Build the Ultimate Robot

Part 1 AUG 2008

By Michael Simpson

Warning !!!

Before you read any further, I feel it only fair to warn you that this series is going to be akin to a very fast roller coaster ride.

Over the years I have built several robots of various shapes and sizes. Most of them were controlled by a microcontroller of one form or another. I have even built a few that were tethered to a desktop computer. It's time to build a robust robot with an on board PC computer. This will not be a toy.

In this series I am going to build two robots:

- 6 Wheeled Robot utilizing 6 RS-64 actuators
- 3 Wheeled Robot utilizing 2 RS-64 actuators

These robots will be built around the RS-64 actuator that I will get into later. The code I use to control these motors will be isolated into a set of subroutines so that you may utilize other types of drive trains. For instance, you could use a brushless motor controller and motors as long as the routines to control the speed and direction of the motors are named the same. This will allow you to plug them into this system. The same applies to most of the sensors that I am going to use. While I will be using MaxBotix sonar sensors, you should be able to make your own substitutions as long as you work out the interface and return the distance to your objects in inches.

The reason I am going to build these two types of robots is simple. The cost of 6 RS-64 actuators is over $1700. The cost for two is $570. The cost difference is the same if you are using some other motor/controller system. The cool thing is that you should be able to build the three-wheeled robot, then later upgrade to the six-wheedled bot.

Unlike other projects that I built well in advance before publishing, this is going to be a work in progress. I will provide you with step-by-step instructions as well as a source for all the components that I use in this project, and even some that I haven't used. I will show you various techniques and options along the way so even if you don't build the exact same robot, you should be able to use much of the information that I will provide.

Let's start by writing down a few requirements for the project.

Payload

The first requirement is payload. It is important that you look at this requirement early on in the design process. My robot will need to carry the following items:

- Main Controller - 5lbs
- Battery - 8lbs
- Robot Arm and Accessories - 3 lbs
- Miscellaneous Extras - 1 lbs

As you can see, based on my estimates I will need a robot that can carry 17lbs in addition to the base, wheels and actuators. You may have noticed that I set the main controller payload to 5lbs. If you use a Pocket PC then you will only need to allocate .5lbs. For a CE device about 1.5lbs will be needed. What I am trying to say here is there will be a large disparity in weights of various controllers. Keep this in mind.

Size

The type of controller you use will most likely set the size of your robot. If you are going to use a 17" laptop you will probably need a much larger platform than you would for a Pocket PC. If you create one large base you can place all your Items at the same level. This will make them easier access for modifications. In my case, I will size both robots to fit a small laptop, battery, robot arm, and various other electronics and sensors I might need. Better too large than too small.

Base Materials

What you make your base out of will probably be determined by availability and your tools and skills. I plan on using 1/4" hardboard. It's cheap and easy to work with both power and hand tools. You could use 1/4" acrylic, but it's prone to cracking and a little harder to tool. I like a little flex in my robot and the 1/4" headboard will be perfect. As an option you could also use 1/4" pegboard. Something to keep in mind is that will probably build a couple variations to your robot. Since hardboard is so cheap, the cost of going back to the drawing board will only cost you a couple of dollars. Once perfected, you can always later move to different material.

Run Time

I wanted my robot to be able to run for at least 2 hours at a time. The type of controller, motors and batteries will determine this. I plan on using a 14-18v battery pack rated at 12,000-14,000mAh. This should give me plenty of runtime. This power source should allow you to power a pocket PC or CE device, but it may be a little challenging to power a laptop. However, we won't be using the screen on the laptop so you should get 3-6 hours on most laptops with the screen turned off.

Terrain Type

You need to take into account the type of terrain on which you plan to operate your robot. In my case I want to run the robot on indoor surfaces such as tile or carpet. I also want to operate the robot on my driveway, which is half paved and half gravel. The wheel types, number of wheels and ground clearance will affect the type of terrain you can transverse.

Processing Power

Since I am planning on using a PC we should have plenty of processing power to do just about any task. Even the CE and Pocket PC devices, while not as powerful as the PC, will perform adequately. Each type PC, Pocket PC and CE device will have its own advantages and disadvantages. For instance, the CE device runs considerably slower than the PC but has both power and weight advantages.

The PC with its USB 2.0 ports has the ability to interface with all components using one or more USB2Dynamixle interfaces. While the CE device does not have the ability to communicate with the USB2Dynamixle, it does have an RS485 interface that can talk to the RS-64 actuators directly. For the Pocket PC, we will have to create an RS232-RS485 converter.

Again, these are very high level requirements and like any project, are subject to change. For any robot project of this nature, it is important that you do some research on your own. Here are a few factors that will affect the exact details of your project:

- Availability of Components
- Availability of Tools
- Availability of Funds
- Availability of Skills

Let’s take a look at each of these in more detail.

Availability of Components

While I will provide you with a source of components that I use on this project, you may or may not decide the use them. If you decide to use different components, you will only be able to use my instructions as a basic guide. This could be as simple as using a different material for the robot base, which will probably only have minimal impact on the project. You could also decide to use a different programming language for the controller or even a different type of controller. In this case, none of the programs that I provide will work on your robot.

Availability of Tools

If you are already into building custom robots then you most likely have some or most of the tools needed for a project such as this. Later in this article I will go over some of the tools that will be needed. So what if you don't have the tools needed for a particular phase of the project? Does that mean you can't build it? Absolutely not. You can always ask a friend to help you out. In some cases, such as building the main robot base, you may be able to get your local home center or hardware store to help you out.

Availability of Funds

If you decide to build the robots I present in this series it will cost you $1000 to $4000 depending on the base, computer and extras you plan on adding to your robot. If you have an old laptop or Pocket PC, you could probably get started for under $500.

Availability of Skills

If you build the exact robot I present here and use the code that I provide, you won't need much more than basic mechanical skills. If, however, you plan on writing your own programs or using a different controller, you will need some programming skills. You will also need to be able to use a soldering Iron. Contrary to popular belief, you don't need to be a rocket scientist or an electronic engineer to build a robot.

Project Overview

It's time for me to give you an overview of the project. At this point I won't go into any of the actual technical or construction details. Think of it as an introduction to the types of components, tools and techniques I will be going over in more detail as the series continues.

Brain

As I mentioned previously, there are three types of computer controllers that I intend on using on our robot. The first is a laptop running Windows Vista or XP. I recommend at least a 900mHz machine like the HP shown here in Figure 1. The second type is a Windows CE device like the CUWIN3500 shown in Figure 2. It has a built-in touch screen that could allow us to provide some sort of human interface to our robot. The third type is a Windows Pocket PC like the one shown in Figure 3. I will be using an HP Pocket PC 2003 device running at 600mHz.

Figure 1 **Figure 2**

Figure 3

I plan on using Zeus for the programming language for this project. With Zeus you can create a program that will run on the Windows PC, Windows CE and Windows Pocket PC platforms with little or no changes to the code. Zeus is a very simple Basic programming language with some advanced features like GPS processing built-in.

In addition to the main controller, we need to access our various sensors and motors through some sort of interface. For the XP based controller we can use a USB device called the USB2Dynamixel shown in Figure 4. It's manufactured by Robotis, and sold by Crustcrawler.

Features of the USB2Dynamixel

- RS-485 interface Support
- AX-12 TTL Serial Interface Support
- RS-232 Interface Support
- Shows up as a standard PC com port
- Compatible with Windows 2000, Windows XP, or Windows Vista
- Several USB2Dynamixel interfaces can be used at once
- Can be used as a limited USB to Serial interface (Does not support control leads)
- Built-in library for ZeusPro compiler

If you wish to create your own library using .net, the folks at Crustcrawler have developed .net Visual Studio Project that will give you a good start. You can download the project from their web site.

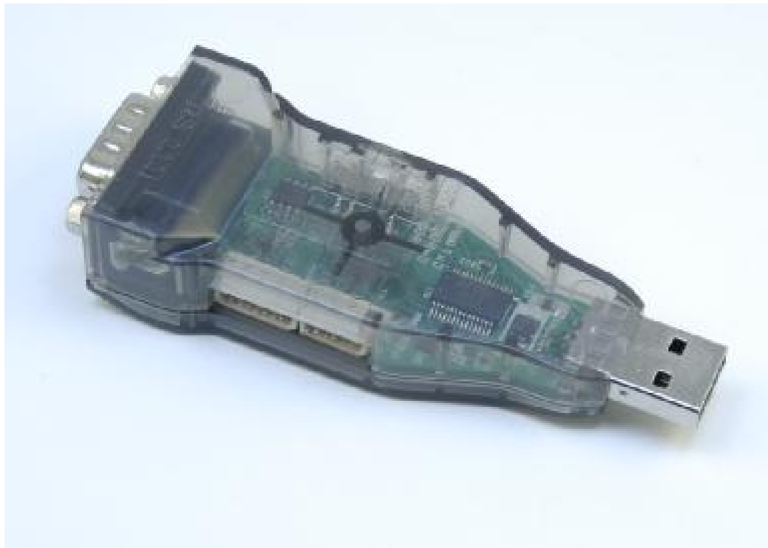

Figure 4

To make life easier I have added a new library to the KRMicros ZeusPro compiler. It is called USB2AX, and I will be using it extensively throughout this series.

Since our ultimate robot will be using both RX-64 and AX-12's, you will need two USB2Dynamixels attached to your computer. There is a small switch on the USB2Dynamixel interface shown in Figure 5. This switch is used to configure the interface for the type of bus that you will be using. For all your AX-12's, you will set the interface to TTL. For your RX-64 and RX-28, set the switch to RS485.

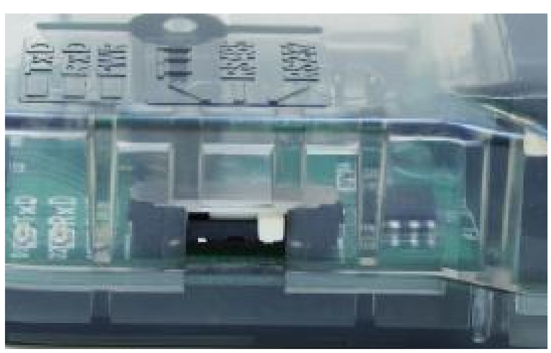

Figure 5

Each bus has its own special connector shown in Figure 6. The larger 4-pin connector is used for the RX-64 and RX-28 actuators. The smaller 3-pin connector is used for the AX-12 and AX-S1 actuators and sensors.

Figure 6

Unfortunately, the USB2Dynamixel will not work on Windows CE, or Windows PocketPC devices so we will have to use a different interface. What this means is that the Windows PC platform will be a little simpler to implement as the hardware interfacing to the various devices has been done for us. If you plan on using a Pocket PC or Windows CE device and have access to a laptop, I recommend building your robot with this controller first.

Base Configuration

I was playing with the a Dynamixel RX-64 actuator when the idea for this project came to mind. The RX-64 shown in Figure 7 delivers a whopping 888 ounces per inch of torque. It utilizes a RS-485 control system that allows you to daisy chain and control up to 254 units. This actuator can run in servo mode or in continuous operation and can report position, temperature, load and input voltage. This will not only allow us to detect collisions, but the level of our batteries as well.

The RX-64 has a full metal gear set and utilizes an axis bearing that will insure no efficiency degradation with high external loads. It also features an aluminum servo arm. Its ability to operate in full rotation mode makes it perfect for our drive train. It’s my plan to connect a 5.5” wheel to each of six RX-64s in order to provide the best load distribution for our base.

Figure 7

The RX-64 has a little brother called the RX-28 shown in Figure 8. The RX-28 has a much smaller foot print than its bigger brother. It does, however utilize the RS-485 interface and the same protocol so both the RX-64 and RX-28 can be placed on the same bus. The features on these little gems come at a price. The RX-64 will run you $285 per actuator. The RX-28 is a little cheaper at $200 each.

Figure 8

For the wheels I plan on using the Du-Bro 550TV wheel shown in Figure 9. These wheels are 5.5 inches in diameter and have pneumatic tires. By adding or removing air from the tire you can set the amount of traction or firmness desired. Later in this series I will show you step-by-step how to attach this wheel to the RX-64.

Figure 9

I will show you how to build a six-wheeled robot by attaching six of these wheels to six actuators. For the three-wheeled robot we will attach two wheels to two actuators. This is a $1140 difference in price, and can mean the difference in the ability to fund this project.

Robot Arm

I want to add a small manipulator. The manipulator I have in mind is the Crustcrawler AX-12 Smart Arm shown in Figure 10. The Smart Arm utilizes 7 AX-12 Dynamixel actuators. For more details check them out at:

http://www.crustcrawler.com/products/smartarm/index.php?prod=12

It is my plan to place some sensors on the arm as well as a pocket PC like the one shown back in Figure 3. Even if I use another controller, I think a face mounted on a pocket PC controlled by the arm would be very cool and invite a great amount of attention at the next Robot Fest I attend.

Figure 10

Tools

Before I close out this introduction, I think it's important that you understand what kind of tools you may need for this project. First, you will need both Philips and flathead screw drivers. I recommend various sizes. Many of the machine screws I will use will be #10 and smaller so size your screwdrivers accordingly. A set of small wrenches will also come in handy. In lieu of these, a small crescent wrench will suffice.

There is no way of getting away from it; you have to have a drill for this project. As a minimum I recommend an electric drill like the one shown in Figure 11. Look for a drill with both variable speed and reverse. If you get one with a clutch you can use it to drive and remove screws. A drill with a high/low gear option will give you more speed and power options. There are times when a drill press like the one shown in Figure 12 will come in handy. They give you more control over the drilling process and allow you to use various accessories like sanding drums. A drill press is not a requirement but may come in handy. Check out your local classifieds. You may be able to get a bench top model for $15-$25. In addition to the drill you will also need a set of bits. You can purchase these one at a time or in sets.

Figure 11

Figure 12

In addition to the drill, I also recommend a rotary tool like the one shown in Figure 13. You can use them for drilling small holes, but they excel at sanding and cutting. Many of these come with a complete bit set. There are many additional accessories available like cutoff wheels and various grinding bits. Again, this is not 100% required but can make some tasks easier.

Figure 13

For the electronics, you are going to need a pair of needle nose pliers and wire cutters. In addition, you will need a soldering iron like the one shown in Figure 14. When purchasing a soldering iron, make sure you get one with disposable tips. Two power settings will also come in handy. If the iron you purchase does not come with a stand, you will need to purchase one. I also own a higher powered soldering gun but find that I never use it.

Figure 14

While you won't need a 25" measuring tape, I do recommend a steel rule and set of calipers like the ones shown in Figure 15. I prefer the digital calipers with both inch and mm readings.

Figure 15

This project will require you to cut various small pieces of plastic or wood. The best tool for this job is the scroll saw like the one shown in Figure 16. For instance we will need to create a special wheel mount that is used for attaching the wheel to the RS-64.   This is a 2-1/4" disk and is easy to cut with a scroll saw. You can also use a small band saw. As a last resort you could rough it out with a rotary tool, then sand it to the exact size with a sanding drum bit. You don't have to spend a lot of money on a scroll saw. I have seen them on sale at Sears for as little as $49. If you are going to do a lot of robot building. I recommend including one in your arsenal of tools. I did a complete review of scroll saws back in the Feb, 2005 issue of Servo Magazine.

Figure 16

Once we start adding microcontrollers and sensors to our robot, an oscilloscope will become an invaluable to help us setup and test our components. The Hitachi oscilloscope shown in Figure 17 is a 100Mhz 4 channel scope that I have used for years and has served me well. Some PC based, oscilloscopes have recently become available. These scopes connect to your PC. This helps keep the price down and adds a few nice features. For instance, the Bitscope shown in Figure 18 is not only a 2-channel oscilloscope, it is also an 8-channel logic analyzer. It can be used as a data recorder and is perfect if you need to make hard copies of your captured signals, like the one shown in Figure 19.

Figure 17

Figure 18

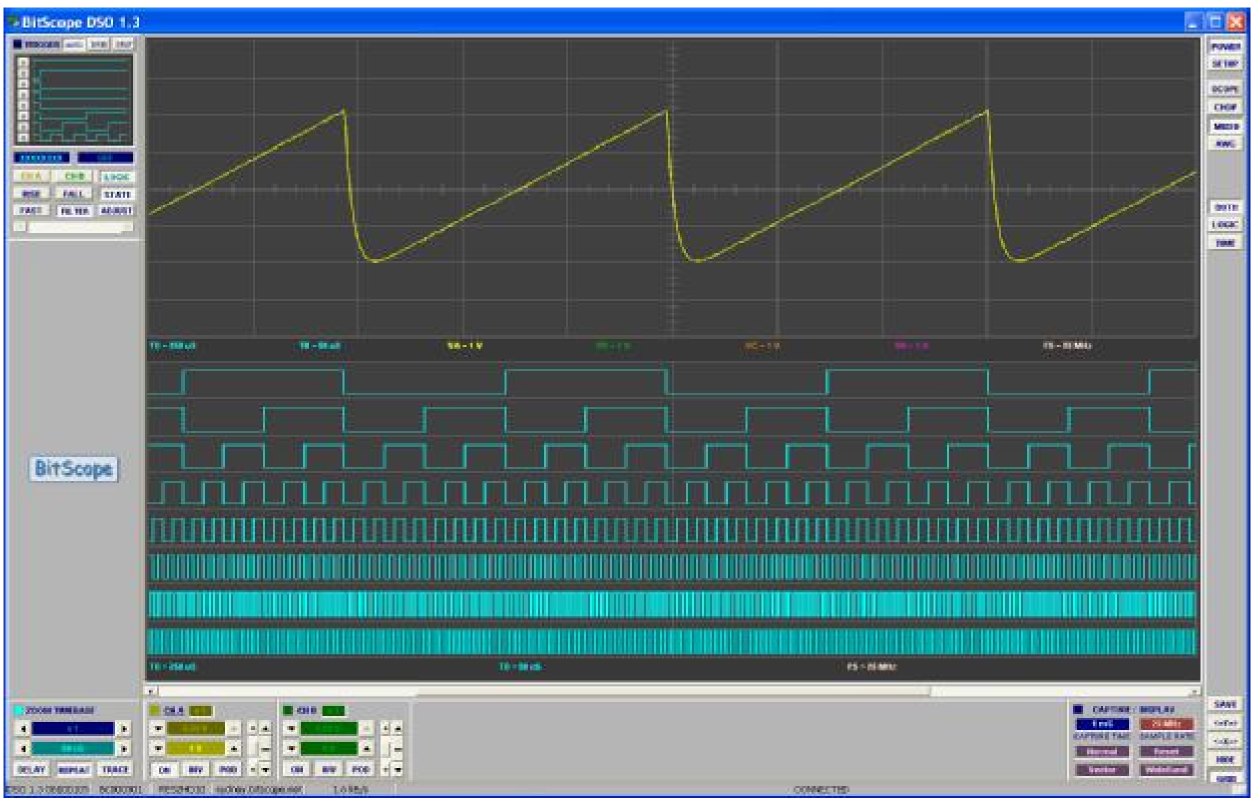

Figure 19

Batteries

Probably the heaviest piece of cargo will be the battery. This will be used to power the wheel actuators, Smart Arm and various electronics. Originally I was thinking of a 12v sealed lead acid battery, but didn't think this would be enough to drive the RS-64s for any length of time. After much research I decided on the use of an external laptop battery. These seem to have the best weight to capacity ratio. The battery shown in Figure 20 will provide 19V at almost 5Amps at 133Wh. They are available from AtBatt.Com. They come with there own charger and several tips to connect to various devices. I will be going into more detail as the series progresses.

Figure 20

What's Next

In part 2 of the series we will start the base construction by building the wheel assemblies for both the 6-wheeled and 3-wheled robots.

Be sure to check out the KronosRobotics website for updates to this project at:

http://www.kronosrobotics.com/Projects/megabot.shtml

Links

Crustcrawler

AX-12 Smart Arm

http://www.crustcrawler.com/products/smartarm/index.php?prod=12

RS-64

http://www.crustcrawler.com/motors/RX64/index.php?prod=67

USB2Dynamixel

http://www.crustcrawler.com/electronics/USB2Dynamixel/index.php?prod=65

USB2Dynamixel .net API

http://www.crustcrawler.com/electronics/USB2Dynamixel/software/Usb2Dynamixel.zip

AtBatt.COM

P133 External Laptop Battery.

http://www.atbatt.com/product/7901.asp

KRMicros

ZeusPro

http://www.krmicros.com/Development/ZeusPro/ZeusPro.htm

ZeusLite

http://www.krmicros.com/Development/ZeusLite/ZeusLite.htm

BitScope

BitScope Model 100

http://www.bitscope.com/product/BS100/

COMFILE TECHNOLOGY

CUWIN3500

http://www.cubloc.com/product/05_01.php