



Communication protocol for EmStat Pico

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Chapter 1. Introduction

This document describes the “online” communication protocol of the EmStat Pico.

Initial communication with the EmStat Pico is always done using this online communication. Measurements and other scripts can be started by sending a MethodSCRIPT, more information about MethodSCRIPT can be found here: <http://www.palmsens.com/methodscript>

1.1. Terminology

PGStat	Potentiostat / Galvanostat
EmStat	PGStat device series by PalmSens
CE	Counter Electrode
RE	Reference Electrode
WE	Working Electrode
Technique	A standard electrochemical measurement technique
Iteration	A single execution of a loop
Int	Integer value
Float	Floating-point number (e.g. 3.14)
SI	International System of Units
Var	(MethodSCRIPT) variable (usually command input)
HEX	Hexadecimal (= base 16) number (e.g. 0xA1)
RAM	The (volatile) work memory of the instrument, which is lost after a power cycle
NVM	Non-Volatile Memory, i.e. memory that retains its contents after a power cycle
CRC	Cyclic Redundancy Check, an error-detecting code
CRC16	A 16-bit CRC

Chapter 2. Communication

The EmStat Pico has a UART (Serial) port as communication interface. To connect with the instrument, the below settings should be used. Note that the bootloader uses slightly different settings than the application firmware. Normally the application firmware is used. The bootloader is only used for maintenance tasks such as firmware updates.

Table 1. EmStat Pico UART connection details.

Property	Bootloader	Application
Signal level	3.3 V	
Baud rate	230400 bps	230400 bps ¹
Number of data bits	8	
Number of stop bits	1	
Parity	None	
Flow control	None	Software (XON/XOFF)

¹ Default baud rate. This can be configured.



The EmStat Pico firmware uses XON/XOFF (software) flow control. It is highly recommended to enable XON/XOFF flow control on the host side as well. This ensures a reliable communication, even at high speeds and when the instrument or host is busy with other tasks.

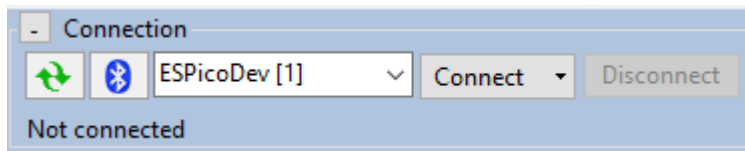


During startup the instrument may send an XON character (ASCII character with decimal value 17). In case software flow control is not enabled on the host, the host software should ignore the XON character.

2.1. Connection viewer

PSTrace version 5.6 or higher has a hidden feature that is useful when the communication protocol is used for development of software for the EmStat Pico. PSTrace will open the *Connection viewer* window when you double-click on the "Not connected" label before connecting to the device.

The "Not connected" label used to activate the Connection Viewer window.



Once connected, the connection viewer window will show all messages transmitted to the instrument (in red), and messages received from the instrument (in green). This can be helpful to understand the communication between the host and the instrument. Below is an example of the connection viewer window.

The connection viewer window.

```
t
tespico11#Jun 18 2019 09:47:31
R*
G06
G001200000000897B
a83DB8F00BC66B3624F678202A892F9EA
a3A0000000000000000000000000000018DFE1D858D978E65E5F3DC57D36DFF2D30BD261B6289
2A3F2D92F8CAE78A795700FD571F86DFE5541
e
set_pgstat_chan 1
set_pgstat_mode 0
set_pgstat_chan 0
set_pgstat_mode 3
set_cr 850n
set_autoranging 850n 850n
set_max_bandwidth 100
cell_off
set_pot_range 0 0
set_e 0

e
e
set_cr 850n
cell_off
```

Pause

2.2. Communication protocol

All commands and responses are terminated with a newline character. The used newline character is the Line Feed (LF) character ('`\n`', ASCII code 10 or 0x0A). The instrument never transmits a Carriage Return (CR) character ('`\r`', ASCII code 13 or 0x0D) and CR characters received by the instrument are ignored.

When a command is received by the instrument, it will echo the first character of the command and then respond with the command-specific data. After executing the command, a newline character is transmitted. If an error occurs during the execution of a command, the error is returned just before the newline character. See section [Chapter 8, Error handling](#) for more information about errors.

2.3. Communication modes

The device can be in two communication modes on which a subset of commands are available. These modes are listed below.

- Idle mode: for storing scripts and changing settings
- Script execution mode: during script execution



While in idle mode the EmStat Pico will automatically go into a *sleep* mode where the processor is stopped to preserve power. All other hardware stays active and it will automatically resume execution when commands are received. From the user perspective this is unobservable, so it will behave the same as if the processor would be running.

Chapter 3. Command summary

The following table gives an overview of all communication protocol commands.

ID	Command	Modes	Description
0x01	t	All modes	Get firmware version
0x20	CC	Idle	Get runtime capabilities
0x21	CM	Idle	Get MethodSCRIPT capabilities
0x22	S	Idle	Set register
0x23	G	Idle	Get register
0x24	l	Idle	Load MethodSCRIPT
0x25	r	Idle	Run loaded MethodSCRIPT
0x26	e	Idle	Execute (= load and run) MethodSCRIPT
0x27	dlfw	Idle	Enter bootloader
0x2B	Fmscr	Idle	Store loaded MethodSCRIPT to NVM
0x2C	Lmscr	Idle	Load MethodSCRIPT from NVM
0x30	i	Idle	Get serial number
0x31	v	Idle	Get MethodSCRIPT version
0x33	fs_dir	Idle	Get directory listing
0x34	fs_get	Idle	Read file
0x35	fs_put	Idle	Write file
0x36	fs_del	Idle	Delete file or directory
0x37	fs_info	Idle	Get file system information
0x38	fs_format	Idle	Format storage device
0x39	fs_mount	Idle	Mount file system
0x3A	fs_unmount	Idle	Unmount file system
0x3B	fs_clear	Idle	Clear file system
0x3C	m	Idle	Get multi-channel serial number
0x60	h	Script	Halt script execution
0x61	H	Script	Resume script execution
0x62	Z	Script	Abort script execution
0x63	Y	Script	Abort measurement loop
0x65	R	Script	Reverse CV sweep

Chapter 4. Command details

A list of all commands is given in the previous chapter. In this chapter, each command is described in more detail.

Some commands have one or more arguments. The format and meaning of such arguments is documented in those sections as well.



Commands are case-sensitive. For example, `s` (hibernate) is a different command than `S` (Set register).

4.1. Get firmware version (t)

Get the device firmware version. This includes the device type, firmware version, build date and release type.

Command format

```
t
```

Response format

Unlike most other commands, this command has a response consisting of multiple lines. The last line is terminated with an asterisk and a newline character (`'*\n'`). The format is as follows:

```
tddddddvv..vv#mmm dd yyyy hh:mm:ss  
R*
```

Key	Type	Size	Description
dddddd	text	6	The device type. For the EmStat Pico this is <code>espico</code> .
vv..vv	text	2/4	The firmware version. This could be either: <ul style="list-style-type: none">a 2-digit version identifier <code>xy</code>, denoting firmware version <code>x.y</code> (e.g. <code>10</code> corresponds to firmware version 1.0).a 4-digit version identifier <code>xyzz</code>, denoting firmware version <code>x.y.zz</code> (e.g. <code>1201</code> corresponds to firmware version 1.2.01).
mmm dd yyyy hh:mm:ss	text	20	The build date and time.
R	text	1	The release type: <ul style="list-style-type: none"><code>R</code> for Release versions.<code>B</code> for Beta versions.
*	text	1	Marks the end of the response.

Example

Below are some examples to demonstrate the format of the output.

Example output for an EmStat Pico with firmware v1.0

```
tespico10#Apr 1 2019 15:48:13  
R*
```

Example output for an EmStat Pico with firmware v1.3.04

```
tespico1304#Oct 22 2021 14:38:26  
R*
```



Since firmware V1.3 the versioning switched to semantic formatting and gained 2 digits.

4.2. Set register (S)

Sets the value of a register. Registers contain instrument specific configuration, settings and information that are accessible to the user. See [Chapter 6, Register details](#) for more information.



Some registers require a specific permission level to be accessed. See [Section 6.2, "Permission level \(0x02\)"](#) for more details.

Command format

```
Sxxyy...yy
```

Key	Type	Size	Description
xx	hex	2	Register identifier (see Chapter 6, Register details)
yy...yy	hex	variable	Value to write to the register, the number of digits depend on the register.

Response format

```
S
```

Example

The following example demonstrates writing the value `0xABCDEF12` to register `0x99` (= 153 decimal).

Example set register command

```
S99ABCDEF12
```

Example output

```
S
```

4.3. Get register (G)

Gets the value of a register. Registers contain instrument specific configuration, settings and information that are accessible to the user. See [Chapter 6, Register details](#) for more information.



Some registers require a specific permission level to be accessed. See [Section 6.2, "Permission level \(0x02\)"](#) for more details.

Command format

```
Gxx
```

Key	Type	Size	Description
xx	hex	2	Register identifier (see Chapter 6, Register details)

Response format

```
Gyy...yy
```

Key	Type	Size	Description
yy..yy	hex	variable	The value of the register when queried, the number of bytes depends on the register (see Chapter 6, Register details).

Example

The following example demonstrates how to get the device serial (register 0x06) from the instrument.

Example get register command

```
G06
```

Example output

```
G001200000000899B
```

4.4. Load MethodSCRIPT (l)

Load a MethodSCRIPT into RAM. The end of the script is indicated by an empty line (i.e., a line containing only the newline character `\n`). The MethodSCRIPT is parsed during reception. Some script errors that can be detected during parsing, such as syntax errors, are reported directly. If an error is encountered during parsing, the script memory is cleared, so a new script must be loaded. If the script was loaded successfully (no error was returned during loading), then the script can be executed by the `r` command (see [Section 4.5, "Run loaded MethodSCRIPT \(r\)"](#)).

Command format

This command consists of multiple lines. The first line contains only the `l` command. Then, the MethodSCRIPT is transmitted, line by line. After the last MethodSCRIPT line, an empty line must be transmitted to end the command.

```
1 l
2 mm
3 ..
4 mm
```

Key	Type	Size	Description
<code>mm..mm</code>	text	variable	The MethodSCRIPT to load, terminated with an empty line. See the MethodSCRIPT documentation for more information.

Response format

```
l
```

Example

The following example loads a MethodSCRIPT that prints "Hello World" 5 times when executed. It can then be executed with the run command, see [Section 4.5, "Run loaded MethodSCRIPT \(r\)"](#),

Example command (the newline characters are included here for clarity)

```
l\n
var i\n
store_var i 0i ja\n
loop i < 3i\n
  send_string "Hello World"\n
  add_var i 1i\n
```

```
endloop\n\n
```

Example output (the newline characters are included here for clarity)

```
l\n
```

4.5. Run loaded MethodSCRIPT (r)

Run (execute) loaded MethodSCRIPT from RAM.

Command format

```
r
```

Response format

The output of this command starts with `r\n` to denote the successful start of the script. This response is then followed by the output of the MethodSCRIPT, which depends on the actual script that is running. See the MethodSCRIPT documentation to see what type of responses can be expected. Note that a MethodSCRIPT does not have to transmit data, but most scripts do. When the MethodSCRIPT is finished (either successfully or with an error), an empty line is transmitted.

Summarized, the output format is:

```
r\npp..pp\n...\npp..pp
```

Key	Type	Size	Description
pp..pp	text	variable	The MethodSCRIPT output. See the MethodSCRIPT documentation for more information.

Example

The following demonstrates running the MethodSCRIPT loaded in the example from [Section 4.5, “Run loaded MethodSCRIPT \(r\)”](#).

Example command (the newline characters are included here for clarity)

```
r
```

Example output (the newline characters are included here for clarity)

```
r
L
THello World
THello World
THello World
+
```



L and + are MethodSCRIPT hints about entering and leaving a loop.

4.6. Execute (= load and run) MethodSCRIPT (e)

Load and run a MethodSCRIPT (same as L followed by r).

Command format

```
e
mm
..
mm
```

Key	Type	Size	Description
mm..mm	text	variable	The MethodSCRIPT to load, terminated with an empty line. See the MethodSCRIPT documentation for more information.

Response format

```
e
pp..pp
...
pp..pp
```

Key	Type	Size	Description
pp..pp	text	variable	The MethodSCRIPT output. See the MethodSCRIPT documentation for more information.

Example

The following demonstrates loading and running the same MethodSCRIPT as used in the example from [Section 4.5, "Run loaded MethodSCRIPT \(r\)"](#).

Example command

```
e
var i
store_var i 0i ja
loop i < 3i
  send_string "Hello World"
  add_var i 1i
endloop
```

Example output

```
e
L
THello World
THello World
THello World
+
```

4.7. Store loaded MethodSCRIPT to NVM (Fmscr)

Store a loaded MethodSCRIPT to non-volatile memory (NVM).

Command format

```
Fmscr
```

Response format

```
F
```

Example

The following example demonstrates loading a script with `l` and storing it into the instrument's non-volatile memory.

Example command

```
l
send_string "Hello World!"

Fmscr
```

Example output

```
L  
F
```

4.8. Load MethodSCRIPT from NVM (Lmscr)

Load a MethodSCRIPT from non-volatile memory (NVM). After the script has been loaded successfully, it can be executed by the `r` command (see [Section 4.5, “Run loaded MethodSCRIPT \(r\)”](#)).

A MethodSCRIPT can only be loaded from NVM if it was written using the same MethodSCRIPT version as the current firmware supports.

Command format

```
Lmscr
```

Response format

```
L
```

Example

This example shows how to load a script from non-volatile memory (NVM) and execute it with an `r` command. The loaded script here was loaded in the example from [Section 4.8, “Load MethodSCRIPT from NVM \(Lmscr\)”](#)

Example command

```
Lmscr  
r
```

Example output

```
L  
r  
THello World!
```

4.9. Get serial number (i)

Get the serial number of the instrument.



For some instruments, this is not the same as the serial printed on the housing.

Command format

```
i
```

Response format

```
ixx..xx
```

Key	Type	Size	Description
xx..xx	text	variable	The serial number.

Example

The following example queries the device serial.

Example command

```
i
```

Example output

```
iEP1CA8CX
```

4.10. Get multi-channel serial number (m)

Get the device serial number from a multi-channel instrument.



The EmStat Pico does not support multi-potentiostat configurations, so this command will always throw an error.

Example output for devices without multichannel support

```
m!0048
```

4.11. Get MethodSCRIPT version (v)

Get the MethodSCRIPT version. This number indicates the internal storage representation of a MethodSCRIPT rather than the version of MethodSCRIPT specification. The MethodSCRIPT version number is used to determine if the MethodSCRIPT stored in NVM (using the `Fmscr` command) can be loaded or not. A list of EmStat Pico firmware versions and the associated MethodSCRIPT versions is given below.

EmStat Pico firmware version	MethodSCRIPT version
1.0	0001
1.1	0002
1.2	0003
1.3.0	0004
1.3.1	0004
1.3.2	0004
1.3.3	0005
1.3.4	0005
1.3.5	0005
1.5.0	01.07.00

Command format

```
v
```

Response format

```
VXX.XX
```

Key	Type	Size	Description
xx.xx	text	variable	The MethodSCRIPT version supported by the firmware.

Example

This example demonstrates reading the MethodSCRIPT version.

Example command

```
v
```

Example output (MethodSCRIPT version = 1.6.0)

```
v01.06.00
```

4.12. Enter bootloader (dlfw)

Resets the instrument into bootloader mode. The bootloader is mainly intended to perform firmware updates.



On the EmStat Pico, this command will erase the current application firmware before entering the bootloader. This means that no measurements can be performed anymore until a firmware update has been performed successfully.

Command format

```
d\fw
```

Response format

```
d
```

4.13. Get directory listing (`fs_dir`)

Get a list of all files in the specified directory.



It might take some time to find all files on the file system.



On EmStat4 and EmStatPico based devices `fs_dir` recursively shows files in subdirectories. On the Nexus, only the immediate directory contents are shown.

Command format

```
fs_dir [path]
```

Key	Type	Size	Description
[path]	text	variable	(Optional) Path of the directory to search. If no path is provided, all files on the file system are included.

Response format

The response will consist of one line of information for each file found. The information includes the file date and time, type (directory or normal file), size, and path. The response ends with an empty line.

```
f  
YYYY-MM-DD hh-mm-ss;TTT;SS..SS;pp..pp  
...  
YYYY-MM-DD hh-mm-ss;TTT;SS..SS;pp..pp
```

Key	Type	Size	Description
YYYY	dec	4*	File date [†] , year
MM	dec	2*	File date [†] , month (01-12)
DD	dec	2*	File date [†] , day (01-31)
hh	dec	2*	File time [†] , hours (00-23)
mm	dec	2*	File time [†] , minutes (00-59)
ss	dec	2*	File time [†] , seconds (00-59)
TTT	text	3	File type (FIL for file, DIR for directory)
SS..SS	dec	variable (1-10)	File size in bytes
pp..pp	text	variable	Path to the file/directory



* Older firmware versions may print the decimal fields without padding, e.g:
`0-0-0 0-0-0;FIL;0;empty.txt`



† The file date and time are based on the [system date and time](#). In order to have a meaningful file date/time, make sure to set the system date and time before creating a file.



Depending on the device, the timestamp associated with a file may be its creation time or its last modification time. On the EmStatPico, Sensit Wearable, and EmStat4, it is the creation time. On the Nexus, it is the last modification time.



In case a file is not closed correctly, the file size will be reported as 4294967295 bytes. This can happen if an instrument is powered down while a file was still open. In this case, a small amount of data that was not flushed to the file storage yet might be lost. However, the file should still be readable, and the correct amount of data (that has been successfully written) will be returned.

Example

The following example lists the content of the `example/doc` directory.

Example command

```
fs_dir example/doc/
```

Example output

```
f
2022-02-22 20:22:02;FIL;4;example/doc/test.txt
2022-02-22 22:22:22;FIL;14;example/doc/measurement.txt
```

Example output in case no files are found

```
f
```

4.14. Read file (fs_get)

Read a file from the file system on the instrument.

Command format

```
fs_get <path>
```

Key	Type	Size	Description
<path>	text	variable	Path of the file to retrieve.

Response format

The command `fs_get <path>\n` prints `f\n`, followed by the contents of the requested file. The end of the file is indicated by an ASCII file separator character (`0x1C`). The output ends with an empty line (i.e., a newline character) if the file was read and transmitted successfully, otherwise it ends with an error code. The file separator character is always transmitted, even in case of a file error.

```
f
cc..cc
cc..cc
cc..cc
\x1C
```

Key	Type	Size	Description
cc..cc	text	variable	The file content in ASCII format.
\x1C	-	1	The file separator character (<code>0x1C</code>).

Example

This example requests the contents of the file `example/hello_world.txt`.

Example command

```
fs_get example/hello_world.txt
```

Example output

```
f
```

```
This is an example. Hello World!  
The next line contains an file separator indicating end of transfer.  
\x1C
```

4.15. Write file (fs_put)

Write a file to the file system of the instrument. The file path must be unique. If a file with the same path already exists, an error is returned.

Command format

The command starts with `fs_put <path>\n`, where `path` is the path of the file to write. The following lines are the file contents, that are written to the file. The end of the file is indicated by an ASCII file separator character (`0x1C`).

```
fs_put <path>  
xx..xx  
\x1C
```

Key	Type	Size	Description
<path>	text	variable	The file path.
xx..xx	text	variable	The file content in ASCII format.
\x1C	-	1	The file separator character (<code>0x1C</code>).

Response format

The command returns a `\n` when it is accepted, as all commands do. It also returns an additional empty line (`\n`) when the command is finished.

```
f
```

Example

Example command

```
fs_put example/hello_world.txt  
This is an example. Hello World!  
The next line contains a file separator indicating end of transfer.  
\x1C
```

Example output

```
f
```

4.16. Delete file or directory (`fs_del`)

Remove a file or directory (recursively) from the file system.



This can take a long time for file trees containing many elements.

Command format

```
fs_del <path>
```

Key	Type	Size	Description
<code><path></code>	text	variable	Path of the file or directory to remove.

Response format

```
f
```

Example

The following example removes the file `/log.txt`.

Example command

```
fs_del /log.txt
```

Example output

```
f
```

4.17. Get file system information (`fs_info`)

Get information about the file system (free/used/total space).

The file system information consists of free space, used space and total space.



Due to file system overhead, the total space will be less than the nominal capacity of the storage medium. For example, on a flash chip of 16 MB, the total space could be 15345 kB (approximately 15 MB). Furthermore, files will generally occupy more space than their actual data size. For example, by writing 100 bytes to a file, the used space could increase with 8 kB, and the free size decrease accordingly. The exact amount of overhead depends of the type and size of storage medium.

Command format

Example command

```
fs_info
```

Response format

```
f  
used:UU..UUkB free:FF..FFkB total:TT..TTkB
```

Key	Type	Size	Description
UU..UU	dec	variable	Used size in kB*
FF..FF	dec	variable	Free size in kB*
TT..TT	dec	variable	Total size in kB*

* 1 kB = 1024 bytes

Example

Example command

```
fs_info
```

Example response

```
used:192kB free:7878464kB total:7878656kB
```

4.18. Format storage device (fs_format)

Format the file storage medium (e.g. flash or SD card). This prepares the storage medium to be used as file system. It also removes all existing data.

Formatting a (large) storage device can take some time.

Once the storage device is formatted, it is generally not necessary to use this command again. To only remove all files, it is recommended to use the `fs_clear` command instead. Especially when using an SD card, the `fs_clear` command is much faster than the `fs_format` command.



Formatting the file storage erases all files. This operation cannot be undone.

Command format

```
fs_format
```

Response format

```
f
```

4.19. Mount file system (`fs_mount`)

Mount the file system.



Ensure the file storage medium GPIO pins are configured correctly. See the MethodSCRIPT command `set_gpio_cfg` for more information.

Command format

```
fs_mount
```

Response format

```
f
```

4.20. Unmount file system (`fs_unmount`)

Unmount the file system. This can be used to re-mount the filesystem, in combination with `fs_mount`.

Command format

```
fs_unmount
```

Response format

```
f
```

4.21. Clear file system (`fs_clear`)

Remove all files and folders from the storage medium.

by the instrument, as hexadecimal value. Each bit represent one command, the mapping between bits and commands can be found in [Appendix B, MethodSCRIPT capabilities bit fields](#)

Command format

CM

Response format

CYY

Key	Type	Size	Description
YY..YY	hex	32	Bit fields for MethodSCRIPT commands

Example

Example command

CM

Example response

C0002BFFF87FFFFFFFFFFFFBFFFEE

4.24. Halt script execution (h)

Halt execution of the running MethodSCRIPT.

This "pauses" the script. Execution can be resumed using the **H** command (see [Section 4.25, "Resume script execution \(H\)"](#)).

Command format

h

Response format

h

Example

See the [examples](#) in [Section 4.27](#).

4.25. Resume script execution (H)

Resume execution of the halted MethodSCRIPT.

Command format

```
H
```

Response format

```
H
```

Example

See the [examples](#) in [Section 4.27](#).

4.26. Abort script execution (Z)

Abort execution of the current MethodSCRIPT. This has the same effect as the MethodSCRIPT command `abort`. It effectively stops the execution of the script as soon as possible. If an abort occurs during a (measurement) loop, all `endloop` commands are still executed. Consequently, the `*` and `+` characters that denote the end of a loop will still be transmitted. If the MethodSCRIPT contains an `on_finished:` tag, the commands after it will still be executed. MethodSCRIPT commands after the `on_finished:` tag cannot be aborted.

Unlike the MethodSCRIPT command `abort`, the command can also abort some long-running MethodSCRIPT commands, such as `await_int` and certain measurements.

Command format

```
Z
```

Response format

```
Z
```

Example

See the [examples](#) in [Section 4.27](#).

4.27. Abort measurement loop (Y)

Abort the current measurement loop. This will break the execution of a MethodSCRIPT measurement loop command (i.e., a command starting with `meas_loop_`) after the current iteration. The current measurement iteration, i.e., all MethodSCRIPT commands between the start and the end of the measurement loop, will be executed, but no new iteration will be started. The script will then continue execution after the `endloop` command.

Command format

Y

Response format

Y

Example

Below is an example MethodSCRIPT that performs a linear sweep from -1 V to +1 V, with steps of 250 mV and a scan rate of 100 mV/s. This results in 9 measurements, each 2.5 second apart, with a total runtime of approximately 22.5 seconds. In our example setup, a 100 k Ω resistor was connected to the working electrode, so the measured current is expected to be between -10 μ A and +10 μ A, and the current range is set accordingly.

```
var c
var p
var i
var t
store_var i 0i ja
set_pgstat_mode 2
set_range ba 10u
cell_on
timer_start
meas_loop_lsv p c -1 1 250m 100m
  add_var i 1i
  pck_start
  pck_add i
  pck_add p
  pck_add c
  pck_end
endloop
timer_get t
meas 100m c ba
pck_start
pck_add t
pck_add c
pck_end
on_finished:
cell_off
send_string "Finished"
```

When the program is executed completely, the output will be something like this:

```
e
M0000
Pja8000001i;da7F0BDF9u;ba7678CD7p,10,20F,40
Pja8000002i;da7F48ED6u;ba78DBCE5p,10,20F,40
Pja8000003i;da7F85FB4u;ba7B3E948p,10,20F,40
Pja8000004i;da7FC3092u;ba7DA1200p,10,20F,40
Pja8000005i;da8059967n;ba8D7055Ef,14,20F,40
Pja8000006i;da803D24Cu;ba8265C17p,10,20F,40
Pja8000007i;da807A32Au;ba84C8C26p,10,20F,40
Pja8000008i;da80B7408u;ba872B4DDp,10,20F,40
Pja8000009i;da80F44E5u;ba898E141p,10,20F,40
*
Peb9570C36u;ba898E141p,10,20F,40
TFinished
```

The values in the data packages indicate that the measurement loop took approximately 22.5 seconds, and that the measured current after the measurement loop has the same value as during the last iteration of the loop.

However, if a **Y** command is send after the second iteration, the output will be something like this:

```
e
M0000
Pja8000001i;da7F0BDF9u;ba7679082p,10,20F,40
Pja8000002i;da7F48ED6u;ba78DB93Ap,10,20F,40
Y
Pja8000003i;da7F85FB4u;ba7B3E1F1p,10,20F,40
*
Peb872184Au;ba7D9E9A2p,10,20F,41
TFinished
```

...or, depending on the exact time the **Y** command is received, like this:

```
e
M0000
Pja8000001i;da7F0BDF9u;ba767942Ep,10,20F,40
Pja8000002i;da7F48ED6u;ba78DC43Cp,10,20F,40
Y
*
Peb84D7686u;ba7B3E948p,10,20F,40
TFinished
```

In this case, the values indicate that the measurement loop only took 5 seconds, and that the WE potential remained at the value it had at the end of the last iteration that was executed.

By halting the program after the second iteration, the output would be:

```
e
M0000
Pja8000001i;da7F0BDF9u;ba767942Ep,10,20F,40
Pja8000002i;da7F48ED6u;ba78DB93Ap,10,20F,40
h
```

If the program would now be continued and then aborted after three more iterations, the output would be:

```
H
Pja8000003i;da7F85FB4u;ba7B3E59Dp,11,20F,40
Pja8000004i;da7FC3092u;ba7DA0E54p,10,20F,40
Pja8000005i;da8059967n;ba8C8AFADf,14,20F,40
Z
*
TFinished
```

As can be seen in the above example, the metadata of the 3th iteration (the value 11) indicates that a timing error occurred. It can also be seen that the code directly following the measurement loop is not executed when the script is aborted using the Z command, in contrast to the Y command, which only aborts the measurement loop but continues executing the remainder of the MethodSCRIPT.

4.28. Reverse CV sweep (R)

During a CV (but not fast CV) sweep, reverse the sweep direction. This has the same effect as the MethodSCRIPT command `set_scan_dir 0`. Depending on the exact location where the reversal occurs, this may end the current scan early and advance to the next, if present. This command has no effect if run outside of a CV sweep.

Command format

```
R
```

Response format

```
R
```

Example

The plots below show the behaviour of the CV reverse command.

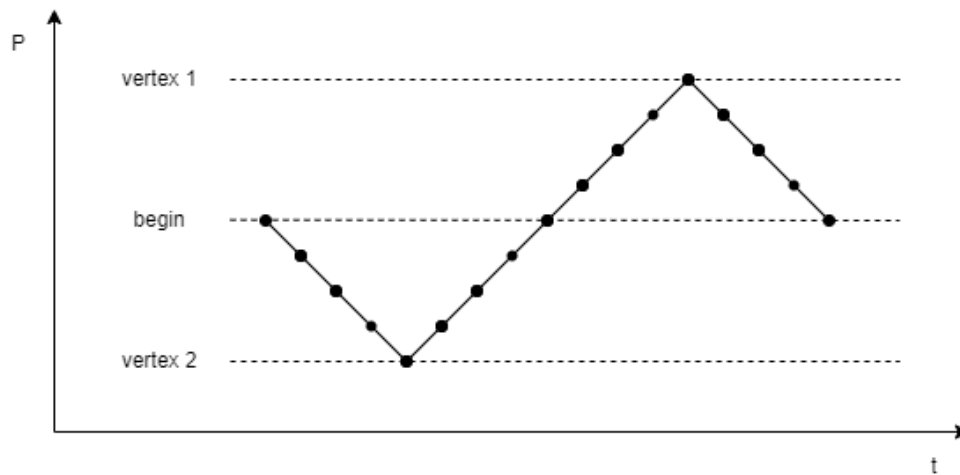


Figure 1. CV Sweep without reversal

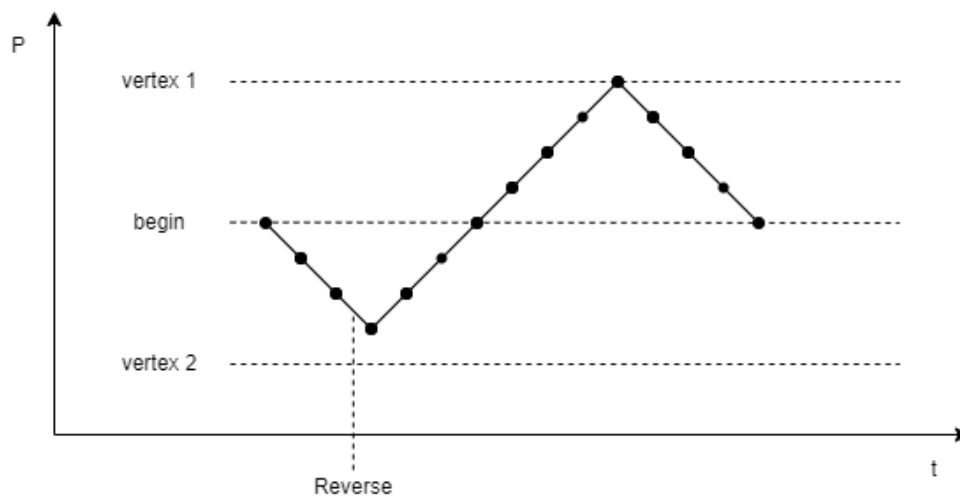


Figure 2. CV Sweep reversal short-cutting to next segment

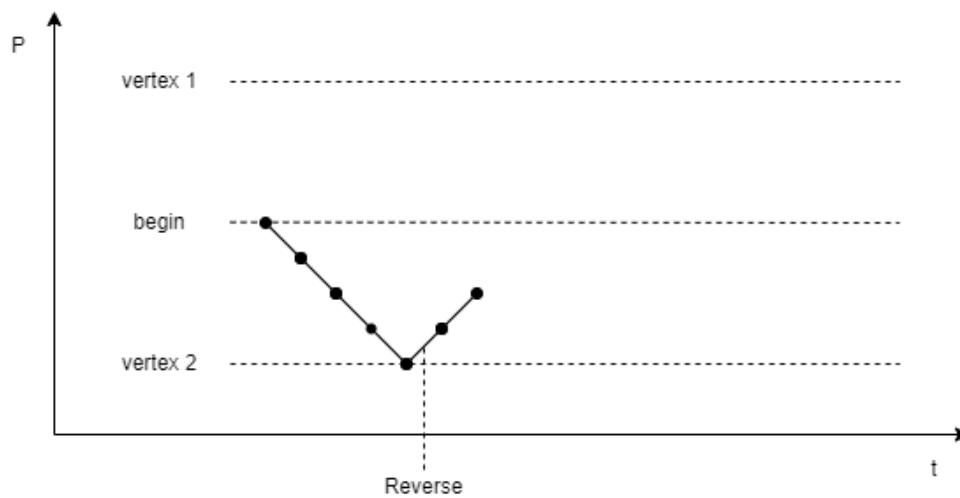


Figure 3. CV Sweep reversal ending the scan

The following MethodSCRIPT examples demonstrate the same behaviour.

This script performs a 3 vertex CV measurement, from 0 V to -1 V to 1 V, with steps of 250 mV and a scan rate of 1 V/s. Here only the potentials are sent back, for simplicity.

```
e
var c
var p
set_pgstat_chan 0
set_pgstat_mode 2
set_max_bandwidth 40
set_range ba 2100u
set_autoranging ba 210n 21m
set_e 0
cell_on
meas_loop_cv p c 0 -1 1 250m 1
pck_start
pck_add p
pck_end
endloop
on_finished:
cell_off
```

This results in 17 points.

```
e
M0005
Pda8000000
Pda7FC2F23u
Pda7F85E45u
Pda7F48D67u
Pda7F0BC8Au
Pda7F48D67u
Pda7F85E45u
Pda7FC2F23u
Pda8000000
Pda803D0DDu
Pda807A1BBu
Pda80B7299u
Pda80F4376u
Pda80B7299u
Pda807A1BBu
Pda803D0DDu
Pda8000000
*
```

Issuing the reverse command causes the sweep to change direction early. Below it can be seen that the sweep

only performs 3 steps in its initial direction instead of 4.

It can be seen that there is a delay between the R command being echo'd, and the data reversing. This occurs due to the sweep potentials being set in advance, and so it shouldn't be expected that the R command will take immediate effect.

```
e
M0005
Pda8000000
Pda7FC2F23u
Pda7F85E45u
R
Pda7F48D67u
Pda7F85E45u <--- Previously this was another step down to Pda7F0BC8Au
Pda7FC2F23u
Pda8000000
Pda803D0DDu
Pda807A1BBu
Pda80B7299u
Pda80F4376u
Pda80B7299u
Pda807A1BBu
Pda803D0DDu
Pda8000000
*
```

If the reversal would cause the sweep to change to a potential and direction that do not appear later in the current scan, then the sweep will advance to the next scan. If the CV is already in the final scan, it will end the CV instead. This can be seen in the below data.

```
e
M0005
Pda8000000
Pda7FC2F23u
Pda7F85E45u
Pda7F48D67u
Pda7F0BC8Au
R
Pda7F48D67u
Pda7F85E45u
*
```

Chapter 5. Register summary

5.1. Generic registers

The following table defines registers that are the same on all MethodSCRIPT instruments.

ID	Description	Length (bytes)	Basic permission	Advanced permission
0x01	Peripheral configuration	4	Read only	Read / write
0x02	Permission level	4	Write only	Write only
0x04	License register	8	Read only	Read only
0x05	Unique instrument ID	16	Read only	Read only
0x06	Device serial number	8	Read only	Read only
0x08	MethodSCRIPT autorun	1	Read only	Read / write
0x09	Advanced options	4	Read only	Read / write
0x0A	UART data rate limit	4	Read / write	Read / write
0x0B	Reset instrument	4	Write only	Write only
0x0D	Multi-channel role	1	Read only	Read only
0x0E	System date and time	7	Read / write	Read / write
0x0F	Default GPIO config	8	Read only	Read / write
0x10	System warning	4	Read only	Read only
0x11	Allowed pin modes	8	Read only	Read only

5.2. EmStat Pico specific registers

The table below lists all registers that are specific to the EmStat Pico.

ID	Description	Length (bytes)	Basic permission	Advanced permission
0x83	Auto calibration	4	None	Write only
0x84	Clear calibration	4	None	Write only
0x89	Baud rate configuration	1	Read only	Read / write
0xA0	Low speed TIA 10M CH0 gain	4	Read only	Read / write
0xA1	Low speed TIA 10M CH0 offset	4	Read only	Read / write
0xA2	Low speed TIA 10M CH1 gain	4	Read only	Read / write
0xA3	Low speed TIA 10M CH1 offset	4	Read only	Read / write
0xA4	High speed TIA 10M gain	4	Read only	Read / write

ID	Description	Length (bytes)	Basic permission	Advanced permission
0xA5	High speed TIA 10M offset	4	Read only	Read / write
0xA6	High speed TIA 1M gain	4	Read only	Read / write
0xA7	High speed TIA 1M offset	4	Read only	Read / write

Chapter 6. Register details

The internal registers are used to retrieve information, configure the device, or perform rarely used actions.

Some registers are write protected at startup and must be unlocked before use. The tables in [Chapter 5, Register summary](#) show which access rights each register has for each permission level. The [Permission level \(0x02\)](#) register can be used to set the permission level.

The data length of each register is given in bytes of represented data. This data is communicated in hexadecimal notation, using 2 characters per byte.

Some registers are stored in the non-volatile memory (NVM) of the instrument, meaning that the setting can be remembered even after a power cycle. On the EmStat Pico, writing to those register will immediately update the NVM.

6.1. Peripheral configuration (0x01)

Reads / writes the peripheral configuration as a bitmask from / to non-volatile memory. Support for external peripherals can be enabled here. Pins for peripherals that are not enabled can be used as GPIO pins. All peripherals default to GPIO. Multiple peripherals can be enabled at the same time by adding the hexadecimal values. For example: bit 1 is 0x01 and bit 5 is 0x20, combining them gives 0x21.



This setting is stored in NVM.

Register format

xxxxxxxx

Key	Size (bytes)	Description
xxxxxxxx	4	Peripheral configuration flags.

Table 2. EmStat Pico peripheral configuration

Mask	Name	Description
0x0020	Enable 1.8 V reference output	When enabled, output 1.8 V reference to the ANALOG_IN_2 pin. ANALOG_IN_2 can no longer be used as an input.
0x0040	(Deprecated) Enable external cell on/off status pin and TC58CVG2S0 support	When enabled, output the cell ON/OFF status on GPIO6. The signal is active-low: Cell ON outputs a logic 0, cell OFF output a logic 1. GPIO6 can not be used for other purposes if this option is enabled. This is intended for Sensit BT devices, and also enables the TC58CVG2S0 memory chip (bit 0x0100). This bit should only be programmed during production. Do not change!
0x0080	Enable external RTC (Ablic S-35390A) support	When enabled, the external RTC (Ablic S-35390A) will be initialized during startup. This stops the RTC from generating a 1 Hz signal, which potential interferes with the EmStat Pico wake-up signal. When external RTC support is enabled, the RTC will also be used for the system date and time.

Mask	Name	Description
0x0700	File storage medium selection	The system will use the selected memory option for file storage. 0x0000: SD card 0x0100: TC58CVG2S0 0x0200: AT25SF128A (only available on request) 0x0700: Disabled
0x0800	Enable external cell on/off status pin	When enabled, output the cell ON/OFF status on GPIO6. The signal is active-low: Cell ON outputs a logic 0, cell OFF output a logic 1. GPIO6 can not be used for other purposes if this option is enabled.
Other	Reserved	Reserved for future use. Do not change!

6.2. Permission level (0x02)

By default, most registers are write protected to prevent accidental writes. This register can be used to disable the write protection. It is advised to turn the write protection back on when access to write protected registers is no longer required.

Register format

kkkkkkkk

Key	Size (bytes)	Description
kkkkkkkk	4	Key to for switching to a specific permission mode. See Table 3, "Permission keys" .

Table 3. Permission keys

Level	Key	Description
Basic	0x12345678	Default configuration at startup. Read-only access to non-volatile registers.
Advanced	0x52243DF8	Full access to all user changeable settings.

6.3. License register (0x04)

Request the licenses programmed into this instrument. For more information [contact PalmSens](#).

Register format

xxxxxxxxxxxxxxxx

Key	Size (bytes)	Description
xx..xx	8	Instrument specific license key.

Example

Command to read the license register.

```
G04
```

6.4. Unique instrument ID (0x05)

Reads the unique ID for this instrument.



This is different than the device serial number.

Register format

```
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

Key	Size (bytes)	Description
xx..xx	16	Unique hardware identifier.

Example

Command to read the instrument ID.

```
G05
```

6.5. Device serial number (0x06)

Contains the device serial number.

Register format

```
ttyybbbnnnnnnnn
```

Key	Size (bytes)	Description
tt	1	A number specifying the device type.
yy	1	Production year.
bbbb	2	Production batch nr.
nnnnnnnn	4	Device ID, unique within all devices of the same type, year and batch.

Example

Command to read the serial number of the device.

```
G06
```

Example output

```
G001200000000899B
```

6.6. MethodSCRIPT autorun (0x08)

If set to 1, the MethodSCRIPT stored in non-volatile memory will be loaded and executed on startup. When the script ends, the EmStat Pico returns to its normal behavior.



This setting is stored in NVM.

Register format

```
aa
```

Key	Size (bytes)	Description
aa	1	Autorun enable (00=disabled, 01=enabled).

Example

Command to read the autorun option.

```
G08
```

Command to enable the autorun option.

```
S0801
```

6.7. Advanced options (0x09)

The advanced options register is a bitmask of advanced options that can be enabled by the user.

Each option has a specific bit value (see table below). The value of this register is a *bitwise OR* of all option flags that are enabled. Writing to this register sets or clears all bits to the specified value. When writing to this register, make sure to set all required bits at once.



This setting is stored in NVM.

Table 4. Advanced option bits

Bit mask	Description
0x00000001	Enable extended voltage range. The EmStat Pico has a device-specific option bit for “Extended voltage range”. Enabling this reduces the accuracy of measured currents and is not recommended.
0x80000000	Enable CRC16 protocol extension .

Register format

```
aaaaaaaa
```

Key	Size (bytes)	Description
aa..aa	4	Advanced options

Example

Command to read the advanced options register.

```
G09
```

Command to clear the advanced options register.

```
S0900000000
```



If the CRC16 protocol extension is (accidentally) enabled, it can only be disabled using a command including valid CRC. In this case, the command `S0900000000AA9D43` can be used to clear the advanced options register, including the CRC16 protocol extension.

6.8. UART data rate limit (0x0A)

This register allows limiting the number of bytes per second that are sent by the device using UART. This is independent of the UART baud rate. This can be useful when no flow control mechanism is used with UART and the host cannot keep up with the data rate defined by the baud rate. A value of 0 disables data rate limiting, so the instrument will transmit at the maximum achievable speed.

Register format

```
dddddddd
```

Key	Size (bytes)	Description
dd..dd	4	Data rate limit in bytes per second

Example

Command to read the UART data rate limit.

```
G0A
```

Command to set the UART data rate limit to 5000 (=0x1388) bytes/sec.

```
S0A00001388
```

6.9. Reset instrument (0x0B)

Writing 0x93628ADE to this register will initiate a software reset of the device.



This command will not return a newline if the reset is successful.

Register format

```
93628ADE
```

Key	Size (bytes)	Description
93628ADE	4	Magic key to reset the instrument.

Example

Command to reset the instrument.

```
S0B93628ADE
```

6.10. Multi-channel role (0x0D)

Instrument role in a multi-channel setup. This feature is not supported for the EmStat Pico, so this register will always return 0x00 (Stand-alone, no multi-instrument) when read.

6.11. System date and time (0x0E)

The system date and time in hex format. This is used for the time/date shown on files in the file system and for the MethodSCRIPT command `rtc_get`. Depending in the instrument, the time may or may not be kept on a restart.

Register format

```
yyyymmddhhaass
```

Key	Size (bytes)	Description
yyyy	2	Year, in HEX format
mm	1	Month (1-12), in HEX format
dd	1	Day (1-31), in HEX format
hh	1	Hour (0-23), in HEX format
aa	1	Minute (0-59), in HEX format
ss	1	Second (0-59), in HEX format

6.12. Default GPIO config (0x0F)

Default GPIO settings at startup. Once set (and committed to NVM) the instrument will initialize it's GPIO to this state on startup.



This setting is stored in NVM.



The GPIO config is not checked when this register is updated. An incorrect configuration can cause a system warning during startup.

Register format

```
ccccccccoooopppp
```

Key	Size (bytes)	Description
cc..cc	4	GPIO configuration mode with 2 bits per pin. The values are: 0 = Mode 0 (Input) 1 = Mode 1 (Output) 2 = Mode 2 (alternate function 1) 3 = Mode 3 (alternate function 2)
oooo	2	Output level with 1 bit per pin (only applicable for output pins)
pppp	2	Pull-up enabled with 1 bit per pin (only applicable for input pins)

Example

Command to configure pin 0 as input pin with pull-up and pin 1 as output pin with output value 1.

```
S0F0000000400020001
```

6.13. System warning (0x10)

Read and clear the system warning.

If a problem occurred that can not be displayed or handled at that moment, a system warning is set. This is indicated with the blinking LED and available in this register. Reading this register will return the first error code that caused a system warning. This is usually the most meaningful error code, since any subsequent errors might be a consequence of the first error. This register is cleared when read.

Register format

```
wwwwwwww
```

Key	Size (bytes)	Description
ww. .ww	4	Last encountered error code For a list of error codes, see Appendix A, Error codes .

Example

Command to read and clear the system warning.

```
G10
```

6.14. Allowed pin modes (0x11)

Get allowed pin modes (input / output / peripheral) for all GPIO pins.

Each nibble (4 bits) represents 1 GPIO pin, the least significant nibble is GPIO0. Each bit within this nibble represents a pinmode, where a high bit means the mode is allowed.

bit 0: input

bit 1: output

bit 2: peripheral 1

bit 3: peripheral 2

Register format

```
mmmmmmmmmmmmmmmm
```

Key	Size (bytes)	Description
mm. .mm	8	Bitmask representing the allowed pinmodes per GPIO pin

Example

Command read the allowed pin modes

```
G11
```

6.15. Auto calibration (0x83)

Writing the correct key to this register will initiate the built-in auto calibration routine. This routine requires the WE to be unconnected and takes up to 60 seconds. The auto calibration will not affect the 1M and 10M calibrations (which are accessible via dedicated registers).



PalmSens does not recommend re-calibrating factory-calibrated instruments.

Register format

4321ABCD

Key	Size (bytes)	Description
4321ABCD	4	Key triggering auto calibration.

6.16. Clear calibration (0x84)

Clears all auto calibrated registers. This does not affect the 1M and 10M calibrations (which can be set using dedicated registers).



PalmSens does not recommend clearing these calibrations on factory-calibrated instruments.

Register format

4321ABCD

Key	Size (bytes)	Description
4321ABCD	4	Magic key to clear auto calibration.

6.17. Baud rate configuration (0x89)

Get or set the instrument's UART baud rate. This register expects an index, which is specified for each baud rate in the table below. The default baud rate can be found in [Chapter 2, Communication](#). A restart is required for the new baud rate to be applied.

Index	Baud rate
0	Default baud rate (see Chapter 2, Communication)
1	9600
2	19200
3	38400

Index	Baud rate
4	57600
5	115200
6	230400
7	460800
8	921600



Make sure to note which baud rate is set, because you can only connect to the device using the configured baud rate.

Register format

BB

Key	Size (bytes)	Description
BB	1	Baud rate index

Example

Command to set the baud rate to 230400 bits per second.

S8906

6.18. Low speed TIA 10M CH0 gain (0xA0)

Calibration gain value for the low speed TIA of channel 0 at a 10M Ω resistor. This value will be applied to the measured current in the low speed channel 0 100 nA current range. The register value can be calculated using the following formula:

```
register_value = gain_factor * 0x4000
```



PalmSens does not recommend re-calibrating factory-calibrated instruments.



Reading 0xFFFFFFFF implies that this option was not calibrated and will use a gain of 1.

Register format

cccccccc

Key	Size (bytes)	Description
cc.cc	4	Gain factor for low speed TIA

6.19. Low speed TIA 10M CH0 offset (0xA1)

Calibration offset value for the low speed TIA of channel 0 at a 10M Ω resistor. This value will be applied to the measured current in the low speed channel 0 100 nA current range. The register value can be calculated using the following formula:

$$\text{register_value} = \text{offset (A)} * 10e6 / 14e-6$$



PalmSens does not recommend re-calibrating factory-calibrated instruments.



Reading 0xFFFFFFFF implies that this option was not calibrated and will use an offset of 0.

Register format

ccccccc

Key	Size (bytes)	Description
cc.cc	4	Offset value for low speed TIA

6.20. Low speed TIA 10M CH1 gain (0xA2)

Calibration gain value for the low speed TIA of channel 1 at a 10M Ω resistor. This value will be applied to the measured current in the low speed channel 1 100 nA current range. The register value can be calculated using the following formula:

$$\text{register_value} = \text{gain_factor} * 0x4000$$



PalmSens does not recommend re-calibrating factory-calibrated instruments.



Reading 0xFFFFFFFF implies that this option was not calibrated and will use a gain of 1.

Register format

ccccccc

Key	Size (bytes)	Description
cc.cc	4	Gain factor for low speed TIA

6.21. Low speed TIA 10M CH1 offset (0xA3)

Calibration offset value for the low speed TIA of channel 1 at a 10M Ω resistor. This value will be applied to the measured current in the low speed channel 1 100 nA current range. The register value can be calculated using the following formula:

$$\text{register_value} = \text{offset (A)} * 10e6 / 14e-6$$



PalmSens does not recommend re-calibrating factory-calibrated instruments.



Reading 0xFFFFFFFF implies that this option was not calibrated and will use an offset of 0.

Register format

ccccccc

Key	Size (bytes)	Description
cc.cc	4	Offset value for low speed TIA

6.22. High speed TIA 10M gain (0xA4)

Calibration gain for the high speed TIA at an 10M Ω resistor. This value will be applied to the measured current in the high speed 100 nA current range for both channels. The register value can be calculated using the following formula:

$$\text{register_value} = \text{gain_factor} * 0x4000$$



PalmSens does not recommend re-calibrating factory-calibrated instruments.



Reading 0xFFFFFFFF implies that this option was not calibrated and will use a gain of 1.

Register format

ccccccc

Key	Size (bytes)	Description
cc..cc	4	Gain value for the high speed TIA

6.23. High speed TIA 10M offset (0xA5)

Calibration offset for the high speed TIA at an 10M Ω resistor. This value will be applied to the measured current in the high speed 100 nA current range for both channels. The register value can be calculated using the following formula:

$$\text{register_value} = \text{offset (A)} * 10e6 / 14e-6 + 0x4000$$



PalmSens does not recommend re-calibrating factory-calibrated instruments.



Reading 0xFFFFFFFF implies that this option was not calibrated and will use an offset of 0.

Register format

cccccccc

Key	Size (bytes)	Description
cc..cc	4	Gain value for the high speed TIA

6.24. High speed TIA 1M gain (0xA6)

Calibration gain for the high speed TIA at an 1M Ω resistor. This value will be applied to the measured current in the high speed 1 μ A current range for both channels. The register value can be calculated using the following formula:

$$\text{register_value} = \text{gain_factor} * 0x4000$$



PalmSens does not recommend re-calibrating factory-calibrated instruments.



Reading 0xFFFFFFFF implies that this option was not calibrated and will use a gain of 1.

Register format

cccccccc

Key	Size (bytes)	Description
cc..cc	4	Gain value for the high speed TIA

6.25. High speed TIA 1M offset (0xA7)

Calibration offset for the high speed TIA at an 1M Ω resistor. This value will be applied to the measured current in the high speed 1 μ A current range for both channels. The register value can be calculated using the following formula:

$$\text{register_value} = \text{offset (A)} * 1e6 / 14e-6 + 0x4000$$



PalmSens does not recommend re-calibrating factory-calibrated instruments.



Reading 0xFFFFFFFF implies that this option was not calibrated and will use an offset of 0.

Register format

cccccccc

Key	Size (bytes)	Description
cc..cc	4	Gain value for the high speed TIA

Chapter 7. CRC16 protocol extension

7.1. Introduction

For certain applications of the EmStat Pico, data validity is of critical importance. For such applications, all data communication from and to the instrument has to be verifiable. In order to make the communication verifiable, an extension of the protocol was implemented that adds a sequence number and a 16-bit CRC to each line. The CRC makes it possible to verify if received data is correct, i.e., if no part of the line was corrupted or lost during transmission. The sequence number allows the host to verify that no complete lines were missed.

The CRC16 protocol extension can be enabled in the instruments non-volatile configuration by setting the corresponding option bit (by issuing the command `S098000000` in normal mode). See the [Set register](#) command and the [Advanced options](#) register for more details on how to enable this extension.

Enabling the CRC16 protocol has the following effects:

- All lines transmitted by the EmStat Pico include a sequence number and CRC.
- All lines transmitted by the host software must include a sequence number and CRC.
- For each line correctly received by the EmStat Pico, an acknowledge message is transmitted.
- In case the received sequence number is different than expected, an error message (`!002C`) is transmitted. This can happen if a line is lost, but can also happen at the start of the communication, for example if the host application has been restarted. A sequence number error is treated as a warning and is not considered an error by the EmStat Pico. The received line will still be acknowledged and processed.
- For each corrupted line received by the EmStat Pico, an error message (`!002B` or `!002D`) is transmitted. In this case, the message is not processed by the firmware.
- Some commands have a slightly different response.

The following section describes the protocol extension details.

7.2. Line format

The CRC extension adds an 8-bit sequence number and 16-bit CRC to each line before the newline separator (`\n`). This applies to all data transmitted to and from the device.

Line format when CRC16 protocol extension is enabled

```
nnnnnnnnSSCCCC\n
```

Key	Type	Size	Description
nnnnnnnn	text	variable	The normal line that would be transmitted if the CRC16 protocol extension was disabled.
SS	hex	1 byte	The sequence number (0-255).
CCCC	hex	2 bytes	The 16-bit CRC, calculated over nnnnnnnnSS.

The sequence number allows the receiver to detect if there are missing lines. There are separate, independent,

sequence numbers for data in both directions (from and to instrument). At startup, the EmStat Pico initializes its sequence number to 0 and also expects the host to start with sequence number 0. After every transmitted line, the corresponding sequence number is incremented with one. After sequence number 255, it rolls over to number 0.

The CRC allows the receiver to verify the integrity of the received data. The CRC is calculated over the full line, excluding the newline character, but including the sequence number. The used CRC is the CRC-CCITT polynomial $x^{16} + x^{12} + x^5 + 1$, often represented as 0x1021. The initial value is 0xFFFF.



When using Python, the standard library function `binascii.crc_hqx()` can be used to calculate the CRC.

7.3. Acknowledge messages

To give the host more certainty that the data is actually received by the EmStat Pico, the instrument will acknowledge every received line with an acknowledge message. The acknowledge message simply contains the sequence number of the received line, between angle brackets, e.g. `<00>`. The message itself also contains a sequence number and CRC like any other message transmitted by the instrument. The acknowledge messages are only transmitted by the instrument and should not be transmitted by the host.

Acknowledge message format

```
<AA>SSCCCC\n
```

Key	Type	Size	Description
AA	hex	1 byte	The sequence number (0-255) of the received line.
SS	hex	1 byte	The sequence number (0-255) of the instrument.
CCCC	hex	2 bytes	The 16-bit CRC, calculated over <code>nnnnnnnnSS</code> .

7.4. Other changes

The EmStat Pico will respond mostly in the same way as it does without the CRC16 protocol extension. An exception is with MethodSCRIPT related commands (`e` and `L`). These will normally return with just a letter without newline and a send the newline when the entire script is received. Since this would interfere with the acknowledge messages it was decided that when the CRC16 protocol extension is enabled it will add an additional newline directly after the command response letter.

7.5. Examples

Below are some examples to demonstrate the differences between communication with and without the CRC16 protocol extension.

Example command without CRC16 protocol extension

Host to instrument	Instrument to host
t\n	
	tespico12#Apr 23 2020 15:41:46\n
	R*\n

Example command with CRC16 protocol extension enabled

Host to instrument	Instrument to host
t0A9524\n	
	<0A>454FBA\n
	tespico12#Apr 23 2020 15:41:4646DA41\n
	R*47D271\n

Note: \n is the newline character, initial sequence IDs are 0x0A for the host and 0x45 for the instrument.

MethodSCRIPT example without CRC16 protocol extension (Note that there's no \n after the e response from the instrument!)

Host to instrument	Instrument to host
e\n	
	e
send_string "Hello World"\n	
\n	
	\n
	THello World\n
	\n

MethodSCRIPT example with CRC16 protocol extension enabled

Host to instrument	Instrument to host
e03BFA2\n	
	<03>4CFEF6\n
	e4D7D16\n
send_string "Hello World"04A94C\n	
	<04>4ECF1D\n
057E6C\n	
	<05>4F89CA\n
	50D13C\n
	THello World5142CE\n
	52F17E\n

Chapter 8. Error handling

After sending a command to the device, the device may respond with an error code. This may occur if a command or parameter is not supported by the connected instrument or otherwise outside of its capabilities.

The general error format is an exclamation mark (!) followed by a 4-digit (hexadecimal) error code. However, when an error is encountered during reception (loading) of a MethodSCRIPT, the error response also contains the line and column number. When an error is encountered during *execution* of a MethodSCRIPT, the error response only contains the line number. Because a newline character has already been transmitted at the start of the script execution, the exclamation mark will be on the start of the line (not prepended by the `e`) in this case.

General error format of the device communication protocol

```
c!XXXX\n
```

Error format during MethodSCRIPT parsing (loading)

```
l!XXXX: Line LL, Col CC\n
```

Error format during MethodSCRIPT execution

```
!XXXX: Line LL\n
```

Key	Type	Size	Description
<code>c</code>	text	1	The first letter of the received command.
<code>XXXX</code>	hex	4	The error code (see Appendix A, Error codes).
<code>LL</code>	dec	variable	The line number of the MethodSCRIPT on which the error occurred.
<code>CC</code>	dec	variable	The column number (character position within the line) on which the error occurred.

For a full list of error codes, see [Appendix A, Error codes](#)



Error codes can be different on different instruments and firmware versions.

After an error occurred, the instrument will ignore further input for a short time (roughly 50-100 ms). It is recommended to wait for more than 100 ms before transmitting the next command, to make sure it will be received and processed normally.

Examples

Example of wrong communication protocol command

Host to instrument	Instrument to host
wrong_command\n	w !0003\n

Example of wrong MethodSCRIPT command (parsing error)

Host to instrument	Instrument to host
e\n wrong_methodsript_command\n	e !4001: Line 1, Col 27\n \n

Example of MethodSCRIPT runtime error (division by zero)

Host to instrument	Instrument to host
e\n var x\n store_var x 0i ja\n send_string "1"\n div_var x 0i\n send_string "2"\n \n	e \ T1\ !0028: Line 4\ \

Chapter 9. Version changes

Version 1.0

- Initial version.

Version 1.2

- Added file browser commands
- Updated error codes table
- Added extra registers

Version 1.3

- Added CRC16 protocol extension (option bits, error values and chapter)
- Removed `cali` command (replaced by register)
- Added `fs_put` command
- Updated `fs_*` commands to include extra acknowledgement newline
- Fixed broken MethodSCRIPT link
- Updated registers
- Updated error codes
- Updated capability definitions
- Updated version string with extra *patch* field

Version 1.5

- Updated to MethodSCRIPT 1.7
- Updated communication details (UART baudrate and flow control)
- Added `R` reverse command for CV
- Clarified register permissions
- Clarified calibration registers
- Added registers:
 - Multi-channel role
 - System date and time
 - Default GPIO config
 - System warning
 - Baud rate configuration
 - Allowed pin modes
- Added support for "S35390A" RTC, enabled at startup in the [Peripheral configuration](#) register
- Clarified CRC16 protocol extension

- Clarified error handling
- Removed deprecated `s` command, use MethodSCRIPT hibernate instead
- Increased max line length to 256
- Increased underload warning from 2% to 4% of range for EmStat Pico and Sensit Wearable
- Updated error codes
- Updated document format
- Updated errata

Appendix A: Error codes

The following table lists all error codes that can be returned by MethodSCRIPT instruments.



The error codes and their meaning are the same for all instruments and firmware versions. However, in some cases, the same error condition could result in a different error code when using another instrument or firmware version.

Table 5. Error code lookup table

Error code	Description
0x0001	An unspecified error has occurred
0x0002	An invalid <i>VarType</i> has been used
0x0003	The command was not recognized
0x0004	Unknown register
0x0005	Register is read-only
0x0006	Communication mode invalid
0x0007	An argument has an unexpected value
0x0008	Command exceeds maximum length
0x0009	The command has timed out
0x000B	Cannot reserve the memory needed for this var
0x000C	Cannot run a script without loading one first
0x000E	An overflow has occurred while averaging a measured value
0x000F	The given potential is not valid
0x0010	A variable has become either "NaN" or "inf"
0x0011	The input frequency is invalid
0x0012	The input amplitude is invalid
0x0014	Cannot perform OCP measurement when cell on
0x0015	CRC invalid
0x0016	An error has occurred while reading / writing flash
0x0017	The specified flash address is not valid for this device
0x0018	The device settings have been corrupted
0x0019	Authentication error
0x001A	Calibration invalid
0x001B	This command or part of this command is not supported by the current device
0x001C	Step Potential must at least 1 DAC LSB for this technique

Error code	Description
0x001D	Pulse Potential must at least 1 DAC LSB for this technique
0x001E	Amplitude must at least 1 DAC LSB this technique
0x001F	Product is not licensed for this technique
0x0020	Cannot have more than one high speed and/or max range mode enabled
0x0021	The specified PGStat mode is not supported
0x0022	Channel set to be used as Poly WE is not configured as Poly WE
0x0023	Command is invalid for the selected PGStat mode
0x0024	The maximum number of vars to measure has been exceeded
0x0025	The specified PAD mode is unknown
0x0026	An error has occurred during a file operation
0x0027	Cannot open file, a file with this name already exists
0x0028	Variable divided by zero
0x0029	GPIO pin mode is not known by the device
0x002A	GPIO configuration is incompatible with the selected operation
0x002B	CRC of received line was incorrect (CRC16-ext)
0x002C	ID of received line was not the expected value (CRC16-ext)
0x002D	Received line was too short to extract a header (CRC16-ext)
0x002E	Settings are not initialized
0x002F	Channel is not available for this device
0x0030	Calibration process has failed
0x0032	Critical cell overload, aborting measurement to prevent damage.
0x0033	FLASH ECC error has occurred
0x0034	Flash program operation failed
0x0035	Flash Erase operation failed
0x0036	Flash page/block is locked
0x0037	Flash write operation on protected memory
0x0038	Flash is busy executing last command.
0x0039	Operation failed because block was marked as bad
0x003A	The specified address is not valid
0x003B	An error has occurred while attempting to mount the filesystem
0x003C	An error has occurred while attempting to format the filesystem memory

Error code	Description
0x003D	A timeout has occurred during SPI communication
0x003E	A timeout has occurred somewhere
0x003F	The calibrations registers are locked, write actions not allowed.
0x0040	Memory module not supported.
0x0041	Flash memory format not recognized or supported.
0x0042	This register is locked for current permission level.
0x0043	Register is write-only
0x0044	Command requires additional initialization
0x0045	Configuration not valid for this command
0x0046	The multiplexer was not found.
0x0047	The filesystem has to be mounted to complete this action.
0x0048	This device is not a multi-device, no serial available.
0x004A	MCU register access is not allowed, only RAM and peripherals are accessible.
0x004B	Runtime (comm) command argument too short to be valid.
0x004C	Runtime (comm) command argument has an invalid format.
0x004E	Hibernate wake up source is invalid
0x004F	Hibernate requires at least one wake up source, none was given.
0x0050	Wake pin for hibernate not configured as <code>input</code>
0x0051	The code provided to the permission register was not valid.
0x0052	An overrun error occurred on a communication interface (e.g. UART).
0x0053	Argument length incorrect for this register.
0x0055	The GPIO pins requested to change do not exist on this instrument.
0x0056	The selected GPIO pin mode is not allowed (by NVM config or device type).
0x0057	The on-board flash module has timed out.
0x0058	Timing error during fast measurement (possibly caused by communication).
0x005A	The instrument cannot meet the requested measurement timing.
0x005B	The variable type is already being measured.
0x006D	The COMM command expected a hexadecimal value, but received something else.
0x006E	The COMM command expected a decimal value, but received something else.
0x0071	The provided key does not fit the lock on this register.
0x0072	I2C port expander did not acknowledge a command

Error code	Description
0x0073	Filesystem module not supported
0x0074	The IP address is not available (yet).
0x007A	There is no measurement channel left for the requested measurement.
0x007B	Temperature measurements during EIS with > 8 kHz are not supported.
0x007C	The specified mode is unknown
0x007D	The ADXL367 did not acknowledge an I2C command
0x007E	An unexpected error occurred during an I2C operation.
0x007F	I2C bus timeout during I2C operation (probably caused by I2C target device).
0x0080	The CE is oscillating.
0x0082	Operation requires system warnings to be cleared.
0x0083	Filesystem operations are not supported on this device.
0x4001	The script command is unknown
0x4004	An unexpected character was encountered
0x4005	The script is too large for the internal script memory
0x4008	This optional argument is not valid for this command
0x4009	The stored script is generated for an older firmware version and cannot be run
0x400B	Measurement loops cannot be placed inside other measurement loops
0x400C	Command not supported in current situation
0x400D	Scope depth too large
0x400E	The command had an invalid effect on scope depth
0x400F	Array index out of bounds
0x4010	I2C interface was not initialized with i2c_config command
0x4011	This is an error, NACK flag not handled by script
0x4012	Something unexpected went wrong.
0x4013	I2C clock frequency not supported by hardware
0x4014	Non integer SI vars cannot be parsed from hex or binary representation
0x4016	RTC was selected as wake-up source and selected time is not supported
0x4018	The script has ended unexpectedly.
0x4019	The script command is only valid for a multichannel (combined) device
0x401A	The script command cannot be called from within a measurement loop.
0x401B	the pck sequence is called wrong

Error code	Description
0x401C	The maximum amounts of variables per packet has been exceeded.
0x401D	The file path is too long for the file system.
0x401E	Insufficient memory to store array index
0x4020	A timeout has occurred for one of the script commands
0x4021	The mux is not initialized/configured.
0x4022	Measurement loop timing is too fast to use with multiplexer
0x4023	The script command is only valid for a device with iR compensation
0x4024	The resistance value is to big for the whole autorange range
0x4025	The resistance value is to big for current current range
0x4026	The variable already exists when declared
0x4027	This command requires the cell to be enabled with the <code>cell_on</code> command
0x4028	This command requires the cell to be disabled with the <code>cell_off</code> command
0x4029	The technique requires that at least one step should be made
0x402A	The variable names do not fit in memory anymore, try using shorter names.
0x402B	The variable name did not start with 'a'-'z' or otherwise contained anything other than 'a'-'z', '0'-'9' and '_'.
0x402C	The variable name is too long to be processed.
0x402D	The file mode is invalid.
0x402E	The file mode does not support a counter in the file path.
0x402F	The file path with the maximum counter value already exists.
0x4030	There are too many files open already.
0x4031	The specified multi device type is not defined.
0x4032	Cannot set the potential (or potential range) within the active measurement loop.
0x4033	Cannot set the current (or current range) within the active measurement loop.
0x4034	The used feature is not licensed on this product.
0x4035	The given filter type is unknown or not supported.
0x4036	The given command is only allowed within measurement loops.
0x4037	A computation has resulted in an overflow
0x4038	The array access was not correctly formed
0x4039	The literal argument was not correctly formed
0x4200	MScript argument value cannot be negative for this command
0x4201	MScript argument value cannot be positive for this command

Error code	Description
0x4202	MScript argument value cannot be zero for this command
0x4203	MScript argument value must be negative for this command (also not zero)
0x4204	MScript argument value must be positive for this command (also not zero)
0x4205	MScript argument value is outside the allowed bounds for this command
0x4206	MScript argument value cannot be used for this specific instrument
0x4207	MScript argument datatype (float/int) is invalid for this command
0x4208	MScript argument reference was invalid (not 'a' - 'z')
0x4209	MScript argument variable type is invalid or not supported for this command
0x420A	An unexpected, additional, (optional) MScript argument was provided
0x420B	MScript argument variable is not declared
0x420C	MScript argument is of type var, which is not supported by this command
0x420D	MScript argument is of type literal, which is not supported by this command
0x420E	MScript argument is of type array, which is not supported by this command
0x420F	MScript argument array size is insufficient
0x4210	An f-string contains an opening brace that is never closed
0x4211	MScript argument is an array element, which is not supported by this command
0x7FFF	A fatal error has occurred, the device must be reset

Appendix B: MethodSCRIPT capabilities bit fields

The following table lists all MethodSCRIPT commands and their respective bit field in the [Section 4.23, “Get MethodSCRIPT capabilities \(CM\)”](#)

Table 6. MethodSCRIPT capabilities lookup table

Bit number	Command string
0	RESERVED
1	var
2	array
3	store_var
4	copy_var
5	add_var
6	sub_var
7	mul_var
8	div_var
9	set_e
10	set_int
11	await_int
12	wait
13	loop
14	endloop
15	breakloop
16	if
17	else
18	elseif
19	endif
20	get_time
21	meas
22	RESERVED
23	meas_loop_lsv
24	meas_loop_cv
25	meas_loop_dpv
26	meas_loop_svv

Bit number	Command string
27	meas_loop_npv
28	meas_loop_ca
29	meas_loop_pad
30	meas_loop_ocp
31	meas_loop_eis
32	set_autoranging
33	pck_start
34	pck_add
35	pck_end
36	set_max_bandwidth
37	set_cr
38	cell_on
39	cell_off
40	set_pgstat_mode
41	send_string
42	set_pgstat_chan
43	set_gpio_cfg
44	set_gpio_pullup
45	set_gpio
46	get_gpio
47	set_pot_range
48	RESERVED
49	set_poly_we_mode
50	file_open
51	file_close
52	set_script_output
53	array_get
54	array_set
55	i2c_config
56	i2c_read_byte
57	i2c_write_byte

Bit number	Command string
58	i2c_read
59	i2c_write
60	i2c_write_read
61	hibernate
62	abort
63	timer_start
64	timer_get
65	set_range
66	set_range_minmax
67	meas_loop_cp
68	set_i
69	meas_loop_lsp
70	meas_loop_geis
71	int_to_float
72	float_to_int
73	bit_and_var
74	bit_or_var
75	bit_xor_var
76	bit_lsl_var
77	bit_lsr_var
78	bit_inv_var
79	set_channel_sync
80	set_acquisition_frac
81	mux_config
82	mux_get_channel_count
83	mux_set_channel
84	set_gpio_msk
85	get_gpio_msk
86	set_e_aux
87	RESERVED
88	set_ir_comp

Bit number	Command string
89	<i>RESERVED</i>
90	meas_fast_cv
91	set_acquisition_frac_autoadjust
92	alter_vartype
93	meas_loop_acv
94	meas_ms_eis
95	meas_fast_ca
96	mod_var
97	notify_led
98	set_scan_dir
99	meas_loop_ca_alt_mux
100	meas_loop_cp_alt_mux
101	meas_loop_ocp_alt_mux
102	smooth
103	peak_detect
104	set_bipot_mode
105	set_bipot_potential
106	meas_loop_eis_dual
107	rtc_get
108	<i>RESERVED</i>
109	beep
110	battery_perc
111	get_progress
112	pow_var

Appendix C: Communication capabilities bit fields

The following table lists all MethodSCRIPT commands and their respective bit field in the [Section 4.22, “Get runtime capabilities \(CC\)”](#).

Table 7. Communication capabilities look up table

Bit number	Command string	Description
0		RESERVED
1	t	Get firmware version
2 - 31		RESERVED
32	CC	Get runtime capabilities
33	CM	Get MethodSCRIPT capabilities
34	S	Set register
35	G	Get register
36	L	Load MethodSCRIPT
37	r	Run loaded MethodSCRIPT
38	e	Execute (= load and run) MethodSCRIPT
39	dLfw	Enter bootloader
40 - 42		RESERVED
43	Fmscr	Store loaded MethodSCRIPT to NVM
44	Lmscr	Load MethodSCRIPT from NVM
45 - 47		RESERVED
48	i	Get serial number
49	v	Get MethodSCRIPT version
50		RESERVED
51	fs_dir	Get directory listing
52	fs_get	Read file
53	fs_put	Write file
54	fs_del	Delete file or directory
55	fs_info	Get file system information
56	fs_format	Format storage device
57	fs_mount	Mount file system
58	fs_unmount	Unmount file system
59	fs_clear	Clear file system

Bit number	Command string	Description
60	m	Get multi-channel serial number
61 - 95		<i>RESERVED</i>
96	h	Halt script execution
97	H	Resume script execution
98	Z	Abort script execution
99	Y	Abort measurement loop
100		<i>RESERVED</i>
101	R	Reverse CV sweep

Appendix D: Errata

Long file names

Issue:

In EmStat Pico firmware before version 1.4.0, under certain circumstances, files with a name (path) of more than 63 characters could be lost or become inaccessible.

Fix:

This issue has been fixed in firmware version 1.4.0.

Work-around:

- With EmStat Pico firmware before version 1.4.0, do not use file names longer than 63 characters.
- If files with names longer than 63 characters are already stored on the instrument, it is highly recommended to download these files to a computer or other device to avoid losing data.
- If files with names longer than 63 characters are lost after a firmware update, downgrading to the previous version *could* recover those files.
- Formatting the storage device using the `fs_format` command will permanently erase all files and make all disk space available for new files.

Bootloader

Issue:

The bootloader on the EmStat Pico may refuse to update firmware under special circumstances. Instead an error with code `!000A` is returned. This will trigger when the EmStat Pico has received around a multitude of 1024 bytes since startup when receiving the last block.

Fix:

This issue has been fixed in bootloader version 1.2.

Work-around:

In most cases, retrying the upload will succeed.

Alternatively, if uploading firmware fails with a specific firmware version, a more deterministic solution is to:

- Reset the device
- Send 10 line feed ('\n') characters
- Upload firmware as normal

This will ensure the communication buffer is in a different position when the last block is received. This fix will always work for a binary that failed without sending line feeds, but it is only recommended for binaries that normally fail to upload.

Data sent to the EmStat Pico can be corrupted during EIS measurements

Issue: There are a few microseconds during each `meas_loop_eis` iteration where data sent to the EmStat Pico over UART can become corrupted. This happens because the UART clock frequency is altered briefly. If this happens, the EmStat Pico will return a `!0003` (unknown command) or `!0009` (timeout) error. This cannot happen to data sent by the EmStat Pico.

Work-around: Retry the command until it succeeds.