ASTRO-PHYSICS

Precision Encoder Included with the 3600GTOPE

What does the encoder do?

The driving mechanics of the 3600 mount contain a motor with integral shaft encoder, a gearbox, a driving worm gear and a final worm wheel. While the speed of the motor shaft is strictly regulated via the shaft encoder and a digital feedback loop, the final output of the worm wheel's speed is fixed only by the gear reduction ratio. If every tooth on every gear was made in a perfect manner, down to the molecular level, then we would always have an exact sidereal driving speed at the worm wheel's output, and a scope would then track a star without any back and forth wandering due to periodic error. It is not possible to build a gear reduction system that maintains the exact sidereal speed; therefore there will always be some small periodic error in the tracking rate. The 3600 PE is specified to be equal to or less than 5 arc seconds. One can use PEM to correct for this small error, but this does not fully guarantee that you can have long term sub-arc second tracking on every worm cycle.

This is where the auxiliary precision encoder comes in. Since it is attached to the output worm wheel itself, the pulses from this encoder can be used to gauge the speed exactly. At the sidereal rate, there are approximately 170 pulses per second coming from this large encoder ring, so it is able to resolve sub-arc second speed errors to a high degree of accuracy. In the auxiliary GTOELS control box, these signals are compared to a highly accurate crystal clock reference, and any difference is sent to the servo every few seconds to update the sidereal speed to keep the worm turning evenly to a very high accuracy. In actual measurements in the lab, the RA axis of a random 3600GTO mount from the first production run went from 2.33 arc sec peak-to-peak periodic error to 0.26 arc-seconds for a 20-minute test period. When this mount was used with a CCD camera on the sky, the mount tracked smoothly with no periodic error for long exposure times. Tracking error stayed under 1 arc second for a 20-minute test period in RA. The Dec error was virtually the same, showing that almost all the residual error was due to atmospheric movement.

How does the encoder do this?

Basically, the encoder is simply a finely divided ring of 9" diameter with a pickup consisting of laser and pin diode receiver. The pickup has a resolution of 0.09 arc seconds and the encoder ring itself has a guaranteed accuracy of +/- 0.97 arc seconds for the entire 24 hour period. The accuracy for any normal exposure time is many times higher. The pulse stream generated by the encoder is fed to a microprocessor where it is compared to a fixed reference pulse stream. Any speedup or slowdown of the worm wheel is instantly noted and a compensation signal is sent directly to the servo. This works the same as a guider signal from a guide star, except that it is done at a finer resolution rate.

How does this affect guide signals from a guider camera?

While this encoder has its principal use in precision unguided tracking, a guide camera can still be used to control the servo, even when this encoder is operational. The guide signal always has precedence over the encoder signal, so one does not negate the signals of the other. The advantage of having the encoder engaged during autoguiding, is that you are assured of a clean accurate tracking rate during the guide interval, regardless of how long that interval is. So, it becomes practical to guide at 20, 30 and even 60 second integration times, something that might be needed when guiding on a very faint star through narrow band filters. Even when normal 2 to 5 second integration times are used, the increased sidereal drive accuracy and total lack of any small deviations will produce a cleaner overall guider result. In tests on various nights of average seeing, the guiding was always spot on with the encoder activated.

Can the encoder be used to position the mount more accurately during a Go-To slew?

The short answer is no. The present shaft encoder on the motor already insures that the output of the worm wheel is on average always within the periodic error range. Practically speaking, this is going to be within +/- 2.5 arc seconds worst case. Using the encoder to enhance slewing accuracy will not amount to anything, and will indeed very much complicate the servo loops that are already in place. We want to keep the system as modular as possible so that any one failure in any system will not affect the overall usability of the mount. If the encoder should fail to function properly, it can be easily disabled, either via software command or simply by pulling the plug, and the mount will continue to operate normally.

Are there any limits to the operation of the encoder?

We have done a number of tests on the system under the night sky and find the encoder to be rugged and reliable. It was originally designed for the machine tool industry to operate under high vibration levels and in dirty environments. We do not operate it under these conditions, plus the maximum speed is hundreds of times lower than it would see in a machine tool setup. Both pickup and ring are ruggedly constructed of stainless steel and will not rust in moist environments. The maximum temperature range on the high end is no problem, being that it can operate to +70C (+158F). The minimum operating temperature spec is 0C (32F), however the company representatives have assured us that it can indeed operate to -20C and lower. The limitation being the temperature point at which the laser diode stops operating. In mid-January 2009, the temperatures dropped to -25F (-32C) degrees during an astro-imaging session at our observatory. The precision encoder functioned correctly throughout this session. However, if the encoder stops working, the mount will automatically revert back to its normal periodic error profile. There is no other effect on the operation of the mount.

Who would benefit most:

The mount itself has a raw PE error well under 5 arc seconds P-V, and since one can use PEMPro to reduce this further to less than 1 arc second for each 6 minute worm cycle, this encoder is really not needed when doing guided imaging. The advantage of zero-periodic error control is that it allows long periods of unguided imaging, as well as long guide exposures when guide stars are dim, and this is especially useful when operating large long focus instruments. Another application would be in situations where an astrograph (even a short focus fast scope) is used in totally unguided applications. Here one would map the sky with proper software which is then used to vary the sidereal drive rate, as well as add slight motions in declination to reduce or eliminate any drift due to flexure, refraction, etc. This way, large areas of the sky can be covered quickly and automatically without having to use any guide stars. The RA encoder will always produce exact tracking with no variations – declination of course would have such little drift that the inherent gear accuracy is plenty high enough to allow accurate drift tracking in that axis. The encoder option is meant for those who want the ultimate tracking and guiding accuracy for all precision applications.

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