an offset of several seconds between the real time (in the opinion of the PC) and the time learned by the Arduino.

The serial monitor will begin to display the time and date as shown in Figure 8.

Note that the time is expressed as a 24 hour clock — as in military time.

Also note that the time is UTC — Coordinated Universal Time that is more or less synonymous with Greenwich Mean Time (GMT).

Note that converting UTC to your time zone (if you live in the USA) requires considering daylight savings time. I
live in the Eastern time zone which is UTC-5:00, but since daylight savings time is in effect it is actually UTC-4:00. The time shown in Figure 8 as 16:32 was UTC-4:00 or 16:32 - 4:00 = 12:32.

Lab 2: Using Processing to Set the Arduino Time

Hand-typing the Unix timestamp is not so hard, but chances are you will not get the exact seconds this way. You could add a couple of seconds to the total, but you could also use Processing to set it more accurately than you can by hand.

Parts required:
1 Arduino
1 Computer with Internet connection

Estimated time for this lab: 20 minutes

Check off when complete:
- Download Processing 2 from www.processing.org. This application is large, so the download may take a while.
- Open the Processing IDE as shown in Figure 9.
- Download the following program into the Processing IDE. [You can find all the code files at the article link.]

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- Download the following program into the Processing IDE. [You can find all the code files at the article link.]

```cpp
// a101_ch9_receive_serial.pde Joe Pardue
// 7/11/14
// Processing program to receive strings from
// the Arduino

import processing.serial.*;
Serial mySerial;
// Create object from Serial class
String input;
// Data received from the serial port
void setup()
{
  // Find the COM port you are using by looking
  // in the Arduino Tools/SerialPort menu item.
  mySerial = new Serial(this, "COM5", 57600);
}
void draw()
{
  if ( mySerial.available() > 0)
  {
    // If data is available,
    // put it in the input string
    input = mySerial.readStringUntil(‘\n’);
    println(input); //print it out in the console
  }
}
```

Leave the Processing IDE open, but do not run the program yet.
- Download this program into the Processing IDE:

```cpp
// a101_ch9_hello_world.ino Joe Pardue 7/11/14

void setup()
{
  Serial.begin(57600);
}
void loop()
{
  Serial.println("Hello, world!");
  // send Hello, world!
  delay(250); // pause for 1/4 second
}
```

- Compile and run the Arduino program first.
- Compile and run the Processing program second.
- The order is important because the Arduino has to open the COM port first.
- You will see the Processing console (the black area at the bottom of the Processing IDE) begins to print “Hello, world!” as shown in Figure 10.
- Now that you have tested the Processing and Arduino serial connections, reload the Arduino TimeSerial example shown in Lab 1. Compile and run that program.
- In the Processing IDE, load the SyncArduinoClock program. We will not discuss this file since it uses some features that are beyond the scope of this article.
- Run SyncArduinoClock in Processing, and you will see a blank window appear as shown in Figure 11.
- Click on this window and the correct time will be sent to the Arduino, which will then print the date and time to the Processing console as we see in Figure 11.
Lab 3: One Numeral Clock

Now that we can tell the time, what if we don’t have a PC with a USB serial connection to send that time out to a serial terminal? Well, we could display the time on the Arduino using the seven-segment LED. You may well ask, how can we display all that information on a single digit display? We could do something similar to what we learned in Lab 5 of Chapter 8 where we built “The World’s Smallest Moving Message Sign.”

We could then display the hour, minute, and second; say, 1:35:12 as H01 M35 S12. By controlling the timing of the character output, this makes a nominally readable display if you know what you are looking for and pay attention.

Parts required:
1 Arduino
1 Computer with Internet connection
1 Arduino proto shield and jumper wires
1 Seven-segment LED
1 100 Ω resistor

Estimated time for this lab: 1 hour

Check off when complete:
- Build the circuit shown in Chapter 8 Lab 4. The figures from that lab are repeated here in Figures 12, 13, and 14 for your convenience. Notice that this circuit uses a single 100 Ω resistor between the seven-segment LED anode pin 3 and the five volt power supply.
- Load the following program into the Arduino IDE:

```cpp
// a101_ch9_time_display.ino Joe Pardue 7/13/14
// Modification of TimeSerial.ped
#include <Time.h>
// time sync to PC is HEADER
```
// followed by unix time_t as ten ascii digits  
#define TIME_MSG_LEN 11  
// Header tag for serial time sync message  
#define TIME_HEADER  'T'  
// ASCII bell character requests a time sync message  
#define TIME_REQUEST  7  

byte integer[] = {0x3F, 0x06, 0x5B, 0x4F, 0x66, 0x6D, 0x7D, 0x07, 0x7F, 0x6F, 0x08};  
byte character[] = {0x77, 0x7C, 0x39, 0x5E, 0x79, 0x71, 0x6F, 0x76, 0x30, 0x1E, 0x70, 0x38, 0x15, 0x54, 0x3F, 0x73, 0x67, 0x50, 0x6D, 0x78, 0x3E, 0x1C, 0x2A, 0x46, 0x06E, 0x52};  
#define DPMASK 0x80  
#define GMASK 0x40  
#define FMASK 0x20  
#define EMASK 0x10  
#define DMASK 0x08  
#define CMASK 0x04  
#define BMASK 0x02  
#define AMASK 0x01  
#define DPPIN 9  
#define GPIN 13  
#define FPIN 12  
#define EPIN 6  
#define DPIN 7  
#define CPIN 8  
#define BPIN 10  
#define APIN 11  
#define PAUSE 500  

// lowest segment starts with LED 6  
// hightest segment ends with LED 12  
int low = 5;  
int high = 13;  

void setup()  
{  
  // Set LED pin modes to output  
  for(int i = low; i <= high; i++)  
  {  
    pinMode(i, OUTPUT);  
  }  
  Serial.begin(57600);  
  Serial.println("a101_ch8_time_display  
rev 1.0");  
  //set function to call when sync required  
  setSyncProvider(requestSync);  
  Serial.println("Waiting for sync message");  
}  

void loop(){  
  if(Serial.available() )  
  {  
    processSyncMessage();  
  }  
  if(timeStatus()!= timeNotSet)  
  {  
    // on if synced, off if needs refresh  
    digitalWrite(13,timeStatus() == timeSet);  
    sevenSegDisplay();  
  }  
  delay(1000);  
  //*********************************************************************  
  // Functions to display the time on the  
  // 7-seg LED  
  //*********************************************************************  
  void sevenSegDisplay(){  
    // show the hour  
    setLEDS('H');  
    delay(PAUSE);  
    showDigits(hour());  
    sevenSegDisplay();
delay(PAUSE*2);

// show the minute
setLEDs('M');
delay(PAUSE);
showDigits(minute());
delay(PAUSE);

// show the second
setLEDs('S');
delay(PAUSE);
showDigits(second());
delay(PAUSE);

// Display all time values as two digits
// use leading 0 if value less than 10
void showDigits(int digits){
    int high, low;
    if(digits > 59) high = 6;
    else if(digits > 49) high = 5;
    else if(digits > 39) high = 4;
    else if(digits > 29) high = 3;
    else if(digits > 19) high = 2;
    else if(digits > 9) high = 1;
    else high = 0;
    low = digits - (high*10);
    setLEDs(high+48);
delay(PAUSE);
    setLEDs(low+48);
delay(PAUSE);
}

void setLEDs(int input){
    // verify input is integer or character
    if( (input > 47) & (input < 58) )
    {
        input = integer[input - 48];
    }
    else if( (input > 64) & (input < 91) )
    {
        input = character[input - 65];
    }
    else // it isn’t an integer or character
    {
        return; // do nothing if invalid input
    }

    // Turn the segments on or off
    digitalWrite(DPPIN,! (DPMASK&input));
    digitalWrite(GPIN,! (GMASK&input));
    digitalWrite(FPIN,! (FMASK&input));
    digitalWrite(EPIN,! (EMASK&input));
    digitalWrite(DPIN,! (DMASK&input));
    digitalWrite(CPIN,! (CMASK&input));
    digitalWrite(BPIN,! (BMASK&input));
    digitalWrite(APIN,! (AMASK&input));
}

for(int i=0; i < TIME_MSG_LEN-1; i++)
{
    c = Serial.read();
    if( c >= '0' && c <= '9')
    {
        // convert digits to a number
        pctime = (10 * pctime) + (c - '0');
    }
}

// Sync Arduino clock to time from the
// serial port
setTime(pctime);
}

time_t requestSync()
{
    Serial.print(TIME_REQUEST);
    // the time will be sent later in response
    // to serial msg
    return 0;
}

Compile and run the program.
Do you find it easy to read the hours, minutes, and seconds?

Lab 4: Cut the Apron Strings

So far, we have used the Arduino tethered to the PC. This provides both power and a convenient way to program and talk to the Arduino. We do have to ask, though, what is the use of learning about how to put time on the Arduino if it can always just get the time from the PC? Of course, there isn’t any reason to. We would only want to occupy the Arduino with the chore of keeping time if it is detached from a PC, say sitting out in the garden soaking up the sunshine while leisurely gathering data about the weather.

If, for instance, it takes the temperature every five minutes, it will need to know when five minutes have passed. It will also need to know which particular five minutes in a day of lots of five-minute intervals that this particular five minutes occurred. If it isn’t attached to a PC out in the garden, where will it get its power?

From a battery, of course. The Arduino has a barrel connector so you can power it with a nine volt battery using a snap connector as shown in Figure 15. You can
get one at www.adafruit.com/products/80. Connect the nine volt battery as shown in Figure 16 and you are ready to run your Arduino away from a computer.

This process of gathering information external to a computer is called data logging, and it is used to record sensor readings over known intervals at known dates and times. In later chapters, we will learn how to use sensors, but first we will learn how to keep time so that we can log the sensor data and know when we took our readings.

Parts required:
1 Arduino
1 Computer with Internet connection
1 Barrel connector with snap connections
1 Nine volt battery

Estimated time for this lab: 15 minutes (+24 hours)

Check off when complete:
- Attach a nine volt battery to the snap connections as shown in Figure 15.
- Plug the nine volt battery into the Arduino barrel connector as shown in Figure 16.
- Calibrate the clock as you did in Lab 2.
- Remove the USB connector and wait 24 hours.
- DO NOT plug in the USB cable. If you attempt to contact the Arduino via USB, it will reset and you will lose the time and have to start over.
- Refer to your PC time clock for the correct time and then compare this to the time being displayed on the Arduino.
- What is your error in seconds per day?

As we said earlier, this isn’t a particularly accurate clock. In order to get really good accuracy, you’ll need to use an external RTC like what was discussed in the Smiley’s Workshops mentioned earlier. However, as we will see when we look at data logging, our clock is good enough to time a days’ worth of measurements, and you can resync it each day when you upload the data you have logged.

Next month, we will learn to use light and temperature sensors with the Arduino in preparation for the following month when we will use those sensors and what we have learned about time to build a data logger.

Remember that all the components used in the Arduino 101 series are available from the Nuts&Volts webstore for convenience. If you have any questions about this series, be sure to visit the forum at www.arduino.classroom.com and ask. NV
HumRC™ At below $9 in volume, the HumRC is a very low cost/complete wideband transceiver with a microcontroller module.

The HumRC is designed for reliable bi-directional remote control and sensor applications. The module includes a Frequency Hopping Spread Spectrum (FHSS) protocol and supports versions at 2.4 GHz and 900 MHz with a common footprint and pin-out in this initial release, with 868 MHz and others to follow in the near future. This common footprint across the available frequencies makes it suitable for global sale, so one product can be manufactured and sold around the world.

Designed with low cost in mind, the RF module

Continued on page 81.
>>> QUESTIONS

555 for PWM

Does anyone have a simple circuit/schematic to use a 555 timer to dim a 120 VAC incandescent bulb? In the little bit of research I’ve done, it seems like using the 555 for PWM should do the trick, but I don’t understand "zero crossing" and why it’s important. Pointers welcome!

#10141 Chuck Pearson
Kansas City, MO

Commodore Troubleshooting

I recently inherited a 1980's era Commodore SX-64 computer. Though it looks cosmetically perfect, it doesn’t power up (i.e., the little monitor lights up with a plain gray color, but there is no sound or picture). Anyone have any pointers on where to begin troubleshooting this unit?

#10142 Dani Sanders
Salt Lake City, UT

Carbon or Metal?

Is there a rule of thumb for when it is better to use carbon film resistors over metal film resistors?

#10143 Brayden Lawlor
Norfolk, VA

Chinese Capacitor Problem

I have a Viewsonic model VG2230WM LCD monitor that has quit. I read that these monitors have the "Chinese capacitor problem" but I can't figure out what exactly that means and what to do to fix it. Do I just replace all the caps on the PCB?

#10144 Jouko Koskela
Memphis, TN

>>> ANSWERS

[7141 - July 2014]

Photoresistor Switcher

I would like to know if I have correctly connected my photoresistors (CdS photocells) in order to turn the two LED circuits attached to them OFF during the day and ON during the night. (If not, please indicate by a new diagram.)

Also, I would like to know:

a) If any photoresistor would work?

b) What would be the optimum dark/light resistance values be for such a photoresistor?

c) How would I calculate the values (any formula?) from the transistor side (2N2222) that would best fit this ON/OFF photoresistor switcher?

First of all, a power supply was not specified. The top circuit operating range using common 555s is from five to 15 volts according to the datasheet. The IC 4017 datasheet specifies current drive limit to be about one milliamp. Some amplification is required to drive an LED at 10 to 20 milliamps. The bottom circuit requires at least 12 volts to operate a series string of LEDs. Three LEDs in series add up to: G(3.2) + R(1.8) + G(3.2) = 8.2 volts. This requires at least 12 volts of power to allow for a current-limiting resistor voltage drop. LEDs will load down a ring oscillator. You need a high impedance buffer to isolate the LEDs from the resistor capacitor time constant.

a) The logic of operation of CDS photocells is:
No Light = High resistance
Max Light = Low resistance

As shown, that logic will tend to turn on the transistor during the daytime and turn it off during the night. A simple solution is to swap the 100K resistor with a photoresistor in-circuit. You will probably need to adjust the resistor values to operate the way you require. You also need to limit the current into the base of the transistor. Not every photoresistor will work as the range of resistance variation must match the required transistor bias. You could measure the resistance of the photoresistor with an ohmmeter for both dark and light conditions and adjust the resistor values to operate the way you require. You also need to limit the current into the base of the transistor. Not every photoresistor will work as the range of resistance variation must match the required transistor bias. You could measure the resistance of the photoresistor with an ohmmeter for both dark and light conditions and adjust the resistor values to operate the way you require.
environments, or look up the datasheet from Digi-Key, Mouser, or the manufacturer. Refer to Figure 1 from the Linear Technology SPICE program.

Some CDS photoresistors are about 200K ohms in the dark and about 4K ohms in light. If the range is less, the transistors will always stay on. Measure the photoresistor in light with an ohmmeter. Cover the photo resistor to measure dark resistance.

b) Optimum bias would provide about 0.6 to 1.0 volts or more at the transistor base (relative to the emitter) to turn on, and less than that threshold to turn off. Depends on required current from collector to emitter.

As mentioned, you did not specify your power supply voltage. The 555 IC works best from about five to 15 volts. Three LEDs in series need at least 12 volts as shown.

Two red LEDs and 470 ohms minus (diode drops and IC drop):
(12 - (1.8 + 1.8) volt -1) = 6.4 volts
Max current = 6.4 volts/470 ohms = 14 milliamps
The three LEDs with a 1K resistor operating at 10 milliamps would require:
VDC = (0.01 amp * 1000 ohm)+ (1.8)R+(3.2)G+(3.2)G 8.2
12 - 8.2 = 3.6 volts
3.6 volts/470 ohms = 7.6 milliamps
R8 is 330 ohms for 10 milliamps.
Current limit for the 4017 source is about one milliamper out. You’ll need transistor drivers. 470 ohms drives about 14 milliamps. A ring oscillator may not work as LEDs are loading RC timing; transistor emitter followers may help. The Linear Technology SPICE program can be used to experiment with different values.

Calculation for transistor bias:
R1 = base to power bus VCC
R2 = base to ground or common
Vbase = VCC * (R2 / (R1 + R2))

This is the first approximation as some current will go into the base of the transistor. The switch point is in the range from 0.6 to 1.0 volts. High on; low off. Take a look at Ohm’s Law.

The circuits shown here are available in the Tech Forum at www.nutsvolts.com. The .PDF file is directly viewable. The .asc format is editable within Linear Technology SPICE. LTspice is free from the Linear Technology website.

Adjust the photoresistor value for the version you have in a light and dark environment. Verify that the LOAD has a reasonable current (ON value) of about 10 to 100 milliamps or negligible current (OFF value).

Flashlight to Flashing Light
I have a small LED flashlight that I mount on my handlebars while riding my bike at night. I’ve seen some people put a flashing white light on the front of their bikes. Is there a circuit to convert my “regular” flashlight to a “flashing” flashlight?

b) There are a number of different multi-mode LED flashlight driver modules available — many of which include flashing modes. Check out the selection at dx.com. Make sure to get one that supplies a current appropriate for the LED in your light. They also carry complete lights based around similar modules, which might be easier than trying to modify your existing flashlight.

James Sweet
via email

When I read the question, I remembered that RadioShack sold a blinking LED but in red (part 276-0036). I bought the LED, and tested the current flow while it was blinking. I discovered that the IC inside reduces the current to less than 0.03 mA (30 µA) when off, and conducts over 40 mA when on. So, you can buy the blinking LED and add it in series to your LED flashlight. When you turn the flashlight on, the red LED will blink, and make the main LED blink, too.

You will have to open the bicycle flashlight to wire the blinking LED in series to the white LED. This LED can handle up to five volts and up to 80 mA (as printed on the package) with no additional components. If you do a Web search on the part number, you can find other bicycle projects using the same blinking red LED to flash an array of nine red LEDs for the rear light.

Raymond J. Ramirez
via email

UV LED vs. UV Bulb
I’m been working a lot with high power LEDs now that they’re so affordable. I’m especially fond of the UV LEDs for visual effects at night, but I’ve heard that some UV LEDs can cause blindness, and that I should use a UV bulb to create the effects. Is this true? Can someone explain the difference?

The safety difference between a UV light bulb and a UV LED stems from the difference in radiance between the two sources. Radiance is basically the density of light in the source.

The surface area of an incandescent-size lamp is approximately 100,000 sq-mm. The source area of a high power LED is perhaps 2 sq-mm. While its likely a single high power LED will produce less optical energy than the bulb, the radiance is still likely thousands of times greater for the LED and hence its greater potential for eye damage.

In practice, as long as you don’t look directly at the light source but rather the light reflected from the objects of interest, there is little difference between the two sources.

Steve Paolini
via email
Electronic Troubleshooting, Fourth Edition
by Daniel Tomal, Aram Agajanian

Electronic Troubleshooting, Fourth Edition provides technicians with a wealth of problem-solving methods and information on troubleshooting theory, techniques, and practices for a wide variety of electrical and electronic devices. Special emphasis is placed on the digital electronics and microprocessor-based systems that are used in today’s industrial and personal applications.

Regular Price $70.00
Sale Price $59.95

Beginner’s Guide to Reading Schematics, 3E
by Stan Gibilisco

Navigate the roadmaps of simple electronic circuits and complex systems with help from an experienced engineer. With all-new art and demo circuits you can build, this hands-on, illustrated guide explains how to understand and create high-precision electronics diagrams. Find out how to identify parts and connections, decipher element ratings, and apply diagram-based information in your own projects.

Regular Price $27.00
Sale Price $14.95

Make Your Own PCBs with EAGLE
by Eric Kleinert

Featuring detailed illustrations and step-by-step instructions, Make Your Own PCBs with EAGLE leads you through the process of designing a schematic and transforming it into a PCB layout. You’ll then move on to fabrication via the generation of standard Gerber files for submission to a PCB manufacturing service. This practical guide offers an accessible, logical way to learn EAGLE and start producing PCBs as quickly as possible.

Regular Price $51.95
Sale Price $29.95

Programming the BeagleBone Black: Getting Started with JavaScript and BoneScript
by Simon Monk

Learn how to program the BeagleBone Black — the wildly popular single-board computer — using JavaScript and the native BoneScript language. You’ll find out how to interface with expansion capes to add capabilities to the basic board, and how to create a Web interface for BBB. Two hardware projects demonstrate how to use the board as an embedded platform.

Regular Price $25.00
Sale Price $15.00

Build Your Own Transistor Radios
by Ronald Quan

A Hobbiest’s Guide to High Performance and Low-Powered Radio Circuits
Create sophisticated transistor radios that are inexpensive yet highly efficient. Inside this book, it offers complete projects with detailed schematics and insights on how the radios were designed. Learn how to choose components, construct the different types of radios, and troubleshoot your work. *Paperback, 496 pages

Regular Price $44.95
Sale Price $29.95

The Steampunk Adventurer’s Guide
by Thomas Willeford

Steampunk stalwart Thomas Willeford cordially invites you on an adventure — one in which you get to build ingenious devices of your own! Lavishly illustrated by award-winning cartoonist Phil Foglio, The Steampunk Adventurer’s Guide: Contraptions, Creations, and Curiosities Anyone Can Make presents 10 intriguing projects ideal for makers of all ages and skill levels, woven into an epic tale of mystery and pursuit.

Regular Price $25.00
Sale Price $15.95

How to Diagnose and Fix Everything Electronic
by Michael Jay Geier

Master the Art of Electronics Repair
In this hands-on guide, a lifelong electronics repair guru shares his tested techniques and invaluable insights. How to Diagnose and Fix Everything Electronic shows you how to repair and extend the life of all kinds of solid-state devices, from modern digital gadgetry to cherished analog products of yesteryear.

Regular Price $25.00
Sale Price $14.95

Programming PICs in Basic
by Chuck Hellebuyck

If you wanted to learn how to program microcontrollers, then you’ve found the right book! Microchip PIC microcontrollers are being designed into electronics throughout the world and none is more popular than the eight-pin version. Now the home hobbyist can create projects with these little microcontrollers using a low cost development tool called the CHIPAXE system and the Basic software language. Chuck Hellebuyck introduces how to use this development setup to build useful projects with an eight-pin PIC12F683 microcontroller.

Regular Price $15.00
Sale Price $9.95

Programming Arduino Next Steps: Going Further with Sketches
by Simon Monk

In this practical guide, electronics guru Simon Monk takes you under the hood of Arduino and reveals professional programming secrets. Also shows you how to use interrupts, manage memory, program for the Internet, maximize serial communications, perform digital signal processing and much more. All of the 75+ example sketches featured in the book are available for download.
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### PROJECTS

<table>
<thead>
<tr>
<th>Project</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fading Eyes Deluxe Board</strong></td>
<td>The fading eyes circuit gives you two LED eyes that can be adjusted between a slow fade-in/fade-out to quick pulses. The speed is changed by simply adjusting the variable resistor with a small screw driver. Another adjustment allows you to set how long the LED stays on within the on/off fade cycle. Includes a battery snap and two red LEDs and two 24 inch eye cables.</td>
<td>$16.95</td>
</tr>
<tr>
<td><strong>Peek-a-Boo Ghost Kit</strong></td>
<td>The Peek-a-Boo Ghost kit is a fun, low cost multi-use microcontroller kit. When triggered by the included motion sensor, this mini animatronic waves its arms, lights its LED eyes, and plays back the sounds you record. Perfect for kids, this kit can be used to create a fun Halloween prop for your desk, front door, or walkway. Watch the video to see this cool kit in action. Available in both a program-it-yourself version or with a pre-programmed PICAXE chip option. Unprogrammed Chip Kit $29.95 Preprogrammed Chip Kit $37.95</td>
<td></td>
</tr>
<tr>
<td><strong>Talking Skull Kit</strong></td>
<td>Now back in the Nuts Volts webstore, the new and improved Talking Skull Kit. The new kit includes the much improved audio, servo driver board, see all the improvements in our webstore. This kit provides are supplies necessary to build one talking skull. You provide the labor and tools and you’ll have a great Halloween prop in no time!</td>
<td>$97.95</td>
</tr>
<tr>
<td><strong>Geiger Counter Kit</strong></td>
<td>As seen in the March 2013 issue. This kit is a great project for high school and university students. The unit detects and displays levels of radiation, and can detect and display dosage levels as low as one micro-roentgen/hr. The LND712 tube in our kit is capable of measuring alpha, beta, and gamma particles. Partial kits also available.</td>
<td>$169.95</td>
</tr>
<tr>
<td><strong>Solar Charge Controller Kit 2.0</strong></td>
<td>If you charge batteries using solar panels, then you can’t afford not to have them protected from over-charging. This 12 volt/12 amp charge controller is great protection for the money. It is simple to build, ideal for the novice, and no special tools are needed other than a soldering iron and a 9/64” drill!</td>
<td>$27.95</td>
</tr>
<tr>
<td><strong>Super Detector Circuit Set</strong></td>
<td>Pick a circuit! With one PCB you have the option of detecting wirelessly: temperature, vibration, light, sound, motion, normally open switch, normally closed switch, any varying resistor input, voltage input, mA input, and tilt, just to name a few.</td>
<td>$32.95</td>
</tr>
</tbody>
</table>

### FOR BEGINNER GEEKS!

- **The Learning Lab 1: Fundamental Concepts** - $59.95
- **The Learning Lab 2: Basic Digital Concepts and Op-Amps** - $49.95
- **The Learning Lab 3: Basic Electronics, Oscillators and Amplifiers** - $39.95

The labs in this series — from GSS Tech Ed — show simple and interesting experiments and lessons, all done on a solderless circuit board.

As you do each experiment, you learn how basic components work in a circuit, and continue to build your arsenal of knowledge with each successive experiment.

For more info and a promotional video, please visit our webstore.
combines simplicity and advanced system on chip (SoC) technology in a tiny PLCC32 footprint package less than 14 mm x 12 mm. It is nearly half the cost of similar modules, and becomes very competitive with the concept of discrete designs. Having this common footprint across all of its available frequencies complementing its small size, the HumRC appeals to OEMs who have a limited budget to incorporate RF.

The transceiver offers agility by having eight lines that can be configured as either inputs for buttons or outputs to drive circuitry. It has selectable automatic acknowledgements that can include up to two bytes of custom data which can be additional control codes, sensor values, or battery voltage — whatever the application needs. No programming is required for basic remote control operation, but a serial UART interface is included for more advanced operation.

All functions can be controlled by serial commands, allowing more functionality with fewer hardware connections. It also has two analog lines that can be connected to sensors, and the capability to interrogate the voltage on those lines remotely. For basic sensor applications, the module can replace the microcontroller, reducing the overall cost of the end product and the programming burden in design.

To aid rapid development, the HumRC Series transceiver is available as part of a newly conceived type of master development system. This comprehensive development kit is designed to assist in the rapid evaluation and integration of the HumRC remote control and sensor transceiver modules. The all-inclusive system features several pre-assembled evaluation boards which include everything needed to quickly test the operation of the transceiver modules. Due to the advanced modular approach to the Master development kit, designers can take advantage of only buying certain boards such as additional prototype boards, remote boards, and other components.

For more information, contact: Linx Technologies
Web: www.linxtechnologies.com

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**Blinking-Eyes Animated Display**
- Animated display of 66 super bright LED’s!
- Microcontroller controlled
- Changes brightness automatically!
- Animated with constant motion!

The ultimate animated LED kit that will dazzle you and delight your friends! Uses a microcontroller to randomly select from many different animations such as a long pause before a wink, or a blink of the eye to stare passers-by! Four modes to satisfy any enthusiast’s desires: 1. Off for long random periods, then blinks or winks. Designed to scare! 2. On for long periods before performing an animation, perfect for costumes and displays. 3. Animates all the time for constant motion, perfect for display attention-grabber. 4. Random Fire! When placed in a pumpkin it will light up if you wouldn’t believe! As if this weren’t enough, the BE66 can also control a small hobby motor to shake bushes at random intervals or signal an external player to make a scary sound! Also has a CDS sensor so it can turn off in one mode, the display will dim as it gets dark for battery operation, and in the other mode it will turn off when it’s too bright, so it plays only in the dark!

**Specifications:**
- Simple & safe 9V battery operation
- Everlasting LED’s won’t burn out!
- Graphical LED display allows you to adjust pattern & size!
- Generates up to 25kV @ 20 kHz from a solid state circuit!

**Price:** $59.95

**Halloween Pumpkin**
- 23 bright LED’s!
- Random flash simulates flickering candle!
- Super bright LED illuminates entire pumpkin!
- Simple & safe 9V battery operation

The perfect “starter” kit with a terrific Halloween theme! You won’t be believing the size of this pumpkin! Six transistor circuit provides a neat random flash pattern that looks just like a flickering candle. Then a super bright LED illuminates the entire pumpkin with a spooky glow!

**Specifications:**
- Uses standard stereo RCA audio connectors.
- Safe low voltage construction, no fragile "electrical" parts!
- Adjustable sensitivity
- Built-in microphone!
- Runs on safe 12-15VDC so a great kit for the kids to build!

**Price:** $21.95

**Spark Generating HV Plasma Generator**
- Generate 2” sparks to a handheld screwdriver!
- Light fluorescent tubes without wires!
- Build your own Plasma Balls!
- Generates up to 23kV @ 20 kHz from a solid state circuit!

This popular kit was conceived by one of our engineers who likes to play with things that can generate large loud sparks, and other frightening devices! And at Halloween there’s no better effect than high voltage sparks flying through the air! The PG13 Plasma Generator creates a very impressive 25,000 volts at 20 kHz, to provide a stunning display of high voltage! It will draw a cool looking 2" spark to a hand held screwdriver, or light fluorescent tubes without any connection!

**Specifications:**
- Produces stunning lighting displays, drawing big sparks, to perform lots of high voltage experiments. In the picture, we took a regular clear "Decora" style light bulb and connected it to the PG13 - WOW! A storm of sparks, light traces and plasma ball effects! Don’t bite your hand on the bulb, it doesn’t hurt a bit and you can control the discharge! It can also be used for powering other experiments; let your imagination be your guide! Operates on 16VAC/VDC for maximum output. Can also be driven with 5-16VAC/VDC to reduce the output voltage.

**Price:** $64.95

**TFM3C Tri-Fiel Meter & ‘Ghost Detector’**
- See electric, magnetic, and RF fields!
- Watch the magnetic fields of the earth!
- Sense different magnetic poles
- Detect RF transmitters
- Graphical LED display allows you to see the invisible fields!
- Great learning tool for EMF, RF, and magnetic field theory!

The TFM3C has three separate field sensors that are user selectable to provide a really cool readout on two high graphic bargraphs! Utilizing the latest technology, including Hall Effect sensors, you can walk around your house and actually “SEE” these fields around your! You will be amazed at what you see. How sensitive is it? Well, you can see the magnetic field of the earth... THAT’S sensitive!

**Specifications:**
- See electric, magnetic, and RF fields!
- Sense different magnetic poles
- Detect RF transmitters
- Graphical LED display allows you to see the invisible fields!
- Great learning tool for EMF, RF, and magnetic field theory!

**Price:** $74.95

**Automatic Animated Ghost**
- Automatically greets your visitors!
- Responds to sudden noises!
- Built-in CDS sensor!
- Automatic "light" up!
- Adjustable sensitivity

Who says ghosts are just make-believe? Once your friends come upon this one they’ll think differently! The LED board design includes two ominous blinking eyes that change with various conditions, including sudden changes in ambient noise. A highly sensitive built-in microphone picks up anything from noises to talking and makes the ghost dance with its built-in motor, make eee sounds with the built-in speaker, and randomly blink a white cloth and a hanger are included as shown to make it look like the real thing. Runs on 2 AAA batteries (Not included).

**Price:** $21.95

**LED Strobe Light**
- Everlasting LEDs won’t burn out!
- Variable flash rate and audio trigger!
- Bass and treble trigger modes
- Safe low voltage construction, no fragile "electrical" parts!
- Generates up to 25kV @ 20 kHz from a solid state circuit!

This populer kit was conceived by one of our engineers who likes to play with things that can generate large loud sparks, and other frightening devices! And at Halloween there’s no better effect than high voltage sparks flying through the air! The PG13 Plasma Generator creates a very impressive 25,000 volts at 20 kHz, to provide a stunning display of high voltage! It will draw a cool looking 2" spark to a hand held screwdriver, or light fluorescent tubes without any connection!

**Specifications:**
- Produces stunning lighting displays, drawing big sparks, to perform lots of high voltage experiments. In the picture, we took a regular clear "Decora" style light bulb and connected it to the PG13 - WOW! A storm of sparks, light traces and plasma ball effects! Don’t bite your hand on the bulb, it doesn’t hurt a bit and you can control the discharge! It can also be used for powering other experiments; let your imagination be your guide! Operates on 16VAC/VDC for maximum output. Can also be driven with 5-16VAC/VDC to reduce the output voltage.

**Price:** $64.95

**Halloween Light Show**
- See the invisible fields
- Watch the magnetic fields of the earth!
- Sense different magnetic poles
- Detect RF transmitters
- Graphical LED display allows you to see the invisible fields!

You’ve probably seen a laser show at concerts or on TV. They’re pretty impressive to say the least! Knowing that you can’t afford a professional laser display we challenged our engineers to design one that’s neat and easy to build, yet inexpensive.

Well, the result is the LLS1 Laser Light Show! This thing is sweet and perfect for your haunted house or Halloween parties! It utilizes two small motors and a small standard laser pointer as the basics. Then, we gave it variable pattern and speed controls to customize the pattern!

Not enough, you say? How about a line level audio input to modulate the pattern with your CD’s, music, or spooky sound effects? You bet! Everything is included, even the small laser pointer. Runs on 6-12 VDC or our standard AC adapter.

**Price:** $49.95

**MK145 Electronic Halloween Pumpkin Kit**
- See the invisible fields
- Watch the magnetic fields of the earth!
- Sense different magnetic poles
- Detect RF transmitters
- Graphical LED display allows you to see the invisible fields!

The pumpkin face is the actual PC board, and assembly is easy through-hole soldering and electronics at the same time!

**Price:** $11.95
PLL synthesized for drift-free operation
Built-in mixer - 2 line inputs and one microphone input, line level monitor output
Frequency range 80 to 108.0, 100 kHz steps
Precision active low-pass "brick wall" audio filter!
Dual LED bar graph audio level meters!
Automatic adjustable microphone ducking!
Easy to build through-hole design!

The true professional workhorse of our FM Stereo transmitter line, the FM100B has become the transmitter of choice for both amateur and professional broadcasters around the world. From the serious hobbyist to churches, drive-in theaters, colleges and schools, it continues to be the leader. Not just a transmitter, the FM100B is a fully functional radio station and provides everything but the audio input and antenna system! Just add that and you're on the air!

This professional synthesized transmitter is adjustable directly from the front panel with a large LED digital readout of the operating frequency. Just enter the setup mode and set your frequency. Once selected and locked you are assured of a rock stable carrier with zero drift. The power output is continuously adjustable throughout the power range of the model selected. In addition, a new layer of anti-static protection for the final RF stage and audio inputs has been added to protect you from sudden static and power surges.

Audio quality is equally impressive. A precision active low-pass brick wall audio filter and peak level limiting devices give your signal maximum "punch" while preventing overmodulation. Two sets of rear panel stereo line level inputs are provided with front panel level control for both. Standard unbalanced "RCA" line level inputs are also provided to the audio output of your computer, MP3 player, DVD player, cassette deck or any other consumer audio source. Get even more creative and use our KB094 below for digital storage and playback of announcements and ID's. In addition to the line level inputs, there is a separate front panel microphone input.

All three inputs have independent level controls eliminating the need for a separate audio mixer! Just pot-up the source control when ready, and cross fade to the 2nd line input or mic! It's that simple! In addition to the dual stereo line inputs, a stereo monitor output is provided. This is perfect to drive studio monitors or local in-house PA systems.

The FM100B series includes an attractive metal case, whip antenna and built in 110 /220 VAC power supply. A B N C connector is also provided for an external antenna. Check out our Tru-Match FM antenna kit, for the perfect mate to the FM100B transmitter.

We also offer a high power kit as well as an export-only assembled version that provides a variable RF output power up to 1 watt. The 1 watt unit must utilize an external antenna properly matched to the operating frequency to maintain a proper VSWR to protect the transmitter.

(Note: the FM100W is a do-it-yourself learning kit that you assemble. The end user is responsible for complying with all FCC rules & regulations within the US or any regulations of their respective governing body. The FM100W is for export use and can only be shipped to locations outside the continental US, valid APO/FPO addresses or valid customs brokers for end delivery outside the US.)

FM100B Super-Pro FM Stereo Radio Station Kit, 5uW to 25mW Output
FM100BEX Super-Pro FM Stereo Radio Station Kit, 5uW to 1W Output

Digital Controlled FM Stereo Transmitters

PLL synthesized for drift free operation
Built-in Mixer and control of all set-
ing parameters!
Professional metal case for noise-free operation
FM filtering on audio and power inputs
Super audio quality, rival commercial broadcasts
Available in domestic kit or factory assembled
export versions

For more than a decade we’ve been the leader in hobbyist FM radio transmitters. We told our engineers we wanted a new technology transmitter that would provide FM100 series quality without the advanced mixer features. They took it as a challenge and designed not one, but TWO transmitters!

The FM30B is designed using through-hole technology and components and is available only as a do-it-yourself kit with a 25mW output very similar to our FM25S model. All the engineers redesigned their brand-new design using surface mount technology (SMT) for a very special factory assembled and tested FM35BWT version with 1W output for our export only market!

All settings can be changed without taking the cover off. Enter the setup mode from the front panel and step through the menu to make all of your adjustments. A two line LCD display shows you all the settings! In addition to the LCD display, a front panel LED indicates PLL lock so you know you are transmitting.

Besides frequency selection, front panel control and display gives you 256 steps of audio volume (left and right combined) as well as RF output power. A separate balance setting compensates for left/right differences in audio level. In addition to settings, the LCD display shows you your levels and optimizes your sound quality. All settings are stored in non-volatile memory for future use! Both the FM30B and FM35BWT operate on 13.8 to 18VDC and include a 15VDC plug-in power supply. The stylish black metal case measures 5.25 W x 3.5 D x 1 H. (Note: After assembly of the do-it-yourself hobby kit the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the US.)

FM30B Digital FM Stereo Transmitter Kit, 0-25mW, Black
FM35BWT Digital FM Stereo Transmitter, Assembled, 0-1W, Black (Export ONLY)

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### WHAT'S HOT
Test & Measurement and Other Essentials!

#### OSCILLOSCOPES

**Rigol**
RIGOL's test & measurement instruments compete with industry leaders – but more affordably: Analog & Mixed-signal Scopes to 1GHz with AWG, Function/AWG's from 20MHz-350MHz RF Signal Gen's to 6GHz, Pwr Supplies, DMMs, & Spectrum Analyzers.

**Owon**
OWON's affordable, reliable, easy-to-use precision benchtop & handheld scopes are unbeatable in their price range. Battery powered and portable options for field use. Owon's Triple Output Power Supplies offer remote control & preset configurations.

**Pico**
PICO TECHNOLOGY - the world's best PC-based oscilloscopes & data acquisition equipment with the performance of good bench scopes; compact & lightweight - ideal for field work. Award-winning automotive scopes find engine & electric faults quickly.

#### MISC.

**USB Control**
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We stock numerous power supplies from simple “wall-warts” for low-voltage/low-current needs, to more complex bench-top supplies with single or multiple outputs, programmable supplies, flexible output current/voltage supplies with multiple communication options.

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3D printing makes product and device development faster and cheaper – rapidly build concept parts and projects. We have the latest 3D printers from industry leaders MakerBot and Afinia, as well as the best 3D printing filament available for creating high quality parts quickly!

#### CIRCUIT/PCB TEST

**ABI Electronics**
ABI ELECTronics - PCB test/repair: BoardMaster 8000: easy-use PCB test system; JTACMaster: programs/tests via JTAG port; RevEng Schematic Learning System: generates schematics from PCBs; SENTRY: detects counterfeit components.

**MQP**
MQP ELECTRONICS - USB2.0 Analyzers /Gens, Protocol/Electrical Test equipment, offering unbeatable value/performance ratio and Vbus monitoring. GraphicUSB software offers full analysis of std USB2.0 protocol with Class Analysis options.

**Cosview**
COSVIEW - range of extremely affordable USB-connected inspection microscopes & stands, very useful for examining printed circuit boards and small integrated circuits for production faults or part number markings. Polarizing filter option which excludes surface glare is available.

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