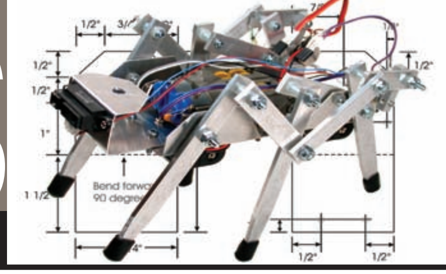


PART 1

■ BY VERN GRANER

ROBOBENCH: Putting the CrustCrawler AX-12+ "Smart Arm" to Work

IT'S INEVITABLE. When working on a project at your workbench, at some point you'll wish that you had a third hand. When you're holding together two parts that need to be soldered or you need a screwdriver but you don't want to take your eyes off of some small parts to reach for it, an extra hand would be awfully uhm ... "handy." In response to this need, the industry has developed all sorts of "third hand" devices such as the alligator clip "helping hands" sold by RadioShack (Figure 1) or specialized vises such as the ones sold by PanaVise (Figure 2). Though these tools each do their jobs very well, it's up to you to do the (re)positioning any time you want to have your item at a different orientation.

Just a short while ago, some robot enthusiasts and I went to see the movie *Iron Man*. The hero of the story had a pair of autonomous, intelligent, mobile robot arms that would assist him by holding lights and handing him tools as he worked. In one scene, the arm is intelligent enough to know where to hold a magnifying glass to help the hero build part of his suit (Figure 3) by simply observing the human and discerning his needs. Though we obviously have a long way to go before we get to the level of robotic helpers depicted in science fiction movies such as this, it made me wonder how far off a useful robotic bench accessory was. For example, would it be possible to re-purpose a hobby-level robotic arm to "earn its keep" by helping out on our workbenches?

CHILD'S PLAY

The first robot arm I owned was the venerable RadioShack "Armatron" (Figure 4), purchased in the early 1980s. When I got it home and (of course) disassembled it, I was both impressed and a bit disappointed. Turns out the Armatron used a compact (and complex!) plastic gear box with a single motor to drive all the motions of the arm. The two joysticks mechanically engaged different

■ FIGURE 1. RadioShack "Helping Hands."

■ FIGURE 2. PanaVise workbench vise unit.

■ FIGURE 3. Robert Downey Jr. as "Tony Stark" in the Paramount feature film *Iron Man*. Photo Copyright © Paramount Pictures.

gear trains with the constantly spinning motor, causing the various joints of the arm to move. Though ingenious in design, it wasn't very "hackable" since there were no individually addressable motors to control. Today, most robot arms you see for sale in electronics/robotics hobby magazines are composed of some plastic or metal parts and a handful of model aircraft-type servo motors. From a hacking/programming perspective, this is a big step up from the Armatron single motor approach.

Most of these robot arms are quite useful for teaching robotic and automation concepts. They do a good job of introducing the subject and showing someone just how complicated a simple human task such as "hand me the TV remote" can be for a robot. I've seen these "educational" robotic arms used to teaching the computational complexity involved in stacking small wooden blocks or moving disks to solve the "Tower of Hanoi" puzzle. Yet, I had not seen one employed doing real work in a real workbench environment. Could it be that a sufficiently powerful and accurate arm just wasn't available yet?

ENTER THE CRUSTCRAWLER!

When CrustCrawler announced the AX-12+ intelligent arm, I remember reading reports of its strength and accuracy. More importantly, the arm used the Dynamixel servo motors that had real feedback capabilities. This would make it possible to attain new levels of accuracy when using the arm since, unlike a standard hobby servo, it can determine if the arm had actually reached a position. With these advanced features, I wondered if the AX-12+ SmartArm would be able to do real work like the commercial robotic arms used in manufacturing. Could it hand me tools? Could it hold a printed circuit board (PCB) while I was soldering? The more I thought about it, the more I began to wonder why not?

I began to catalog the various tasks that I might need the arm to perform. Using it while constructing devices was the first thing that came to mind. Holding parts or fetching the right tool seemed useful, as well. Need a #2 Phillips? The arm can hand it to you. Need someone to hold these parts while you solder them? The arm can do that AND it won't burn its fingers! The possibilities seemed endless. All I would need was a CrustCrawler AX-12+ to experiment with.

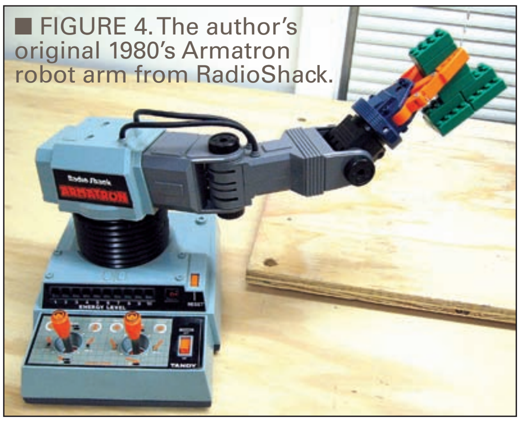


FIGURE 4. The author's original 1980's Armatron robot arm from RadioShack.

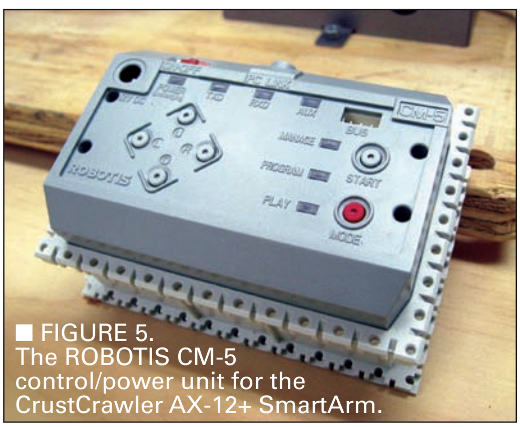


FIGURE 5. The ROBOTIS CM-5 control/power unit for the CrustCrawler AX-12+ SmartArm.

HEY BUDDY, CAN YOU SPARE AN ... ARM?

I spoke with my top-secret contacts over at *Nuts & Volts* and gave them the broad outlines of the idea I had and asked if they thought CrustCrawler might be interested in this experiment. I told them I thought the AX-12+ would be the perfect candidate for testing out the idea of a useful bench-top robot arm. They put me in touch with Alex Dirks over at CrustCrawler, Inc., and he was happy to send an arm out for torture ... er ... experimentation. I dug through the CrustCrawler website and examined all the various configurations at length. I finally sent off a wish-list to Alex of the parts I thought I would need and, before I knew it, I had a bouncing baby cardboard box on my porch. Time to build!

FIGURE 6. The USB2Dynamixel USB to TTL/RS-485 adapter.

"SOME ASSEMBLY REQUIRED"

When I opened the AX-12+ box, I was delighted to see little bags of clearly labeled parts and a nice thick detailed manual. Other than some typical hand tools, the only thing I had to supply was the Loctite liquid to lock down the screws so they don't wiggle loose during use of the arm (good practical advice that was stated right at the front of the manual). The arm went together in a couple of fun evenings in no small part due to that very nice thick guide!

Now that I had the arm all together, I was ready to get it to move. Besides the AX-12+ itself, the package from Alex included a cool little interface box called the CM-5 (Figure 5) and the USB2Dynamixel unit (Figure 6). The CM-5 is a record/playback device that can be used to play sequences of moves. It also houses a rechargeable battery pack to allow portable use of the arm and is recharged with the included hefty 12V, five amp power supply.

To program the arm, you connect your PC to the USB2Dynmixel, connect a three-pin cable from the USB2Dynamixel to the CM-5 unit, then connect another three-pin cable from the CM-5 to the Dynamixel servo in the arm's base. Once the connections above are established, you connect the 12V supply to the CM-5 and you're ready to go. I started out using the Robotis "motion editor" software that comes with the CM-5. Though the software is fairly intuitive, I found it a bit cumbersome to use. It appears to have been designed with the "Bioloid" plastic models in mind. Sadly (at the time of this writing), there was no "template" for my nice new all-metal AX-12+, making positioning the joints a bit tough for me.

TIME FOR SOME GNU SOFTWARE

While digging around for demo sequences on the CrustCrawler website, I discovered a link to the "AX-12+ Arm Sample" project by Scott Ferguson. Scott's code allows you to map joystick controls to the various AX-12+ joints and then "puppet" the arm. Once you move the arm into a position, you can record the joint values as a "pose" and then step forward/backward through these poses. This is very similar to the "teaching pendants" that many commercial robot arms use to create their processes. To top it off, Scott released the software under the GNU public license so all the source code is available, as well (this would come in handy down the road!).

This software looked very promising, however it was designed to communicate directly with the Dynamixel servos and would not talk to them through the CM-5. I would have to remove the CM-5 from the communication chain in order to get Scott's software to work. Though this would be fairly simple to do, it would leave me without a power source for the arm as the CM-5 was handling converting the 12V from the supply down to the acceptable 9.6V voltage levels required by the servos. As a quick and dirty solution, I took one of the extra three-pin cables and spliced a 2.1 mm power connector into it and included four high-current diodes in series to drop the 12V from the supply down to a voltage that would not exceed the 10V maximum rating of the servos (Figure 7).

■ FIGURE 7. Four high-current diodes wired in series to drop the 12V power source.

GET A GRIP!

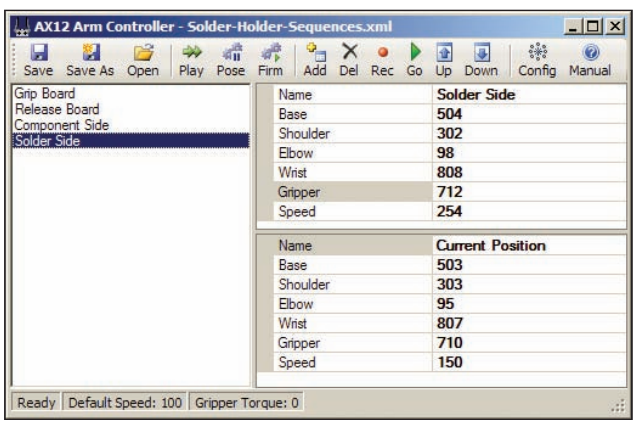
I booted up Scott's software and mapped an old joystick to the various joints of the AX-12+ and, in a matter of minutes, was moving the arm all around the desk. A word of warning for those of you that may end up with this arm: it is strong! I've knocked things off my workbench, dumped over a perfectly good can of Dr. Pepper, put a nice nick in the corner of my LCD monitor, and one time I even managed to smack myself right in the funny bone! If you are using the joystick to control the arm, use caution and make sure breakable things are not in its path. Don't learn this the hard way like I did!

Now that I had the arm in place (and a bandage on my elbow!), I was finally ready to try some work experiments. I started with a task that was both repetitive and fairly common, namely holding a PCB for soldering. When I build through-hole PCBs, I have to flip the board back and forth between solder-side and component-side as I stuff components and then solder them into place. I wanted to see if the arm could do this for me to eliminate the time spent manually repositioning the mechanical "helping hands" I normally used for this task.

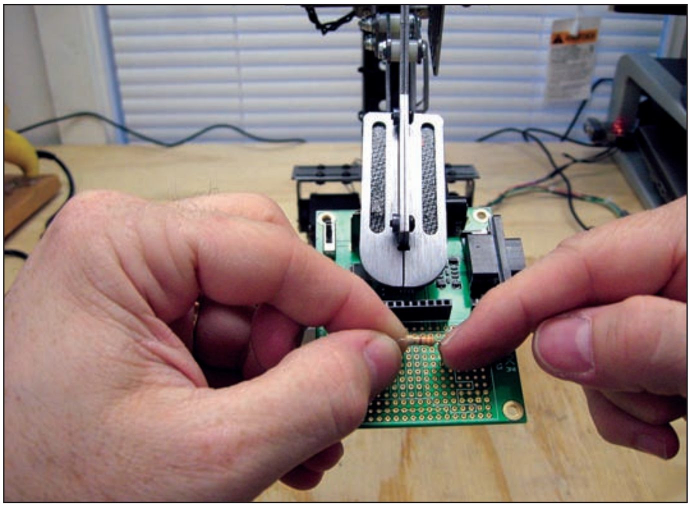
FLIP IT! FLIP IT GOOD!

I started by using the joystick to maneuver the arm into a braced position with the elbow joint resting at the end of its travel, then I moved the shoulder joint so that it was holding the gripper at a comfortable angle for soldering. I then fully opened the gripper and named this pose "Release Board." Next, I brought the gripper completely shut and named this pose "Grip Board." I executed the Release Board pose, placed a small project board in the gripper's range, and executed the Grip Board pose. The gripper took a nice strong hold of the board. I now used the joystick to rotate the wrist joint so the board was solder side up and named this pose "Solder Side." Lastly, I rotated the wrist so the component side was up again and named this pose "Component Side."

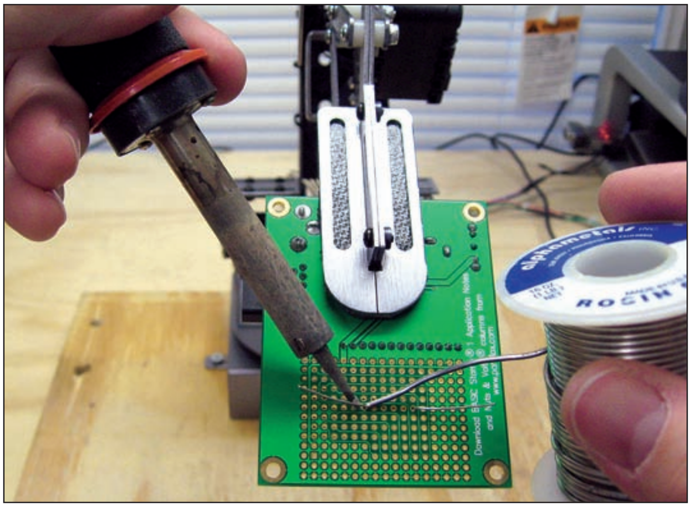
So now, with a click of a mouse I could have the arm grab a PCB and hold it while I used two hands to install a component on it (Figure 9), then another couple of clicks flipped the board over so I could use both



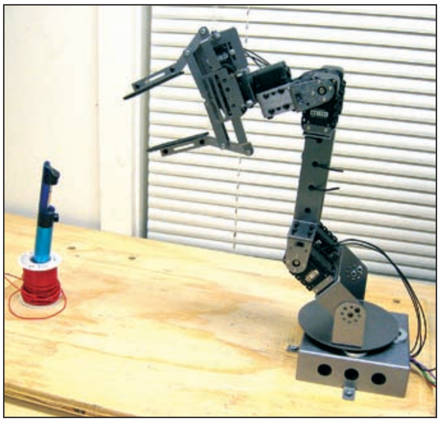
■ FIGURE 8. The AX12 Arm Controller software by Scott Ferguson.



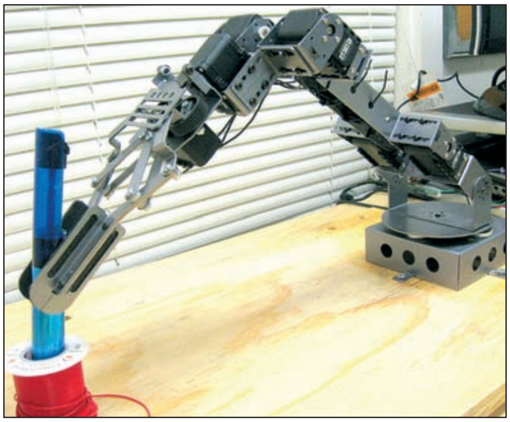
■ FIGURE 9. Placing components into a PCB held by the AX-12+ SmartArm.



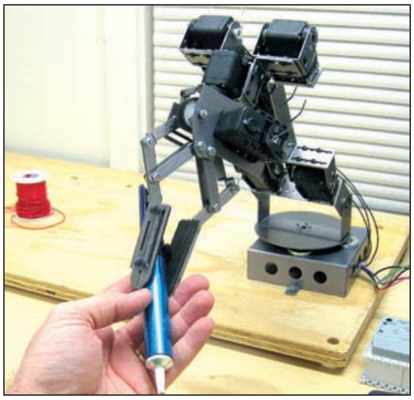
■ FIGURE 10. Soldering components into place while PCB is held steady by AX-12+.



■ FIGURE 11. AX-12+ gripper open, ready to reach for the solder vac.



■ FIGURE 12. The AX-12+ gripper clamps down on the solder vac.



■ FIGURE 13. A slight tug removes the solder vac from the AX-12+ gripper.

hands to solder on it (Figure 10). This process was so deceptively easy and the result so useful that I just swaggered on to the next task!

WHEN UNSTOPPABLE OPTIMISM MEETS UNMOVABLE REALITY

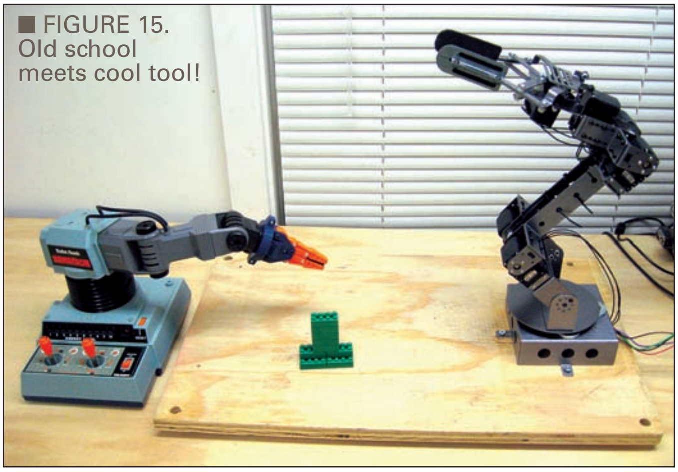
The rumble you felt and that distant screaming sound wasn't an earthquake, it was just my ambitious ideas coming in direct contact with reality. With the board flipping function under my belt, I decided to take things up a notch and see about having the arm hand me one of the other more popular and useful devices on my workbench: a solder vac.

I started by placing a spool of hookup wire on the bench and then placing the solder vac in the center of the spool to hold it upright where it could be easily gripped by the arm. I then used the joystick to move the arm through the series of poses as I had done above, naming them "Open Gripper" (Figure 11), "Fetch Solder Vac" (Figure 12), and "Offer Solder Vac" (Figure 13). I then placed the solder vac back in the spool and executed the Open Gripper and the Fetch Solder Vac routines. Unfortunately, the gripper missed the vac and ended up dumping the spool over!

A bit (okay, more like hours) of experimentation later and I discovered that to reliably retrieve the solder vac, I would have to make a much more accurate resting spot for it. Since the arm was reliably repeating the positions I had recorded, the solder vac had to be at the same angle and height every time or there was a good chance the arm would miss.

Logically, this also meant that any tool I wanted to have the arm handle would have to be equally well

■ FIGURE 14. Foot pedal control expected to add hands-free control to the AX-12+ motions.



■ FIGURE 15. Old school meets cool tool!

THANK YOUS

■ I would like to take a moment to thank the good folks over at CrustCrawler for providing this most excellent robotic arm for use in the project, *Nuts & Volts Magazine* for helping set it up, and Paul Atkinson and James Delaney for their invaluable assistance with this project.

situated. Could be this “hand me a tool” business is a bit trickier than I had imagined! I sat back and started to think about how I could make sure the robot’s environment would be as reliable as the arm itself.

SAME BAT TIME, SAME BAT CHANNEL!

Luckily, I’ve got tough calluses on my ambition and I was able to pull myself from the wreckage of first contact and continue on my quest for a robotic helping hand on my bench. I’ve managed to sweet-talk one of my regular roboteers into helping write some software to allow foot-pedal control of the arm (Figure 14) and another one to help me build a “tool gallery” to hold the tools exactly where the arm can find them.

Look for all the details of my continuing quest for a helping hand at the workbench in ROBOBENCH — Part 2! As always, if you have any questions or comments, I can be reached at vern@txis.com. **NV**

RESOURCES

■ CrustCrawler (AX-12 Smart Arm Source) — **www.crustcrawler.com**

■ Forest Moon Productions (GNU Smart Arm software) — **www.forestmoon.com/Software/AX12ArmSample/**