ROBOT HANDS - ARD UINO BOT - LEGOBOT

SERVO MAGAZINE

FOR THE ROBOT INNOVATOR

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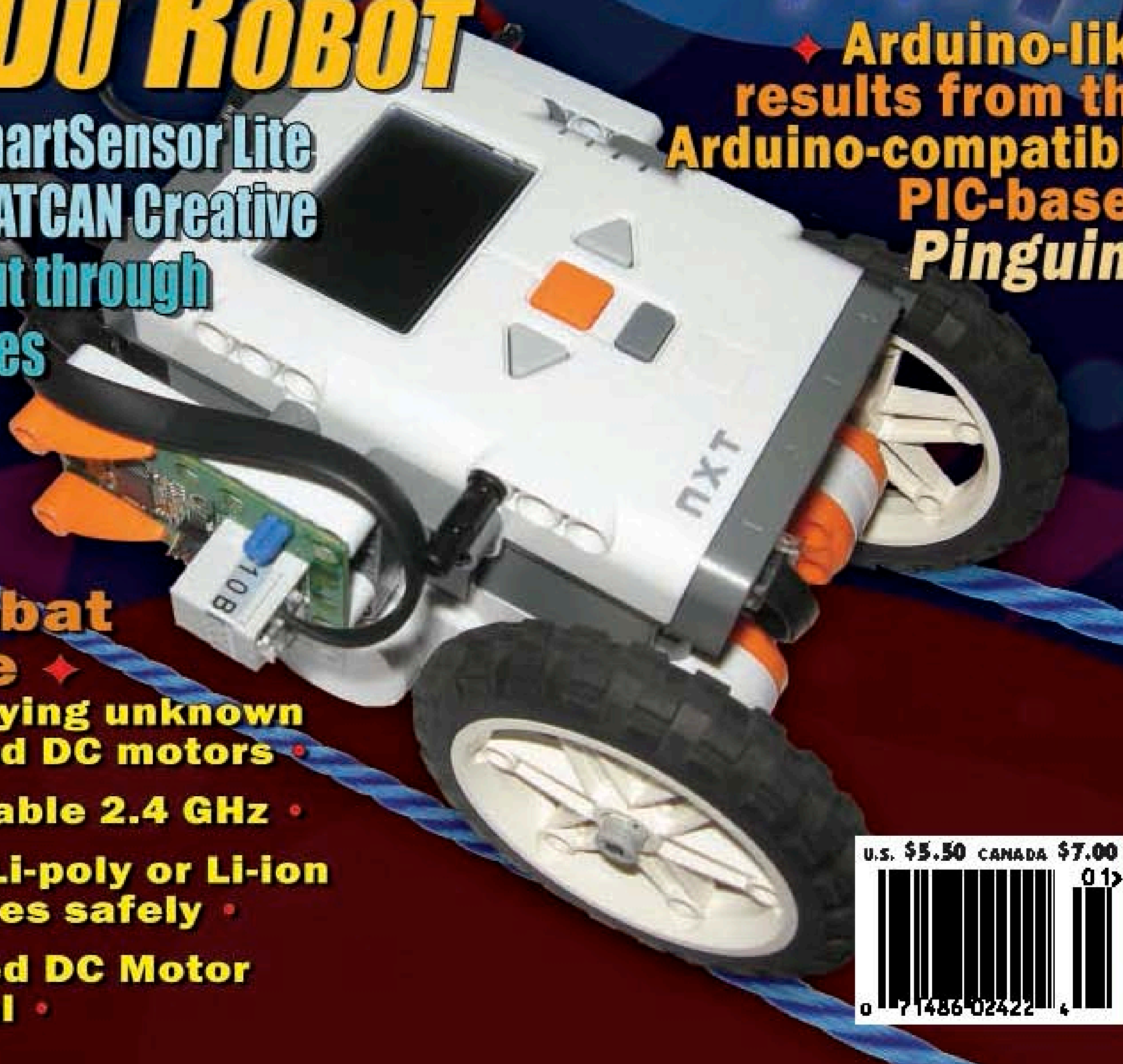
CIRQUE DU ROBOT

The SmartSensor Lite from CATCAN Creative gets put through its paces



Arduino-like results from the Arduino-compatible PIC-based *Pinguino*

Combat Zone

- Identifying unknown brushed DC motors
- Affordable 2.4 GHz
- Using Li-poly or Li-ion batteries safely
- Brushed DC Motor Tutorial

U.S. $5.50 CANADA $7.00

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LINKS

Sewer Snake and Death and Taxes fight videos
www.youtube.com/watch?v=IUBBOPBbJpk&sns=em

Another camera view of the fight and fire
www.youtube.com/watch?v=amvqgyqtr74

RC Group's complete guide to Li-poly batteries
www.rcgroups.com/forums/showthread.php?t=209187

LipoSack
www.liposack.com/products.htm

Fastrax LiPo Charge Bag. This bag is made from Kevlar and Nomex
www.cmldistribution.co.uk/cml_product.php?productId=000004476

Ansul Lith-X
www.ansul.com/en/support/search_combo.aspx?txtSearchPhrase=lith-x

smoke contains several toxins. It is recommended that protective clothing and a full-face SCBA breathing system be used by anyone fighting this type of fire. The smoke is one of the more difficult issues to control and it's a good idea for event organizers to provide a high flow ventilation system for their arenas and buildings. They should not allow people to enter the arena until the smoke has been cleared. Due to the nature of this battery chemistry and the volume of smoke produced, this could take a long time. This is definitely something to consider and in some event venues, it may be difficult to achieve.

At Combots, We had a Simple Battery Fire Plan

During the safety meeting, the builders were told that they were responsible for removing the robot from the arena and the building when it was judged safe to do so. There was a clear path maintained from the arena to the outside doors of the building. The builders were shown the path to the exit. The builders were instructed to wear leather welding gloves if they had to handle the hot robot. Steel carts were provided either by the builders or the event to place robots on, so they could be quickly wheeled outside.

When possible, the event crew would put out the open fire with CO_2.

The builder would then remove the robot from the building, then remove the batteries from the robot.

The builder would smother the batteries with the provided dry sand.

The Future

It should be noted that the use of other cells like the Lithium-Ion A123 brand have much less of a chance of fire or this smoke hazard. Of course, they are bulkier and a little heavier than many of the Li-poly packs. They may prove to be a better idea but not quite yet ... trial and terror testing is still the nature of the game.

As usual, combat robotics consistently pushes available technology to its limits and often way beyond; this is the nature of the sport. Hopefully, with a better understanding of this impressive and powerful battery technology, better building practices, and improved event safety measures we can continue to provide a great show and high standards of performance in this dangerous and yet safe sport. SV

Photo by Jon Swenson. See more of Jon's work at ***www.sharkspage.com/?p=2668.***

RioBotz Combot Tutorial Summarized — DC Motors

● Original Text by Professor Marco Antonio Meggiolaro; Summarized by Kevin M. Berry

Editor's note: Professor Marco Antonio Meggiolaro, of the Pontifical Catholic University of Rio de Janeiro, Brazil, has translated his popular book, the RioBotz Combot Tutorial, *into English. In previous editions of the Combat Zone,* SERVO *has summarized many portions of the tutorial. In this article, we present a much simplified version of the "Brushed DC Motors" section of Chapter 5 — a major treatise on bot motors. Marco's book is available free for download at* ***www.riobotz.com.br/en/tutorial.html,*** *and for hard copy purchase (at no profit to Marco) on Amazon, published by CreateSpace. All information here is provided courtesy of Professor Meggiolaro and RioBotz. In reviewing this article, Prof. Marco took the opportunity to update some information that is now obsolete in the published version.*

Brushed DC Motor Overview

Motors are probably the combat robot's most important component. They can be powered electrically, pneumatically,

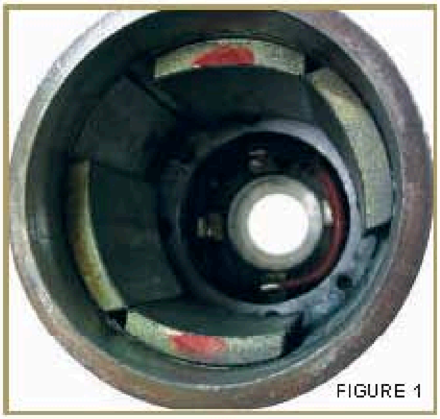
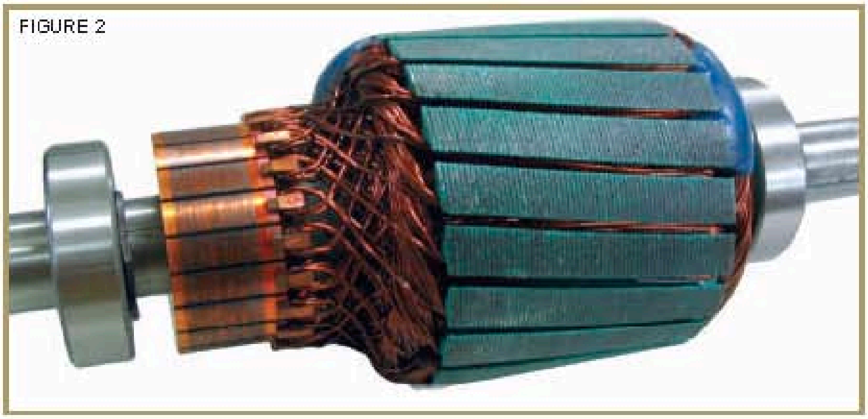


FIGURE 1

FIGURE 2



hydraulically, or using fuels such as gasoline. One of the most used types is the brushed direct current (DC) electrical motor because it can reach high torques, it is easily powered by batteries, its speed control is relatively simple, and its spinning direction is easily reversed. They are also a good choice because they're not as expensive as they used to be. There are other types of electrical motors, but not all of them are used in combat. For instance, stepper motors have — in general — a relatively low torque compared to their own weight. The speed of AC motors is more difficult to control when powered by batteries which can only provide direct current.

The three main types of brushed DC motors are the permanent magnet (PM), shunt (parallel), and series. The series type motors are the ones used as starter motors; they have high initial torque and high maximum speed. If there is no load on their shaft, starter motors would accelerate more and more until they would self-destruct which is why they're dangerous. In a few competitions, they can be forbidden for that reason. They are rarely used in the robot's drivetrain because it is not easy to reverse their movement; however, they are a good choice for powerful weapons that spin in only one direction.

The PM DC motors and the shunt type have similar behaviors, which are quite different from the starter motors. The PM ones are the most used, not only in the drive system but also to power weapons. They have fixed permanent magnets attached to their body (as shown in **Figure 1**) which forms the stator (the part that does not rotate), and a rotor that has several windings (**Figure 2**). These windings generate a magnetic field that — together with the field of the PM — generates torque in the rotor. To obtain an approximately constant torque output, the winding contacts should be continually commutated which is done through the commuter on the rotor and the stator brushes (pictured in **Figure 3**). Electrically, a DC motor can be modeled as a resistance, an inductance, and a power source, connected in series. The behavior as a power source is due to the counter electromotive force which is directly proportional to the motor speed. The choice of the best brushed DC motor depends on several parameters, modeled next.

To discover the behavior of a brushed DC motor (permanent magnet or shunt type), it is necessary to know some parameters:

- I_{no_load} — Electric current drawn by the motor to spin without any load on its shaft.
- I_{input} — Electric current that the motor is drawing.
- I_{stall} — Electric current drawn by the motor when so much load is applied it can't turn at all.
- τ — Applied torque at a given moment.
- ω — Angular speed of the rotor.
- P_{output} — Mechanical power output.
- η — Efficiency = P_{output}/P_{input} which results in a number between 0 and 1. In an ideal motor (which doesn't exist in practice), there would be no electrical resistance and no mechanical friction losses; in that case, η = 1 (100% efficiency).

The curves in **Figure 4** show the drawn current I (I_{input}), angular speed ω, output power P_{output}, and efficiency η as a function of the torque τ applied to the motor by a load such as a wheel or spinning weapon.

(Editor's note: A section showing the use of many interesting but slightly scary equations to derive the curve below and its results were omitted from this summary.)

FIGURE 3

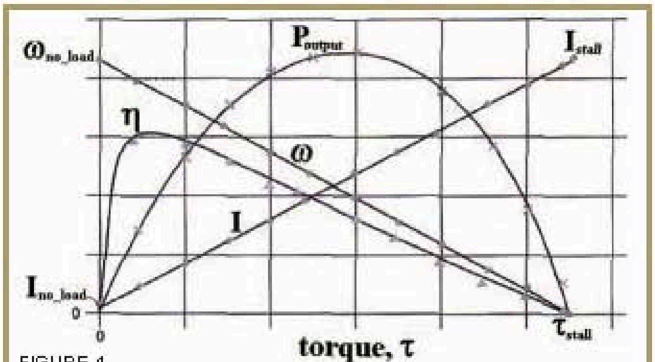


FIGURE 4

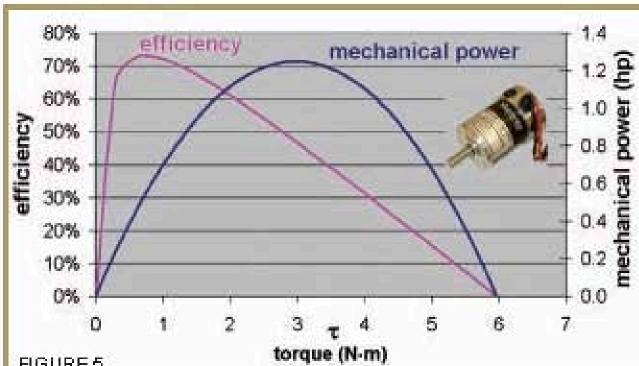


FIGURE 5

The plot in **Figure 4** shows that:

- The maximum speed ω_{no_load} happens when the motor shaft is free of external loads, with $\tau = 0$.
- The maximum current I_{stall} happens when the motor is stalled, with speed $\omega = 0$, so at I_{stall} the motor is generating the maximum possible torque.
- The maximum value of the mechanical power P_{output} happens when ω is approximately equal to half of ω_{no_load}.
- The highest efficiency happens in general between 80% and 90% of ω_{no_load}.

Example: Magmotor S28-150

The guide calculates the values (shown in **Figure 5**) for the popular Magmotor S28-150 connected to one NiCd 24V battery pack. The guide's "teaching point" — aside from providing sample calculations — is twofold.

First, the calculated maximum input power — 5.2 HP (at stall), — does not mean you'd actually get that much horsepower. All this power is wasted when the motor is stalled; converted into heat by the system resistance. The maximum mechanical power is actually calculated to be 1.25 HP. Notice that the manufacturer says that the maximum power is 3 HP for that motor which you would only get if the battery and electronic system resistances were zero, leaving only the motor resistance R_{motor} (not a real world case.)

The second point is that (as it can be seen in the graph) the maximum mechanical power happens at speeds that are not necessarily efficient.


FIGURE 6

Typical Brushed DC Motors

The Magmotor example can be repeated for several other motors. **Table 1** shows a few of the most used motors in combat robots and their main parameters. Several parameters are based only on motor specs (as a standalone item). Their actual values in a battery/controller/wire/motor system would not be as good. (Note: Kt and Kv — not used elsewhere in this summary — are the motor torque and motor speed constants.)

The Bosch GPA and GPB shown in the **table** have been extensively used in Brazil to drive middleweights. However, they have a low ratio between maximum power and their own weight. In addition, the GPA generates a lot of noise which can reduce the range of 75 MHz radio control systems. This problem can be minimized using capacitors between the motor brushes, or switching to (for instance) 2.4 GHz radio systems.

The DeWalt 18V motor with gearbox is a good choice for the drive system; we've used it in our middleweight Ciclone. It has an excellent power-to-weight ratio. Its main disadvantages are that it is not easy to mount to the robot structure, the gearbox casing is made out of plastic, and its resulting length including gearbox ends up very high to fit inside compact robots. Note that some older discontinued DeWalt cordless drills had other disadvantages, using Mabuchi motors instead of the higher quality DeWalt ones, and using a few plastic gears among the metal ones in their gearbox.

The NPC T64 already includes a gearbox with typically a 20:1 reduction. The data in the **table** already include the power loss and weight increase due to the gearbox which explains the relatively low power-to-weight ratio. But, even disregarding that, the performance of this motor is still not too high. The reason many builders use it is due to its convenience, it is easily mounted to the robot, and it is one of the few high power DC motors that comes with a built-in gearbox. Care should be taken with the NPC T64 gears (shown in **Figure 6**, with red grease). They might break under severe impacts if used to power weapons. As recommended by the manufacturer, only use them as drive motors.

An excellent motor for driving middleweights is the Magmotor S28-150 (a.k.a., Ampflow A28-150). It is used in our robots Titan and Touro. A good weapon motor for a middleweight would be the Magmotor S28-400 (a.k.a., Ampflow A28-400) with higher torque and power, which we use to power Touro's drum. Using a single S28-150 to power the weapon of a middleweight is not a good idea. There's a good chance that it will overheat.

Because of that, to spin the bar of our middleweight Titan, we use two Magmotor S28-150s mechanically connected in parallel by acting on the same gear of the weapon shaft.

The D-Pack motor is a good candidate to replace the Magmotors, besides being much cheaper. However, its electrical resistance is so low that it almost shorts the batteries and electronics. Because of that, its current must be limited if used with speed controllers. Otherwise, there's a good chance of damaging the electronics, especially since this motor is usually overvolted to 24V instead of powered by its nominal 12V. If used with solenoids to power weapons, make sure that they can take the high currents involved. This motor is difficult to find even in the US.

The Etek motor is really impressive. It may deliver up to 15 HP (1 HP = 746W), and it can deliver high torque and high speed at the same time. It is a little too heavy for a middleweight. We ended up using it in our spinner Ciclone but we had to power it at only 24V because the additional battery packs that would be needed to get to 48V would make the robot go over its 120 lb weight limit. The super-heavyweight shell spinner Super Megabyte only needs one of these motors (powered at 48V) to spin up its heavy shell. A few daring builders have overvolted it to 96V, but current limiting is highly recommended.

A few DC motors allow the permanent magnets fixed in their body to be mounted with an angular offset with respect to their brush housings (typically about 10 to 20 degrees, it depends on the motor) which allows you to adjust their phase timing. If the motor is used in the robot drive system, it should have neutral timing. In other words, it should spin with the same speed in both directions, helping a tank steering robot to move straight. If it is used to power a weapon that only spins in one direction, you can advance the timing to typically get a few hundred extra RPM. (On the other hand, in the other direction the

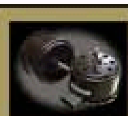
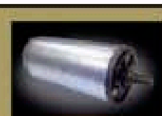
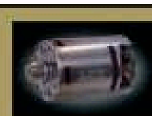
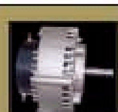
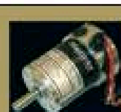
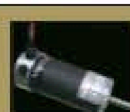
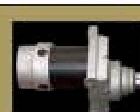
TABLE 1				
Name	Bosch GPA	Bosch GPB	D-Pack	DeWalt 18V
Voltage (V)	24	12	12 (nominal)	24
P_{output_max} (W)	1,175	282	3,561	946
Weight (lb)	8.4	3.3	7.7	1.0
Power/Weight	140	85	462	946
I_{stall}/I_{no_load}	23	25	63	128
K_t (N×m/A)	0.061	0.042	0.020	0.0085
K_v (RPM/V)	167	229	485	1,100
R_{motor} (W)	0.13	0.121	0.00969	0.072
I_{no_load} (A)	8.0	3.9	19.6	2.6
				
Name	Etek	Magmotor S28-150	Magmotor S28-400	NPC T64 (w/gearbox)
Voltage (V)	48	24	24	24
P_{output_max} (W)	11,185	2,183	3,367	834
Weight (lb)	20.7	3.8	6.9	13.0
Power/Weight	540	574	488	64
I_{stall}/I_{no_load}	526	110	127	27
K_t (N×m/A)	0.13	0.03757	0.0464	0.86
K_v (RPM/V)	72	254	206	10
R_{motor} (W)	0.016	0.064	0.042	0.16
I_{no_load} (A)	5.7	3.4	4.5	5.5

FIGURE 7

motor speed would decrease.)

To advance the timing, loosen the motor screws that hold its body, power it without loading its shaft, and slightly rotate its body (where the permanent magnets are attached to) until the measured I_{no_load} current is maximum, and then fasten the body back in place. For neutral timing, rotate the body until I_{no_load} is identical when spinning in both directions.

Regarding hobbyweights (12 lbs, about 5.4kg), a few inexpensive gearmotor options for the drive system are the ones from the manufacturers Pittman and Buehler, which can be found in several junk yards. Our hobbyweight drumbot Tourinho originally used (in 2006) two Buehler gear motors (with 300 grams each, about 0.66 lb), and our hobbyweight wedge Puminha used four Pittmans (with 500 grams each, about 1.10 lb). We've bought used ones in Brazil for about US$10 to US$15 each (after bargaining). Most of them have nominal voltage at 12V. However, we've used them at 24V for three minute matches without overheating problems. Remember that by doubling the voltage, the power is multiplied by four.

The only problem is that the small gears can break due to the higher torques at 24V — we've broken quite a few 12V Pittmans after abusing them in battle at 24V. The only way to know whether they'll take the overvolting is by testing them. It's also a good idea to always have spare motors.

There are much better gearmotor options for hobbyweights and even heavier robots than the ones from Pittman and Buehler, however, they usually need some modifications to get combat-ready. We've been using Integy Matrix Pro Lathe motors (**Figure 7**) for the drive system in our hobbyweights, I adapted to 36 mm BaneBots (**www.banebots.com**) gearboxes that were modified following Nick Martin's recommendations that were described in the March '08 edition of *SERVO Magazine*. Recently, we've upgraded the gearboxes to BaneBots' P60.

A good combination for the drive system of a featherweight is the discontinued 42 mm BaneBots gearbox (or its improved version Magnum 775), connected to a 775-sized motor. For Touro Feather's drivetrain, we've adapted 18V DeWalt motors to modified Magnum 775 gearboxes with great results. This overkill combination for a featherweight can even drive a lightweight. Other lightweight drive options are 18V DeWalts connected to custom-made gearboxes, such as the DeWalt Powerdrive Kit or Team Whyachi's TWA69 gearbox with Astroflight 990 Cobalt motors which we use in Touro Light.

For middleweights, S28-150 Magmotors are usually a good choice for the drive system, connected (for instance) to Team Whyachi's famous TWM 3M gearbox (pictured in **Figure 8**). The S28-400 Magmotors are more appropriate for the drive system of heavyweights and super heavyweights, connected (for example) to the TWM 3M gearbox (used in Touro Maximus) or to the stronger TWM3.

A good option for the drive system of beetleweights used in Mini Touro is the Beetle B16 gearmotor (**Figure 9**), sold at The Robot Marketplace (**www.robotmarketplace.com**). For antweights and fairyweights, the Sanyo 50 micro geared motor (**Figure 10**) is a very popular choice.

There are several other good brushed DC motors besides the ones presented above, not only for the drive system, but also to power the weapon. Brushless motors (to be studied in a later article) have been successfully used as weapon motors in several weight classes. It is useful to do research on which motors have been successfully used in combat. Several motors can be found at The Robot Marketplace and much more information can be obtained in the RFL Forum (**http://forums.delphiforums.com/therfl**).

FIGURE 8


FIGURE 9


FIGURE 10

Summary

I've managed to grossly simplify this subject in this tutorial. Detailed calculations are available for those wanting to understand the math behind these seemingly simple (but actually amazingly complex) pieces of bot technology. SV