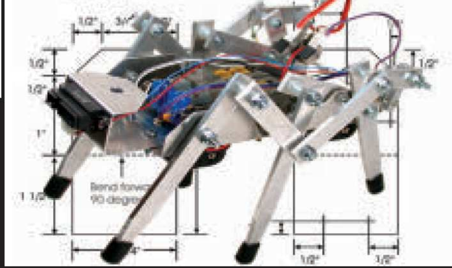


■ BY VERN GRANER

THE SAGA OF THE SONAR STATION

THE SONAR STATION IS AN INTERACTIVE KIOSK that entices visitors to experiment with, play with, and learn about sonar distance measurement. Using a combination of robotic, acoustic, and visual devices, the kiosk responds to visitor's motions with fun and entertaining real-time reactions.

PLAY IT BY EAR

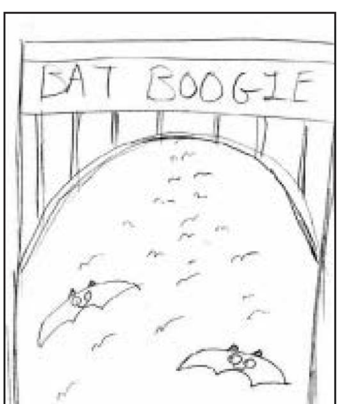
When the Austin Children's Museum was gearing up to host the Bay Area Discovery Museum's "Play It By Ear" exhibit (see Resources), they decided it would be neat to add some Texas flair. They set aside some funds and drafted a "Call To Artists" announcement which was sent to various art groups in the city. As The Robot Group has been a consistent supporter and contributor to Austin Children's Museum events, it wasn't long before the announcement popped up on The Robot Group mailing list and I immediately started drafting ideas on how we might be able to participate.

After reading the announcement, my original thought was to re-package the popular Thereping instruments that create music by detecting the player's hand position over a sonar sensor (see the complete writeup in the April 2006 issue of *Nuts & Volts*). The Therepings had been well received every time we brought them out to museum events but they are designed to be held by the "musicians" and, if operated by visitors, they require a "conductor" to supervise the operation.

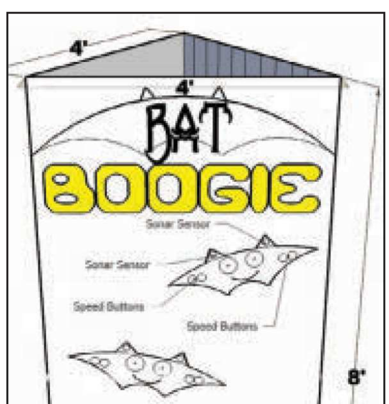
The trick would be to integrate the instrument's functions into a kiosk style device that would eliminate the need for visitors to wear the instrument and also eliminate the need for a conductor. In addition, we wanted to find a fun and educational tie-in for sonar range finding and the city of Austin. The obvious answer was ... bats.

THE BAT BOOGIE

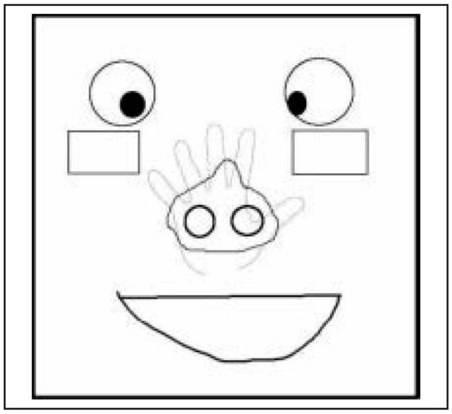
The Congress Avenue Bridge in downtown Austin, TX is home to the largest urban colony of Mexican free-tail bats in North America (the colony is estimated at 1.5 million!). The Congress Bridge bats are a well-known city attraction, so I decided to base the theme of the kiosk on a mixture of the Thereping instruments and the sonar echo-location capabilities of bats. I made some pencil drawings of the concept piece (**Figure 1**) which I then visualized in Google Sketchup (**Figure 2**). I wrote up a comprehensive proposal with my renderings and the proposed kiosk's capabilities which I



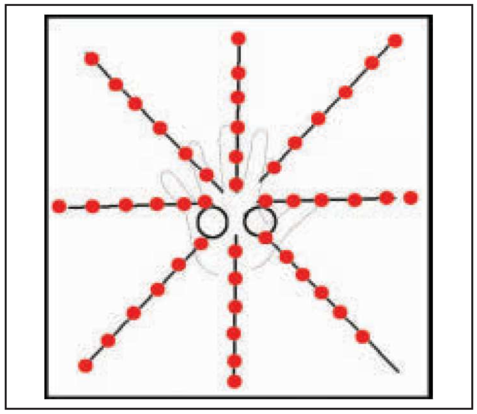
■ FIGURE 1. First concept sketch of the Bat Boogie kiosk.



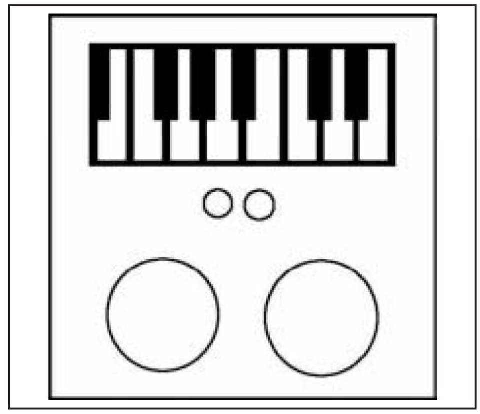
■ FIGURE 2. Google Sketchup version of the Bat Boogie kiosk.



■ FIGURE 3. The FACE window concept sketch.



■ FIGURE 4. The STAR window concept sketch.



■ FIGURE 5. The PIANO window concept sketch.

sent off to The Children's Museum. Before long, I received a response from the Exhibit Director. My proposal was approved!

ITS PERFECT! BUT, CAN WE CHANGE ... EVERYTHING?

With the proposal accepted and the funding allocated, all we needed to do was have a small meeting with The Powers That Be at the museum to work out the "details" of the project. At the meeting, the museum folks let me know that, though they loved the proposal, they would like to make some small changes.

For starters, they didn't want the kiosk to use bats in its design theme. Secondly, they wanted the unit to be mostly transparent so the visitors could see the inner workings. And lastly, they wanted the unit to operate without playing music. At first I thought they were kidding. Turns out they weren't (uh oh).

Of course, this was all presented in a very positive way. In fact, I could take it as a compliment of sorts that they believed I was creative enough to take my gutted project and resurrect it into what they envisioned. But, no matter how I looked at it, it simply meant a lot more thinking, designing, and work.

BACK TO THE DRAWING BOARD

I spent the next few days banishing the bats and banning the "boogie" from all the designs. I decided to focus on making a kiosk where visitors could simply interact with sonar ranging in a real-time, visceral way. I settled on three different interactive experiences that would be solid examples of sonar ranging. In my new design, the three-sided kiosk would have three separate clear plastic "windows" that would each reveal the components inside. In my new sketches, I named the windows "FACE," "STAR," and "PIANO," and they worked like this:

FACE WINDOW

The FACE window (**Figure 3**) used a robotic positioning system that moved servo motors in proportion to values received from the sonar sensor. A pair of ping-pong ball "eyes" would appear to follow the visitor's hand as they moved it closer and farther away from the sonar sensor "nose" in the window. The eyes in the window would eventually cross in a fun and silly manner when you had your hand right up against the nose.

STAR WINDOW

The STAR window (**Figure 4**) was designed to provide a very visual display of sonar ranging. This window would be filled with concentric rings of colored LEDs in a circular shape. As a visitor would bring their hand closer to the center of the circle, more sets of lights would activate, creating a moving, colorful star burst that expands and contracts in relation to the distance of the

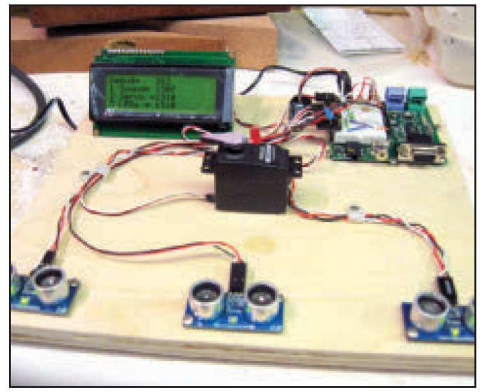
■ FIGURE 6. Bruce Tabor marking up the panels for the kiosk.

■ FIGURE 7. Cutting the window holes in the kiosk panels.

■ FIGURE 8. Window holes cut and routed in the kiosk panels.

■ FIGURE 9. Mike Scioli test fits the top plate on the kiosk.

■ FIGURE 10. Paul Atkinson assembling the "back boxes" for each kiosk panel.



■ FIGURE 11. The Propeller Demo Board prototyping platform.

hand from the sonar sensor.

PIANO WINDOW

The PIANO window (**Figure 5**) would provide an audible response to the sonar range readings. A drawing of a piano keyboard would be placed behind the window and LEDs placed behind each piano "key" to indicate what note is being played. A speaker would be mounted in the middle of the window so the visitor could hear the notes as they play. Bringing a hand close to the display would cause the piano to play notes that increase in pitch, and lower pitches would play as the hand moved away.

THINKING OUTSIDE THE BOX

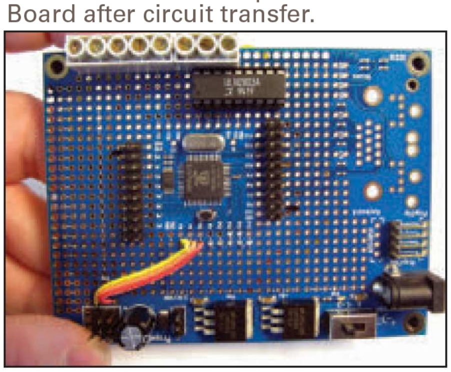
Once I had the three windows defined, I decided I would keep some of my original design criteria such as placing three windows per panel and having each window at a different level to accommodate different viewing heights (children/adults/wheel chairs). The windows would be placed in an offset configuration to accommodate multiple visitors at once. For example, a parent could interact with the top window while a small child could stand in front of the parent and play with the bottom window. The middle window would be off-set to the side to allow someone to stand next to the parent/child and easily interact with the middle window. To make each window type accessible to all three height levels, they would rotate positions on each panel. For example, Panel 1 would have the Star in the top location; Panel 2 would have the Star in the middle; and Panel 3 would have the Star on the bottom. A person of any height would only need to walk around the kiosk to experience all of the different window types at the height they prefer (or require).

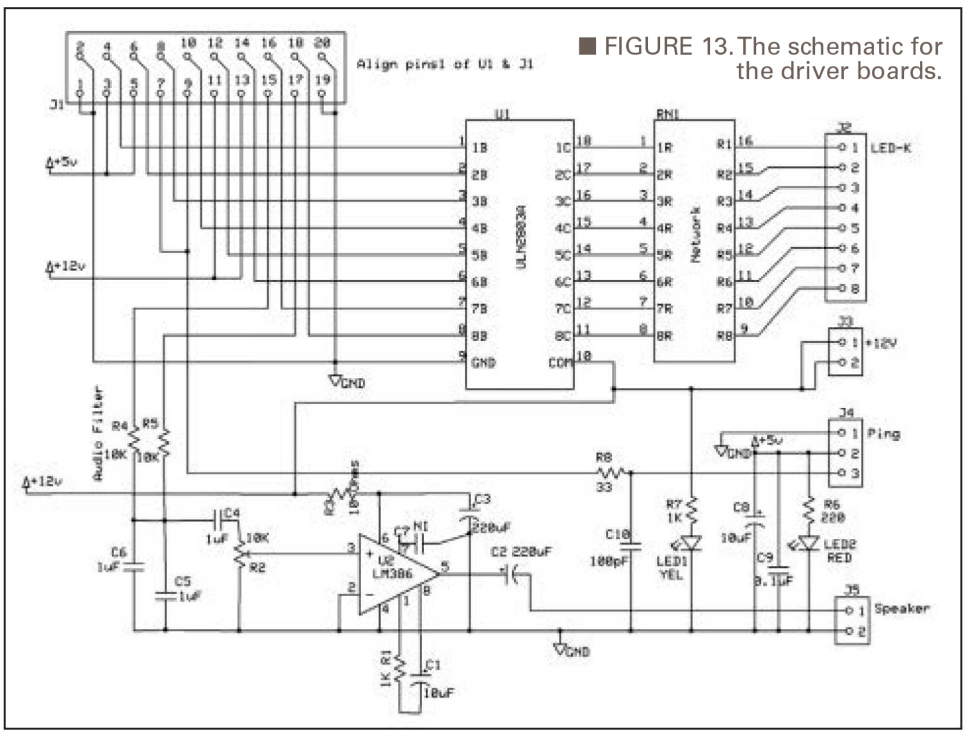
In order to make the unit function no matter the lighting level of the venue, I planned to install CCFT lights in each window that could be switched on and off by the micro-controller. This would allow the visitor to see the inner workings of the machine even in low-light situations. As I worked on the design, I sent progress updates to the museum folks to make sure we stayed on the same page. After a few weeks, we settled on a design we could all agree upon. It was time to get busy and build it.

LETS MAKE SOME SAWDUST

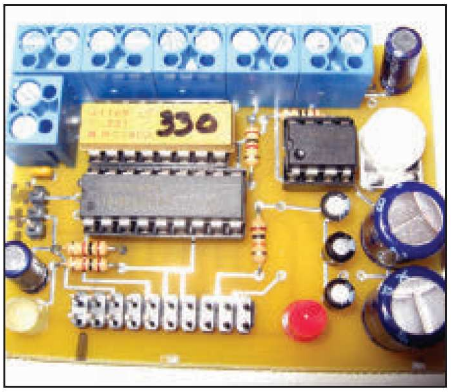
The final design called for a three-

■ FIGURE 12. The Propeller Proto Board after circuit transfer.

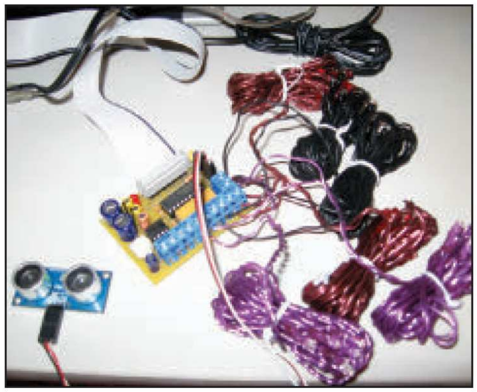




■ FIGURE 13. The schematic for the driver boards.



■ FIGURE 15. The PCB fully populated.



■ FIGURE 16. The PCB with lights and sensor connected and working.

■ FIGURE 17. The Parallax Sonar Sensor mounted behind the plastic window.

sided kiosk with three windows in each panel. This design would be flexible in that the three panels could be arranged in a triangle for a stand-alone display, or the panels could be placed in a row flat against a wall to take up a minimum amount of space. With rough-sketched plans in hand, I went to visit (and frustrate the heck out of) my good friend Bruce Tabor. Bruce is an experienced professional carpenter with a well-stocked shop. As he is used to building precision crafted pieces, my hand-cobbled drawings that were devoid of reasonable scale or sane measurements caused him no end of grief.

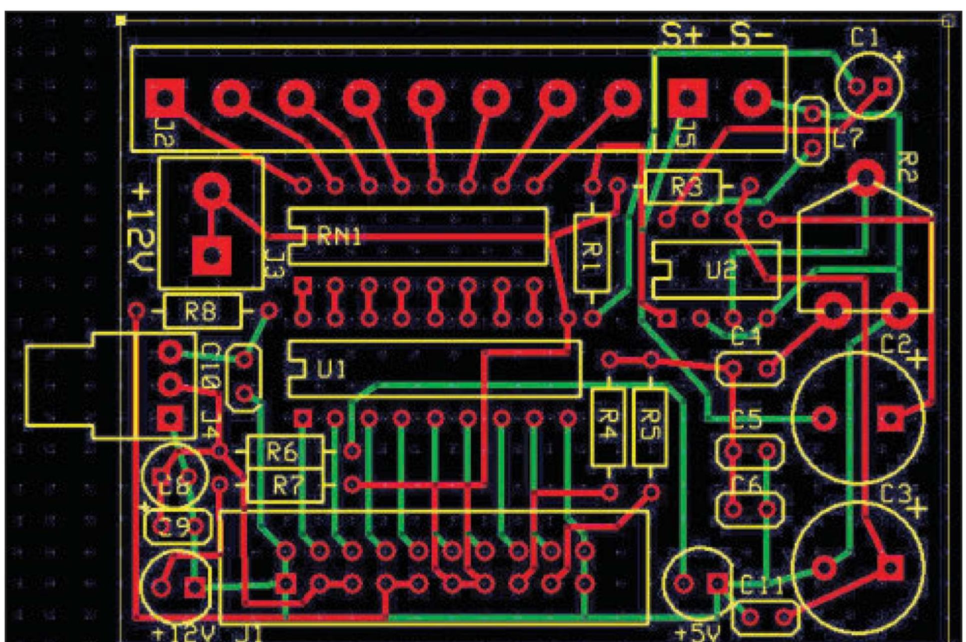
In spite of my 50% burro plans, Bruce got right to work making the panels. In seemingly no time, he had all three panels marked (**Figure 6**), cut to size (**Figure 7**), and routed for the windows (**Figure 8**). I dragged along some of my friendly neighborhood roboteers to help with the sanding, cutting, drilling, and other assembly. While we completed that, Bruce finished up the kiosk top, bottom (**Figure 9**), and the window backing-boxes (**Figure 10**). When we were done, I carted everything back home and had my three-sided kiosk standing in the dining room ready to stuff with electronics!

SPINNING UP A SOLUTION

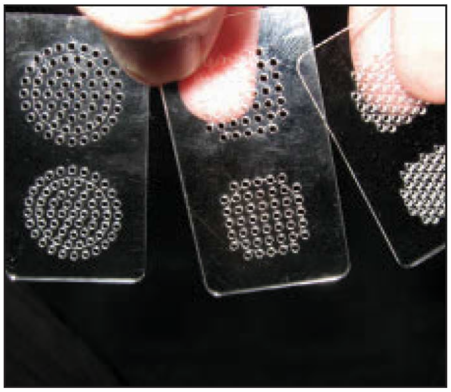
The Propeller chip from Parallax has some amazing capabilities and I had been looking for a project where I could experiment with this powerful, new multi-core microcontroller. The Sonar Station seemed to be the ideal candidate. Though I hadn't had any experience coding in the SPIN language, I had done quite a bit of programming in PBASIC on the BASIC Stamp series of microprocessors from Parallax. With a background in PBASIC, the SPIN language is surprisingly simple to understand. In addition, I had the good fortune of knowing some local "Propeller heads" that could help me if I got stuck. As luck would have it, one of the foremost experts on the Propeller, André LaMothe (see Resources) had recently moved to Austin! Not only had he come out to some Robot Group meetings, but when I told him about this project, he graciously offered to assist with the design and troubleshooting of the code.

PROPELLER PROTOTYPE

To get started, I created a board that I could use to test and prototype the software (**Figure 11**). In previous projects where I had time-sensitive peripherals to control, I would normally have mounted a dedicated servo controller or other "helper" hardware on this test board. This is because with a single microcontroller dealing with more than one time-sensitive device, you would have to code very carefully to insure you service all time-sensitive devices. For example, if a single microprocessor is waiting for a sonar sensor to return a pulse from a distance measurement, the microcontroller is "blocked" from



■ FIGURE 14. The PCB layout for the driver boards.



■ FIGURE 18. Various sonar sensor test bezels.

■ FIGURE 19. The three panels set up together.

■ FIGURE 20. A custom laser-cut sign to top off the Sonar Station.

doing anything else until that measurement is complete. If during this blocked time the servo motor needs a pulse to update its position, the single microcontroller cannot perform this task and so the servo is liable to move erratically. Typically, a serial servo controller of some type would be employed to provide consistent pulses to the servo motors and to make programming less critical. Unfortunately, this additional hardware adds cost.

With the Propeller chip and its multiple "cogs," I effectively had eight separate microcontrollers I could use at the same time. The SPIN language allowed me to assign tasks to each cog such as controlling a servo motor or fetching a sonar distance measurement. I used the freely available "objects" from the Parallax website (see Resources) to do both of these tasks without having to spend additional money on external helper hardware. I effectively replaced hardware with software for free.

ONE THING LEADS TO ANOTHER

Once I had the Propeller Demo Board prototype up and running, I turned again to Paul Atkinson for his help in creating the schematics and printed circuit boards (PCB). Paul started by porting the design from the original Propeller Demo Board over to the Propeller Proto Board (**Figure 12**). He then used free software from ExpressPCB (see Resources) to whip up a schematic that would include a small audio amp for the PIANO window, a ULN2803a driver for the strings of LEDs in the STAR window, a header for the servo in the FACE window, and connectors for the 12 volt CCFT lights (**Figure 13**).

He then laid out a PCB (**Figure 14**) and we sent the board off to ExpressPCB to have it made. When the finished boards arrived, Paul was able to populate them (**Figure 15**) and test them with all components mounted and working (**Figure 16**). If you ever are planning to build a project of this scope, my advice to you is to make friends with a professional electrical engineer!

WINDOWS FOR WOOD WALLS

As Paul was busy soldering up the PCBs, I called on my old friend Rick Abbot to help me with the creation of the actual clear plastic windows. Rick started by fabricating an aluminum template so he could cut each window to size and to position identical holes on each panel. Then, using a two-step drilling process, he crafted special holes to hold the sonar sensors in place while shielding the delicate front screen of the sensor from direct exposure to the kiosk visitors (**Figure 17**). Lastly, he drilled the holes for the speaker in the PIANO window and the pattern of holes in the STAR window.

I did a press-fit of the LEDs for the star to see how it would look and was very impressed with how well the plastic panels carried the lights. So, with the custom PCBs completed without a failure, the cabinet built without a hitch, and all the windows fabricated and ready to mount, it was obviously past the time for something to go wrong.

THE PATH TO SUCCESS IS PAVED WITH PERSISTENCE

The first indication we had of a problem came when we noticed that when mounted in the window, one of the sonar sensors was no longer responding. As we had nine different panels and we had been inserting and removing sonar sensors quite often, we assumed we had damaged a sensor. I replaced it and the window began to work. Then, in a bit, we notice another one of the windows ceased to work. We soon discovered that all the sonar sensors would work intermittently when they were inserted into the mounting holes in the windows!

For those of you who enjoy drama, chaos, and panic, feel free to visit the Parallax forum thread mentioned in the Resources section. There you can follow along as I franticly searched for help in discovering how much of the front of the sensor could be obscured, how resonance of mounting material might affect the sonar distance readings, the effect alternate grill materials would have on the sensor readings, and the like. For those who just want to know how it all turned out, this is what happened: After swapping sensors, trying different grill materials, and even testing precision laser cut bezels with different patterns and densities from my buddy Ed Gonzalez at Oak Hill Laser (**Figure 18**), in the end we discovered that by simply "angling" the sensor very slightly in its mounting hole, it would work reliably.

Our guess is that the sensor was picking up reflections from the flat material between the exit holes. We noted that the sensor front and the grill surface of the window were in parallel with each other creating a resonant chamber. In the finished windows, I would turn the unit on, insert the sensor into the mount, then angle it slightly until it would start to work. Once in the "sweet spot," I fixed the sensor in place with a blob of hot melt glue. Problem solved.

ATTRACT MODE?

Now that we finally had the basic functions up and running, it was time to tweak the software a bit to make the display more eye-catching. I wanted the display to entice people to interact with it. As designed, when the display was waiting for someone to use it, it was fairly static. There was no motion, no flashing lights, nothing that might draw you to see what the kiosk was all about. I decided to take a cue from video arcade game designers of yester-year and add an "attract" mode to each panel.

The idea was to keep track of the time that has elapsed since the last interaction with any of the windows and, if that time went beyond a certain threshold (30 seconds or so), the unit would do things to attract attention. With some programming help from fellow roboteer Gray Mack we settled on an attract mode that would exhibit the following behaviors:

- The CCFT back lights for each window sequence on and off to create an interesting light and dark pattern.
- The "eyes" in the FACE window periodically track together looking left and right as if watching for the next visitor to approach.
- The LED lights in the keyboard of the PIANO window would sequence up and down, casting interesting shadows from the interior wiring.
- The LED lights in the STAR windows sequence back and forth creating growing and shrinking concentric rings that are compelling to watch.

I toyed with the idea of having the unit emit sounds during the attract mode, but ultimately decided against it as I didn't want to annoy the exhibit staff who may be stationed nearby for extended periods of time.

Once we had the three panels assembled and programmed, I set them side by side back in the dining room (**Figure 19**) and let them lapse into Attract mode. I turned the lights off and the light show was dazzling! NOTE: If you would like to see a video of the Sonar Station panels in action, check out the video link in the Resources section.

GOOD THINGS COME TO THOSE WHO WAIT

Though we now had a fully-functioning Sonar Station, we were sadly way past our delivery date. Between all the painstaking hand-construction and the hard stop we hit when we couldn't get the sonar sensors to reliably operate, the Premiere of the Play It By Ear exhibit had come and gone. Lucky for me, the good folks at the Children's Museum we both patient and kind. They listened to the stories of sensor failure and other issues and only offered support and encouragement. They even offered to extended our run at the museum and welcomed us without question when the project was finally finished.

The night before we were due to deliver the unit, Ed Gonzalez came by to drop off the finishing touch. Laser cut from clear acrylic panels, emblazoned with the kiosk name in hot-red letters and pre-drilled with holes for a string of RGB color-changing LEDs, this three-sided custom crafted sign gave the unit a distinctive professional look (**Figure 20**). We were finally ready to deliver this baby!

SETUP IT UP!

In the early hours of a Saturday morning, Paul Atkinson, Ed Gonzalez, and I loaded the Sonar Station into Ed's truck and headed downtown to The Children's Museum. We had a slim installation window as the Museum was scheduled to open at 10:00 A.M. We had to have it assembled, installed, tested, and all our tools cleaned up and out no later than 9:55. The Museum's Technical Director, Chris Brown, met us at the door and helped us unload (**Figure 21**) and assemble the panels (**Figure 22**). It took only two hours to get power run

■ FIGURE 21. Vern Graner assembling the Sonar Station.

■ FIGURE 22. Paul Atkinson and Ed Gonzalez putting the top on the Sonar Station.

■ FIGURE 23. Children's Museum visitors interact with the Sonar Station minutes after its installation.

and to get everything together. At 9:50 A.M. that morning, the Sonar Station was live!

AND NOW, THE REST OF THE STORY

As we were packing up and talking to the museum folks, parents and children had already started to interact with the machine (**Figure 23**). The Sonar Station ran all that day and continued to run without failure for the remainder of the Play It By Ear exhibit. It continued on to be featured at The Children's Museum for a number of weeks even after the show had closed. Comments from the visitors were very positive and the machine only experienced a single failure just before it was retired from the floor. Seems a rather enthusiastic child hammered his fist on one of the lower windows until the hot melt glue came loose and the sonar sensor fell out of place (a few drops of hot glue brought the unit back online).

All in all, I feel the project was an unmitigated success and I expect to place the machine in other locations around Austin and the Central Texas area in the future. In the meantime, it's a pretty neat dining room ornament. :) As always, if you have any questions please feel free to contact me at vern@txis.com. **NV**

Credit Where Credit is Due

I'd like to thank Erich Rose, Becky Jones, and Chris Brown with the Austin Children's Museum for making the Sonar Station a reality. I'd also like to thank The Robot Group and all the members of the Sonar Station team:

Andre LaMothe: Propeller SPIN code programming
Gray Mack: Propeller SPIN programming
Paul Atkinson: PCB design and layout, cabinet assembly and installation
Bruce Tabor: Lead Carpenter and cabinet design
Mike Scioli: Cabinet assembly and finishing
Edward Xavier Gonzalez: Laser cut plastics, cabinet assembly, delivery, and installation
Rick Abbott: Plastic window fabrication & bracket machining
Kym Graner: Planning and logistics

Thanks everyone! It wouldn't have been possible without you!

RESOURCES

- Bay Area Discovery Museum "Play It By Ear" exhibit
  www.baykidsmuseum.org/tour_the_museum/special_exhibitions/play_it_by_ear/
- The Austin Childrens Museum Press Release
  www.austinkids.org/About-Us/Newsroom/-Play-It-By-Ear-.aspx
- The Robot Group
  www.TheRobotGroup.org
- The Therepings
  www.thereping.com
- Google Sketchup
  http://sketchup.google.com
- André LaMothe
  http://en.wikipedia.org/wiki/Andre_Lamothe
- Parallax Object Exchange
  http://obex.parallax.com
- ExpressPCB
  www.expresspcb.com
- Sonar Sensor discussion on Parallax forums
  http://forums.parallax.com/forums/default.aspx?f=10&m=256496
- Video of the Sonar Station in Action
  www.youtube.com/VernGraner