Postprint: Design of an Astronomical Motorized Focuser Based on the ASCOM Standard

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Abstract

With the continuous advancement of astronomical technology, remote and autonomous observations have gradually emerged as the mainstream trend in astronomical observation, placing increasing emphasis on automatic focusing technology. The electric focuser represents an indispensable accessory for astronomical telescopes and a critical device for achieving automatic focusing. To implement automatic focusing for the 10-inch Meade telescope at the Lijiang Astronomical Observatory Station of Yunnan Observatories, we independently developed an astronomical electric focuser, designed the associated control circuits, established a serial communication protocol, and developed an open-source ASCOM driver program designated as SS Focuser. This paper presents a detailed exposition of the structural principles and implementation methodology of this electric focuser. Experimental results demonstrate its excellent stability and full satisfaction of design requirements, thereby providing valuable experience and methodology for the design of astronomical electric focusers.

Full Text

Design of an Astronomical Electric Focuser Based on the ASCOM Standard

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Abstract

With the continuous development of astronomical technology, remote and autonomous observation have gradually become the mainstream trends in astronomical observing, and automatic focusing technology has received increasing attention. The electric focuser is an indispensable accessory for astronomical telescopes and a key device for realizing automatic focusing in remote and autonomous observations. To achieve automatic focusing for the 10-inch Meade telescope at the Lijiang Astronomical Observatory station of Yunnan Observatories, we have developed a set of astronomical electric focusers, designed the relevant control circuits, formulated a serial communication protocol, and written an open-source ASCOM driver called SS Focuser. This paper introduces in detail the structural principles and implementation methods of this electric focuser. The test results demonstrate excellent stability and full compliance with design requirements, providing a valuable reference for the design of astronomical electric focusers.

Keywords: Electric focuser; Serial communication protocol; ASCOM; SS Focuser

1 System Architecture

The system architecture of the astronomical electric focuser is shown in [FIGURE:N]. The system consists of a control circuit (including the control chip and serial communication module), a stepper motor, and a focuser body. The 10-inch Meade telescope at Lijiang Observatory uses a 5G141 CCD for imaging observations, which places extremely high demands on focusing accuracy. The focuser body employs a 120:1 reduction gear set to drive the focusing knob, enabling precise control of the focusing mechanism. The stepper motor has a step angle of 7.5°, and the reduction gear set further subdivides each step into smaller increments. The control circuit drives the stepper motor through the motor driver module, while the serial communication module facilitates data exchange between the focuser and the computer. The control chip uses PWM signals to regulate the motor driver’ s operating current and implements a temperature compensation algorithm to mitigate the effects of temperature drift on the focal position. The communication interface supports both USB and Bluetooth connections, allowing control via computer software or a mobile application.

3 Circuit Design

The circuit design comprises five main modules: the control circuit, power supply module, motor driver module, communication module, and temperature sensor module, as illustrated in [FIGURE:N].

Control Circuit: The core component is the STM32F103C8T6 microcontroller, which integrates the control program, motor driver, and communication interface. It uses an 8MHz external crystal oscillator. USART1 interfaces with the USB communication module, USART2 with the Bluetooth module, and USART3 with the motor driver module via STEP/DIR signals. A single-wire protocol is implemented for temperature sensor communication.

Power Supply Module: The circuit operates on 12V input through a DC5.5-2.1 interface, with diode D1 providing reverse polarity protection. The stepper motor requires 12V, while the control circuit needs 3.3V, supplied by an LM2596-3.3 regulator that converts 12V to 3.3V. Given that astronomical electric focusers operate outdoors for extended periods, we designed a power-off protection circuit. When the power supply is interrupted, a large capacitor temporarily sustains the system voltage, allowing the microcontroller to save the current focus position to flash memory. Upon restart, the system can either resume from the saved position or return to a mechanical zero point. This design prevents position loss due to power failures and enhances system reliability. The power-off protection circuit follows the design principles outlined in reference [5], enabling the microcontroller to detect power interruptions.

Communication Module: The module includes both USB and Bluetooth interfaces. The USB interface uses a CH340C chip (USB-to-UART converter) for USART1 communication, while the Bluetooth module employs an HC-08 Bluetooth-to-serial adapter for USART2. Both interfaces connect to the STM32' s USART1 and USART2 respectively.

Motor Driver Module: The TMC2208 stepper motor driver module controls the motor with a maximum current of 1.4A (RMS) and supports supply voltages from 5V to 36V. It offers up to 256 microsteps and includes both spreadCycle and stealthChop modes. The module configures microstepping via MS1 and MS2 pins set to 8 microsteps, with the PDN pin connected to the STM32' s USART3 for control.

Temperature Sensor Module: The DS18B20 temperature sensor uses a single-wire protocol for temperature data acquisition, enabling temperature compensation algorithms [6].

The physical circuit board measures 52mm × 52mm × 44mm, as shown in [FIGURE:N].

4 Software Design

The software system consists of three components: the focuser firmware, computer control software, and mobile APP.

4.1 Serial Communication Protocol

The serial communication protocol operates over USB at 9600 baud using the CH340C converter. It is a custom ASCII-based protocol with simple, readable commands. The protocol supports both on-chip storage (when n=0) and computer storage (when n=1) of focus positions. The command set is summarized in [TABLE:N].

Table 1: Custom Serial Command Protocol

Command	Return	Description
`:FIn#`	-	Slew outward
`:FDsn#`	-	Slew inward
`:FPsnn#`	-	Initialize (on-chip storage when n=0, computer storage when n=1)
`:psn#`	-	Query initialization state
`:sn#`	-	Query move state (Stopped when n=0)
`:snnn#`	-	Define position
`:Mnnn#`	-	Move to position
`:p#`	-	Query position
`:tsn.n#`	-	Query temperature

The protocol implementation is available on GitHub under project SS Focuser.

4.2 Focuser Firmware

The focuser firmware runs on the STM32 microcontroller and is developed in C. It controls the stepper motor via PWM signals and GPIO pins [7][8], implementing a microstepping algorithm with acceleration and deceleration to ensure smooth operation and prevent motor stalling. The main program loop consists of four functional modules: (1) Serial command processing (USB and Bluetooth commands), (2) Position control module, (3) Motor driver module, and (4) Temperature compensation module.

The flowchart in [FIGURE:N] illustrates the software architecture. The serial processing module parses commands and executes corresponding actions. The position control module handles both absolute and relative positioning, with the relative mode enabling backlash compensation to eliminate mechanical play. The motor driver module generates PWM waveforms with acceleration/deceleration profiles. The temperature module reads the DS18B20 sensor and applies compensation algorithms.

Manual control is supported through physical buttons that trigger `:F+#` and `:F-#` commands, initiating continuous movement at a constant speed for a duration corresponding to one full step, enabling fine manual adjustments without a computer.

4.3 Computer Software

The computer software implements the ASCOM standard interface, allowing integration with popular astronomy applications like MaxIm DL and FocusMax [9]. Developed in C#, it requires ASCOM Platform 6.3. The Focuser class implements standard properties and methods as shown in [TABLE:N].

Table 2: Common Properties and Methods of Focuser Class

Property/Method	Description
`Connected`	Connection property
`Position`	Position property
`Absolute`	Encoder property
`IsMoving`	Moving state property
`Move()`	Move method
`Halt()`	Stop method
`Temperature`	Temperature property
`MaxStep`	Maximum step property

The software flowchart is shown in [FIGURE:N]. The interface includes connection controls, backlash compensation settings, and focusing operations. When `Connected=True`, the software establishes communication with the focuser. The backlash compensation interface allows configuration of mechanical play parameters. The focusing interface provides four functions: (1) Status display showing `IsMoving`, `Position`, and `Temperature`; (2) `Move()` method for absolute positioning; (3) `Halt()` method for emergency stop; and (4) Manual button controls (`:F+#` and `:F-#`) that operate independently of ASCOM commands for manual adjustment.

4.4 Mobile Bluetooth APP

A mobile APP was developed using a cross-platform framework to enable wireless control. The Bluetooth communication uses the HC-08 module, allowing the APP to connect via Bluetooth and send the same serial commands as the computer interface, providing full wireless control capability.

5 System Testing

The electric focuser was tested on the 10-inch Meade telescope at Lijiang Observatory for one month, operating continuously without failure. The focuser demonstrated excellent stability under actual observing conditions. The system achieves a focusing accuracy of 3.472 m per step, calculated as follows: the stepper motor has a 7.5° step angle with 8 microsteps, resulting in 48 steps per revolution. Combined with the 120:1 reduction gear, this yields 5760 steps per revolution of the focusing knob. With a total travel of 20mm per revolution, the step size is 20mm/5760 = 3.472 m, meeting the precision requirements for CCD imaging.

The focuser integrates seamlessly with MaxIm DL' s autofocus routine (and FocusMax), as shown in [FIGURE:N]. The software interface displays the focusing process, with the ability to define a zero position and perform automated focusing runs.

5 Conclusion

This paper presents the design of a compact astronomical electric focuser based on the ASCOM standard. The system has been successfully deployed on the 10-inch Meade telescope at Lijiang Observatory, demonstrating stable and reliable performance. The open-source ASCOM driver (SS Focuser) and mobile APP provide flexible control options. The design offers a complete solution for astronomical electric focusers, including hardware circuits, communication protocols, and software implementations, serving as a valuable reference for similar projects.

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Note: Figure translations are in progress. See original paper for figures.