**COVID-19 (coronavirus) impact:** We are still operating and **shipping all orders** with a reduced staff. All in-stock orders continue to ship within a business day; for critical requirements, including fighting the coronavirus, please contact us so we can prioritize orders appropriately.

# Micro Metal Gearmotor Calculations

**Accipiter** **Apr 2010**

Hello,

I am currently trying to decide on which gear ratio to choose for the micro metal gearmotors for a robotics project and I have to mathematically justify my decision. So…

I have performed some simple calculations using the following equations:

V = IR + E
(V = voltage applied to motor terminal, I = current into motor, R = resistance of armature, E = back emf),

E = kw
(k = electrical constant, w = angular speed of motor)

and

T = kI
(T = motor torque, k = torque constant (equal to the other k above as well)).

Using the above, I get very different results for "k" depending on how I calculate it.

Method 1: k = (6volts) / (no load speed)

Method 2: k = (stall torque) / (stall current)

So, about the stall torque:
Is that a number that you all measured, or is that a number that you calculated as I did above, and then rounded?

Also, about the no load speeds listed in the table:
Why don't they match with the gear ratios? If I compare the 5:1 with the 30:1, it's plain that 2500RPM/(30:1/5:1) = 417RPM and not 440RPM. So, I don't know which numbers to go with.

As another example of the kind of contradictions I keep coming across:

If I calculate the torque constant using method 1 above for the 210:1 gear ratio (non-HP), i get the following:

k = 6V/60RPM = 6V/(60/602pi rad/sec) = 0.955 (newton-meters per amp).

WIth the second method, I get:

k = (1.3kg-cm *(9.8newtons/kg)*(1meter/100cm)) / ( 360mA ) = 0.354.

Quite different indeed. I mean, I don't think I can attribute a difference of a factor of 2.7 to rounding errors…

Any advice would be most greatly appreciated.

Thanks.

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**Ben** Pololu Employee **Apr 2010**

Hello.

We received stall-torque specifications from the manufacturer (I'm not sure how they were measured or if they were the result of calculations) and then conducted independent tests to verify the numbers, but in general it's difficult to measure torque without expensive equipment, so the numbers we came up with should be considered rough estimates. The situation is further complicated by the fact that the motor very quickly gets hot while stalled, which causes the coil resistance to rise and the current draw (and hence the torque) to drop. The stall torque can significantly decrease over a matter of seconds if the motor is held stalled.

As far as your calculations go, I'll need to give this some more thought when I have more time, but there are a couple of things that immediately come to mind:

1. E is not 6V in the free-run case (this would only be true for an ideal motor). Rather, E = 6V - IR. If the stall current is 360 mA at 6V, we get that the coil resistance is approximately 6V/0.36A = 17 Ohms. Since the free-run current is approximately 40 mA, E = 6V - 0.04mA*17Ohms = **5.3V**. This doesn't come close to making up for the factor of 2.7 difference, but it does decrease the k from your first calculation to 0.84.

2. In a gearbox, torque is lost with every gear, but speed is not. That is to say, if you have a system of two same-size gears (1:1), the output speed will match the input speed, but the output torque will be less than the input torque. I believe the result is that the *k* from your torque equation is not the same as the *k* from your back-EMF equation. I think they would match if you were looking at measurements taken at the motor output without the gearbox present (or if you got your gearbox from the ideal-physics stockroom), but I think the gearbox changes things and our measurements were taken at the gearbox output. I wouldn't be surprised if the torque lost in the gearbox coupled with the rough nature of the stall-torque estimate accounts for the calculation discrepancy you're seeing, though I also wouldn't be surprised if I've just stuck my foot in my mouth by totally forgetting to consider some crucial element of the problem in the few minutes I've been thinking about it.

- Ben

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**Accipiter** **Apr 2010**

> Ben:
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> 1. E is not 6V in the free-run case (this would only be true for an ideal motor).

Ah, yes. Good point. I'll have to adjust my calculations a bit.

> Ben:
>
> 2. In a gearbox, torque is lost with every gear, but speed is not.

So, why, then, do the free running speeds not match with the gear ratios? As I said in my previous post, if I compare the 5:1 with the 30:1, it's plain that 2500RPM/(30:1/5:1) = 417RPM and not 440RPM. I know it's not really that much off (like 5%), but still, why not put 417 if it's 417? Would 417RPM actually be the value I should use in my calculations? Or, maybe it's the 2500RPM that's lacking in accuracy? I guess it would be good to know if the "no load" speed of the motor without any gearing is actually 2500*5 = 12500RPM.

Thanks,
John

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**Ben** Pololu Employee **Apr 2010**

The 2500 RPM measure is a conservatively rounded number; it might actually be closer to 2600 RPM. Also, you should note that there is variance from motor to motor, and that variance can be a few percent. If you take two 30:1 micro metal gear motors and apply 6V to each, it is very unlikely that their speeds will be identical, so you've got to factor in a reasonable level of uncertainty when looking at these specifications. I think you are trying to be much more presice in your calculations than is reasonable for real-world motors like these where all sorts of complicating factors come into play (gear efficiency, temperature, number of coil windings, etc). I haven't measured the speed of the motor by itself, but I'll try to find time to do so.

In general, if you're looking for a motor, you should figure out how much torque and speed you need (and how much current and voltage you have available), and pick something that comfortably exceeds those requirements given what you can supply. The specifications we supply are adequate for this level of selection.

- Ben

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**Accipiter** **Apr 2010**

Okay, that makes sense. Thanks for your help.

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laidlaw1546 Mar 2017

I know it is a very stale topic, but it is still relevant. I want to get the Kb and Kt (should be equal) for a motor (37d 30:1). If I use the calcs mentioned in the FAQ, I get two different answers that differ by a large percentage (more than double). I read this thread and it suggests that no load RPM might be somewhat variable (say 10%) and that the stall torque value might be completely unreliable.

I have been told that Kb=Kt. This is what I've read numerous places, but I don't believe it. All proofs that state this start with the assumption power in = power out but they assume all power out is mechanical power to the load. Some power is IR loss in the windings.

How do I get the most accurate answer for the motor constant? In particular, extra friction from the gearbox (comment 2 above where Ben said "In a gearbox, torque is lost with every gear, but speed is not") may be very relevant, but this should NOT affect the motor constants.

Suggestions:

1. Based on the previous emails, each of the two versions of motor constant uses inaccurate raw data but the Kb calc might be better (speed spec is more reliable than torque).
2. When calculating Kb, don't simply follow the FAQ recommendations. Remember that the voltage is the nominal supply voltage less the IR drop in the winding. I is spec'd but R must be calculated.
3. Using the motor only data and adjusting for the gearbox reduction (multiplying by the reduction ratio) should improve things a bit (data less affected by friction)
4. Ideally, Kb can be measured by driving the motor to a known speed and measuring the open circuit voltage on the terminals then dividing the voltage by the speed (in rad/sec) to get the Kb.

So the big questions:

How to calc Kt and Kb reliably?

Is it safe to assume Kt=Kb?

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**Why are motor constants (Kt, Ke) not same, given the motor spec?**

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**Ben** Pololu Employee **Mar 2017**

Hello.

We have just recently started performing more detailed, systematic characterizations of our metal gearmotors, which makes it possible to compute some of these motor constants more accurately. One early observation is that using the actual stall torque to try to calculate the torque per amp of armature current does not work well, since the amount of torque a motor can produce drops significantly as it heats up, and in a real system, a stalled motor gets very hot very quickly.

From the data we have taken so far for our **30:1 37D gearmotor** , the torque constant appears to be approximately 0.25 Nm/A. This is the slope of the torque-vs-current curve in the region where the current is less than around 50% of the stall current. In this region, the curve is very well approximated by a line, and it should be noted that this line does not pass through the origin (since the current does not reach zero at zero load).

The speed constant can actually be accurately calculated using the no-load speeds we provide, and it is approximately 2.9 rad/s/V for this gearmotor. If you are calling Kb the inverse of this, or 0.34 V*s/rad, then it ends up not being that different from the torque constant.

- Ben