Analysis of Feather Touch 3545 Motorized Focuser Repeatability

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The Feather Touch (FT) 3545 focuser on my TMB-130SS telescope has the accessory motorizing kit that uses a stepper motor to move the drawtube in and out.

Accurate positional repeatability is essential when using software such as FocusMax to automatically focus the telescope. Often I noticed instances of poor automated focusing, so I decided to measure it and improve it if possible.

To conduct the tests, I securely attached a dial indicator to the top of a telescope mounting ring, arranged so its tip pressed against the camera attached to the focuser, as shown here. My imaging equipment consists of an SBIG ST-8 camera with a CFW-10 color filter wheel and an Optec Pyxis camera rotator, with an estimated total weight of eight pounds, right at the specified maximum for the motorized FT 3545.

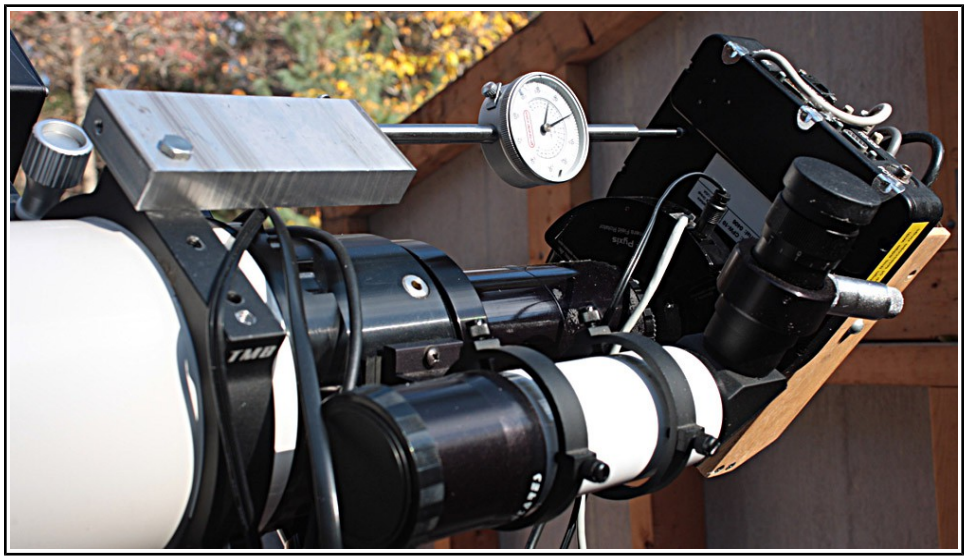

Illustration 1: Repeatability test setup.

Good positional repeatability requires free movement, so I loosened the FT's drawtube friction adjustment screw, as well as the tension screw on the focuser knob shaft.

To begin, I positioned the telescope approximately level and set the FT to an arbitrary position with the drawtube mostly racked-in, then adjusted the dial indicator to a zero-reference reading. I applied power to the FT focuser control box, and verified that the display read 0000. I launched FocusMax and verified that its position display also read 0000. All focuser positioning during the test runs was accomplished using the FocusMax Jog control dialog window.

With the telescope still level, I commanded FocusMax to move the FT drawtube from position 0 to 500 (steps), from 500 to 1000, then back from 1000 to 500, and from 500 to 0. Table 1 shows the dial indicator reading, in thousandths of an inch, at the end of each movement in this reference run.

The test runs measured repeatability, so the tables show only the indicator's thousandths reading, not the total distance the drawtube traveled with each movement. The important numbers in the tables are the variances between the outward and inward ending positions. The total drawtube movement is not important.

Table 1: Reference positions, telescope level, stepper motor speed 255.

Movement	***Dial Indicator End Reading***	***Variance From Outward Movement Ending Position***
Zero-reference	0	N/A
Outward, 0 → 500	60	N/A
Outward, 500 → 1000	17	N/A
Inward, 1000 → 500	58.5	-0.0015"
Inward, 500 → 0	**0**	**0**

After taking the reference measurements, I elevated the telescope to 78°, where all subsequent measurements were made.

I performed four runs. The first two duplicated the reference run: 0 → 500 → 1000 → 500 → 0. The third and fourth runs moved the focuser from 0 directly to 1000 without the intermediate stop at 500, and back from 1000 to 0.

Each run began at the zero-reference point. If a final inward movement did not end exactly at this starting point, I used the FT control box to manually move the drawtube until the dial indicator read 0. The final row in each table shows the number of steps and direction needed to reach the starting position.

Poor repeatability in the first two runs at 78° elevation (tables 2 and 3) convinced me that the FT motor was stepping too fast. The ASCOM driver has a motor speed setting, and the default value of 255 was used for the reference run and the first two runs at 78°. Based on the poor initial results, I reduced the motor speed to 64 and conducted the third and fourth runs, which produced much better results. The following tables show the results from the four runs.

Table 2: First run with telescope elevation 78°, stepper motor speed 255. Outward movement is downward, inward movement is upward.

Movement	***Dial Indicator End Reading***	***Variance From Outward Movement Ending Position***	***Variance From Same Position with Telescope Level (table 1)***
Zero-reference	0	N/A	0
Outward, 0 → 500	58	N/A	**0.002" short**
Outward, 500 → 1000	15	N/A	**0.002" short**
Inward, 1000 → 500	56	**0.002" short**	**0.0025" short**
Inward, 500 → 0	**91**	**0.009" too far**	**0.009" too far**
22 steps outward on hand box needed to back-up to zero-reference after 500 → 0 over-travel			

Table 3: Second run with telescope elevation 78°, stepper motor speed 255. Outward movement is downward, inward movement is upward.

Movement	***Dial Indicator End Reading***	***Variance From Outward Movement Ending Position***	***Variance From Same Position with Telescope Level (table 1)***
Zero-reference	0	N/A	0
Outward, 0 → 500	59	N/A	**0.001" short**
Outward, 500 → 1000	16	N/A	**0.001" short**
1000 → 500	57.5	**-0.0015" short**	**0.001" short**
500 → 0	**95.5**	**0.0045" too far**	**0.0045" too far**
16 steps outward on hand box needed to back-up to zero-reference after 500 → 0 over-travel			

Table 4: Third run with telescope elevation 78°, stepper motor speed 64. Outward movement is downward, inward movement is upward.

Movement	***Dial Indicator End Reading***	***Variance From Outward Movement Ending Position***	***Variance From Same Position with Telescope Level (table 1)***
Zero-reference	0	N/A	0
Outward, 0 → 1000	16	N/A	**0.001" short**
Inward, 1000 → 0	**98**	**0.002" too far**	**0.002" too far**
5 steps outward on hand box needed to back-up to zero-reference after 1000 → 0 over-travel			

Table 5: Fourth run with telescope elevation 78°, stepper motor speed 64. Outward movement is downward, inward movement is upward.

Movement	***Dial Indicator End Reading***	***Variance From Outward Movement Ending Position***	***Variance From Same Position with Telescope Level (table 1)***
Zero-reference	0	N/A	0
Outward, 0 → 1000	16	N/A	**0.001" short**
Inward, 1000 → 0	**98**	**0.002" too far**	**0.002" too far**
7 steps outward on hand box needed to back-up to zero-reference after 1000 → 0 over-travel			

Graphical Test Results

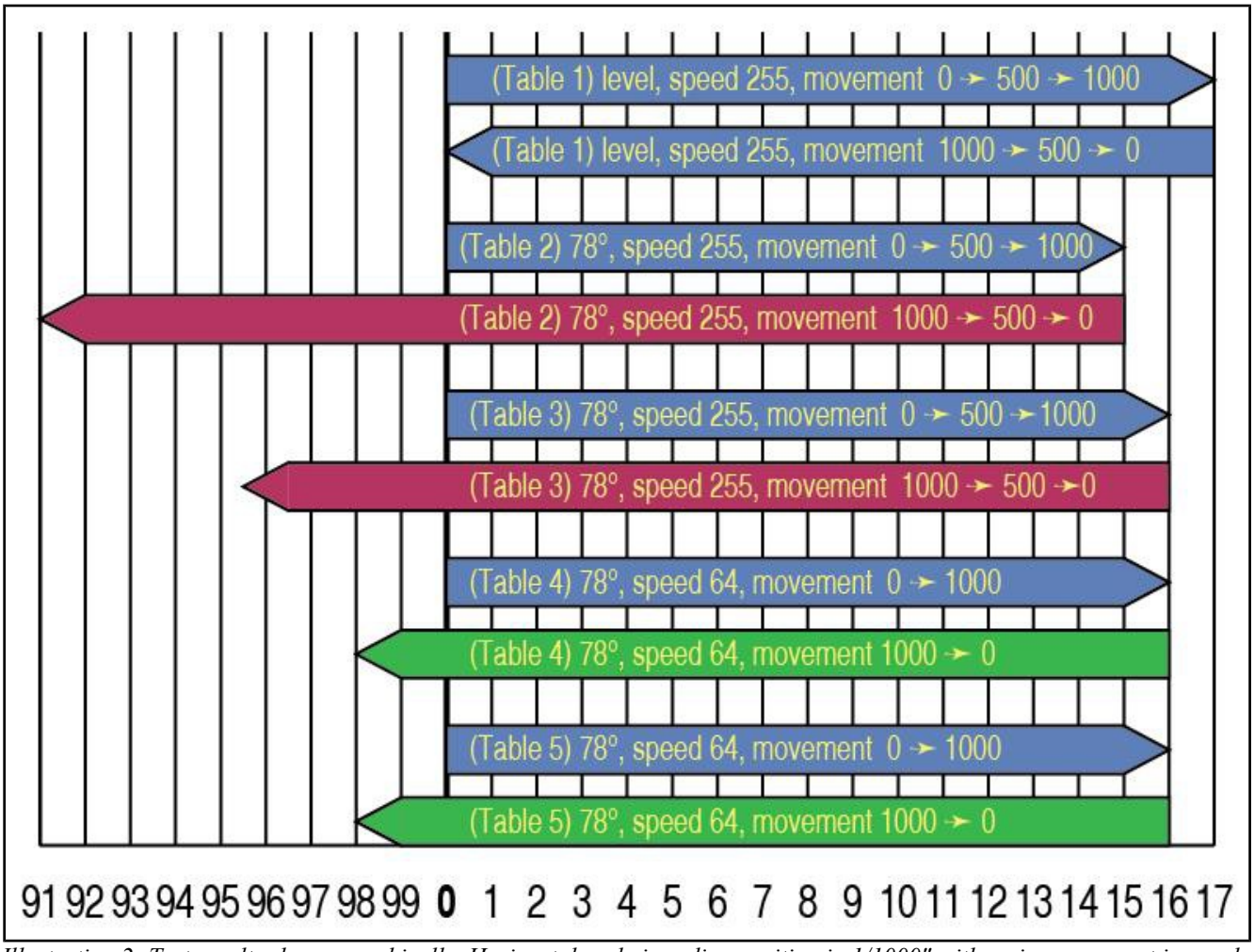

Illustration 2: Test results shown graphically. Horizontal scale is ending position in 1/1000" with major movement ignored.

This chart shows the results from tables 1-5 graphically. I eliminated the 0 → 500 movement shown in tables 1-3 so the chart could end at 17 instead of extending to 60. Note that this chart, like the tables above, includes only the dial indicator's outer-dial reading in thousandths of an inch. The indicator's inner-dial pointer visible in the photographs on the next page shows the drawtube moved several tenths of an inch between the 0 and 1000 positions.

Conclusions

The FT friction and tension adjusting screws should be loosened until there is almost no resistance against drawtube movement.

Not surprisingly (based on my experience with stepper motors), motor speed appears to be a significant factor in repeatability. With the speed set to 255 and the telescope elevated to 78°, moving from the zero-reference to position 1000 and back to zero again resulted in a variance of 0.009" in the first run and half that (0.0045") in the second run. Reducing the stepper motor speed to 64 resulted in a variance of only 0.002" in the third and fourth runs.

In the original version of this paper, I speculated that an underpowered stepper motor caused the poor repeatability at high speed. However the data don't support that theory. As the Tables and chart show, high-speed gravity-assisted *downward* movement at 78° elevation stopped short of the same spot in the level reference run (but not by much). Even more odd, high-speed *upward* movement continued beyond the 0-reference starting position by as much as 0.009". One would think that downward movement would push the drawtube *beyond* its intended ending position, not stop short of it. Likewise, upward movement with gravity fighting an underpowered motor ought to stop short of the starting position, not continue moving past it.

So I've concluded I don't know why repeatability is poor at high speed, only that it is. Slower speed works better, so that's what I'll use.

The fact that I had to move the focuser drawtube outward 5 steps (third run) and 7 steps (fourth run) to back-up to the zero-reference point after returning from position 1000 indicates there is some backlash in the motor reduction gears. I set the ASCOM driver backlash value to 5 to compensate for this.

The critical focus zone (CFZ) for my TMB-130SS telescope and ST-8 camera is 107.8 microns (0.0042"). The FT repositioned to one-half of this value (0.002") on the third and fourth runs with the motor speed set to 64, so I conclude the FT is able to achieve focus within the CFZ at this speed, and with the ASCOM driver backlash set to 5. To be on the safe side, I reduced the ASCOM driver motor speed to 32 for normal operation.

Performance Results

After the tests, and with the telescope elevated to about 60°, FocusMax built 14 V-curves with these settings and achieved excellent results. The intercept point (where the sides of the V-curve meet) varied only 1.16 steps across the 14 curves.

Using these V-curves, FocusMax accurately focused a magnitude 4 star, and subsequent 5-step in-and-out jog movements of the focuser drawtube did not improve the focus, indicating that FocusMax got it spot-on.

Test Procedure Photographs

The following photos show the dial indicator readings taken at various drawtube positions. Notice that the inner dial pointer moves considerably between positions. This large movement is not included in the tables or the chart. The goal was to measure the focuser's ability to move the drawtube consistently to specified positions, so only the thousandths reading is used.

Illustration 3: Zero-reference position for all measurements

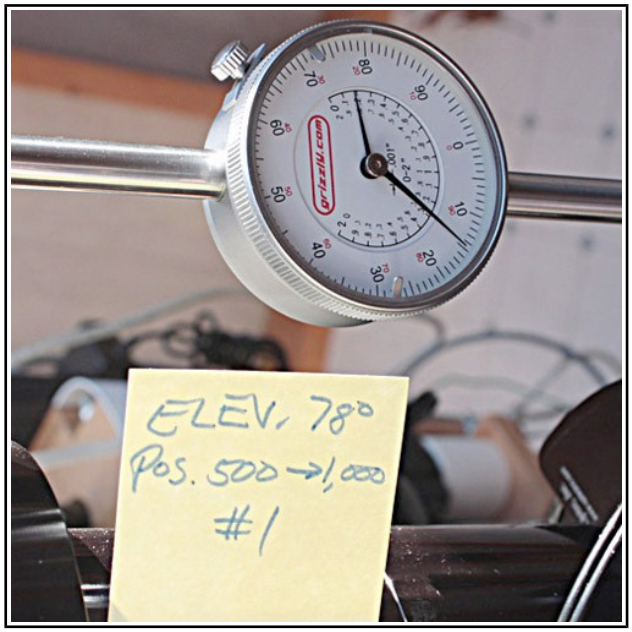

Illustration 4: Outward movement end position 1000 at 78°, motor speed 255. Reading is 15 thousandths, shown in table 2.

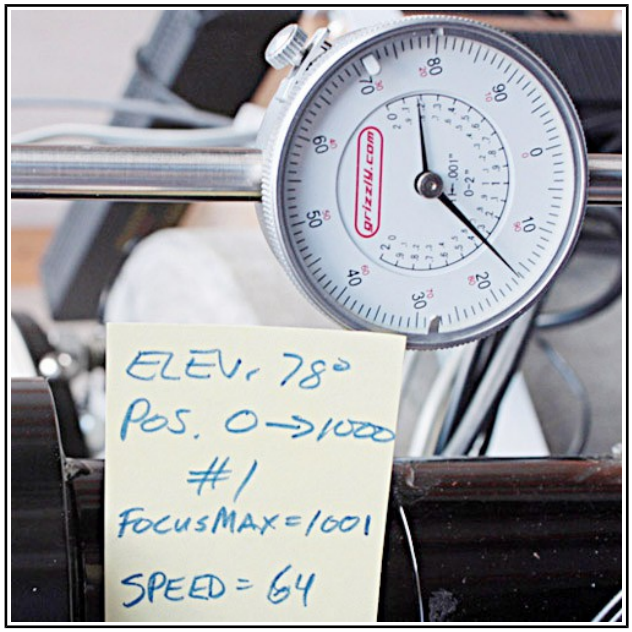

Illustration 5: Outward movement end position 1000 at 78°, motor speed 64. Reading is 16 thousandths, shown in tables 4 and 5.

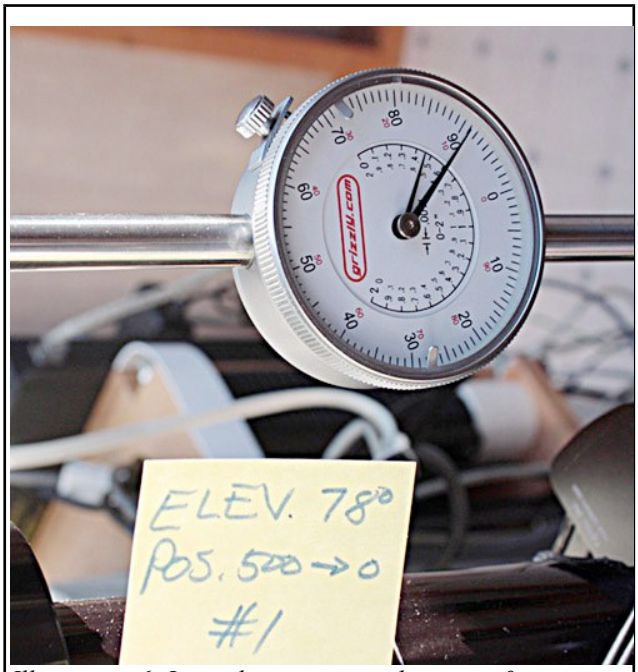

Illustration 6: Inward movement end position 0 returning from 500, 78°, motor speed 255. Reading is 91 thousandths, (0.009" too far) shown in table 2.

Illustration 7: Inward movement end position 0 returning from 1000,78°,motor speed 64. Reading is 98 thousandths, (0.002" too far) shown in tables 4 and 5.