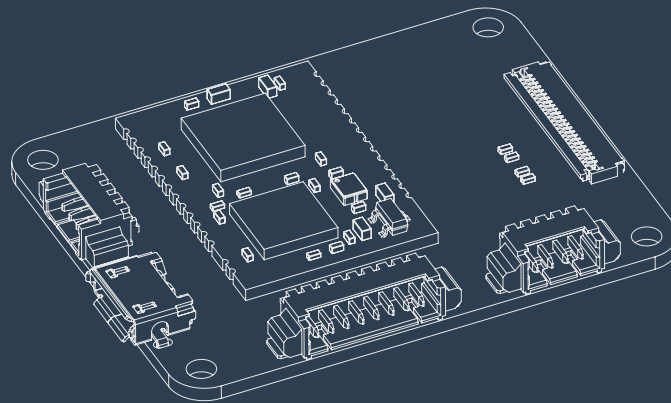

MOTORIZED LENS CONTROLLER SYSTEM ON MODULE SCF4

USER MANUAL

KUROKESU



2019-07-23, v1.2

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Revision history

Documentation revision history

Document version	Date	Changes
0.1	2019-07-01	Initial documentation created
1.0	2019-07-22	Internal release
1.1	2019-07-22	Disclaimers and precautions added, more complete command description added
1.2	2019-07-23	Minor corrections and mistypes, document public release

Firmware revision history

Module	FW version	Date	Changes
SCF4-M RevB	0.6.52	2019-07-01	<ul style="list-style-type: none">Initial public release version
SCF4-M RevB	EVb.1.0.0	2019-07-14	<ul style="list-style-type: none">Bump to 1.0.0 releaseConsolidated version reporting into single stringCode cleanup
SCF4-M RevB	EVb.1.0.1	2019-07-14	<ul style="list-style-type: none">Minor bugfixesStable release

Module	FW version	Date	Changes
SCF4-M RevB	EVb.1.0.2	2019-07-18	<ul style="list-style-type: none">• Added new advanced commands: M241..M244• Fixed: set motor idle power to 0 is not allowed• Fixed: default relative movement mode after reset

Overview

SCF4 multi-axis stepper motor controller System On Module (SOM) targets applications where time to market, reliability and small footprint is important. Main control MCU is ST Cortex STM32F103 powerful enough either to run standard or run dedicated standalone firmware. The motor front end is based on ON Semiconductor new and highly specialized chipset LC898201.

Some standalone use examples:

- React to lidar distance sensor and adjust focus/zoom accordingly
- Switch day/night filter by measuring ambient light intensity (with dedicated analog or digital sensor)
- Take R/C inputs and control Remote-controlled drone or vehicle lens
- Switch / reconfigure lens by single GPIO input (for example: reconfigure lens for wide/near operation by toggling GPIO pin)
- And much more...

Managed mode (default) target applications worth mentioning:

- Computer vision and analysis applications
- Scientific applications
- Neural network image processing and recognition applications
- Transport systems (ITS)
- Universal Pan/Tilt/Zoom and/or Focus/Zoom/Iris/+ driver
- Toll systems
- Traffic or segmental speed measurement
- ROV/Drone lens control unit
- Face recognition applications
- Long term time-lapse cameras
- Distant camera installations that may require reconfiguring optical train remotely
- And much more...

Precautions and disclaimers

General disclaimer

- ALL PRODUCTS, PRODUCT SPECIFICATIONS, AND DATA ARE SUBJECT TO CHANGE WITHOUT NOTICE TO IMPROVE RELIABILITY, FUNCTION OR DESIGN OR OTHERWISE
- Kurokesu UAB, its affiliates, agents, and employees, and all persons acting on its or their behalf (collectively, “Kurokesu”), disclaim any and all liability for any errors, inaccuracies or incompleteness contained in any datasheet or any other disclosure relating to any product.
- The Information given herein is believed to be accurate and reliable. However, users should independently evaluate the suitability of and test each product selected for their applications
- See Kurokesu standard terms and conditions for warranty and other information

Precautions

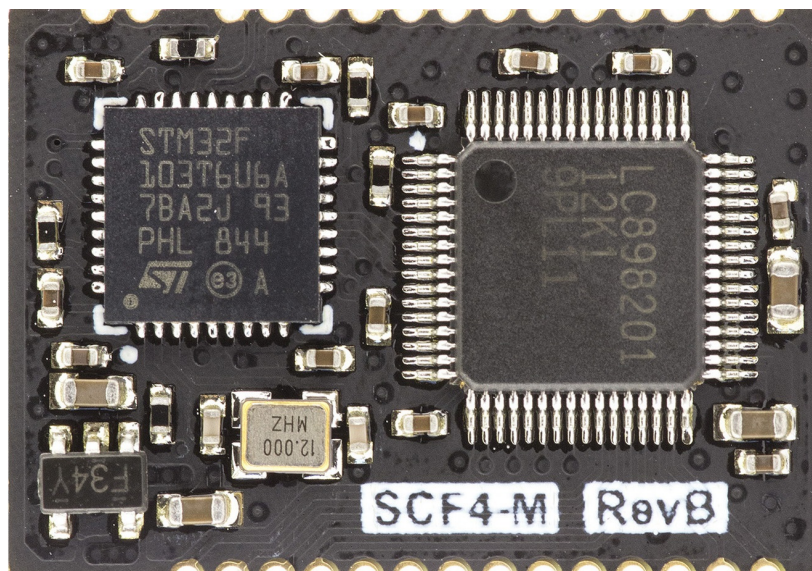
- Do not short circuit any part of the module
- Do not exceed nominal input
- Do not overload outputs
- Keep the module dry
- Observe the electrostatic discharge (ESD) precautions when handling the product. Damage caused by non-observance of the above instructions is not covered by the warranty
- Power electronics equipped with thermal shutdown circuitry, but if controller becomes too hot disconnect it
- Module is designed exclusively for installation into a device or housing to prevent external influences such as humidity/water or dirt
- Add active and/or passive power filtering circuitry in an electromagnetically noisy environment if a module becomes unstable
- Add active and/or passive power filtering circuitry if module exceeds allowed EMC emissions

SCF4-M module

Brief description

Tiny self-sufficient stepper motor controller **SCF4-M** module is designed for high integration customer products and can drive FIZ+ lens with 3 stepper motors (for example Focus/Zoom/P-Iris with micro-stepping up to 1/1024 steps for inaudible operation) and IR filter simultaneously. Also has 3 limit switch inputs and 4 GPIO (IN/OUT/ADC) pins for custom application control. The controller expects industry-standard G-code formatted commands for fastest and easiest integration. Designed to be connected over single USB cable (USART and I2C can be supported in custom firmware). Firmware modifications can be tailored to suit customer requirements.

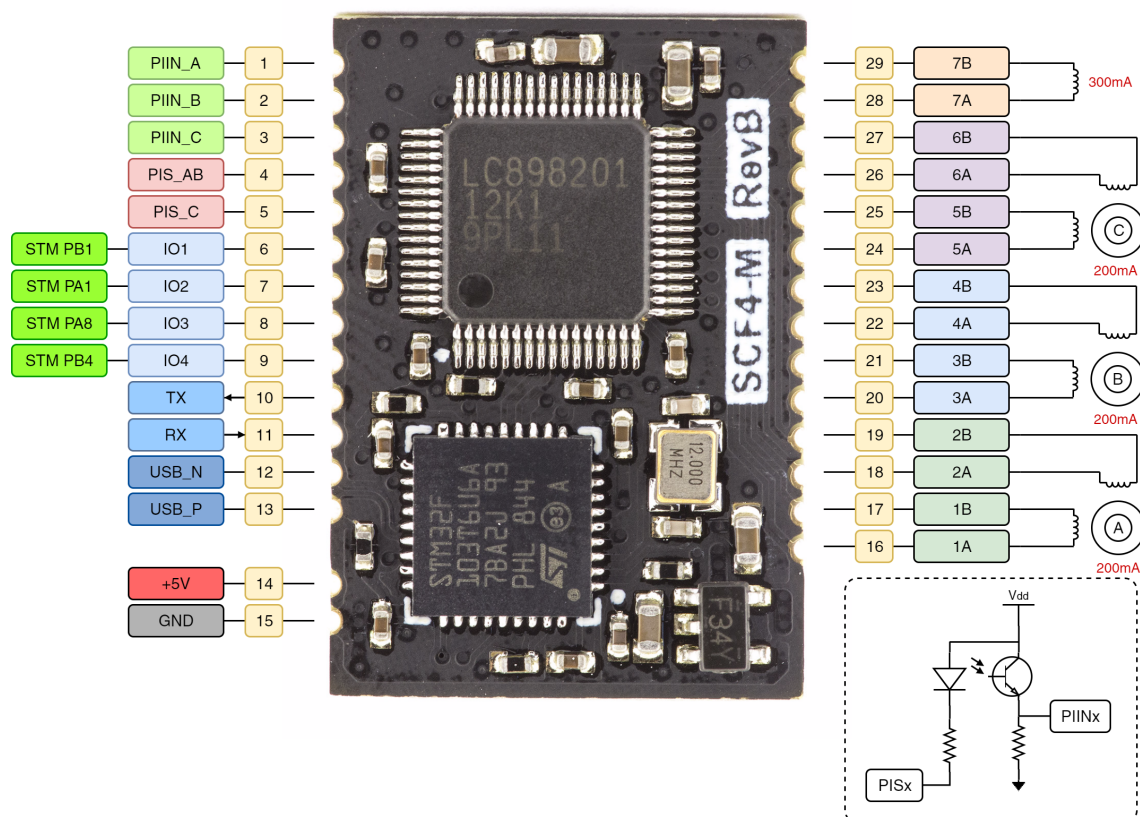
SCF4 - is a one in a series of Kurokesu stepper motor controllers and stands for Stepper Controller Model F, 4'th modification.



Features

- Small footprint 16 x 23 x 2.3 mm [0.63 x 0.91 x 0.09 in]
- 3x stepper motor controller with up to 1/1024 micro-stepping support for each motor
- 1x H-bridge for coil control (day/night filter switch)
- 3x limit switch processing for precise lens homing/referencing
- Direct USB Full-speed (12 Mbit/s) connectivity
- 4x GPIO's with Input/Output/Analog functionality
- Industry standard G-code command set
- Can drive most lenses with bipolar stepper motors with minor or none tuning

- Certificates: REACH, RoHS ## Pin description



Technical specifications

Module dimensions	16 x 23 x 2.3 mm [0.63 x 0.91 x 0.09 in]
Controlled stepper motors	3
Connectivity	USB (optional USART, I2C, SPI)
Module pin count	29
Stepper motor resolution	up to 1/1024 micro-steps (1/64 default)
PWM voltage levels for filter switch	H-Bridge (128 voltage levels)

Absolute maximum ratings

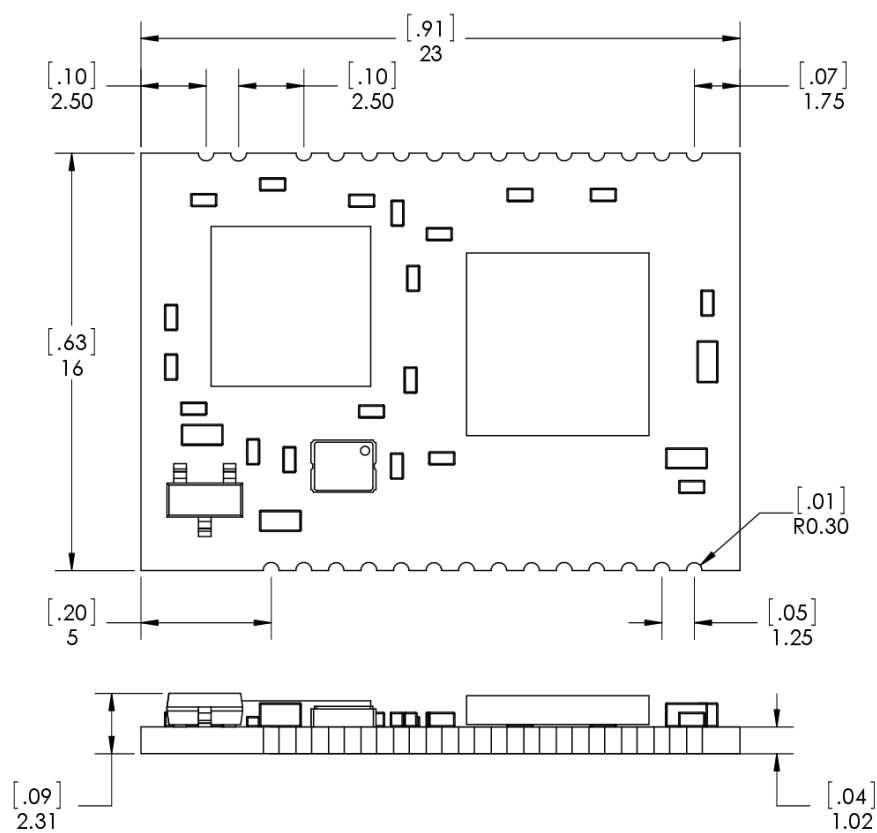
Min supply voltage	4.3 V
--------------------	-------

Max supply voltage	7.0	V
Stepper motor max current	200	mA @ 5V
IR Filter coil max current	300	mA @ 5V

Operating parameters

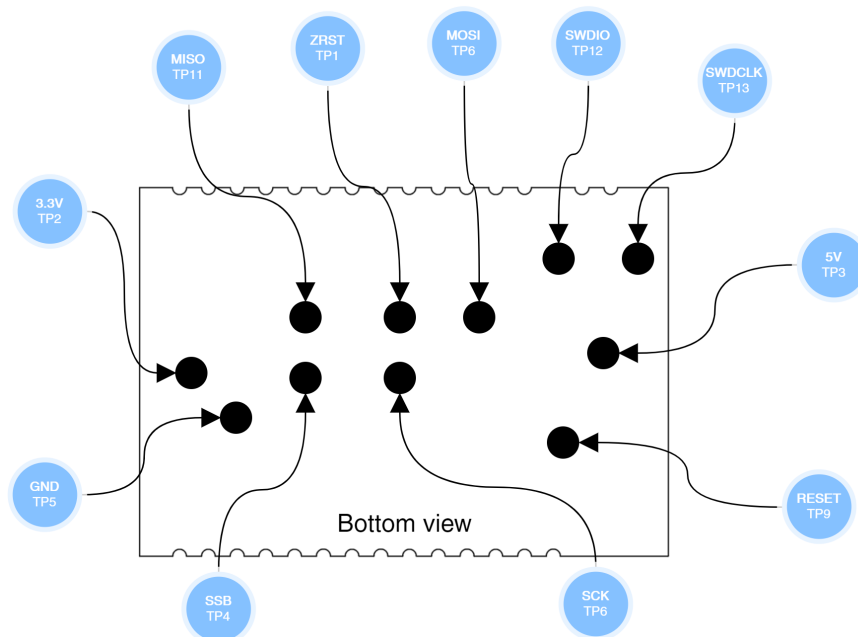
Operating voltage	4.5 ~ 5.5	V
Controller max current consumption	1	A @ 5V
Controller power rating	5	W
Relative Humidity	Non-Condensing	
Operating Temperature	-40 ~ 85	°C

Mechanical dimensions



Test points

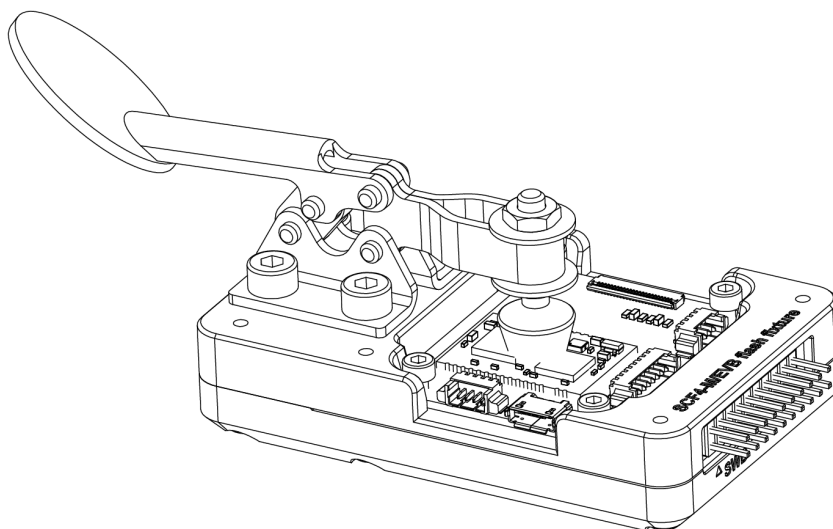
For testing, flashing firmware and post-production purposes SCF4-M module has several test points.



For exact dimensions and locations check 3D STEP file.

Flash/test/post-production fixture

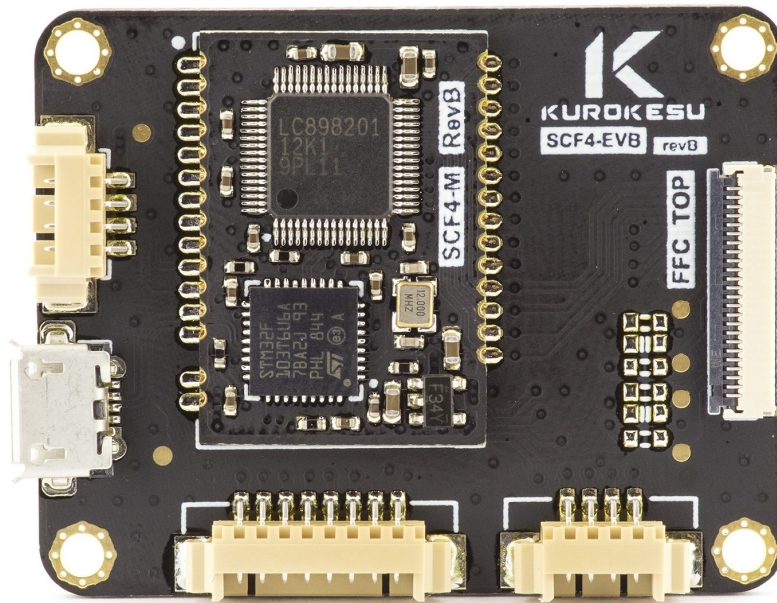
For large scale module or assembled evaluation board customizations, testing or post-production procedures at customer premises test fixture can be supplied.



SCF4-EVB Evaluation Board

Brief description

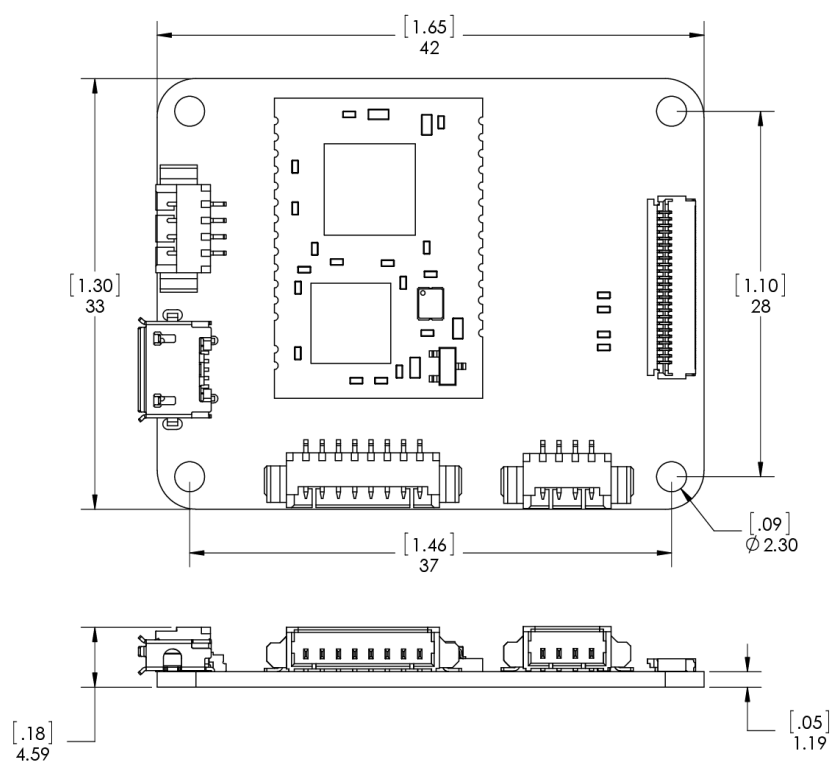
Stepper motor controller evaluation board **SCF4-EVB** is designed to demonstrate **SCF4-M** module capabilities. It can drive two different types of Focus/Zoom/P-Iris lenses. Can be used as a complete product, easily redesigned to drive other lens or fit specific needs.



Features

- Small footprint 42 x 33 x 4.6 mm [1.65 x 1.3 x 0.18 in]
- Supports two kinds of lenses
- 3x stepper motor controller with up to 1/1024 microstepping support for each motor (1/64 set by default)
- 1x H-bridge for coil control (day/night filter switch)
- 2x limit switch processing for precise lens homing/referencing (3x supported by module)
- Direct Full-speed micro USB 2.0
- Optional USART connectivity / GPIO
- Certificates: REACH, RoHS

Evaluation board dimensions

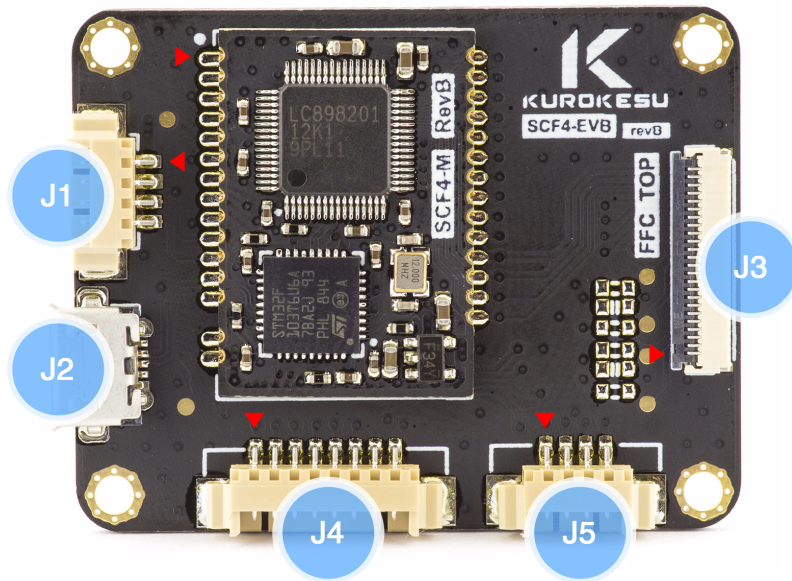


Technical specifications

Evaluation board dimensions	42 x 33 x 4.6 mm [1.65 x 1.3 x 0.18 in]
Power rating	+5V (USB powered)
Supported lenses	L012-MFZ-2.8Z12-D14, L051-MZFD-5.4Z96-DIRECT

Pinout

Evaluation board has following populated connectors:

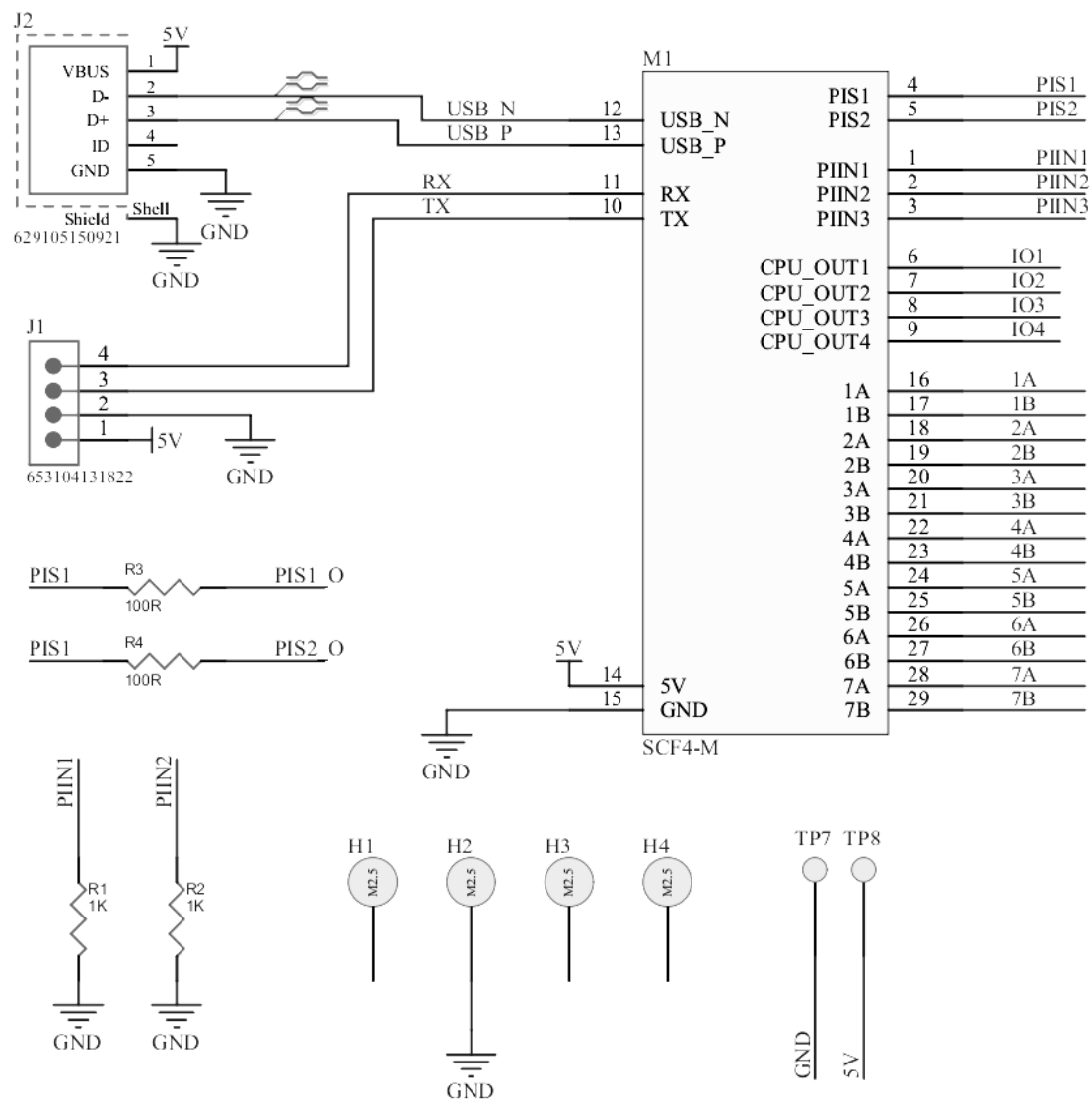


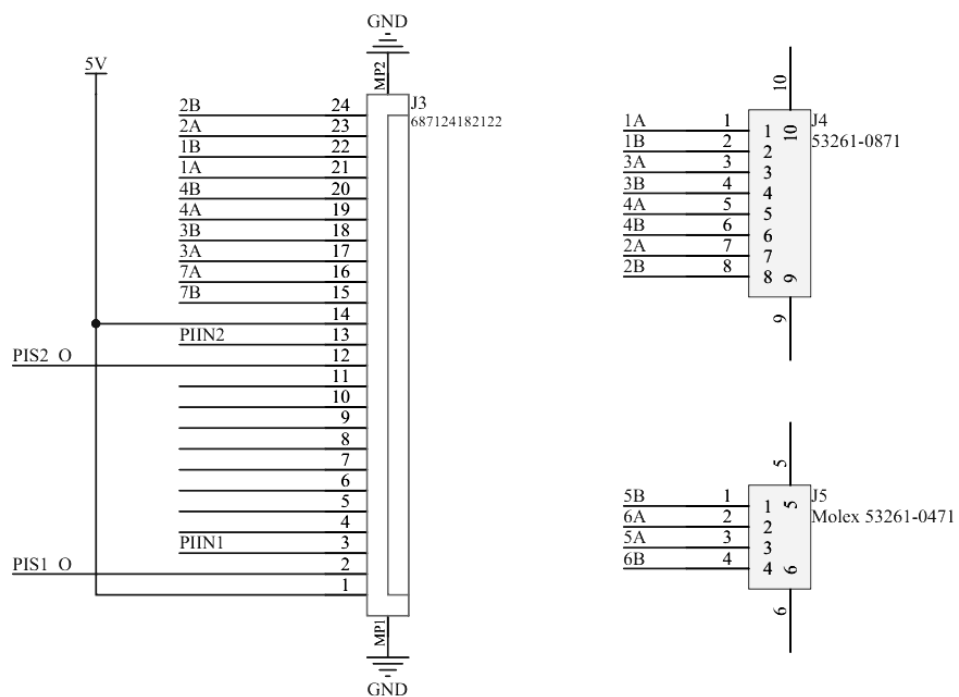
- J1 - USART / GPIO (optional)
- J3 - FFC connector for advanced lens connectivity
- J4 - Double motor connector
- J5 - P-Iris motor connector

Pin	J1	J3	J4	J5
1	IN 5V	ZOOM Motor XB	ZOOM Motor A	P-Iris Motor XA
2	GND	ZOOM Motor B	ZOOM Motor XA	P-Iris Motor B
3	USART TX	ZOOM Motor XA	FOCUS Motor A	P-Iris Motor A
4	USART RX	ZOOM Motor A	FOCUS Motor XA	P-Iris Motor XB
5		FOCUS Motor XB	FOCUS Motor B	
6		FOCUS Motor B	FOCUS Motor XB	
7		FOCUS Motor XA	ZOOM Motor B	
8		FOCUS Motor A	ZOOM Motor XB	
9		IR Drive +		
10		IR Drive -		
11		FOCUS PI (Anode, Collector)		
12		FOCUS PI (Emitter)		
13		FOCUS PI (Cathode)		

Pin	J1	J3	J4	J5
14				
15				
16				
17				
18				
19				
20				
21				
22		Zoom PI (Anode, Collector)		
23		Zoom PI (Emitter)		
24		Zoom PI (Cathode)		

Evaluation board schematics





Demonstration software

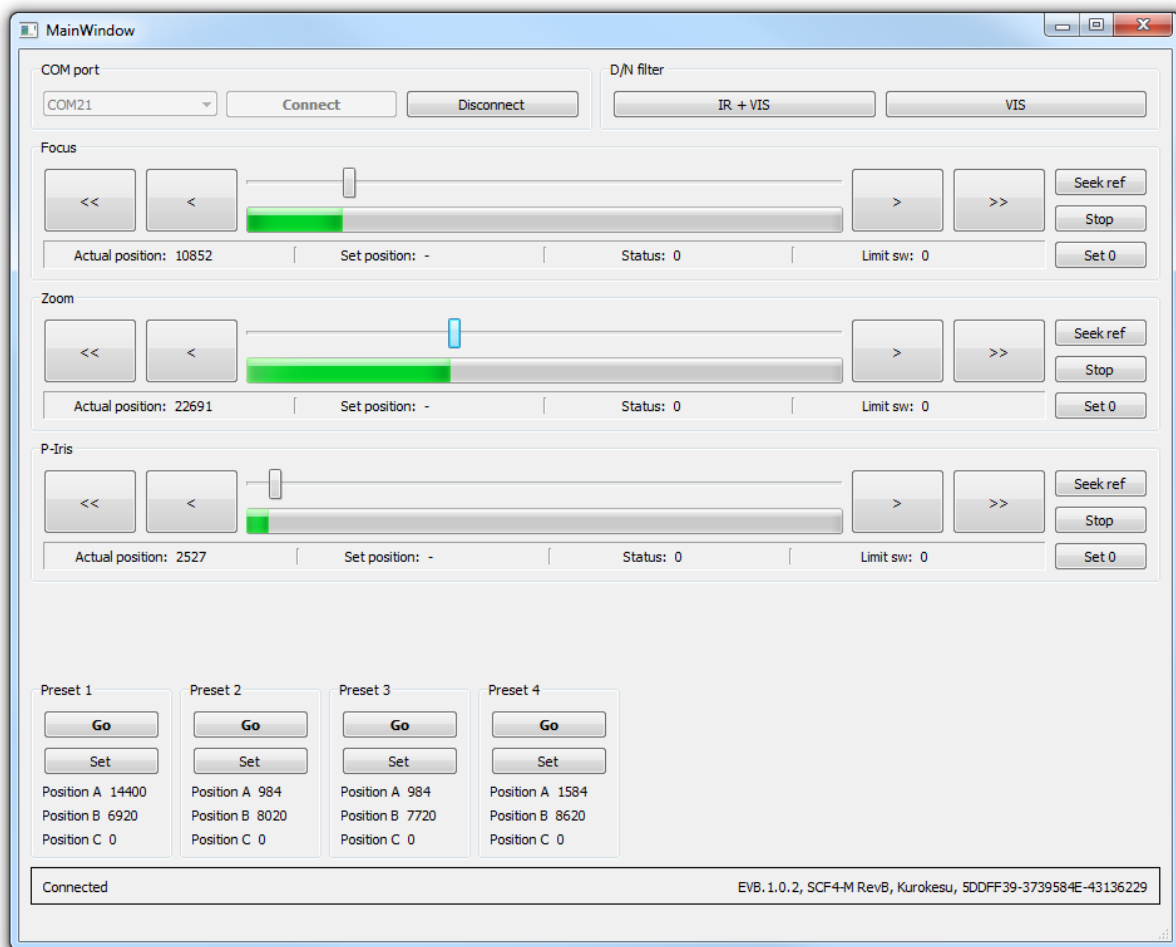
Overview

SCF4-SDK comes with open-sourced command line and GUI sample programs for rapid controller evaluation. A simple control software example is provided for testing and demonstration. Software is given “as is” to help with getting started and testing.

GUI

Python program with a graphical user interface allows many parameters to be controlled by an inexperienced user. To keep user interface uncluttered some parameters are not displayed. After connecting to SCF4 controller virtual serial port version string should be displayed at the bottom. Also, all controls will be activated. From now relative movement commands should be issued to check if connected motors turn properly (once button is pressed it will change positioning mode to absolute). When sliders operated positioning is switched to absolute mode, it makes sense after the axis is referenced.

Python scripting language with PyQt5 user interface was chosen because of rapid development and clear syntax. Python 3.6 and a few dependencies should be installed before running any examples. Python and PyQt5 enables modern cross-platform user interface capable of running on high DPI monitors correctly.



Many lenses and motion systems can be connected to the controller and they can be split into two groups - with and without limit/reference switch/sensor. So there are two fundamentally different homing approaches.

1. Homing without limit switch is not very accurate but universal and works with all lenses. Idea is to rotate motor until the mechanical system hits its limit, then rotate a bit backwards and mark position as 0. The lens should not sustain any irreversible damage, but this procedure should not be performed often.
2. The lens can incorporate various limit or reference switch configurations, therefore homing procedure should be adapted to a particular geometry. For example, the lens has reference opto-interrupter when it crosses the middle of its travel. By reading status register it becomes is clear at which section lens axis is and motor should be moved to center until switch changes status. To complicate things even more optocoupler or any switch has backlash/hysteresis and controller comparator has adjustable lower and upper thresholds. Good understanding of how particular lens behaves is a must and still, it can take a few experiments to set optimal parameters.

Some lenses depending on each axis position can have variable travel limits.

Current program version has following homing procedure implemented:

- Move motor by a fixed number of steps (lens may hit mechanical stop)
- Move opposite direction until the switch is actuated
- Move back by a fixed number of steps
- Set current position as 0

Program configuration is saved to `settings.json`. It's a read/write file with the purpose to provide default settings for some parameters like motion speed, jog steps, last used COM port, etc. and save settings and last position when program is closed.

Internal stepper motor driver has 16-bit position counter, absolute positioning is possible within a range of 0..65535 steps, (for 200 steps per revolution motor equals 20 full turns). In relative movement, if motion exceeds 16bit counter range it will overflow and continue the motion. The single move command is also 16 bits.

Command line

Command-line programs provide quick clean coding templates, examples to understand G-code usage. Programs explain how to:

- Read version string
- Initialize and perform relative movements
- Perform lens homing
- Change motion speed
- Perform an emergency stop
- And more

For the full list see the examples directory

Terminal

Control commands also can be sent directly from a terminal program of your choice. Baudrate for virtual COM port is irrelevant and communication speed over Full-speed USB 2.0 is 12 Mbit/s.

- Each command must be terminated by a newline
- Each command returns status code or requested information

Lenses

Overview

SCF4 controller supports majority lenses with stepper motors. 3 independent optical axes and Day/Night switch can be manipulated independently and simultaneously.

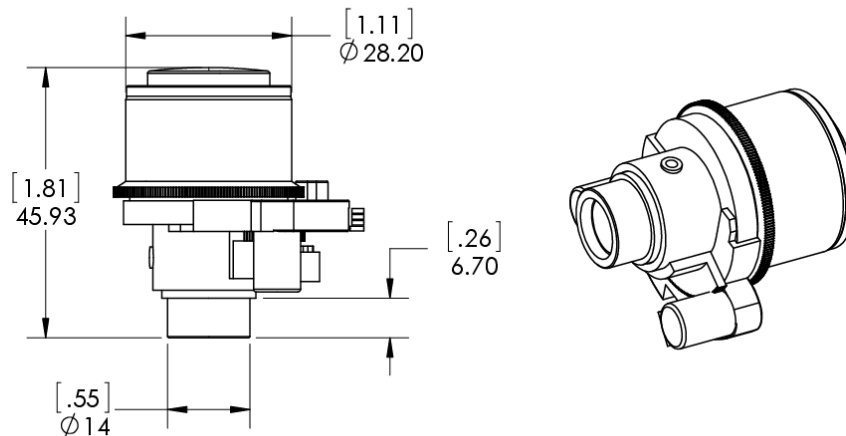
Instead of conventional X/Y/Z axis names they are renamed to A/B/C. Evaluation board has axes assigned as listed below.

- A - Zoom
- B - Focus
- C - Aperture

Lens L012-MFZ-2.8Z12-D14 (2.8-12mm)

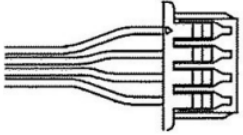
L012 is 2.8-12mm Zoom/Focus and optional P-Iris lens with no reference points designed for D14-mount cameras. With D14 to CS adapter, any CS-mount camera can accept this lens without need of further modifications.

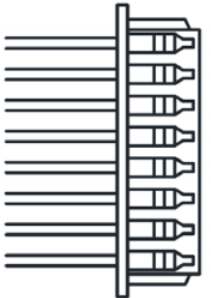
Dimensions



Wiring

Flat Flex Cable (FFC) wire definitions and dimensions described below.

	1	1	White	\bar{A}
	2	2	Black	B
	3	3	Red	A
	4	4	Green	\bar{B}

	1	1	White	Zoom	A
	2	2	Green	Zoom	\bar{A}
	3	3	Red	Focus	A
	4	4	Orange	Focus	\bar{A}
	5	5	Brown	Focus	B
	6	6	Yellow	Focus	\bar{B}
	7	7	Blue	Zoom	B
	8	8	Black	Zoom	\bar{B}

Motor specifications

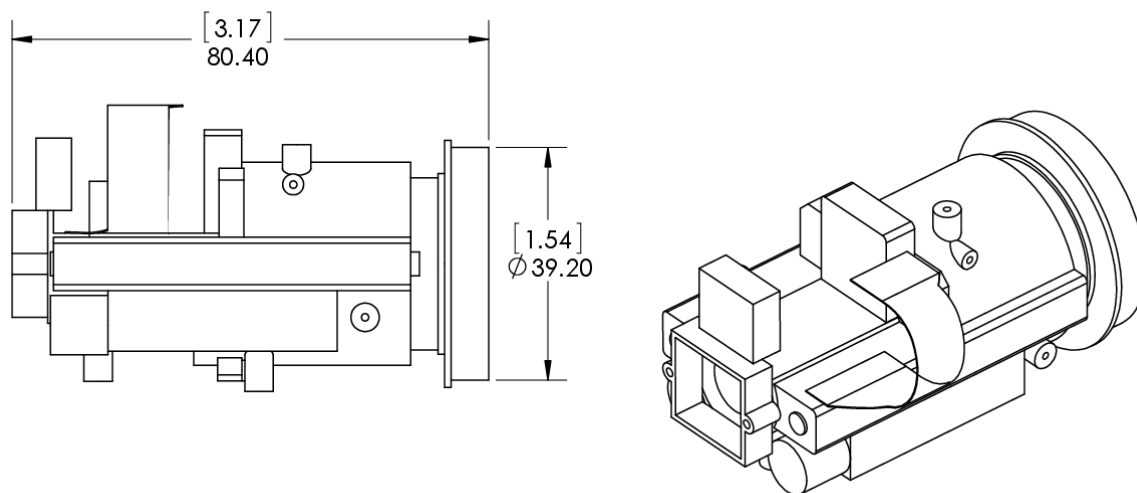
Feature	Zoom	Focus	P-Iris
Full motion range [Steps]	1352	3318	92
Coil resistance [Ohm]	21	21	28.5
Operation voltage [V]	3.5 ~ 5	3.5 ~ 5	2.6 ~ 3.8
Operation frequency [pps]	200 ~ 800	200 ~ 800	200 ~ 800

Lens L051-MZFD-5.4Z96-DIRECT (5-100mm)

L051 5.35-96.3mm Zoom/Focus/P-Iris lens with day/night filter switch is designed for direct PCB mount.

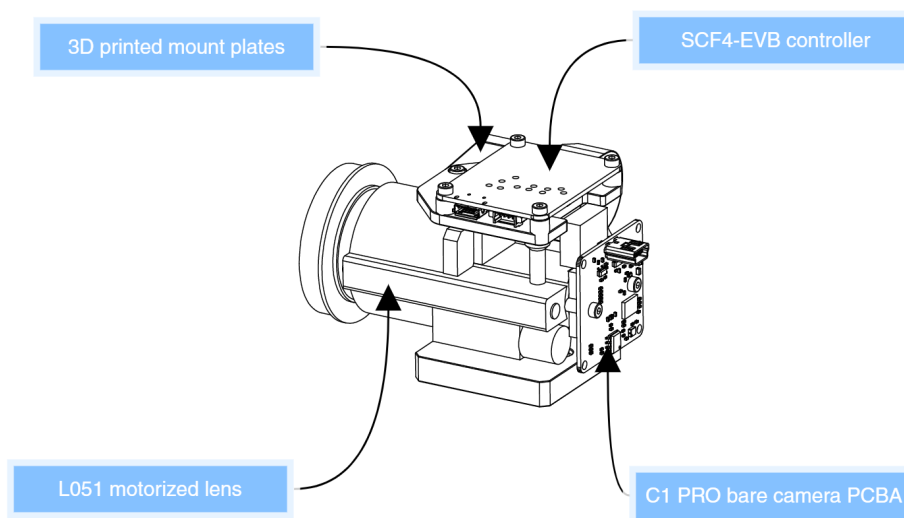
After referencing Zoom and Focus axes and using this information along with in advance calibrated presets precise lens re-configuration is possible without the need to perform auto-focus. This drastically increases the field of view change time and accuracy in complicated situations like low light, vibrations, low contrast or fast-moving scene.

Dimensions



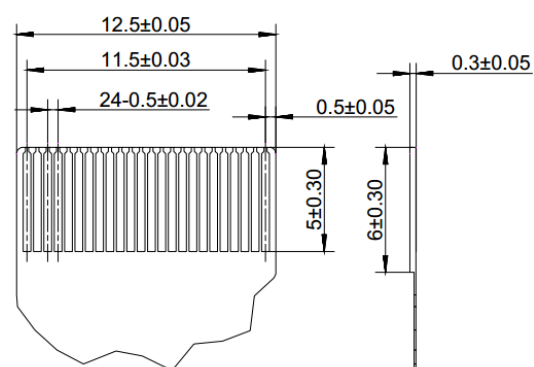
Camera block

Simple DIY lightweight lens / controller / camera stack can form camera block. Parts can be printed with ordinary 3D printer or machined from more durable material.



Wiring

NO.	Function	
1	ZOOM MOTOR XB	ZOOM MOTOR
2	ZOOM MOTOR B	
3	ZOOM MOTOR XA	
4	ZOOM MOTOR A	
5	FOCUS MOTOR XB	FOCUS MOTOR
6	FOCUS MOTOR B	
7	FOCUS MOTOR XA	
8	FOCUS MOTOR A	
9	IR Drive +	IRCUT MOTOR
10	IR Drive -	
11	FOCUS PI(Anode, Collector)	FOCUS PI
12	FOCUS PI(Emitter)	
13	FOCUS PI(Cathode)	
14		
15		
16		
17		
18		
19		
20		
21		
22	ZOOM PI(Emitter)	ZOOM PI
23	ZOOM PI(Cathode)	
24	ZOOM PI(Anode, Collector)	



Motor specifications

Feature	Zoom	Focus	P-Iris
Coil resistance [Ohm]	55	55	55
Max frequency [pps]	1200	1200	1200
Operation voltage [V]	5	5	5
Step angle °deg	18	18	18

Photo interrupter

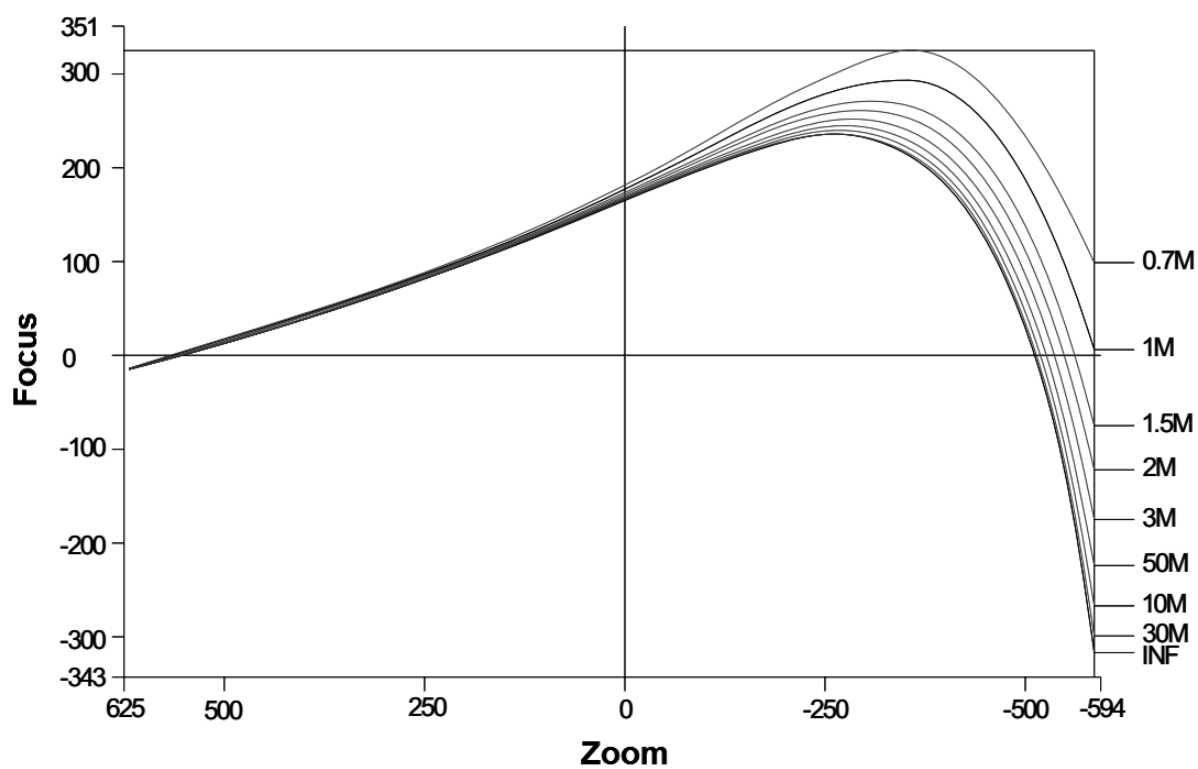
Manufacturer part number: RPI-222 ROHM

IR filter mechanism

Optional lens filter switch is also called: IRC (Infra Red Cut) and D/N (Day / Night). Usually cut off wave length is 650nm.

Feature	D/N filter
Coil resistance [Ohm]	25
Operation voltage [V]	3.6 ~ 5
Rated current [mA]	144 ~ 200
Time of application [ms]	200 ~ 500

Focus / Zoom travel limits and designed focus points



Controlling SCF4 with G-code commands

FIZ+ controller expects industry-standard G-code formatted commands. Commands are text-based and human-readable. Some highlights and behavior notes:

- Controller has limited buffer/cache functionality, a user should rely on single command execution at a time. Each command ends with a response
- Controller never sends commands back to the computer without asking
- G1 linear interpolation is not supported, but it can be implemented by setting motion speeds and feeds manually

G-code introduction

G-code is the common name for the most widely used numerical control (CNC) programming language. It tells the motors where to move, how fast to move, and what path to follow. G-code has many variants and each machine has unique behavior implementation. More details on G-code can be found at <https://en.wikipedia.org/wiki/G-code>

Index of supported G-code commands

Below is a list of supported commands. For a detailed explanation and usage examples see next section.

Version strings and identification commands

Command	Description	Returns
\$S	Return version, sn, model and brand strings	See details

Controller initialization

Command	Description	Returns
\$B1	Reset motor driver	OK
\$B2	Reset and initialize motor driver	OK

Command	Description	Returns
\$B3	Reset STM32F103 processor	OK

Motion commands

Command	Description	Returns
G0	Rapid positioning	OK
G4	Wait / stall	after complete OK
G90	Absolute programming mode	OK
G91	Incremental programming mode	OK
G92	Set position	OK

Miscellaneous function

Command	Description	Returns
M0	Compulsory stop	OK
M7	DN function with filter (VIS)	OK
M8	DN function no filter (IR + VIS)	OK
M230	Set normal move	OK
M231	Set normal + forced move	OK
M232	Set PI low/high detection voltage	OK
M234	Set motor and DN drive current	OK
M235	Set motor idle current	OK
M238	PI LED on (some lenses leak light into sensor)	OK
M239	PI LED off	OK
M240	Set motor drive speed	OK

Advanced function

Command	Description	Returns
M241	Dividing setting 1	OK
M242	Pulse generation control 1	OK
M243	Microstepping	OK
M244	Dividing setting 2	OK

Status commands

Command	Description	Returns
! 1	Return motor pos, limit sw, moving status	4000, 20000, 0, 0, 0, 0, 0, 0

Controlling SCF4 with G-code commands explanation and usage examples

Axis description

Driver support bipolar stepper motors for 3 axes. They are named A/B/C and usually have defined function:

- A - zoom
- B - focus
- C - aperture

Resources

- <https://en.wikipedia.org/wiki/G-code>

\$S - Return version string

Command returns version string concentrated into single line [EVB.1.0.2, SCF4-M RevB, Kurokesu, 5DDFF39-3739584E-xxxxxxx] received information is comma separated:

- EVB.1.0.2 - Module firmware version

- SCF4-M RevB - Module PCB revision
- Kurokesu - Manufacturer Brand
- 5DDFF39-3739584E-xxxxxxx - Unique serial number

G0 - Rapid positioning

The main motor drive command. It moves motor specified number steps. Any or all axes can be specified at the same time. Minimal step size is 1. G0 command replies as soon as the command is parsed and does not wait until motors stop.

- [G0 A100] - drives A-axis 100 steps
- [G0 A-100] - drives A-axis -100 steps
- [G0 A100 B-100 C1000] - drives all three axes by specified step count

G4 - Wait

Instructs controller to delay (stall) defined interval in milliseconds [ms]. This is an only command which sends response not after parsing command but after prolonged execution time. During this time command parser is blocked and the only way to complete this command is to wait until it finishes.

G90 - Relative coordiantes

Switch to relative coordinate programming mode. Motors can be instructed to turn positive or negative 0 ~ 65535 steps (16-bits). When the counter exceeds this range, it will overflow. And will not affect motor movement.

G91 - Absolute coordiantes

Switch to absolute coordinate programming mode. In this mode, the range is limited by the internal 16-bit motor register and can be operated in a range of 0 ~ 65535.

G92 - Set position

The controller sets an internal counter to the specified value.

- [G92 A0] - Set A axis counter to 0
- [G92 A100] - Set A axis counter to 100
- [G92 A100 B1000 C200] - Set all axis counters to specified counter values

M0 - Compulsory stop

If the controller is not in G4 delay mode it will instruct motors to stop moving

M7 and M8 - Infrared filter switch commands

Instructs controller to shift filter one of two fixed positions

M230 and M231 - normal / forced move

- Default is normal mode in which motors turn instructed step count and stop after
- In forced mode controller does not stop turning motor after specified step count is reached, instead seeks corresponding port PIN_x status state change. Internal step counter may overflow. Motion is stopped when input status changes, M0 or reset command is issued. PIN_x is connected to internal 12bit Analog to Digital Converter (ADC), lower and upper thresholds can be controlled with M232 command

M232 - Set PI low/high detection voltage

Set 12bit comparator values for limit switch detection inputs. Upper voltage is 3.3V, lower - 0V

- A, B, C - set lower threshold values
- E, F, G - set upper threshold values
- [M232 A1242 E2483] - If the input voltage is below ~1V - set flag to 0. If the value is above ~2V, set flag to 1. Everything in between - is hysteresis and does not change the flag. Used to debounce and filter the input signal

M234 - Set motor and DN drive current

Sets motor and coil drive current. Expects 8-bit value.

- [M234 A120 B120 C120 D80] - Set A, B, C stepper motors strength to 120 and IR filter driver to 80

M235 - Set motor idle current

When motors are not moving, idle current can be reduced to eliminate heating and save energy. It is not advised to completely turn off motors as the driver can lose micro-step holding position

- [M234 A50 B50 C50] - Sets A/B/C motors holding current to value 50

M238 and M239 - control output pins

Opto-interrupter LEDs can be controlled by connecting them to PIS_AB and PIS_C pins. They can stay in either state, but some lenses in IR mode can leak light into the sensor so after referencing/calibration procedure is complete it is advised to switch them off

M240 - Set motor drive speed

Each motor can drive at different speeds. Speed is 16-bit register. Register specifies internal timing interval, the lower value is the faster pulse rate will be.

- [M240 A800 B800 C1200] - Set motion speeds for each axis to corresponding value

M241, M242, M243, M244 - advanced timing registers

- These registers control motor driver timing and should not be altered normally, however in some cases it can be necessary to make adjustments. Please seek the support of you have questions

! 1 - Return status

Command returns 9 values indicating:

- [4000, 20000, 0, 0, 0, 0, 0, 0, 0] - example output
- A Motor position counter
- B Motor position counter
- C Motor position counter
- A Limit switch status
- B Limit switch status
- C Limit switch status
- A Moving status
- B Moving status
- C Moving status

Support

Troubleshooting guide

It is impossible to describe all troubleshooting situations, but most common are listed below:

Self-guided check

- Motors overheating - check and reduce idle power
- Motors overheating after prolonged movements - check and reduce motor drive power
- D/N does not operate - check driver current and power supply voltage
- Motors buzz, when instructed, but does not turn properly - probably drive power, is not sufficient

Ordering

Module, Evaluation board or Evaluation kit with different options can be ordered separately or bundled together

SCF4-M stepper motor controller module, evaluation board, evaluation kit, and accessories ordering options can be found on https://www.kurokesu.com/shop/motion_system

Support and contacts

For support, documentation and other questions please visit <https://www.kurokesu.com>

To speed up support please provide as much information as possible:

- Controller revision
- Controller firmware version
- Exact workflow preferably with g-code commands
- Expected and actual behavior