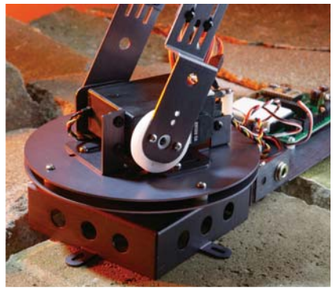


The completed SG6 arm has a sturdy pivot table to which the arm is securely mounted. In the background, the Parallax Board of Education prototyping board is visible. The "grilled" plate at the top of the arm is a sensor bracket.

CRUSTCRAWLER SG6 ROBOTIC ARM

by Peter DelMastro

A rugged, precision-engineered manipulator

Based in Arizona, CrustCrawler has made a name for itself with its powerful walking-robot kits such as the HexCrawler. The kits feature aluminum components and powerful servos and are designed around Parallax microcontrollers. The company has also developed robotic-arm kits that employ the same design elements as its walkers. CrustCrawler offers a range of variations of the arm kit—some with fewer servos, some with more powerful ones and even some without electronics or servos; this allows you to pick a kit, almost à la carte, that best suits your needs. For this article, I assembled and tested an SG6-UT "full kit," which is a 5-axis arm kit that includes servos, electronics and power supplies (available from CrustCrawler for $549).

MECHANICS

I was quite impressed when I began to unpack the kit. All the parts came packaged in clear zip-lock-type baggies. All the hardware bags (and there are a lot!) are labeled to prevent confusion. The kit includes a variety of metal Phillips-head fasteners in no. 4 and no. 6 sizes. CrustCrawler also includes a bag with spare hardware parts for any contingency. The strong, yet light, $^1/_{16}$-inch-thick aluminum parts are also bagged separately. They have a brushed, graphite-color finish that looks rather industrial.

The servos are all high-quality ball-bearing models from Hitec. There are six—from the small, light HS-225MG wrist servo to the massive HS805BB shoulder servo. One servo controls each axis of the arm's movement: rotation of the base, the shoulder, the elbow, the wrist and the gripper.

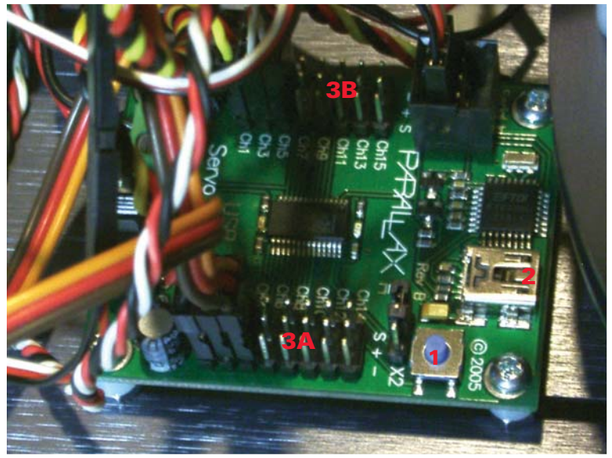
ELECTRONICS

The "full kit" also includes all the electronics needed to operate the arm kit. There is a Parallax Board of Education (BOE) that provides both a carrier for the BASIC Stamp 2p (BS2p) microcontroller and a breadboard area for customization. Next, there's a Parallax Servo Controller (PSC) board. This is the interface between the BOE and the servos; it is used to free the BS2p from having to drive all the servos directly. The BS2p-24 microcontroller is a middle-of-the-line BASIC Stamp microcontroller that Parallax offers in terms of processor speed, number of I/O pins and available RAM. It has a 20MHz processor speed that can execute up to 12,000 instructions per second.

The PSC uses its own microcontroller and power supply—separate from the BOE—to interface with the servos. It has a nice feature called "ramp" that allows you to control how quick-

PHOTOS BY WALTER SIDAS

ly the pulse-width servo control signal changes during a move; it effectively controls the acceleration of the servo move. So, for example, if a servo is holding one position and is then commanded to another, the ramp function controls how quickly the pulse width changes. When the ramp is set to zero, the pulse width changes instantly, and the servo moves as quickly as it can to the next commanded position. When the ramp is increased, however, the PCS gradually changes the pulse width over time, and the servo moves more smoothly. This useful feature is used to blend, or overlap, the movements of two (or more!) joint servos and make arm movement smoother and more graceful.

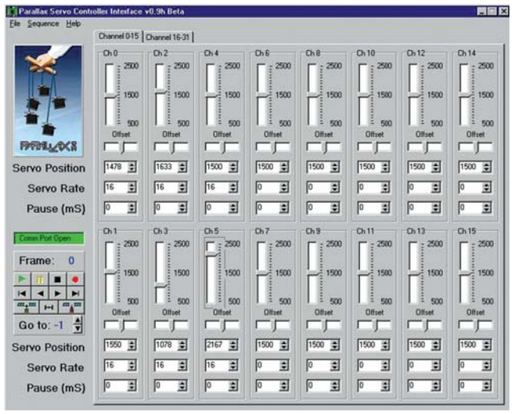


Servo Controller board. 1. Reset button; 2. USB programming connector; 3A and 3B. Servo connectors.

SOFTWARE

You'll use two pieces of software to control the SG6 arm: first, there's the Parallax Servo Controller Interface (PSCI) software and second is the BASIC Stamp Windows editor. PSCI is PC software that interfaces directly with the Servo Controller board and provides a nice graphical interface with sliders and a button to control each of the robot's servos. The PSCI software has two primary uses with the SG6: first, it is a useful tool to sort out and verify the proper electrical connections to each of the servos. With this software, each servo can be controlled directly. Sliding the control on the screen causes the joint to move. Doing this, you can check that the servos are connected in the right order on the PSC. Second, the PSCI software also has the capability to store and replay a series of arm positions. This feature can be used for animatronics control of the arm by stringing together a series of prerecorded movements and then replaying them.

Programmatic control of the arm is available through the BS2p microcontroller. It can be programmed using the BASIC Stamp Windows editor (which is a ~6MB download from Parallax.com). The BS2 is programmed in the PBASIC language that is fairly straightforward to learn. The BS2p microcontroller controls the servos through the PSC board. The BS2p communicates with the PSC using a serial protocol (SEROUT commands) and addresses each servo to move. Each message from the BS2p to the PSC includes the servo channel to move, the ramp rate and the position to move to. You can find further details on programming the PSC along with sample BS2 code on the CrustCrawler and Parallax websites.



Parallax Servo Controller interface.

TIPS FOR A SUCCESSFUL BUILD

For assembly, common hobby tools such as small screwdrivers, needle-nose pliers, an 1/8-inch drill bit and a ruler or calipers are needed. This version of the kit included an external power supply for the servos, so two wires also have to be soldered for that connection.

Organization, patience and attention to detail are the keys to successfully building this kit. Each step in the 85-page manual is nicely illustrated with black-and-white photos and CAD drawings. Nevertheless, I found some of the instructions a bit confusing. At a couple of points, I found that I had mis-assembled some parts and had to backtrack to make corrections. I think that an exploded view of the complete arm with labels on the parts would be a nice addition to the manual. For example, the "forearm" and "bicep" parts look quite similar and can easily be confused at first glance. The focus of the manual is on the mechanical assembly instructions; it gives little guidance on the proper routing of the servo wires, and for programming the arm, you're on your own.

The kit includes almost 300 parts of which 250 are hardware items such as screws, nuts and washers. I used a 15-compartment organizer to keep them all organized. The little time it took me to separate and organize the parts at the start of the build undoubtedly saved me from having to hunt around for the proper hardware throughout the project.

Leave yourself plenty of time to build the SG6 arm. The instructions suggest that it can be completed in three to six hours, but it took me almost twice that long. I spent almost an hour working on properly routing the servo wires because it took a couple of tries to arrange them properly. Routing the wires through the arm is a bit of a balancing act; there has to be enough slack in the wires to allow the full range of joint movement while also allowing the wires to reach back to the servo controller board.

OPERATION

When assembled and operating, the SG6 is impressive. This robotic arm has a reach of about 18 inches (from the middle of the base to the gripper), it weighs about 2 1/4 pounds, and it can lift about 1 pound. If you try to lift heavy objects that are near the edge of the arm's reach, it may tip over. CrustCrawler provides three mounting holes in the base so that it can be secured to a desktop. The gripper opens wide enough to grasp objects that are 3 inches wide. When ramp rates are set low, the powerful servos move the arm very quickly, but it starts and stops with a jerk. This causes the arm to shake and can disturb any payload it is carrying. To make gentler, smoother movements, I found that I needed a ramp rate of at least 8. I also noticed that the arm can more easily pick up heavier objects that are close to its base because it doesn't have to extend its joints until they are nearly straight out.

CONCLUSIONS & RECOMMENDATIONS

The CrustCrawler SG6-UT is a good kit for experienced hobbyists. The number of parts and the complexity of the assembly are well suited to anyone who has successfully completed a project or two. There isn't any tutorial for programming or instruction in PBASIC with the arm. Developers will have to already be familiar with the language or be able to get any information they need from other sources.

The SG6 "full kit" is very capable and can also grow as your interests expand. There are several paths available to upgrade the arm. One is to increase the arm's lifting capacity by adding more powerful servos. Another upgrade would be to add sensors for feedback and logic in the microcontroller so that the arm can interact with the environment. The sensor bracket (near the gripper) and the aluminum frame parts have extra slots and holes where accessories can be mounted. It's easy to imagine adding color sensors and having the arm move objects according to their color, or to add a sonar sensor so that the arm can detect and then home in on an object to pick up.

RESOURCES

CrustCrawler's website includes lots of information about the SG6 arm, including photos, movies and sample PBASIC software. There is also a forum on which you can interact with other users and reach the developers with questions or comments. The forum contains an active sub-forum that's specifically for the SG-series robotic arms; there are discussions about the arms' servos, electronics and programming. Go to www.crustcrawler.com.

You'll also find abundant information about the BS2p microcontroller, the PSC board (along with the FTDI USB drivers for pre-Win2K computers) and the PBASIC programming language on the Parallax website at www.parallax.com.

Links

CrustCrawler, www.crustcrawler.com, (480) 577-5557

Parallax, www.parallax.com, (888) 512-1024

For more information, please see our source guide on page 89.