AstroMAKEr: Frankenscope LIVES!
By Gord Tulloch, RASC Winnipeg Centre

Introduction

Through happy circumstances, I was recently reunited with a CG5 mount I used to own, which includes a pier mount for my observatory and a stock Celestron NexStar GOTO system and controller. Alas, the NexStar system has started to act up and occasionally with embark on runaway slews, which are not really conducive to a quiet evening of observing. So, it seems a good opportunity to test out a DIY computer control system. So, I stripped off the NexStar gear and put it up on AstroMart for parts – someone was willing to play $150 to fix his own CG5 so I was funded for my little project!

Figure 1 – The Frankenscope

In the meantime I added a C8 OTA and a bunch of electronics including an Orion Accufocus focuser motor and Shoestring USB controller, a Canon Rebel XTi DSLR as a main imager again with a Shoestring DSUSB controller, an Orion Off-Axis Guider with an Orion Starshoot guide camera. All controlled via a tiny Raspberry Pi running the StellarMate LINUX operating system from INDI, a LINUX distribution specifically aimed at astronomy users. With all that stuff hanging off the scope, a second hand CG5 with a second hand C8 OTA on it, with a repurposed Home Depot surveyors tripod to boot, the name Frankenscope came pretty easily for this scope!

After poking around the Internet a bit, I observed there's a couple of popular options for motor controller hardware: the AstroEQ (www.astroeq.co.uk) version of the EQMOD electronics, or the OnStep (https://groups.io/g/onstep/wiki) LX200 compatible electronics. OnStep is the brainchild of Howard Dutton (http://www.stellarjourney.com) and seems to have gained quite a following. Obviously LX200 mounts are pretty standard so not a bad choice either. The OnStep software was quite a bit more capable so I decided to go with that, on a pre-built board so I didn't need to do any soldering. I actually got a couple of AstroEQ boards as well to build for other projects – more on this in another article.

This article looks at the options and how my build went. It also looks at how the CG5 revamp ended up working.

OnStep Electronics

The electronics for OnStep are pretty flexible – basically you can build a basic platform to run the software on solderless breadboards, assemble the circuit on printed circuit boards, or use a pre-assembled electronics platform and just add motors. It is Arduino based which is extremely heavily used for DIY electronics projects.

I decided to get a pre-assembled electronics platform instead of soldering something so I could make sure I had something workable by spring time. The easiest option seemed to be the MakeSpace MKS Gen-L v1.0 board. You can get these on Amazon, eBay etc. as they are commonly used as the brains behind DIY 3D printing platforms – cost is about $25 so pretty inexpensive. The beauty of these boards is there's pretty much zero soldering to be done, just plug and play. The downside is the performance of the processor in the board is a lot less than possible if you use a higher end processor but you need to build it yourself. The good news is it supports up to 24v motors so you can run some sizable motors on it. The Gen-L should work well with the CG5 using 12v motors however.
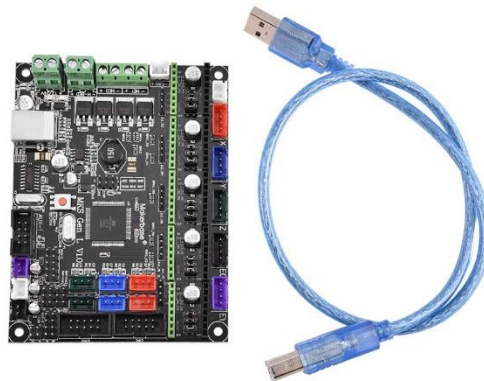

Figure 2 – MKS Gen L V1.0 Board

The board comes as pictured – an unmounted electronics board and a USB cable. To get it fired up, you need to mount it into a case (I used a cheap wooden box from the Dollar Store to prototype things until I knew what the final result would look like, then created a nice case with an aluminum project case for $25) add power and motor drivers, and connect the motors. The DRV8825 drivers actually plug directly into the board so hookup is essentially plug and play.

OnStep Software

The OnStep software emulators an LX200 mount with a lot of support for other devices such as fans, focus motors, dew heaters, etc. Since the Gen-L board has a lot of ports on it, those things are available to me but for the first go around, I just wanted to get the RA and Dec motors running. Installing the software on the Gen-L board involves:

- Downloading the Arduino development environment (https://www.arduino.cc/en/Main/Software)
- Download the OnStep Firmware (on the Wiki above)
- Edit a configuration file to specify the physical characteristics of your mount and motors
- Plug the board into the USB cable provided and into a Windows PC running the Arduino development environment
- Upload the software

Once the software is up and running it now looks like you have an LX200 connected via the USB port of your computer. I tested the software running Starry Nights Pro 8 on my skinny little Surface tablet to ensure it was working properly, then connected the USB to the Raspberry Pi on the mount which will talk to the telescope while I operate it from remote via TeamViewer. Once again an article unto itself!

CG5 Physical Mounting

The physical mounting of the motors (NEMA 17 describes the size of the mounting for the motor) requires some brackets be fabricated. This can be done in two ways – if you happen to have access to a 3D printer you can download a 3d model of the brackets (https://www.thingiverse.com/thing:1833860) and print them out (figure 6). I decided to go this route and although I don't have a 3D printer, I had the parts printed by 3dhubs.com. This site has a network of folks who will print out and ship items to you at a fairly low cost, in this case $25 + shipping. To use this service just upload the 3D models from thingiverse.com and select a material – I chose ABS as it's more resilient than other materials. Lego blocks are ABS and are indestructible!
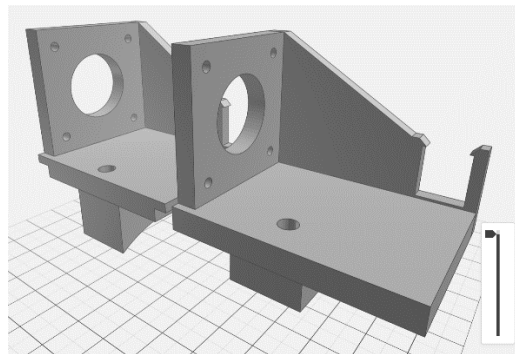

Figure 3 – RA and DEC brackets 3D model

Take a moment to reflect on the fact we can actually download and print out parts for our projects… we live in the freaking future!

Although I opted for 3D printing, fabricating mounts would not be a big chore - a pair of NEMA 17 steel brackets from Amazon.ca go for $10 ea free shipping. They are actually cheaper on eBay, but they come from China so expect a 3 month wait! These brackets can be adapted to the CG5 by mounting a 4mm

thick 45 by 45mm aluminum block for RA and a 10mm thick 45 by 20mm block for Dec to the slotted leg of the brackets. They have the advantage of the rigidity of welded steel and lateral adjust-ability to accommodate your drive train's setup.

Now the drive train can be made up of pretty much any gear sets, but I prefer a belt and pulley system to avoid backlash in the gearing. Over to eBay for a set of pulleys and 6mm belts – the large pulley 80 tooth pulley attaches to the worm for the interior spur gear (1:144 ratio) and the small 20 tooth pulley is mounted on the 5mm motor shaft. I also got a 180mm belt after a few unsuccessful attempts to join the included belt to the right size – not real easy so easier to buy one!

Figure 4 – Belt and pulleys

The gear ratio is thus increased by 4 (80/20 for the pulleys) resulting in a gear ratio of 1:576. That means the motor has to turn 576 times for one revolution of RA or DEC axis. Since the DRV8825 motor drivers allow 1/32 micro-stepping (microstepping makes each increment of the motor 1/12800th of a revolution instead of a full step of 1/400th which improves the smoothness of the motion.) So the maximum slew rate of the completed mount is about 1°/s which is fast enough, and tracking resolution in arc-secs is 0.176 which results in smooth tracking for astrophotography. As you can see from Figure 8 the 80 tooth pulley was very close to too large for the mount, to the degree that on the Dec axis the 2 pulleys actually touch! But I like the higher gear reduction, so I made it work.

Figure 5 – Final RA / DEC gear configuration

The OnStep was connected to the motors via 6 conductor RJ12 (like an RJ11 phone cable except with 6 instead of 4 conductors) cables to cable to the motors. They're cheap, and can be cut to length and re-terminated with a cheap RJ11/RJ12 crimping tool. A 12V 5A power supply was procured from (you guessed it!) eBay for $25 which has plenty of current for the system. The OnStep also allows control of other motors such as focusers, so I'm in the process of moving from the Orion AccuFocus to a dedicated 1.8deg/step motor for focusing so I can reuse that system elsewhere.

I'm still getting my observatory ready for the summer now that the snow is gone (and it's not sitting in a foot of water!) but preliminary testing is positive for a smooth and reliable automated mount that I can run autonomously once I roll the roof back on the shed. Once I get the bugs out time to do some photometry and exoplanet transit observations!

Any questions feel free to send them to gord.tulloch@gmail.com.