Current Measurements of ATA Stepper Motors

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6/18/02

With many thanks to Jim Waite for spending an entire day with me, here are some measurements we took of the current draw from two stepper motors that are being prototyped for the ATA antenna drives (azimuth and elevation). These measurements should be useful for the design of the stepper motor driver power supplies and the power distribution network. NOTE: All the measurements described here are from driving a single motor. The real antenna has two motors, so this should be noted when making projections.

![Average AC Current](image)

Figure 1: Average AC current draw for two motors as a function of step frequency.

We compare results from two motors that Matt provided, which we label as “214$^1$” and “207$^2$.” Matt is trying to decide which of these motors to choose for the ATA antennas. Beginning with the AC current, we measured firstly the average current drawn by the entire stepper motor driver box as a function of step frequency (fig. 1). Notice that even

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$^1$ 214: Part number 34N214S-LW8, $I_s = 5A$, $V_s = 65V$, $P_o = 169 W$.

$^2$ 207: Part number 34N207S-LW8, $I_s = 2.5A$, $V_s = 170V$, $P_o = 221 W$.  

when standing still the stepper motor draws about 0.4 A. This is because stepper motor coils are energized to hold the motor in place when stationary.

At slowest speeds, (e.g. sidereal ~ 40 steps / s), the motors draw comparable currents. The 214 motor draws less total current at moderate speeds, but this situation reverses at slew speeds. Above 4000 Hz (0.4° / sec) the 214 motor current is higher than the maximum of the 207 motor over the entire range. This means that unless we limit our slew speed to less than 4000 Hz, the 207 motor draws a smaller peak power (important for design of power distribution). My guess is that this point will drive us toward using the 207 motor.

Remember that the stepper motor driver is built upon two analog power supplies: one 5 V supply and one 85 V supply. To design these power supplies and the power distribution system it is important to know the peak currents A) for the driver box as a whole, B) for the 5 V supply and C) for the 85 V supply. These are shown as a function of frequency in figures 2-4.

![Figure 2: Peak AC current as a function of frequency. It is 4-5 times larger than the average AC current but follows its shape very closely.](image)
Figures 3 and 4: The peak current draw from the 5 V and 85 V supplies.
Starting with figure 2, we observe that the peak AC current is 4-5 times as large as the average current value. To understand this, remember that each analog power supply uses a transformer and diode bridge to feed a capacitor. When the driver draws charge out of the capacitor, it gets replenished by the bridge, but only when the bridge voltage is higher than the capacitor voltage (i.e. when the AC sine wave it at its extremal values), or about 20% of the time. Also notice that since current is delivered only when the voltage peaks, the peak power calculation must use the *maximum* AC voltage rather than its RMS value.

The overall peak current from each of the 5 and 85 V supplies is around 12 A. The shape of these curves is somewhat confusing, however. In both power supplies, the currents get small at high frequency when you expect them to require the most power. But we must remember that though the currents are small, the step rate is high, so the average power delivered is substantial. This is illustrated in figure 5 where the product of the 85 V current and step frequency is plotted. At low frequencies this product is small whereas at high frequencies it tracks the total output of the stepper driver box.

![Peak 85 V Current * Frequency](image.png)

Figure 5: Peak 85 V current times the step frequency, which is a very crude measure of the average power supplied by the 85 V supply.

From these observations we conclude that at low speeds the 5 V power supply provides most of the power (mostly holding torque) whereas at high speeds the 85 V supply takes over and supplies the current spikes required to produce torque.
Appendix

Here is a brief description of how the measurements were made. The diagram below indicates the circuit diagram of the instantaneous AC and DC current measurements. Only one of the two DC power supplies is shown. For different measurements, different resistors were sometimes substituted.

Starting with the AC current, below is a typical measurement from when the 207 motor was driven at 4 kHz.

In this measurement, the vertical scale 2 A per division, while horizontal scale is as indicated.
Below is a capture of the 5 V current measurement. A vertical division is 4 A.

Finally, here is a measurement from the 85 V series. One vertical division is 4 A.