

KissCAM Datasheet and User Manual

Features

- 1280 x 960 Resolution (1.2 MP)¹
- Colour Bayer Filter
- Stock wide-angle, all glass and metal optics
- S-mount lens holder allows custom lenses
- Miniature size (38 x 20 x 18mm)
- Low mass (10g)
- 3.3 or 5V Supply at 78mA
- RS422 electrical interface
- Simple command and telemetry interface
- Tested from -20 to +60°C
- High-quality component supply chain

Applications

- Engineering/Inspection camera for small satellites
- Simple science payload for CubeSats
- Low-cost camera for educational CubeSats
- Context camera for high-resolution imagers

1. General Description

The MVP KissCAM is a miniature, low-cost, colour imager for satellites. It is designed for small size, ease of use and rapid integration, making it ideal for use as an engineering inspection camera or backup solution.

¹Rev A hardware limited to 480 x 360 resolution

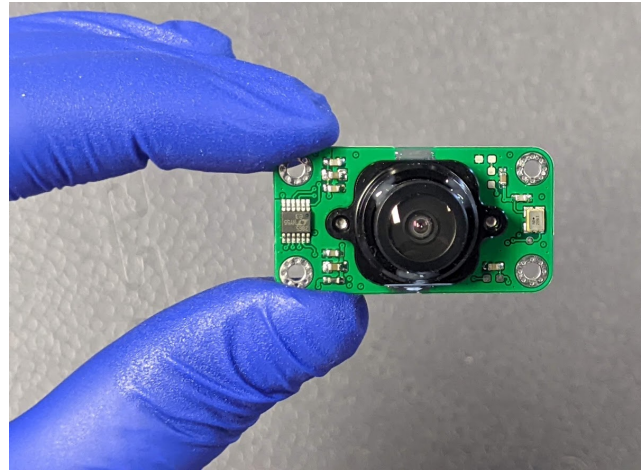


Figure 1: KissCAM miniature CubeSat camera.

The KissCAM is designed around the Microsemi AR0130 automotive CMOS image sensor. Onboard power regulation allows KissCAM to be powered from either 3.3 or 5V at 78mA. Communication with KissCAM is via an RS422 interface, which is readily compatible with most microcontrollers via common RS422/485 bus drivers.

The command and telemetry interface is simple to understand and implement. Essential functions, such as setting the exposure and capturing images can be accessed through single telecommands. Direct access to image sensor registers is also available for advanced users.

Despite its small size (38 x 20 x 18mm) and mass (10g), KissCAM features all glass and metal optics. A low-profile, wide-angle lens is fitted as stock, but the aluminium s-mount lens holder allows compatibility with a wide variety of commercial M12 lenses.

High reliability is achieved through conservative PCB layout, automotive-grade components, IPC-qualified inspection, workmanship thermal cycling and burn-in of every unit.

2. Absolute Maximum Ratings

Table 1: Absolute Maximum Ratings of KissCAM

Parameter	Rating	Unit	Notes
Supply Voltage	−0.3 to +6	V	±15kV ESD protected
RS422 Interface Input	−60 to +60	V	
Current Consumption	120	mA	
Storage Temperature	−20 to +85	°C	

Note: Stresses above those listed under Absolute Maximum Ratings can cause permanent damage to the device.

3. Electrical Specifications

Table 2: Electrical Specifications and standard operating conditions.

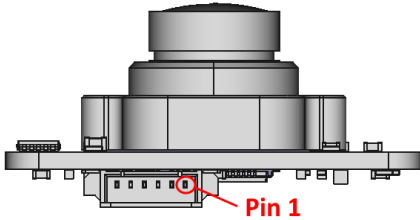
Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions
Supply Voltage	V_{dd}	3.2	3.3	5.5	V	Compatible with 3.3 and 5V supplies.
Current Consumption	I_{dd}	50	78		mA	Minimum after power on.
RS422 Interface Baud	b		115200		baud	8 data bits, 1 stop bit, no parity.
RS422 Output Voltage ²	V_o	1.5		V_{dd}	V	Full RS422 compliance.

² Refer to Linear Technology LTC2865 datasheet.

4. Pinout

Electrical interfacing to KissCAM is via a single 6-way Molex Picoblade connector (53261-0671).

Table 3: Electrical Pinout

Pin	Function	Connector Location
1	Ground	
2	V_{dd}	
3	Rx+	
4	Rx-	
5	Tx+	
6	Tx-	

5. Mechanical Specifications

KissCAM was designed from the ground up to be compatible with even the smallest CubeSats, while still offering the flexibility of a standard M12 lens mount. MVP Aerospace offers a wide-angle lens as standard, but customers can order KissCAM without a lens if they wish to fit their own.

KissCAM is designed to be mounted using four M2 cap-head screws. It is light enough to be mounted as a daughter board on standard 1.6mm thickness PC104 cards, as are common in CubeSats. In this way, KissCAM can easily be added as a primary or auxiliary payload on the Z+/Z- end of the PC104 card stack. Alternatively, KissCAM can be mounted to the X or Y panels using standoffs.

All KissCAM materials have been carefully chosen to be low-outgassing. The Molex Picoblade connector has extensive flight heritage, the lens mount is anodised aluminium, and the stock lens is all metal and glass construction. The PCB material is FR4 Tg 155. All staking is performed with flight heritage epoxy.

The customer is responsible for staking the connector and mounting screws.

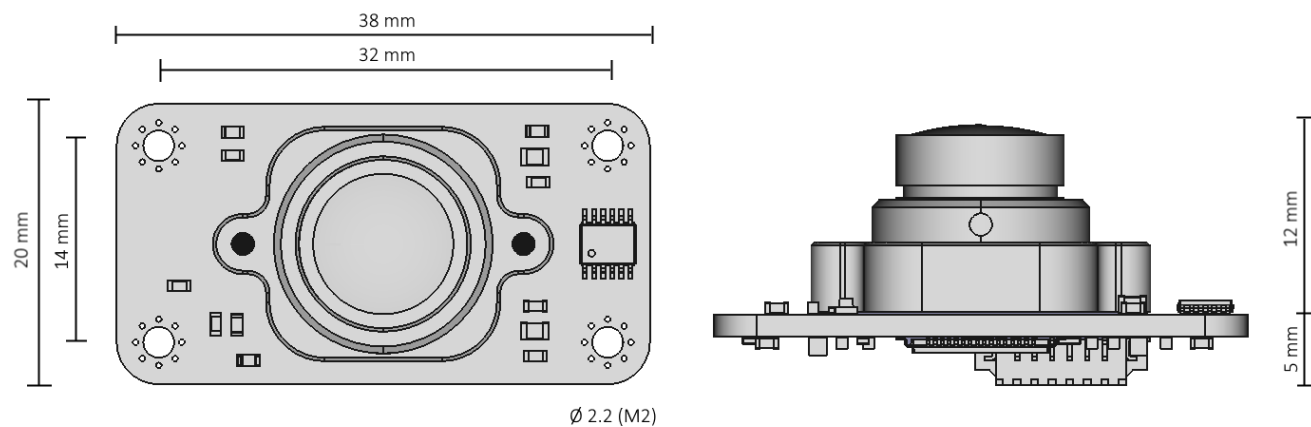


Figure 2: KissCAM primary dimensions. Refer to the CAD model for more detailed information.

Table 4: Mechanical and Optical properties

Parameter	Value	Unit	Notes
Length	38	mm	1mm tolerance.
Width	20	mm	
Height	17	mm	
Weight without lens	7	g	All metal and glass lens
Weight of stock lens	3	g	
Stock Field of View	160 x 120	Degrees	At full resolution
Mounting holes	4 x 2.2mm		Use aerospace standard torquing
Mounting hardware	4 x M2 screws		

6. Command and Telemetry

The command and telemetry interface, which operates over RS422 at 115200 baud, is designed for simplicity and ease of integration. Commands, in the form of byte sequences (packets), are sent to the KissCAM from a host system and telemetry packets are returned. All commands have the same format and length, and all result in a telemetry response. Most commands simply return an acknowledge packet, while others return image or other data. KissCAM sends no unsolicited telemetry.

It is mandatory to wait for a response to a command before sending the next one. A 2000 ms timeout may be used to detect stalled or broken communication, in which case the command can be retried or KissCAM power cycled.

6.1 Command Format

Command Format						
0x40 '@'	Command Byte	Param 1	Param 2	Param 3	Param 4	0x0D '\r'

Every command has the same format and is composed of seven bytes. The first byte is always a start byte of 0x40 '@'. Thereafter comes a command byte. As KissCAM is designed for simplicity, there are only eight unique commands. The command bytes typically have easy to remember ASCII representations, such as 'C' for capture, and 'D' for download. See Section 5.3 for an overview of available commands, and Section 6 for details.

After the command byte there are four parameter bytes. How these bytes are utilised is command dependent. For example, some commands utilise 8-bit parameters, while others use 16-bit parameters (MSB transmitted first). Not all parameter bytes are used by every command. If a parameter is not used by a command it must still be transmitted (keeping the total command length at 7 bytes), but its value is ignored by KissCAM. It is recommended to transmit 0x00 for unused parameters.

Finally, every command must be terminated with a carriage return character: 0x0D '\r'.

6.2 Telemetry Format

Telemetry Format						
0x40 '@'	Command Byte	Reserved	ACK	Telem 1	Telem 2	0x0D '\r'

All telemetry packets, **with the exception of the *Download* response**, have the same format and length of seven bytes. The first byte of a returned telemetry packet is always the start character 0x40 '@', followed by a copy of the command byte. The third byte is reserved and should be ignored.

The fourth byte is important, as it is an Acknowledge byte. A value of zero indicates successful reception and interpretation of the command by KissCAM. Other returned Acknowledge values indicate an invalid command byte or parameter(s).

After the Acknowledge byte come two command dependent telemetry bytes. The details of these telemetry values are given in Section 6. The telemetry bytes can represent two 8-bit values, or a single 16-bit value (MSB transmitted first).

Finally, every telemetry packet is terminated with a carriage return character: 0x0D '\r'.

The format of the ***Download*** telemetry response differs slightly. Image data is additionally included before the end of packet carriage return character. The number of image data bytes depends on the requested image resolution. See Section 6.6 for details.

6.3 Command and Telemetry Summary

The table below gives a summary of the available commands and their responses. It is strongly recommended that all available commands be made available at system telecommand level. The **Read Register** and **Write Register** commands should only be used with guidance from MVP Aerospace, as incorrect use can cause permanent damage to KissCAM. Details on the commands and responses are given in Section 5.4.

Table 5: Command and Telemetry Summary

Command Name	Command	Description	Response	Section
Sensor Initialise	0x58 'X'	Initialise or reset image sensor.	Ack	6.4.1
Ping	0x50 'P'	Basic health check	Ack	6.4.2
Time	0x54 'T'	Return KissCAM uptime (seconds)	Uptime (s)	6.4.2
Set Exposure	0x45 'E'	Set image exposure time.	Ack	6.4.3
Capture	0x43 'C'	Capture a new image	Ack	6.4.4
Download	0x44 'D'	Download a a row of image data	Image data	6.4.5
Read Register	0x52 'R'	Read an image sesor register directly	Register Contents	6.4.6
Write Register	0x57 'W'	Write an image sensor register directly	Ack	6.4.7

6.4 Command and Telemetry Details

6.4.1 Initialise Image Sensor

After power on the image sensor is kept in hardware reset by the microcontroller. Issuing the **Initialise Image Sensor** command brings the sensor out of reset and goes through an initialisation process. This includes checking I2C communication with the sensor and setting up default image sensor register settings. An ACK response of 0x01 is returned upon successful completion of the initialisation process and KissCAM current consumption should increase from 55mA to 75mA. Hereafter, KissCAM can begin capturing images.

The **Initialise Image Sensor** command can be resent at any time to re-initialise the image sensor. This will return the image sensor to its default settings.

Initialise Image Sensor Command						
0x40 '@'	0x58 'X'	0x00	0x00	0x00	0x00	0x0D '\r'

All command parameters are ignored.

Initialise Image Sensor Response						
0x40 '@'	0x58 'X'	Reserved	ACK	RXV	RXF	0x0D '\r'

ACK Acknowledge byte. 0x00 Success, Other Fail.

RXV Number of successfully received commands. Rolls over at 256.

RXF Number of invalid commands received. Rolls over at 256.

6.4.2 Ping

The **Ping** command is used to check communication and basic health status of KissCAM. Nominally, the response to a **Ping** command is a reply with an ACK and two telemetry points giving the number of valid and invalid commands received. Invalid commands have the correct format, but an invalid command byte or parameter(s).

The **Ping** command has a single parameter (the rest are ignored). The parameter byte selects whether the image sensor communication should be tested, too. If a parameter of 0x01 is given, KissCAM will attempt to read the image sensor ID register over I2C. If successful (the ID matches the expected value), KissCAM will return an ACK. No response or an incorrect response from the image sensor will return a NACK (non-zero ACK byte).

Note that issuing a **Ping** command with a parameter of 0x01 before the image sensor has been initialised with the **Initialise Image Sensor** command will result in a NACK (non-zero ACK byte).

Initialise Image Sensor Command						
0x40 '@'	0x50 'P'	P1	0x00	0x00	0x00	0x0D '\r'

^{P1} Ping Type. 0x00 MCU only, 0x01 MCU and Image Sensor.

Initialise Image Sensor Response						
0x40 '@'	0x50 'P'	Reserved	ACK	RXV	RXF	0x0D '\r'

^{ACK} Acknowledge byte. 0x00 Success, Other Fail.

^{RXV} Number of successfully received commands. Rolls over at 256.

^{RXF} Number of invalid commands received. Rolls over at 256.

6.4.3 Time

The KissCAM has an internal uptime clock that starts at zero every time KissCAM is powered on and increments at roughly one second resolution. The clock is read with the **Time** command. Uptime is returned as a 16 bit number, most-significant byte first.

Time Command						
0x40 '@'	0x54 'T'	P1	0x00	0x00	0x00	0x0D '\r'

All command parameters are ignored.

Time Response						
0x40 '@'	0x54 'T'	Reserved	ACK	TM1	TM2	0x0D '\r'

^{ACK} Acknowledge byte. 0x00 Success, Other Fail.

^{TM1} KissCAM uptime in seconds (Most Significant Byte).

^{TM2} KissCAM uptime in seconds (Least Significant Byte).

6.4.4 Set Exposure

By default, KissCAM makes use of manual exposure settings. This is because autoexposure algorithms can struggle with the extreme contrast between the blackness of space and the sunlit Earth, especially if the satellite is rotating. Fortunately, kissCAM makes setting the exposure simple. The command **Set Exposure** takes a single parameter to define the exposure. The parameter specifies the exposure in steps of 89.5 microseconds, and can range from 2 to 960. Therefore, the default setting of 672 gives an exposure time of:

$$672 \times 89.5 = 60.144 \text{ ms.}$$

The default exposure time is typically good for taking indoor images in a lab environment. Much lower exposure settings are required for images taken outdoors or from space. As a starting point, MVP Aerospace recommends an exposure setting of 10 for in-orbit images. More advanced exposure settings can be applied with guidance from MVP Aerospace.

Set Exposure Command						
0x40 '@'	0x45 'E'	EXP1	EXP2	0x00	0x00	0x0D '\r'

EXP1 Exposure Most Significant Byte.

EXP2 Exposure Least Significant Byte.

Set Exposure Response						
0x40 '@'	0x45 'E'	Reserved	ACK	RXV	RXF	0x0D '\r'

ACK Acknowledge byte. 0x00 Success, Other Fail.

RXV Number of successfully received commands. Rolls over at 256.

RXF Number of invalid commands received. Rolls over at 256.

6.4.5 Capture

Capturing an image with the KissCAM is simple. The command **Capture** will capture a new image to memory and return an acknowledge response if successful. Thereafter, the image can be downloaded using the **Download** command (Section 5.4.6). Revision A of the KissCAM hardware is fixed at a resolution of 480 x 360 pixels. Each pixel is represented by a single data byte. Therefore, a full image is $480 \times 360 = 172800$ bytes, or 168.75 kB, in size.

The only parameter used by the **Capture** command selects between two different digital zoom, or field-of-view, settings. A parameter setting of 0x00 gives a 480 x 360 resolution image from the center of the image sensor's full field-of-view. A parameter setting of 0x01 gives a field-of-view twice as wide by skipping every other pixel. See Figure 3 for example images taken with the two different parameter settings.

The image sensor has a bayer colour pattern overlaid. This is a common technique for achieving colour images. The bayer pattern follows the sequence shown in Figure 4. If the raw data is plotted as an 8-bit greyscale image, a checkerboard pattern is typically visible. MVP Aerospace provides a utility for converting the raw images into colour. This utility is based on the Python OpenCV `cvtColor(im, cv2.COLOR_BayerGR2RGB)` function. Alternatively, commercial photo editing software capable of handling RAW images can perform the conversion.

After conversion to colour, most images will require white-balancing. This is a common process in photo editing and can be performed in most photo editing software. For more advice on raw image data processing, please contact MVP Aerospace.



Figure 3: Example images taken in a lab environment with the two field-of-view parameter settings of the Capture command. The image on the left is a 480 x 360 full-resolution extract from the center of the image sensor's field of view (parameter 0x00), while the image on the right gives a FOV twice as wide by skipping every other pixel (parameter 0x01).



Figure 4: Left - The image sensor's bayer pattern. Centre - Raw image data displayed in 8-bit greyscale displays a subtle checkerboard pattern. Right - a zoomed-in view of the checkerboard pattern caused by the bayer filter.

Capture Command						
0x40 '@'	0x43 'C'	PM1	0x00	0x00	0x00	0x0D '\r'

PM1 Field-of-view selection. 0x00 is normal. 0x01 is wide-angle.

Capture Response						
0x40 '@'	0x43 'C'	Reserved	ACK	RXV	RXF	0x0D '\r'

ACK Acknowledge byte. 0x00 Success, Other Fail.

RXV Number of successfully received commands. Rolls over at 256.

RXF Number of invalid commands received. Rolls over at 256.

Note that Revision A hardware does not have non-volatile memory. A single image can be captured to RAM memory at a time. Capturing a new image will overwrite the previously captured image.

6.4.5 Download

Once an image has been captured with the **Capture** command (Section 6.4.5) it can be downloaded. Images are downloaded one image line at a time, simplifying the process of packetising the data for ground-station downlink.

The **Download** command takes two parameters: A line number and a preview flag. The line number parameter specifies which line of image data should be downloaded, starting at line zero. Lines can be downloaded as many times as desired, allowing missed data to be re-downloaded. Not all lines need to be downloaded. A new image can be taken after downloading all, some, or none of the lines.

The preview flag parameter can be set to 0x00 or 0x01. This specifies whether a full resolution (480 x 360) or thumbnail resolution (48 x 36) image should be downloaded. Since CubeSats typically have limited downlink bandwidth, the thumbnail resolution images are useful for checking the usefulness of a captured image. For example, the thumbnail resolution should be sufficient for confirming that the Earth is in the field of view and exposed correctly. The same image can be downloaded in both preview and full resolution as many times as desired.

Every valid **Download** command will result in a KissCAM response. The format of the **Download** response is different to the other response packet types as it additionally contains the specified row's pixel data (480 bytes for full resolution downloads, or 48 bytes for thumbnail downloads). Therefore, to download a full image at full resolution the **Download** command should be sent 360 times with the row parameter incrementing from 0 to 359. Similarly, to download a full thumbnail resolution image, the **Download** command should be sent 36 times with the row parameter incrementing from 0 to 35.

See the **Download** command and response formats below:

Download Command						
0x40 '@'	0x44 'D'	LN1	LN2	PRE	0x00	0x0D '\r'

LN1 Image line number (Most significant Byte).

LN2 Image line number (Least Significant Byte).

PRE Image Preview. 0x00 is full resolution. 0x01 is thumbnail.

Download Response							
0x40 '@'	0x44 'D'	Reserved	ACK	LN1	LN2	IMG	0x0D '\r'

ACK Acknowledge byte. 0x00 Success, Other Fail.

LN1 Image line number (Most significant Byte).

LN2 Image line number (Least Significant Byte).

IMG One line of image data. Either 480 or 48 bytes long.

Note that Revision A hardware does not have non-volatile memory. A single image can be stored in RAM memory at a time. Capturing a new image will overwrite the previously captured image. An image in RAM can be downloaded as many times as desired until KissCAM power is removed and the image data is lost.

6.4.6 Read Register

The **Read Register** command reads a specified 16-bit register directly from the image sensor over I2C. It exposes advanced functionality beyond the basic KissCAM telecommands. Its use should be limited to the specific test cases below, or after consultation with MVP Aerospace.

To test the system-level implementation of this telecommand, the exposure time register can be read at address 0x3012. The value of this register is 0x02A0 after power-up, or as set by the **Set Exposure** command.

Read Register Command						
0x40 '@'	0x52 'R'	AD1	AD2	0x00	0x00	0x0D '\r'

AD1 16-bit Register Address (Most significant Byte).

AD2 16-bit Register Address (Least Significant Byte).

Read Register Response						
0x40 '@'	0x52 'R'	Reserved	ACK	RG1	RG2	0x0D '\r'

ACK Acknowledge byte. 0x00 Success, Other Fail.

LN1 16-bit Register Data (Most significant Byte).

LN2 16-bit Register Data (Least Significant Byte).

6.4.7 Write Register

The **Write Register** command writes a specified 16-bit value to a specified 16-bit image sensor register over I2C. It exposes advanced functionality beyond the basic KissCAM telecommands. Its use should be limited to the specific test cases below, or after consultation with MVP Aerospace. **Writing incorrect register settings can cause permanent damage to the device.**

To test the system-level implementation of this telecommand, the exposure time register can be written at address 0x3012. After a write, the new register value can be verified with the **Read Register** command (Section 6.4.6).

Write Register Command						
0x40 '@'	0x57 'W'	AD1	AD2	RG1	RG2	0x0D '\r'

AD1 16-bit Register Address (Most significant Byte).

AD2 16-bit Register Address (Least Significant Byte).

RG1 16-bit Register Data (Most significant Byte).

RG2 16-bit Register Data (Least Significant Byte).

Write Register Response						
0x40 '@'	0x57 'W'	Reserved	ACK	RXV	RXF	0x0D '\r'

ACK Acknowledge byte. 0x00 Success, Other Fail.

RXV Number of successfully received commands. Rolls over at 256.

RXF Number of invalid commands received. Rolls over at 256.

7. Operations

Typical KissCAM operational sequences are given in this section. Simple Python test scripts demonstrating these sequences are available from MVP Aerospace, as well as a desktop application with graphical user interface for interacting with KissCAM directly via a USB to RS422 converter.

7.1 Comprehensive Image Acquisition

The following sequence describes a full power-up, health-check, exposure setting, image capture, and image download sequence. In all cases a NACK or lack of Acknowledge response to a telecommand should be treated as an error case and the offending telecommand should be retried or the procedure aborted with a KissCAM power cycle.

1. Apply power (3.2 to 5.5V) to KissCAM.
2. Delay 100 ms.
3. Verify via host that current consumption is 50 mA (± 5).
4. Send *Ping* command with parameter **0x00** and wait for ACK.
5. Send *Initialise Image Sensor* command and wait for ACK.
6. Verify via host that current consumption has increased to 77 mA (± 5).
7. Send *Ping* command with parameter **0x01** and wait for ACK.
8. Send *Set Exposure* command with parameter e.g. **0x0123** and wait for ACK.
9. Delay 500 ms or more to allow new exposure setting to apply.
10. Send *Capture* command with parameter 0x00 (narrow field of view) and wait for ACK.
11. Send *Download* command with parameters 0x0000 (row number), and 0x00 (full resolution).
12. Wait for ACK containing first row's 480 bytes of image data.
13. Repeat steps 11 and 12, incrementing the row number parameter through to 359.
14. Remove power from KissCAM

6. Quick Start Guide

To follow.