CONCEPTION

Jean Vallières

DESCRIPTION

The Skypikit Motor Tester Tuner app allows you to experiment, test, adjust settings and analyze the control behavior of a motor to be installed on a telescope mount.

It can be used to pre-test the motor on a prototype assembly even before installing it on the mount.

It can also be used to test motors already installed on the mount. In this case, the application only tests one motor at a time, but can test all motors by selecting the I2C address of the one to be tested.

The application must be used with a control system already mounted and functional, including an ARDUINO with its control sketch already installed and, for each motor, a SKYPIKIT with all the circuits necessary to control it.

However, for calculations of motor choices and gear reductions, it is not necessary to connect the program to a control system.

This application runs on PC and connects to the ARDUINO by its USB port. The Arduino sketch code is available on this site and must be loaded into the ARDUINO for this application to control the motors.

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Download the MotorTesterTuner_311_setup.exe installer from the link on the web page:
www.ngc7000.com/motorisation-telescope.htm

Start this installer and follow the instructions.

The installer installs the application by default in the C:\NGC7000\MotorTesterTuner folder, and also install an icon on the desktop to start it.
For the **SKYPIKIT MOTOR TESTER TUNER** program to be able to communicate and function correctly with circuits including the ARDUINO and SKYPIKIT boards, it is absolutely necessary to install and download either the sketch **SKYPIKIT MINIMAL** or the sketch of the telescope model to be tested in the **ARDUINO**.

Download the necessary sketch, the link of which is on the Web page of the project site.

Install the ARDUINO IDE if it is not done and use it to install the driver that allows your PC to communicate with the Arduino Uno.

Then use the ARDUINO IDE to compile and upload the sketch to the Arduino.
Skypikit Motor Tester Tuner Application

START UP

Install your entire functional circuit, including the ARDUINO, the SKYPIKIT board and the power driver connected to the motor.

Power your circuit with a 12 volt DC source, then make the USB connection between your computer and the USB connector of the ARDUINO.

In the CONNECTION section, choose the USB port (Port Name) that is connected to the ARDUINO (COM1 .. COM15).

Select Baud Rate = 57600 bps. These are the values required for connection to the ARDUINO.

The other default communication parameters are: Parity = none and Stop Bits = 1, and do not need to be entered.

Click the CONNECT button.

If there is no error message, in the Mini Console, go to the CONTROLLER SETTINGS section, select the I2C address and the reference system (fixed or sidereal). The I2C address must match the selected one on the board that contains the SKYPIKIT.

Also select the request frequency, that is the number of times per second that this application SKYPIKIT MOTOR TESTER TUNER asks the SKYPIKIT to return to him his state (see the Controller Status section of this document).

Start with a frequency of 6 requests per second. You can later increase it to the maximum frequency that your set supports. If, for example, everything still works at 15 req./sec, decrease by one notch (12 req./sec) for security.

Finally click on the ACTIVATE button to start the operation and to be able to adjust the control parameters in the SETTINGS tab.

Make the necessary corrections if there is an error message in the Mini Console.

NOTE: If the motor goes in runaway or starts to vibrate, immediately click the RELEASE button and change the necessary parameters. You can also try to swap the two wires connected to the motor rotor if the motor goes in runaway.
DISCONNECTION STEPS

Always do the following steps before leaving the application:

First click on the RELEASE button, which stops and releases the motor.

Then click the DISCONNECT button.

Finally click the EXIT and SAVE button to save your settings and exit the program.

So, the next time you start the app, your adjustments and settings will have been preserved.
CONTROLLER STATUS Section

The CONTROLLER STATUS panel displays the status results that the SKYPIKIT returns to the application as a result of the requests requested with the & Q0 statement, at the frequency you specified in the CONTROLLER SETTINGS section.

**Motor Type:**
The type of motor, DC with encoder or stepper, as coded on pin 12 of the SKYPIKIT.

**I2C address:**
The I2C address of the controller as encoded on pins 2 to 5 of the SKYPIKIT and indicated in the Controller Settings panel.

**Reference system:**
The reference system programmed in the SKYPIKIT when you clicked the ACTIVATE button.

Status:
What the controller and the motor are currently doing:
- STOPPED and LOCKED
- STOPPED and FREE
- RELEASED and FREE
- MOVING
- TRACKING
- LIMIT SW +
- LIMIT SW -
- SENSOR OVER TRESHOLD
- ERROR HALT

For a description of these actions, see the section describing the format of the string returned by the SKYPIKIT in the SKYPIKIT Technical Manual.

**Internal State**
Internal step of SKYPIKIT controller. Used for development and debugging.

**Sidereal clock timestep**
Value of the current sidereal time indicated in encoder step or micro-step. The conversion in seconds depends on the value of the sidereal speed (in steps/second) that you specified in the SETTINGS tab.

**Motor position**
Motor position measured in encoder step for a DC motor or in micro-step for a stepper motor.

---

CONTROLLER STATUS

Motor Type: STEPPER
I2C address: A = 65
Reference system: SIDEREAL
Status: TRACKING
Internal State: (3) ..........

Sidereal clock timestep = 5764
Motor position = -16063
Sidereal position = 21827
Sensor value = 0 Index = 0
CONTROLLER STATUS Section (continuation)

**Sidereal position**
Motor position in steps or micro-steps in the sidereal reference system.

or

**Difference**
Difference between sidereal time and motor position in the fixed reference system.

**Sensor value**
Decimal value corresponding to the voltage on the SENSOR pin (pin 7) of SKYPIKIT. The value 0 corresponds to 0 volts and the value 1023 corresponds to the maximum voltage of 3.3 volts which must not be exceeded.

**Index**
Numeric value of the INDEX signal that can be sent by a position encoder. A value of 0 corresponds to 0 volts on the INDEX pin (pin 6) of SKYPIKIT. A value of 1 corresponds to 3.3 volts (voltage that must not be exceeded).

If your encoder outputs a 5-volt Index signal, you must use a voltage divider to reduce it to 3.3 volts.

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**CONTROLLER STATUS**

Motor Type: STEPPER
I2C address: A = 65
Reference system: SIDEREAL
Status: TRACKING
Internal State: (3) ...........

Sidereal clock timestep = 5764
Motor position = -16063
Sidereal position = 21827
Sensor value = 0  Index = 0
OPENING AND SAVING A MODEL

The application folder already contains models including the settings of the instruments described in the "Examples of applications" section of the website. You can open one of these models so that you don't have to enter all the settings by hand. You can then modify the parameters if necessary and save your model under a file name that you choose so that you can find it later.

A model includes all the settings of the different tabs, including those of the calculations.
**SETTINGS TAB**

The SETTINGS tab allows you to adjust the motor control parameters. Click on UPDATE to take the changes into account. For stepper motors, the steps are actually micro-steps.

Click the “Reset Settings to default “ button or load a model the first time you use the app.

**Important convention for the signs of values :**
In a fixed reference system, the positive direction is always towards the north (declination which increases).
In a sidereal reference system, the positive direction is always towards east (increasing right ascension).
This applies to all signed commands (GoTo, Slew, PulseGuide, Final Approach ...) and to the effects of autoguiding signals and limit switches.

**MOTOR PROPERTIES**

**Acceleration**
Indicates the acceleration value in steps / sec² for acceleration-deceleration ramps in GoTos. Absolute value. The time to reach the maximum speed in seconds is equal to (maximum speed / acceleration).

**Final Approach**
Final approach in steps to compensate for backlash. In right ascension, we always try to have a final approach in the same direction as tracking, so a final approach towards the west (negative).

**Sensor Treshold**
Decimal value 0 to 1023. The signal at the SENSOR input is a voltage between 0 and 3.3 volts which gives the digital values 0 and 1023 respectively when converted by an internal 10-bit A / D converter. This signal can for example detect the too high current of a motor.

The motor is stopped if the digital value of the analog SENSOR signal reaches or exceeds the threshold. This value indicates this threshold to the SKYPIKIT. The motor is never stopped by the SENSOR signal if the threshold is at 1023.

**Step Pulse Width**
Duration in microseconds of the STEP pulse that advances the stepper motors by one micro-step. This value must be an integer between 2 and 10. Leave this value at 2 with the A4988 driver and see the documentation of the SKYPIKIT for the effects of this adjustment to other durations.

**TRACKING**

**Sidereal Speed**
Absolute value of the sidereal speed in steps / second, with precision to the thousandth of a step (3 decimal places). This value determines the speed of the SKYPIKIT sidereal time counter.

For the declination controller in a fixed reference system, the sidereal speed entered for the declination motor is the speed calculated in the DC motor calculation or Stepper motor calculation tab, so that the declination controller correctly calculates the autoguiding corrections. The sidereal declination speed may be different from that of right ascension if the motors and gears are different.

For any other controller with a fixed reference system (focus or other), a value must be entered in the Sidereal Speed box for the controller to operate (choose 2% of maximum speed, minimum 40).

**Offset Tracking Speed**
Absolute value of the speed of offset tracking in steps / second, with precision to the thousandth of a step (3 decimal places). This value can be positive or negative, but is normally equal to zero if we want a tracking at the sidereal speed in R.A. It can however be different to zero if we want to track at the lunar or solar speed. It can be modified during the tracking, which can be useful during periodic error corrections or for the tracking at variable speed from an azimuth mount. Also normally set this offset tracking speed to zero for the declination motor.

**Guiding Speed**
Absolute value of the speed of the guiding or autoguiding corrections. This value can be equal to the sidereal speed if you want the autoguiding corrections to be equal to 100% of the sidereal speed. Acts with the Pulse Guide command and with the signals from an autoguiding camera.
SERVO PI CONTROL
These adjustments are not used with stepper motors, only with DC motors with encoders.

The last section of this document explains in detail how to adjust the KP and KI parameters. In the definitions, the error signal is the difference between the desired target position and the current position of the motor returned by the encoder.

**KP**
Proportional gain of the proportional-integral control. Absolute value. The voltage correction sent to the motor is proportional to the error signal.

**KI**
Integral gain of the proportional-integral control. Absolute value. If the motor stops slightly near the target position due to friction, this slight error signal is integrated (1000 times per second) and accumulates over time, and the motor ends up positioning itself exactly on the target so that it no longer accumulates.

**Error Limit**
In order to avoid over-correctsions in the event of large position errors, the error signal is limited to this limit value and cannot exceed it. Absolute value. It is recommended to adjust it to a value equal to approximately 20% of the maximum speed in steps / s.

**Integral Limit**
In order to avoid over-correctsions in the event of large integrations of position errors, the accumulation of the error signal is limited to this limit value and cannot exceed it. Absolute value. It is recommended to adjust it to a value equal to approximately 20% of the maximum speed in steps / s.

**Integral Max Speed**
The error signal is only accumulated if the speed is below this value. Integration is reset if the speed exceeds Integral Max Speed. This is so that the correction related to the integration is done only when the speed is low, when the motor position is close to the target position. It is recommended to adjust it to a value equal to approximately 10% of the maximum speed in steps / s.

**POLARITY BITS**
The polarity bits are adjusted before doing the connection and activation.

**Limit + Switch et Limit – Switch**
Tells the SKYPIKIT whether the limit switches used are normally open or normally closed.

**Invert DIR signal**
Allows you to reverse the DIR signal to the motor power driver if you want to change the direction of rotation of the motor, for example if it does not rotate in the desired direction.

**Always Free Motor at Stop**
Always releases the engine (FREE) each time the engine is stopped. Can be used with a stepper motor to use less current.

**Enable or Brake Voltage**
Indicates whether the ENABLE signal sent to the motor power driver is active at 0 volts or at 5 volts, depending on the driver model.

**Index Edge Detection**
Indicates whether the change of state of the INDEX signal is detected at its falling transition (3.3 volts to 0 volts) or at its rising transition (0 volts to 3.3 volts).

**Reset All On Index Detection**
Indicates if you want to automatically reset the sidereal counter and the motor position when a rising or a falling transition of the INDEX signal is detected.
Skypikit Motor Tester Tuner Application

**SETTIZNGS**  **CONTROL**  **ANALYZE**  **DC motor calculation**  **STEEPER motor calculation**  **FOCUSER motor calculation**

- **STOP motor**
- **FREE motor**
- **RESET POSITION**
- **Reset Index**

**TRACKING**

- **TRACK**
- **UNTRACK**

Sidereal speed = 40
Offset tracking speed = 0

**SLEWING**

- **continuous slew**
- **button pressed**
- **by steps**

- **MOVE** at 3000 steps/s
- 6000 steps

**GO TO**

- **GO TO** 0 steps at 3000 steps/s

**PULSE GUIDING**

- S/W
- N/E
- Pulse Guide 1000 millsec

at the guiding speed of 40
(maximum 10000 ms, must be tracking)

Next pages for description ...
**CONTROL TAB**

The CONTROL tab is used to test several commands to verify the behavior of the motor. For stepper motors, the steps are actually micro-steps.

**Important convention for the signs of values**:  
In a fixed reference system, the positive direction is always towards the north (declination which increases).  
In a sidereal reference system, the positive direction is always towards east (increasing right ascension).  
This applies to all signed commands (GoTo, Slew, PulseGuide, Final Approach ...) and to the effects of autoguiding signals and limit switches.

**RESET POSITION** (sends the command &R)  
Resets the sidereal counter, encoder step counter, and motor position values. Can be used during a SYNC of the telescope on a reference celestial object.

**STOP Motor** (sends the command &S)  
Command the motor to stop using the current acceleration-deceleration ramp.

**FREE Motor** (sends the command &F)  
Command the motor to stop using the current acceleration-deceleration ramp and then release the voltage to the motor (free).

**Reset Index** (sends the command &J)  
Sets the detection of an INDEX signal transition to "false" so that a next transition can be detected. An INDEX signal transition can be used to start a periodic error correction (PEC) sequence.

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**TRACKING**

**TRACK** (sends the command &tss then &T)  
Tells the SKYPIKIT to start tracking (tracking = ON) at the tracking speed indicated in the SETTINGS tab.

**UNTRACK** (sends the command &N)  
Tells the SKYPIKIT to stop tracking (tracking = OFF).

**SLEWING**

The **MOVE** button acts in different ways depending on the choices made with the radio buttons:

**Continuous slew** (sends the command &Mss)  
Command the motor to move at the top speed indicated in (steps / sec) using the current acceleration ramp chosen in the SETTINGS tab. The movement is stopped by clicking on the **STOP Motor** button or on the **Free Motor** button.

**Button pressed** (sends the command &Mss then &S)  
Command the motor to move at the top speed indicated in (steps / sec) using the current acceleration ramp as long as the **MOVE** button is pressed. Command to stop the motor by decelerating when the **MOVE** button is released.

**By steps** (sends the command &Dss)  
Command the motor to move the indicated number of steps at the current GoTo speed and using the current acceleration-deceleration ramp.

**Update Speed** (sends the command &wss)  
Tells the SKYPIKIT that the current "slew" speed is equal to the indicated value (steps / sec). Allows you to modify the speed even if a movement is in progress.
CONTROL TAB (continuation)

GO TO

**GO TO (sends the command &snn then &Gss)**

Command the motor to go to the position indicated in steps, using the indicated GoTo speed (steps / sec) and the current acceleration-deceleration ramp chosen in the SETTINGS tab. The target position can be positive or negative but the speed of GoTo is an absolute value.

The GoTo can end with a final approach if indicated in the SETTINGS tab.

PULSE GUIDING

Command the motor to move at the guiding speed chosen in the SETTING tab (0% to 1000% of the sidereal speed) for the number of milliseconds indicated. The motor must be tracking for the command to work.

**S/W (sends the command &Pss where ss is negative)**

Displacement in the direction which decreases the coordinate, towards the South in declination in the fixed reference system, or towards the West in right ascension in the sidereal reference system (the right ascension of the targeted object decreases when the telescope moves west).

**N/E (sends the command &Pss where ss is positive)**

Displacement in the direction which increases the coordinate, towards the North in declination in the fixed reference system, or towards the East in right ascension in the sidereal reference system.
**ANALYZE TAB**

**STEP TEST**

In this test, the motor is commanded to move the number of steps indicated at the indicated speed. For example, move 60000 steps at the speed of 10000 steps/second, as shown here.

The red curve shows the position and the green curve shows the speed. The target position of 60000 steps is reached after approximately 7.5 seconds.

The graph also shows the acceleration and deceleration slopes. As can be seen in the graph, it takes 1 second to go from zero speed to the maximum speed of 10000 steps/second with a chosen acceleration of 10000 steps/s².

In this test and the others, it is necessary to choose the highest frequency of requests that the system can reliably support to have a better resolution over time, for example 12 requests/second in the case shown here.
In this test, the motor is commanded to reach the target position (target) of 40000 steps from the zero position (start).

As we chose the sidereal reference system, we reach exactly the target position, for example a star, even if this target star moved during the GoTo movement of the telescope.

Indeed, due to the diurnal rotation of the Earth, the star moves in the sky while the telescope makes its GoTo. The target's inclined curve represents this movement.

When the telescope has reached the target at the end of GoTo, it continues to follow it at the tracking speed of 200 steps / s.

Here, we wanted to reach a target by moving towards the East with a positive value of the displacement (+40000 steps) in the sidereal reference system.

We finished with a negative final approach to the west (-5000 steps) in the same direction as the tracking to correct the backlash in the gears.
In this test, the motor is commanded to move for 3 seconds at a speed equal to 2.5 times the sidereal speed, then to continue its tracking movement at sidereal speed.

The application then uses the data collected for 10 seconds from the 5th second to make calculations related to the tracking accuracy caused by the motor control only.

Choose the highest frequency of requests that the system can reliably support in order to have more points for the calculations.

The blue curve shows the position error during tracking. The mean offset position of 0.435″ is not critical since it is the variations (deviations) from this average that affect the quality of the tracking.

The percentage of light inside a spot of given radius is for a theoretical point star and does not take into account diffraction, turbulence and other effects.

In this graph, the vertical scale is magnified to show even the smallest tracking errors.
Skypikit Motor Tester Tuner Application

DC Motor Calculation Tab

Next page for description ...
DC Motor Calculation Tab

CALCULATION OF SPEEDS FOR MOTORIZATION OF DC SERVO MOTOR

Example taken from the motors of the Losmandy G11 mount

The data are as follows:

The main gear on each axis has 360 teeth.

Each turn of the worm advances one tooth.

The motor reduction box reduces the speed by 30 X (precise value supplied by the manufacturer of the motor).

The reduction of the other gears of the system is 5 X since we have chosen a pinion of 16 teeth on the axis of the reduction box of the motor and a gear of 80 teeth on the axis of the worm (80 / 16 = 5.0).

The number of steps per revolution of the motor rotor is 64 (quadrature encoder with 64 steps / revolution).

At 12 volts, the nominal speed of the DC motor chosen from its reduction gearbox is 350 RPM (350 revolutions per minute).

The results obtained are as follows:

With a nominal voltage of 12 volts, the rotor of the chosen DC motor rotates at a speed of 10500 RPM, or 175 revolutions per second.

With this voltage of 12 volts and this speed of 175 revolutions per second, the quadrature encoder emits a signal at a speed of 11200 steps per second.

The sidereal tracking speed corresponds to 40.1095 encoder steps per second.

One encoder step corresponds to a resolution of 0.374 arcsec.

The maximum suggested speed of movement (SLEW or GOTO) of 8960 steps of encoder per second corresponds to a speed of 0.933 degrees per second for the telescope.

For a moving speed of 1 degree per second, the motor would have to run at 9600 steps of encoder per second, which it is able to do.

We finally choose a maximum movement speed (SLEW or GOTO) of 0.8 degrees per second. This choice also reduces engine noise and can reduce wear.
### Skypikit Motor Tester Tuner Application

#### Stepper Motor Calculation Tab

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>number of teeth of the main worm gear</td>
</tr>
<tr>
<td>1</td>
<td>main worm gear teeth advance / revolution of the main worm</td>
</tr>
<tr>
<td>31.36</td>
<td>reduction of the motor reductor</td>
</tr>
<tr>
<td>1</td>
<td>reduction of the other gears in the system</td>
</tr>
<tr>
<td>200</td>
<td>nominal number of full steps / revolution or the motor rotor</td>
</tr>
<tr>
<td>16</td>
<td>number of microsteps / full steps</td>
</tr>
<tr>
<td>14000</td>
<td>reliable tested maximum speed in microsteps / sec.</td>
</tr>
</tbody>
</table>

#### Results

This motor outputs 3200 microsteps / revolution of the motor rotor.

Calculated sidereal tracking speed with given data = 139,7594 microsteps/sec.

One microstep count = 0.107 arcsec

Realistic motor resolution = 0.429 arcsec

Maximum slew or goto speed = 14000 microsteps/sec or 0.4185 degree/sec

Slew speed for 1 degree/sec = 33450.6667 microsteps/sec

Next page for description ...
Stepper Motor Calculation Tab

CALCULATION OF SPEEDS FOR MOTORIZATION WITH STEPPER MOTOR

Example taken from the original right ascension motor of the EQ3 mount

The data are as follows:

The main gear on the right ascent axis has 120 teeth.

Each turn of the worm advances one tooth.

The motor reduction box reduces the speed by 31.36 X (calculated by trial and error by carrying out tests).

The reduction of the other gears of the system is 1 X since the output of the reduction box of the motor is directly coupled to the axis of the worm.

The number of steps per revolution of the motor rotor is 200 (calculated by trial and error by carrying out tests).

We choose 16 micro-steps per step to control this stepper motor, which will give 16 X 200 = 3200 micro-steps per revolution of the motor rotor.

By tests, we find that this stepper motor can turn reliably up to the speed of 14,000 micro-steps per second before going wrong (with the circuits used).

The results obtained are as follows:

The results are calculated by the application when the CALCULATE button is clicked.

3200 micro-steps are required for one revolution of the motor rotor.

The sidereal tracking speed corresponds to 139.7594 micro-steps per second.

A micro-step corresponds to 0.107 arcsec, but the realistic resolution is rather 0.429 arcsec.

The maximum reliable speed of movement (SLEW or GOTO) of 14,000 micro-steps per second corresponds to a speed of 0.4185 degrees per second for the telescope.

For a movement speed of 1 degree per second, the motor would have to accept 33450.6667 micro-steps per second, which is far above its capacity.

We finally choose a maximum movement speed (SLEW or GOTO) of 0.400 degrees per second, just a little below the reliable maximum (0.4185).
Focuser Calculation Tab

### Skypikit Motor Tester Tuner Application

#### SETTINGS | CONTROL | ANALYZE | DC motor calculation | STEPPER motor calculation | FOCUSER calculation

| 6.78 | number of turns of the slow motion focuser button to move the focus 10 mm |
| 46.851 | reduction of the motor reductor |
| 1.889 | reduction of the other gears or pulleys in the system |
| 48 | q.e. encoder counts/revolution or microsteps counts/revolution of the motor rotor |

#### RESULTS

Number of counts to move the focuser 1 mm = 2880.1941 q.e. counts or microsteps

Next page for description ...
**Skypikit Motor Tester Tuner Application**

**Focuser Calculation Tab**

**CALCULATIONS OF THE NUMBER OF STEPS TO MOVE THE FOCUS 1 mm**

*Example taken from the control of the original focuser of the Mak-Newton telescope installed on the G11 mount.*

**The data are as follows:**

It takes 6.78 turns of the focuser's slow motion button to advance or retract the focus by 10 millimeters. This value is found per test by counting the number of turns necessary to move the focuser by 10 mm.

Note: The situation is different for a Schmidt-Cassegrain telescope of the C14 type in which the primary mirror moves. In this case, it is rather necessary to measure the number of turns of the focus adjustment button (in fact, fraction of a turn) so that the focus moves 10 mm.

The motor reduction box reduces the speed by 46.851 X (precise value supplied by the manufacturer of the motor).

The reduction of the other gears or pulleys of the system is 1, 889 X since we chose a pulley of 18 teeth on the axis of the reduction box of the motor connected by belt to a pulley of 34 teeth which replaces the slow motion button of the focuser (34/18 = 1.889).

The number of steps per revolution of the motor rotor is 48 (quadrature encoder at 48 steps / revolution).

Note: For a stepper motor, the value to be entered must be the total number of micro-steps per revolution of the rotor. For example, if you order a motor at 200 steps per revolution with 16 micro-steps / steps, the value to enter is 3200, that is (16 X 200).

**The results obtained are as follows:**

The results are calculated by the application when the CALCULATE button is clicked.

We find that it takes 2880.1941 encoder microsteps to move the focuser 1 millimeter.
ADJUSTING THE DURATION OF THE STEP PULSE (stepper motors)

Each time the SKYPiKIT sends a STEP pulse (pin 24) to the motor power driver, the stepper motor advances by one micro-step.

However, at high speed, the maximum speed obtained is always lower than the maximum speed requested with the &s command.

The following table gives the actual maximum speeds obtained with pulse durations of 2µs, 6µs and 10µs for several requested maximum speeds. All speeds are in micro-steps / second.

For example, if you send the &s40000 command to the SKYPiKIT to indicate a maximum speed of 40,000 micro-steps / sec during GOTO, the motor will actually run at a maximum speed of 35,000 micro-steps / second with a pulse duration of 2µs.

<table>
<thead>
<tr>
<th>Required speed</th>
<th>Pulse of 2µs</th>
<th>Pulse of 6µs</th>
<th>Pulse of 10µs</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000</td>
<td>5000</td>
<td>4900</td>
<td>4550</td>
</tr>
<tr>
<td>10000</td>
<td>10000</td>
<td>9600</td>
<td>8700</td>
</tr>
<tr>
<td>20000</td>
<td>19300</td>
<td>18200</td>
<td>17000</td>
</tr>
<tr>
<td>40000</td>
<td>35000</td>
<td>30500</td>
<td>27000</td>
</tr>
<tr>
<td>60000</td>
<td>44000</td>
<td>38000</td>
<td>32000</td>
</tr>
<tr>
<td>80000</td>
<td>51000</td>
<td>41000</td>
<td>35000</td>
</tr>
<tr>
<td>100000</td>
<td>55000</td>
<td>42000</td>
<td>36000</td>
</tr>
<tr>
<td>200000</td>
<td>62000</td>
<td>47000</td>
<td>36000</td>
</tr>
</tbody>
</table>

The cause of this slowdown is that between each STEP pulse, the SKYPiKIT firmware must have time to perform other higher priority tasks, and that the duration of this STEP pulse itself must be added to the task time in firmware.

This is why the slowing down is more pronounced with longer STEP pulse durations.

Does this slowdown decrease the performance and accuracy of a Slew or a GOTO?

NO. The motor will run slower than requested, but it will reach the target position with the precision indicated in the specifications. It will just take a little longer to get to the target.

We recommend using the shortest possible pulse duration, 2µs for drivers of small stepper motors like the A4988.

However, it may be necessary to increase the pulse duration and reduce the pull-up resistance of the STEP signal at pin 24 so that the STEP signal can vary correctly between its state 0 (<1 volt) and its state 1 (> 4 volts) with certain power drivers which have lower input impedances.

The best way to do this is to make tests to find the minimum pulse duration necessary for the control to work well, using this application.

Note: the SKYPiKIT accepts STEP pulse durations between 2µs and 10µs. If you request a 15µs pulse (with the & u15 command), the SKYPiKIT will limit it to 10µs.

Note: The pull-up resistance of the STEP signal can have a value between 1K and 7K.
OTHER TESTS

You can do other tests using this app. When you are asked to put pins to GND (0 volts), do not do it directly on the pins of the SKYPIKIT chip but rather on the connectors of the board where the names of the signals are indicated.

Limit Switches
You can simulate and test the operation of the limit switches by temporarily and manually setting the LIMIT- (pin 17) and LIMIT + (pin 16) pins to GND.

For this to work, you must choose Normally Open for the state of the limit switches. You can also run the motor continuously by choosing Continuous Slew mode and a speed not too high in the Control tab.

One of the limit switches is used to stop the motor when it rotates clockwise and the other stops it when it rotates counterclockwise. You must find which ones correspond to each direction of rotation by doing tests.

The motor should stop when you put to GND the limit switch pin that corresponds to the correct direction of motor rotation.

Then check that you can restart the engine in reverse without deactivating the limit switch.

Autoguiding
You can simulate signals from an autoguiding camera by temporarily and manually pinning the GUIDE- (pin 18) and GUIDE + (pin 11) pins to GND.

For this to work, tracking must be active, whether in the sidereal or fixed reference system. Leave the offset tracking at zero.

In the Settings tab, set a guiding speed equal to 100% of the sidereal speed. Then try with a guide speed equal to 50% of the sidereal speed.

To simulate the RA- or DE- signal from the autoguiding camera, manually set the GUIDE- or Gu- signal to GND. You will see the effect on the engine tracking speed.

To simulate the RA + or DE + signal from the autoguiding camera, manually set the GUIDE + or Gu + signal to GND.

INDEX
To simulate the operation of the INDEX signal (pin 6), you can mount the following circuit on a test board.

When the SW1 switch is open, the INDEX signal is at 3.3 volts (state 1).
When the switch SW1 is closed, the INDEX signal is at 0 volts (state 0).

Continuation ...
OTHER TESTS (continuation)

Before doing each INDEX test, always reset the state of the INDEX signal to 0 by clicking on the Reset Index button in the Control tab.

Start with the Index Edge Detection polarity bit set to Rising Edge (change from 0 volts to 3.3 volts detected). Change the voltage of the INDEX pin from 0 to 3.3 volts by opening the switch SW1. You should notice that the INDEX state changes to 1 in the CONTROLLER STATUS section.

Perform a Reset Index then start again with the Index Edge Detection polarity bit set to Falling Edge (change from 3.3 volts to 0 volts detected). Change the voltage of the INDEX pin from 3.3 to 0 volts by closing the switch SW1. You should notice that the INDEX state changes to 1 in the CONTROLLER STATUS section.

Finally, you can repeat the test by setting the Reset All on Index Detection polarity bit to YES, and verify that the INDEX detections set the controller counters to zero (sidereal time, quadrature encoder, motor position).

SENSOR

The SKYPIKIT measures a voltage from 0 to 3.3 volts on its SENSOR pin (pin 7) and transforms the value of this voltage into a numerical value from 0 to 1023 (3.3 volts = 1023) indicated in the CONTROLLER STATUS section.

You can test the operation of this signal by setting the SENSOR pin to 0 volts then to 3.3 volts and checking the numerical value obtained in the CONTROLLER STATUS section.

The motor is stopped if the digital value of the voltage at the SENSOR pin exceeds the Sensor Treshold value entered in the tab Settings. The motor never stops if Sensor Treshold is at 1023.

Test to see that the motor stops when the voltage at the SENSOR pin gives a numerical value that exceeds the value of Sensor Treshold. A simple way is to set the Sensor Treshold value to an intermediate value (e.g. 500), then put 3.3 volts (1023) on the SENSOR pin.

CAUTION DANGER

Voltages on the following pins should never exceed 3.3 volts, otherwise your SKYPIKIT will burn:

- SENSOR
- INDEX
- LIMIT-
- LIMIT +

The following circuit reduces the voltage on the INDEX pin to 3.3 volts if you have a quadrature encoder that provides an INDEX signal at 5 volts.

This circuit can also be used in other circumstances.
ADJUSTING PID PARAMETERS
These adjustments are not used with stepper motors, only with DC motors with encoders.

Powering a DC motor is very simple and is done by only two pins, M1 and M2 on the image. The motor speed is roughly proportional to the voltage between these two pins. Also, if you reverse the voltage, the motor turns the other way.

The SKYPIKIT must send the right signals (IN1, IN2 and PWM) to the power driver so that it sends the voltage to the motor which makes it rotate at the desired speed.

To be able to do this, the SKYPIKIT must be able to know the speed and position of the motor in return at any time. An encoder connected directly to the motor rotor shaft returns the position of the motor through the QEA and QEB pins.

This type of control is therefore a closed loop control, using as feedback the position of the motor given by the encoder to continuously readjust the signals which will give the correct voltage to the motor to make it run at the desired speed and bring it to the desired position.

For example, if the encoder indicates that the motor is behind the desired instantaneous position, the circuit will increase the voltage to make the motor run faster and catch up the lag. In the definitions, the error signal is the difference between the desired target position and the current position of the motor returned by the encoder.

The proportional gain KP
Proportional gain from proportional-integral control. Absolute value. The voltage correction sent to the motor is proportional to the error signal.

If the KP gain is too low, the correction will be too slow and the motor will never be exactly in the right instantaneous position, especially if there is friction. If the KP gain is too high, there will be over-correction and the motor will vibrate and oscillate. It is therefore necessary to choose a value of KP which will make the correction very quickly but without over-correction.

The integral gain KI
Integral gain from proportional-integral control. Absolute value. If the engine stops slightly near the target position due to friction, this slight error signal is integrated (1000 times per second) and accumulates over time, and becomes strong enough for a correction. Finally, this places the motor exactly on the target so that the error signal no longer accumulates.

As for the gain KP, it is necessary to choose a value of the gain KI which will have a sufficient effect to fight friction, but without being too strong to the point of making over-corrections and making the motor vibrate and oscillate.
ADJUSTING PID PARAMETERS (continuation)

The derivative gain KD
This type of gain is not used with the SKYPIKIT. In some systems, it has the effect of damping the oscillations caused by over-corrections. With the SKYPIKIT, we have instead chosen to allow the user to use acceleration and deceleration ramps so that the instantaneous position requested does not make a sudden jump of great value, for example from 0 steps/s to 60,000 steps/s.

PROCEDURE FOR FINDING PARAMETERS

Here is a procedure that should allow you to find the values of the different parameters to obtain optimal control. The tests will first be done with a STEP TEST in the ANALYZE tab.

In this tab, first enter the maximum speed (steps/sec) that you will eventually use for GoTo and fast movements (for example 10000). This example value of 10000 in parentheses is probably not the value you are using. This is only an example for calculating other examples based on this value.

Then choose a displacement equivalent to a duration of 5 seconds, by entering a displacement value (steps) equal to 5 times the speed (for example 50000).

Before clicking on the STEP TEST button, go to the SETTINGS tab and adjust the following values:

**Acceleration**
Enter for the test an acceleration equal to 2 times the maximum speed of the STEP TEST (for example 20000). This will give a jump from zero speed to maximum speed in 0.5 seconds.

**Final Approach**
Enter 0 (zero) because it is not used.

**Sidereal Speed et Tracking Speed**
Enter the value that you will eventually use to track. If there is no tracking, if the motor is used for an eyepiece holder for example, use a value equal to 2% of the maximum speed (200) or a minimum value of 40.

**Error Limit**
In order to avoid over-corrections in the event of large position errors, the SKYPIKIT does not send an additional voltage correction if the error exceeds this limit value. Absolute value. It is recommended to adjust it to a value equal to approximately 20% of the maximum speed in steps/s (for example 2000).

**Integral Limit**
In order to avoid over-corrections in the event of large integrations of position errors, the SKYPIKIT does not send an additional voltage correction if the accumulation of the error exceeds this limit value. Absolute value. It is recommended to adjust it to a value equal to approximately 20% of the maximum speed in steps/s (for example 1000).

**Integral Max Speed**
The error signal is only accumulated if the speed is below this value. Integration is reset if the speed exceeds Integral Max Speed. This is so that the correction related to the integration is done only when the speed is low, when the motor position is close to the target position. It is recommended to adjust it to a value equal to approximately 20% of the maximum speed in steps/s (for example 2000).
ADJUSTING PID PARAMETERS (continuation)

KP et KI
The following pages show the steps necessary to find the values of KP and KI for a DC motor.

These pages contain the graphs obtained in the ANALYZE tab to illustrate the results obtained.

Note that STEP TEST is done in the FIXED reference system.

In these steps, reference is made to the values of KP and KI in the table below.

Limit values for tests only

For tests, only during the search for KP and KI values, adjust the limit values to the following values:
- Error Limit to 50% of the maximum speed (for example 5000);
- Integral Limit at 50% of the maximum speed (for example 5000);
- Integral max speed at 50% of maximum speed (for example 5000);

FINALIZATION

What to do once you find the KP and KI values?

Acceleration
Reset the acceleration to a more normal value, for example half the maximum speed (5000 steps/s² if the speed is 10000 steps/s). The motor will accelerate from zero speed to the maximum GoTo speed in 2 seconds.

Limits
Reset the limit values to the values suggested during use:
- Error Limit to 20% of the maximum speed (for example 2000);
- Integral Limit at 20% of the maximum speed (for example 2000);
- Integral max speed at 20% of maximum speed (for example 2000);

Graphics and other tests
You can also use TRACK TEST and GOTO TEST to check the behavior of the tracking and test the final approach. You can change some parameters if necessary.

<table>
<thead>
<tr>
<th>KP</th>
<th>KI</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>14</td>
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<tr>
<td>10</td>
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<tr>
<td>28</td>
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<tr>
<td>40</td>
<td>80</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>KP</th>
<th>KI</th>
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</thead>
<tbody>
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<td>320</td>
<td>640</td>
</tr>
<tr>
<td>448</td>
<td>896</td>
</tr>
</tbody>
</table>
Start with $KP = 5$ and $KI = 10$

To find the optimal values of $KP$ and $KI$, the tests will first be done with a **STEP TEST** in the **ANALYZE tab** using the values of displacement and maximum speed (for example 50,000 steps with 10,000 steps/s) and the others parameters adjusted in the **SETTINGS** tab.

We start with low values of $KP = 5$ and $KI = 10$. In this test, we always adjust $KI$ to twice $KP$.

We click on the **STEP TEST button** and wait for the result to appear. If the motor has moved well and then stops while remaining completely stationary at the target position (50000), the test can be repeated using the values from the next line of the table, $KP = 7$ and $KI = 14$.
Increasing values until motor instability

We then continue by increasing the values of KP and KI using the values from one line to the next in the table, until we notice that the motor starts to vibrate during or after the jump and is not unable to remain stationary at its target position.

We see the vibrations on the graph. The green speed line does not remain fixed at zero after the 6th second. We also hear the motor vibrate.

The motor therefore starts to vibrate from the moment when the values KP = 20 and KI = 40 are used.

Note: If the motor starts to vibrate dangerously, immediately click on the FREE Motor button in the CONTROL tab to release it, then change the KP and KI values.
Reset to values for stable behavior

We then move back two rows in the table, which amounts to dividing the values of KP and KI by 2 to again obtain stable behavior.

Since the motor starts to vibrate with KP = 20 and KI = 40, we back up using KP = 10 and KI = 20 for the rest.

The green speed line remains fixed at zero after the 6th second and the motor no longer vibrates.

Also the position of the motor remains fixed (at 50,000) in the Controller Status panel.
Increasing KI until the motor becomes unstable again

The search for the KI gain is done in the same way as that for the KP gain. You start with the values which give a stable behavior of the motor, being the values KP = 10 and KI = 20 from the previous step.

You continue the STEP TEST without changing KP but increasing KI from one line to the next in the table until the motor starts to vibrate again.

Here we find that the motor starts to vibrate again from the STEP TEST with KI = 320.
Reset the KI value for a stable behavior

We then move back four rows in the table to obtain the KI. This is equivalent to dividing the value of KI by 4.

As the motor starts to vibrate with KP = 10 and KI = 320, we back up using KP = 10 and KI = 80 for the rest.

We notice that the motor has again a stable behavior with these values.

These latter values are those that will be used for motor control in the telescope.

Note: you don’t have to use the exact values from the table.
Verification with the TRACK TEST

We then do a TRACK TEST to check if the motor has good behavior during tracking, with the values of KP and KI found.

The TRACK TEST must be done in the **sidereal** reference system and the motor must be **tracking**.

You can always slightly modify the KP and KI values to see if it improves tracking, but don't leave them larger than the values found at the end of the previous step.
END