Tuning the 16D Motor

A 16D motor costs $12.50, a Group 27 motor costs about $320. So what is the real difference? A 27 motor has ball bearings and cobalt magnets that cost about $65, but besides that a 27 motor is about as perfect a motor as it is practical to build. So what makes a perfect motor?

1. The armature shaft is straight and round
2. The pole pieces are 120° apart
3. The armature stacks are symmetrical
4. The armature is balanced
5. The armature windings are even and to class specs
6. The windings have no shorts or bad connections
7. The commutator is true
8. The commutator segments are symmetrical
9. The spaces between the commutator segments are not too wide
10. The commutator timing is optimized
11. The motor magnets are at full strength
12. The magnets match the contour of the armature
13. The armature is centered on the magnets
14. The motor bearings are aligned with each other
15. The motor bearings are not too loose
16. The brush hoods are properly aligned
17. Spring tension is optimized
18. The motor brushes are not too tight or loose in the hoods
19. Armature end play is minimal
20. The end bell is held securely in place

You can bet that with a Group 27 motor all of these things are right and that with a 16D motor most of them are not! Looking over the list there are some things that you can fix if they are not right and some that you can’t.

Items 2, 3, 4, 5, 6, 8, 9, and 12 can not be fixed. If you are buying a new motor most of these problems are inside where you can’t see them, that is why you are better off in the long run to rebuild an old motor. Whether you are checking out a new motor or rebuilding an old one, first disengage the motor springs. On Parma motors, bend the retainer tabs just enough to unhook the springs, on Slotworks motors you have to unhook them from the tabs, then pry the other end so it is outside of the brush hood. Before removing the brushes completely, slide each brush out part way and mark it with a scratch on the facing side. I put one scratch mark on the front brush and two on the back (axle side) brush. Remove the endbell and pull out the armature. Once in a while you come across an armature that is plainly crooked, the gaps between the stacks are not even. I would just toss those. A 16D armature is unbalanced by definition, it is not legal to balance them by any means. You can see if the armature windings have been applied evenly. Usually 16D windings look OK, however Super 16D windings look like they were done by a three year old. An armature with ugly windings can still be fast, but if the windings are bulging past the stacks they must be wound too loose.
Extra wire means more resistance and a less powerful motor. You can’t see shorts or bad connections, but you can measure for them. Make measurements across all three poles, they should all be the same: 0.8 ohms for 16D’s and 0.4 ohms for Super 16D’s. Low readings are rare, they indicate a short that will cause the motor to run hot and eventually burn out. High readings are usually caused by a poor connection between the winding and the commutator. This is a more common problem, a complete open will result in a motor that has to be spun by hand to get started. In either case I would recommend tossing the armature. Always measure the resistance before doing any other work on an armature.

Once in a while you come across an armature with crooked commutator segments. Often there is a lot of space between the segments. You are stuck with the contour of the magnets. It is possible to grind them with a diamond hone, but this not legal for 16D motors.

Now for the things that you can fix. **ARMATURES:** Crooked armature shafts are a common problem. If you have a variable speed drill with good bearings you can rotate the armature slowly and detect any wobble. Fixing a bent armature takes a light touch and a machine shop. I clamp the arm into a lathe or milling machine using a collet. I rotate the arm to find the high spot and apply pressure to the unsupported end of the arm with a piece of wood to bend it straight. It sure is easy to overshoot and make things worse! After straightening the shaft at one end I reverse the arm and repeat the procedure, then I turn it around again and double check. It seems obvious to me that you might not want to do all this for an armature that is just a little bent. The next thing to address is timing. More timing advance usually means more power. Parma rules limit advance to 25 degrees, other rules are more liberal. New England Championship rules have no timing restrictions and many tracks never check timing. Ask before you enter a race. Looking a the armature endwise from the commutator end, if the gap between the commutator segments is located right at the center of a stack the arm has no advance. If the gap is left of center the timing is advanced, since the motor runs counterclockwise, when viewed from that end. If the gap was all the way to the left side of the stack the advance would be about 45 degrees. There are several timing gauges on the market. It is hard to judge the exact timing by eye. Stock 16D armatures are usually 15-18 degrees. Super 16D armatures are usually 20-25 degrees. It is often possible to advance the timing further. To do so there must be some slack in all three wires coming from the right of the solder tabs. It is not a good idea to grab the commutator with pliers, so I make a tool to hold the comm while I twist it. Drill a \(5/16\) inch hole in a piece of wood. Insert the comm in the hole and press down lightly to press the solder tabs into the wood a little bit. Using a hobby knife carve little notches where the impressions are. This jig will hold the comm without damaging it. Put the arm in an oven (400 degrees, 2-3 minutes) to soften the epoxy that holds the comm in place. I then insert the arm in the jig and wiggle it a little in both directions to break the comm loose. Looking from the gear end rotate the armature counterclockwise to advance the timing. Turn the comm as far as it will go, DO NOT TWIST HARD, YOU WILL BREAK A WIRE AND DESTROY THE ARMATURE. Now measure the timing. If you are building the motor to Parma rules back off the timing to 25 degrees if it has gone over that.

I have run 16D’s with 35 degrees and Super 16D’s with 45 degrees with good results.
If you have not used the oven method of loosening the comm you will have to glue it in place with a little 5-minute epoxy. Let the epoxy set before you do anything else with the arm. Now it is time to true the commutator. If you bought an armature with a cut commutator and had to straighten the shaft it would be a good idea to re-cut the comm. If you were thinking of turning pro here it would be nice to have your own comm cutting machine. Perhaps you know someone who has one. You can also send it out to companies like Pro Slot, Alpha, Camen and Koford to be cut. Get Super 16D’s re-balanced while you are at it, these arms are only approximately balanced from the factory. In order to balance a Super 16D arm, I have a little balancing jig that is used to roll the arm on parallel razor blades. The jig has adjusting screws and a bubble gage to level it up. I made mine, but there are some on the market. The idea, if you do it yourself, is to make the arm better, not to make it perfect. First mark the armature poles and make a chart:

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I roll the armature ten times and mark where it stops each time. The heavy pole will point down. If the arm stops part way between two poles mark for both of them. For example, you might get something like this on the first pass:

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This armature is out of balance, the totals for all three poles do not match. The pole marked “I” is the heaviest, followed by the one marked “II”. It will be necessary to drill out both of these poles, taking a little less away from “II”. Here is another chance to overdo things. Cut a “V” shaped groove in a block of wood and use it to hold the arm in place. Use a $\frac{1}{8}$th inch drill bit to remove just a little from each heavy pole. Now re-check the arm:

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Now that looks better. Take a little more off “I” and you are there. Remember, if you try to get it perfect, you will almost always overshoot.

**MAGNETS:** The next thing to look at is magnet strength. If you are re-building a used motor and the car that it was in didn’t have any brakes suspect that the magnets are at
less than full strength. Heat, vibration and dynamic braking all take their toll on magnetic strength. Vibration is the leading cause of loss of magnetism. Shaking from an unbalanced armature and the occasional wall shot will gradually wear the magnets down. A gauss meter would be the thing to use here, I have one that cost about $300 and a Magnet Marshal can also be used. Several of the high end motor makers can check your magnets, if you want to send them out. The crude method is to compare your old pair to a new set by bringing them together slowly on a smooth surface and taking note of how far they are apart when they begin to attract each other. A more sophisticated approach is available to someone who has access to a laboratory top loading balance. I took a piece of mild steel 2 X 2 X \( \frac{1}{4} \) inches and leveled it up on the balance pan. I cut two blocks of wood the right height to support a glass plate so that it’s upper surface would be \( \frac{1}{4} \) inch above the steel plate. I then leveled up the glass plate, this is very important since magnetic strength is inversely proportional to the square of the distance between the magnet and the steel plate. Moving the magnet slightly to one side would make a relatively large change in the reading. With no magnet in place I zeroed the balance. I then put the magnet to be tested on the glass plate, centered on the steel plate. Comparing a pair of magnets I read 28.88 grams for one magnet and 25.40 grams for the other. This is not what you want to see, both magnets of a pair should read the same. In this case 10% of the energy would be wasted trying to pull the armature towards the strong magnet, rather than around in a circle. You can put new magnets in or get the old ones zapped. Remember that zapping will only bring the magnets up to their maximum potential. Some magnets simply will not give you full strength because of some defect, which is why it is good to be able to measure them. When it is time to put the magnets in the motor can always turn them so that the color coded end is showing and put the white (North) magnet on the notch or axle side. If you are consistent in the way you put in the magnets you will never have to guess which way the motor will run. Just connect the front brush hood to the positive (that’s right looking in the direction of travel) side of the guide flag and the motor will run in the right direction. You can sometimes increase the performance of a motor by shimming the magnets. Shimming is not legal under most rules. In the cases where it is the cardboard label on most Parma packages is usually the right thickness. Leave an air gap of two thousandths of an inch. You will find that it is nearly impossible to insert Super 16D magnet clips with shimmmed magnets, they will have to be trimmed a little. DO NOT GLUE IN THE MAGNETS YET! Install the armature without any spacers, hold the motor horizontally and give the arm a spin. When the arm comes to rest it should be centered, not pressing against either bearing. The magnets should be directly opposite each other and positioned so that the arm is not touching either bearing. After positioning the magnets glue them in place with epoxy or super glue.

**CAN BEARINGS:** Now check the can bearing by shaking the armature shaft back and forth. If you can detect any play at all the bearing must be replaced. Sometimes even new motors have loose bearings.

Remove the end bell and armature and support the end of the can from inside while pressing out the old bearing to avoid deforming the can. An \( 1 \frac{1}{4} \) inch length of \( \frac{1}{2} \) inch dowel with a \( \frac{5}{16} \) inch hole drilled in from one end makes a good support. At this time you could just press in a new bearing, supporting the can from the outside, however I
have found that the can bearing hole often has not been accurately punched. Drill out the hole to the next larger size, then grind away the plating from the edge of the hole. Wrap masking tape around an old armature one layer at a time until it is a snug fit. With the bearing on the armature shaft push in the armature so that the bearing flange is up against the can and put on the end bell. Put a little acid flux on the ground area and the adjoining bearing surface and solder the bearing in place. The bearings will now be aligned with each other and the armature will be centered between the magnets.

**BRUSH HOOD ALIGNMENT:** Now it is time to look at those motor brushes that you marked so carefully. When viewed from the side they should have a symmetrical wear pattern, indicating that the openings in the brush hoods are perfectly aligned with the center of the commutator. If they are straight you can skip the next few lines, otherwise the hoods will have to be aligned. Remove the offending hood(s), you will notice that the screw holes have been carelessly punched. One of the screw holes will have to be filed out in order to reposition the hood. By looking at the matching brush you can determine where to enlarge the hole. Obtain a brush hood alignment tool and a $\frac{5}{64}$ inch drill blank, Parma sells these as a set. Reassemble all of the end bell hardware, but leave the screws a little loose. Slide in the alignment tool and slip the drill blank through the tool and both motor bearings. Replace the end bell screws and tighten the hood screws. If you tried to do this without enlarging the hood screw holes the hoods would spring back to their original position as soon as the tool was removed.

**MOTOR BRUSHES:** A lot of people like to replace the original brushes with a premium brush, Mura Super Bigfoot II's are very popular. Check the rules to see if this is legal. The hoods will have to be enlarged slightly with a small square file, since Bigfoots do not have rounded corners like the stock brushes. The brushes should not stick or wobble in the hoods. If the motor brushes are worn less than half way and the brush hoods were straight it is all right to reuse them. New brushes should be cut with a brush break in tool. Camen, Koford and others make a tool for this purpose, those wishing to gild the lilly may obtain a diamond covered Magnehone tool. Assemble the motor with the tool in place of the armature, then spin the tool with a Dremel or electric drill. You can just turn a Magnehone by hand. Flush the dust out of the end bell with a shot of motor spray or brake cleaner. Do not break in the brushes by running the motor, this may damage the commutator and will certainly shorten the motor's life.

**MOTOR SPRINGS:** The stock motor springs come with enough tension to keep them in contact with typically out of round commutators. A motor will rev higher and last longer if the spring tension is reduced. I bend the spring so that it makes about a 90 degree angle. Be sure both springs make the same angle.

**MOTOR ASSEMBLY AND BREAK-IN:** Assemble the motor adding enough armature spacers to limit end play to about the thickness of one spacer. Try to keep the armature centered. If the endbell screws are stripped put a dot of super glue on them. I always bend in the can tabs, otherwise the endbell could come out in a bad crash.

Oil the bearings and break in the motor at about 3 volts for 30 minutes. Never apply full voltage to an unloaded motor, especially if the timing has been advanced. To check if the spring tension is correct run the motor at 3 volts and lightly press on one motor brush with the end of a small screwdriver etc. and listen to hear if the motor changes speed. If the motor speeds up the spring tension will have to be increased, if not pry
gently on the portion of the spring that bears on the brush to reduce tension a little. If the motor speeds up the spring tension will have to be reduced.

Congratulations! You have just made a $12 motor into a $50 motor using about $200 worth of labor. Pop that work of art into a car and see what it can do. Chances are it will be very competitive. If the motor is still a little slow remember that you now have a good setup. Try different armatures until you have a superior motor. GOOD RACING!

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