Construction of a Quartz Controlled Camera Mount for Astrophotography

Aside from railways and their models of any gauge, I have interests in satellite imagery and astronomy. This project comes from an Astronomy course in 2001. Its fairly low tech, but I challenge readers to come up with refinements to the design in order to make it more accurate.
Photographs of the stars can be taken with a camera mounted on a tripod. As the stars are generally faint one needs to take exposures of many seconds if not minutes to capture detail. A manual Single Lens Reflex film camera with a 'B' setting is the preferred equipment, digital cameras rarely have long exposure settings above 15 secs, and one wants to avoid batteries which may fail in the cold. Longer exposures with digital technology soon get 'noisy' or very expensive.
However the earth spins on its axis once every 23 hrs 56 mins 4 secs. This is the sidereal day, the time taken for any particular part of the heavens to pass from one culmination, its highest point in the sky, to the next. This rotation means that exposures of longer than 30 secs may show star trails if the camera is fixed. This is more obvious if one is taking photographs of stars close to the celestial equator. The rotation is approximately 15 degrees in one hour. Stars closer to the equator necessarily move further in that time than stars closer to the celestial pole. These problems can be addressed by putting the camera on an expensive german equatorial mount or more cheaply by using some form of 'barn door drive'.
Our solution is to build a camera mount that allows long time exposure Astrophotography without star trailing. One of the designs of Scotch mount, also known as barn door drive (after its appearance) or Haig mount (after its inventor) will meet our need. One should be able to take exposures up to 30 minutes with a standard 50mm lens or use a telephoto lens for exposures up to 15 minutes. One also needs an precision motor drive to maximise tracking accuracy.

The Scotch Mount.
The simplest design of mount is two pieces of wood, hinged at one end driven apart at a fixed rate by a screw thread, manually driven. (Figure 1) This is the tangent drive and will only remain accurate for 10 minutes or so. (Figure 4) Building the mount as an isosceles configuration can bring an improvement, but again tracking accuracy falls off after 20 minutes or so. (Figure 2 & 4) Adopting a double arm configuration can bring a further improvement. Dave Trott described these designs. (Trott 1988) It is the Type 4 configuration is what I adopted with some simple modifications. (Figure 3) Tracking accuracy if well built will continue well beyond problems arising from factors such as light pollution . (Figure 4)

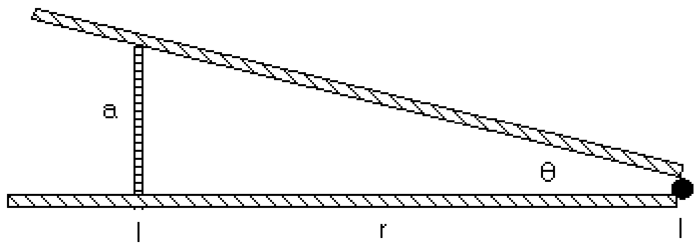


Figure 1. Tangent Drive (Drover 1994)

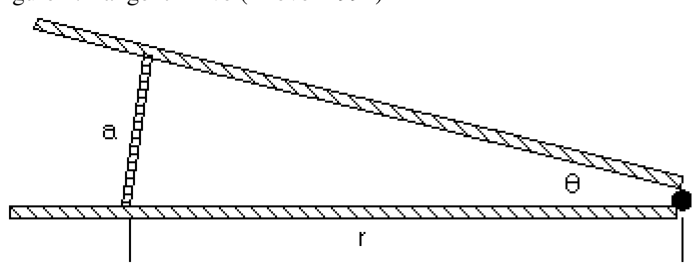
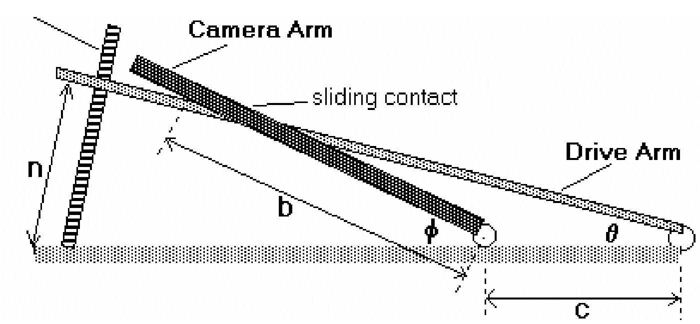


Figure 2. Isosceles Drive (Drover 1994)



r = distance from drive bolt to drive arm hinge
Figure 3. Double Arm Drive In Trott's 'Type 4' configuration. (Trott 1988)

Design and Construction : This mount was made in three parts:

The double arm mount

Chose a 6mm thread for the drive screw as the thread pitch is 1mm. The motor chosen was a 1.8^0 angle stepper motor driven at 4Hz. Therefore each revolution of the screw moves the boards apart by 1mm every 50 seconds.
From information given by Tonkin the relevant dimensions are
r = 399.5mm b = 254mm c = 116mm
In the original design the material for the boards is MDF, painted to prevent moisture being absorbed, causing warping. Aluminium would be a better material.
A swivelling nut assembly was made by force fitting a 6mm nut into a 12mm nut. The larger nut had rods inserted on two opposite faces to act as swivels when inserted into the drive arm at distance ‘r’ from the hinge. Laminate was glued to the drive arm where the camera arm would bear on it. The camera arm has a piece of Teflon screwed to it where it bears on the drive arm. Finally the camera arm should have a bracket for the camera and a bracket for a finder. The original design uses cheap hinges. However the better the hinges are the more accurate will be the drive.

A frame for the mount

This is a simple box with one side cut at 53 deg, the angle of the local latitude. The frame is placed on a flat and level surface. Adjustment for accurate polar alignment can be made by adding adjustable feet under either end of the frame. The frame holds both the electronics and the power battery.

A quartz controlled motor drive

The motor is attached to the baseboard so that its drive shaft was at the distance ‘r’ from the hinge. The motor I used did not need to be geared, so a simple universal joint could be used. The joint I used (from a model boat) has changeable inserts eg. a 3mm plain insert for the motor shaft and a 6mm insert for the drive screw. The circuit for the electronic drive was originally published by Ray Grover on the Web.
A 4.194304 MHz crystal is divided to give a 4 Hz output to an integrated circuit driver for the stepper motor (unfortunately, no longer available). Rewinding is effected by connecting to a 64Hz output, which drives the screw in reverse at 16 times the drive rate. A push to off switch is mounted on the baseboard to stop the reverse when the boards come together. The electronics are mounted on stripboard and housed in a plastic project box. A red LED is used to show when the circuit is live, especially useful in the dark. There is an on-off switch and a reversing switch mounted on the outside of the box. The whole is powered by a 12 volt battery.

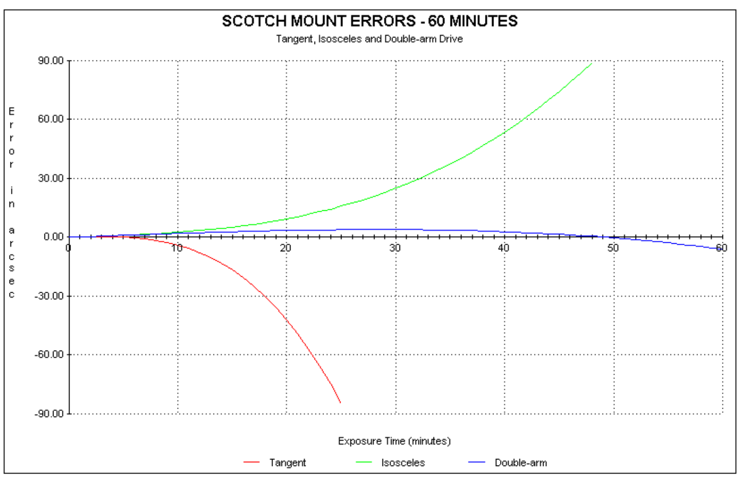


Figure 4. cumulative errors in ‘Scotch’ mounts over time

In use

A camera is attached to the camera bracket with a ball and socket joint. This allows the camera to be pointed at different parts of the sky. In practice I have found it difficult to aim the camera at the zenith. The camera used is a 35mm film SLR, which is totally manual and has a ‘B’ setting. The camera is exposed to quite a bit of damp and it is probably sensible to use something cheaper off the second hand market.
A polar alignment scope is mounted at the distal end of the camera board. This is set up by focusing, in daylight, on a small distant object. When the camera arm is moved the distant object should not be seen to move in the scope. The scope is adjusted as required, it is then parallel to the hinge.

- Move the frame until the hinge of the camera arm and the polar scope are aligned with Polaris
- Move the camera until satisfied the photographic target is in the viewfinder.
- Set the camera focus to infinity
- Open the lens to one or two stops short of its widest aperture
- Set the shutter speed to B
- Use a cable release with lock
- Switch on the motor drive
- Cover the lens with a card (not touching) and release the shutter. This moves the mirror out of the way as well as opening the shutter

- When all vibrations have ceased, remove card and set stopwatch or similar.
- At end of timed exposure, replace card and close shutter
- Reverse motor drive, until stops. Switch off
- Wind on film
- Record details of exposure, film type and speed, target and atmospheric conditions.

Conclusions

Even with MDF boards and crude hinges, this mount enabled me to take long exposure astrophotographs (50mm lens) of up to 30 minutes without star trailing. Better materials and better hinges could allow longer exposures, but more importantly allow the use of longer focal length lenses.

References:

‘Getting started in Astrophotography’. Oates 1995.
‘Amateur Telescope Making’. Tonkin. Springer 1999
‘A quartz controlled scotch mount’. Grover 1994.
http://www.mikeoates.org/mas/projects/scotch/

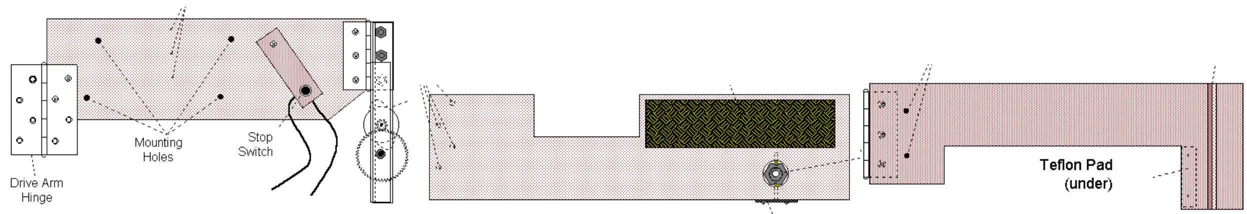


Figure 5. The 3 boards required, shown with a geared drive. For better images contact editor or http://www.astunit.com/tonkinsastro/atm/projects/scotch.htm